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A Multifactorial Approach to the Estimation of Sex using the Facet Joints of the Spine

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by

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ABSTRACT

FACULTY OF ART AND HUMANITIES

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A MULTIFACTORIAL APPROACH TO THE ESTIMATION OF SEX USING THE FACET JOINTS OF THE SPINE

Carolyn Louise Felton

This research aims to demonstrate how "form related to function" can be used to explain differences in the degree of zygapophyseal (facet) joint sexual dimorphism seen in populations with differing lifestyles. Whilst sex can be estimated with a reasonable degree of accuracy from the facet joints of the spine in populations with a high degree of sexual dimorphism, it can be problematic in samples that do not. Bone adapts to reflect the physiological strain placed upon it during life. Analysis of the relationship between bony adaptation to occupational stress and facet morphology identifies extrinsic factors that correlate to changes in facet size and to a lesser degree sagittal angle. Extrinsic factors are external biocultural influences on bone morphology (e.g. nutrition and physical activity). The number of discriminant functions that can be derived from a population with a low degree of sexual dimorphism is increased when these factors are included, increasing the potential to estimate sex. The strength of correlation and prevalence of extrinsic factors can also be used to measure the degree of physical activity undertaken by individuals and is indicative of gendered division of labour in the population under study.

Analysis of facet size and sagittal angle and the relationship and prevalence of extrinsic factors related to physical activity from skeletal material were examined from three contrasting samples. Two were from 18th century London with differing socio-economic status and the third a composite sample from three 5th -7th century Anglo-Saxon cemeteries located in southeast England. A comparative study of facet size and angle identified inter-sample differences in the degree of sexual dimorphism. Further comparison of differences in lifestyle as evidenced by activity patterns was carried out to assess the impact of extrinsic factors on facet remodelling. In particular, this thesis focuses on evidence of the gendered division of labour as manifest by

femoral robusticity, humeral directional asymmetry, vertebral osteophytosis, and osteoarthritis with analysis of the individual diagnostic criteria of eburnation, pitting and osteophytes. A distinct difference in prevalence of these factors was observed in the Anglo-Saxon sample and most obviously in females when compared with the 18th century samples, indicating that there was a difference in intensity of activity undertaken by this group in comparison with the other samples in this study. This suggests that the lack of facet joint sexual dimorphism observed in Anglo-Saxons is attributable to the degree of physical activity undertaken by these females and the subsequent remodelling of the facets as a functional adaptation to the mechanical loading they were subjected to.

This research demonstrates that for some populations, sex can be estimated with reasonable accuracy from vertebral facet dimensions but for less dimorphic samples, inclusion of extrinsic factors related to physical activity when deriving discriminant functions increases the opportunity to estimate sex. Furthermore, analysis of inter-sample prevalence rates for extrinsic factors provides supporting evidence of different levels of physical activity between the samples.

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Academic Thesis: Declaration of Authorship

I, Carolyn Louise Felton declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

A Multifactorial Approach to the Estimation of Sex using the Facet Joints of the Spine.

I confirm that:

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3. Where I have consulted the published work of others, this is always clearly attributed;
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Acknowledgements

I have many people to thank for their help and support, without which I would not have got this far.

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Abbreviations

AA absolute asymmetry

AS Anglo-Saxon

AP antero-posterior

C cervical

DA directional asymmetry

DJD degenerative joint disease

GC Great Chesterford

HDB average diaphyseal diameter

I inferior

Lt left

L lumbar

ML medio-lateral

MOS marker of occupational stress

OA osteoarthritis

R right

S superior

SBC St Bride's Crypt

SBL St Bride's Lower

T thoracic

ZA zygapophyseal joint

Chapter 1 Introduction

"To measure is to know" (William Kelvin 1824-1907).

Human skeletal remains can provide unique insights into the past and the present, insights that cannot be gained elsewhere. This is achieved using bioarchaeological analysis to reconstruct the biological profile of the individuals under study by determination of sex, age and health of a skeleton.

Sex is the key parameter when creating a demographic profile (Scheuer, 2002; Bruzek and Murail, 2006; Işcan and Steyn, 2013). Correct classification of sex increases the accuracy of estimation of other biological attributes such as stature and body mass (Ruff et al., 2005; Sládek et al., 2015). The sex of a skeleton can be estimated from comparison of features that demonstrate sexual dimorphism. Sexual dimorphism is defined as the systematic difference in form between individuals of different sex in the same species (Plavcan and van Schaik , 1994) and is a measure of anatomical differences between males and females determined at time of conception and enhanced in subsequent physiological development (Armelagos, 1998:1). There are many factors involved in the development of the adult human skeleton. Bones can change shape in response to intrinsic or extrinsic factors. Intrinsic factors arise from within the body systematically and are under genetic constraint, e.g. hormone levels, (Gilsanz et al., 1997; Plavcan, 2001). Traits that are under genetic control seem to appear earlier than those affected more by the environment (extrinsic factors) (Moore, 2013). Extrinsic factors are introduced from outside the body e.g. nutrition, biomechanics of activity including the gendered division of labour (Charisi et al., 2011), body mass (Gilsantz et al., 1997), and functional wear of the bones (Acsádi and Nemeskéri ,1970). Load-bearing bones exhibit postnatal plasticity, enabling them to functionally adapt to their biological and cultural environment as a result of external stimuli. These adaptations manifest as subtle nuances in morphological change, recorded as an osteobiography and can be observed during detailed analysis of bone.

The pelvis is considered to display the greatest degree of sexual dimorphism and is the most reliable element for estimation of sex in adults (Bruzek and Murail, 2006; Işcan and Steyn, 2013), especially when used in conjunction with cranial morphology (Meindl et al., 1985). However, it is problematic if these elements are damaged or missing from archaeological contexts, resulting in the need for methods to estimate sex from other bones that demonstrate dimorphism (Cox and Mays, 2000). Vertebrae are suitable elements for estimation of sex because they exhibit sexual dimorphism in size, even before puberty (Moore, 2013).

There have been a number of studies that report the use of vertebral measurements to accurately classify the sex of human skeletons (MacLaughlin and Oldale, 1992; Marino, 1995; Wescott, 2000; Pastor, 2005; Yu et al., 2008; Marlow and Pastor, 2011; Hou et al., 2011; Amores et al., 2013). These studies have developed discriminant functions (DF) from vertebral measurements and achieved up to 90% correct classification. This implies that certain vertebral measurements are the most effective univariate predictors of sex for non-pelvic elements (Spradley and Jantz, 2011). Although these results are very encouraging, there is lack of consistency in the methods used. Individual or small groups of vertebrae are used in these studies rather than the whole spine. Whilst population specificity of the DF is mentioned, there is very little comment of the degree of dimorphism seen in the samples under study and no attempt to control for functional adaptation of the vertebrae to mechanical loading.

Previous vertebral studies can be criticised as they have continually emphasised the use of simple linear measurements and indices to estimate sex, which limits structural interpretation with little consideration of functional correlates and the relevance of findings to more general issues of biological adaptation (Lovejoy et al., 1982). This criticism can be extended to metric sexual dimorphism studies in general, as it has been noted that many are based on the development of statistical techniques to determine sex without any consideration of functional factors that could have led to those differences (Ruff, 1987).

The gendered allocation of labour can lead to differing male and female activity patterns with the resulting biomechanical stress effects manifesting as different degrees of sexual dimorphism (Pomeroy and Zakrzewski, 2009). Lifestyle-related factors are thought to influence vertebral size with the effects appearing more prominent in females than males (Oura et al., 2016; Oura et al., 2017). As there is a link between vertebral size and lifestyle-related factors, this thesis aims to analyse changing morphology of the facet joints to define a novel method of sex estimation and also to gain an understanding of the effects of extrinsic (biocultural) factors on facet size and angle. This analysis addresses the primary debate of this research which is to demonstrate that recognition of not only biological differences but also the effects of biomechanical differences may lead to a better understanding of sexual dimorphism in humans and improve sex discrimination from the skeleton. This approach is an important adjunct to the field of sex estimation as it evaluates the effect of extrinsic influences on degree of sexual dimorphism and adds explanation for the degree of dimorphism seen in a sample when compared to samples from dissimilar backgrounds. It is a response to the criticisms of Lovejoy et al. (1982) and Ruff (1987) that functional adaptation is not included in metric sex assessment and tests to see if that criticism is valid.

Vertebral facet joints were considered to be an appropriate variable for this study because changes in facet joint size and angle of orientation are related to the biomechanical requirements of the joint (movement and weight bearing) (Moore and Dalley, 2006). Facet joints form the posterior weight-supporting pillar of the spine and do not have any direct muscle attachments; therefore, changes in size or angle are not influenced by the exertional pull of muscles (Moore and Petty, 2005). From a methodological point of view, facet joints are readily identifiable and tend to have delineated boundaries of the articular surface allowing for ease of measurement.

To address the issues outlined above, this thesis takes a methodological approach to test the accuracy with which facet joint size and angle of orientation can be used to estimate sex for the whole spine. This novel approach also evaluates the relationship between extrinsic factors as a measure of biomechanical loading with facet morphology and the effect on degree of correct sex classification by inclusion of these factors into discriminant functions.

To facilitate this, data have been collected from three contrasting samples (See Chapter 5):

1) St Bride's Crypt, a documented set of skeletons of known sex and age from 18th-19th century London. These individuals were interred in the crypt of St Bride's Church in Fleet Street, London and were of high socio-economic status.

2) St Bride's Lower Cemetery, also from 18th-19th century London and found in Farringdon Road. The individuals were from the same parish as those of St Bride's Crypt but were of lower socioconomic status. The sex and age of these individuals was unknown prior to analysis.

3) Anglo-Saxon; this sample is comprised of three separate cemeteries from the 5th-7th century (Great Chesterford, Essex; Buckland, Kent and St Anne's, East Sussex). These individuals are from rural locations. The sex and age of these individuals was also unknown prior to analysis.

Discriminant functions (DF) were derived for each sample using facet size and angle and the percentage of correct classification of sex were compared. DF's derived from St Bride's Lower and Anglo-Saxon samples in this study were substituted into the St Bride's Crypt control sample to determine the degree of population specificity.

Discriminant functions (DF) that included scores from the extrinsic factors were also derived for each sample and the percentage for correct classification of sex were compared to the results of using DF derived from facet size and angle alone.

Inter-sample differences were further explored by comparing the difference in crude and true prevalence rates for eburnation, pitting, osteophytes, vertebral osteophytosis and osteoarthritis (as markers of differing degree of activity). The calculation of crude prevalence rate identified the

number of individuals with a specific variable but was not a measure of the degree with which that variable occurs in each individual. There is a risk of over- or under-representation because this method assumes that all bones are equally preserved, which is generally not the case for archaeologically derived skeletons. True prevalence rates were also calculated to identify the number of facets affected. Both crude and true prevalence rates were calculated as recommended by Waldron (2007).

This study was developed to answer two key questions:

1) Does vertebral facet size and sagittal angle demonstrate sexual dimorphism? In the case of incomplete skeletal remains, damaged or co-mingled depositions, the vertebrae may be the only bones available for analysis. Therefore, an extension to the number of existing vertebral parameters that can be used to estimate sex increases the opportunity to accurately profile human remains.

2) Does the inclusion of extrinsic factors relating to physical activity in DFs increase the degree of accuracy for sex estimation? In a sample that is not very sexually dimorphic, it is not possible to generate discriminant functions for sex estimation. Inclusion of extrinsic factors that measure biomechanical differences leading to functional adaptation of the facets is hypothesized to increase the number of functions that can be derived, leading to greater effectiveness in estimating sex.

Overall this thesis demonstrates that to successfully consider sexual dimorphism of the facets, the lifeway of the individual should be taken into consideration. There is wide natural variation in and between samples, which may be explained by different physical activity patterns or lifestyle. A multifactorial approach to the estimation of sex gives a much broader insight into the lives of the individuals under examination whilst creating a novel approach using the facets of the spine to create discriminant functions.

Outline of Chapters

This thesis is organised into eight chapters including this introduction (Chapter 1).

Chapter 2 provides an overview of the anatomy of the spine and vertebrae beginning with development of the spine from embryo to adult. It describes typical and atypical vertebrae for each spinal region and the effects of caudal and cranial shifts of transitional vertebrae.

Chapter 3 explores the relationship between sex, age and vertebral morphology and reviews the existing literature.

Chapter 4 begins with a disciplinary history of bioarchaeology and describes biocultural theory, emphasising the origin and traditional application of this model. A review of bone plasticity, models of bone functional adaptation and the effects of mechanical stress on bone follow this. The chapter continues with an overview of markers of occupational stress in bioarchaeological contexts and discusses the effects that may be observed in bone. The complexities of relating patterns of degeneration to specific activities are also discussed.

Chapter 5 provides details on the materials and methods used in this study. The first part of the chapter provides information about the skeletal samples (materials). A brief history of each skeletal sample is included. The methods section identifies problems relating to the estimation of sex and age from skeletal material, details the parameters measured or scored and the method used, rationale for choice of method and choice of statistical method. The chapter ends with results from intra-observer reliability assessment from the pilot study of the methods used.

Chapter 6 presents the results of descriptive demographic statistics and basic metric data analysis followed by the results of statistical analysis to evaluate each hypothesis in turn

Chapter 7 is a discussion of the results obtained in Chapter 6

Chapter 8 is the conclusion to the thesis and identifies limitations to the study and areas for further research.

Chapter 2 Vertebral Structure

An understanding of the anatomy and physiology of the component parts of the spine is integral to this thesis as the questions posed in this study are related to its structure and function. This chapter begins with a description of the basic structure of a typical vertebra, followed by development of the vertebral column from embryo to adult. It continues with an overview of the structure and function of the cervical, thoracic and lumbar spinal regions. The chapter ends with identification of cranial and caudal shifts and the impact this has on vertebral level identification.

2.1 Structure of a typical vertebra

A typical vertebra (Figure 2-1) (overleaf) consists of an anterior body and a posterior arch (Schwartz, 1995; Moore and Dalley, 2006). These structures join to form the vertebral foramen, which contains the spinal cord surrounded by the meninges (Steele and Bramblett, 1988; Snell, 2004; White et al., 2012). The vertebral arch is formed from two pedicles at the sides and two laminae that join posteriorly (Tucker, 1990; Snell, 2004; Moore and Dalley, 2006). There are seven processes that arise from the vertebral arch, four articular (left and right superior and inferior facets) (Schwartz, 1995; Adams et al., 2006), two transverse processes (Moore and Petty, 2005, Moore and Dalley, 2006) and a single spinous process (Schwartz, 1995; Snell, 2004).

2.2 Development of the vertebral column

The spine is a complex and vital structure, serving as a pillar to support upper body weight whilst protecting the spinal cord. Embryonic development of the spine depends on a cascade of events that allow for the formation of musculoskeletal and neural components. The cascade begins very early in the life of the embryo with the primitive streak, well-defined germ layers and the notochord developing in the third week of gestation (Kaplan, 2005). The notochord and somites are the most significant structures responsible for development of the future vertebral column (O'Rahilly, 1996).

The embryonic spinal cord develops in three key stages that blend into each other rather than being distinct (mesenchymal, cartilaginous and ossification stages) (Oliver and Middleditch, 1999).

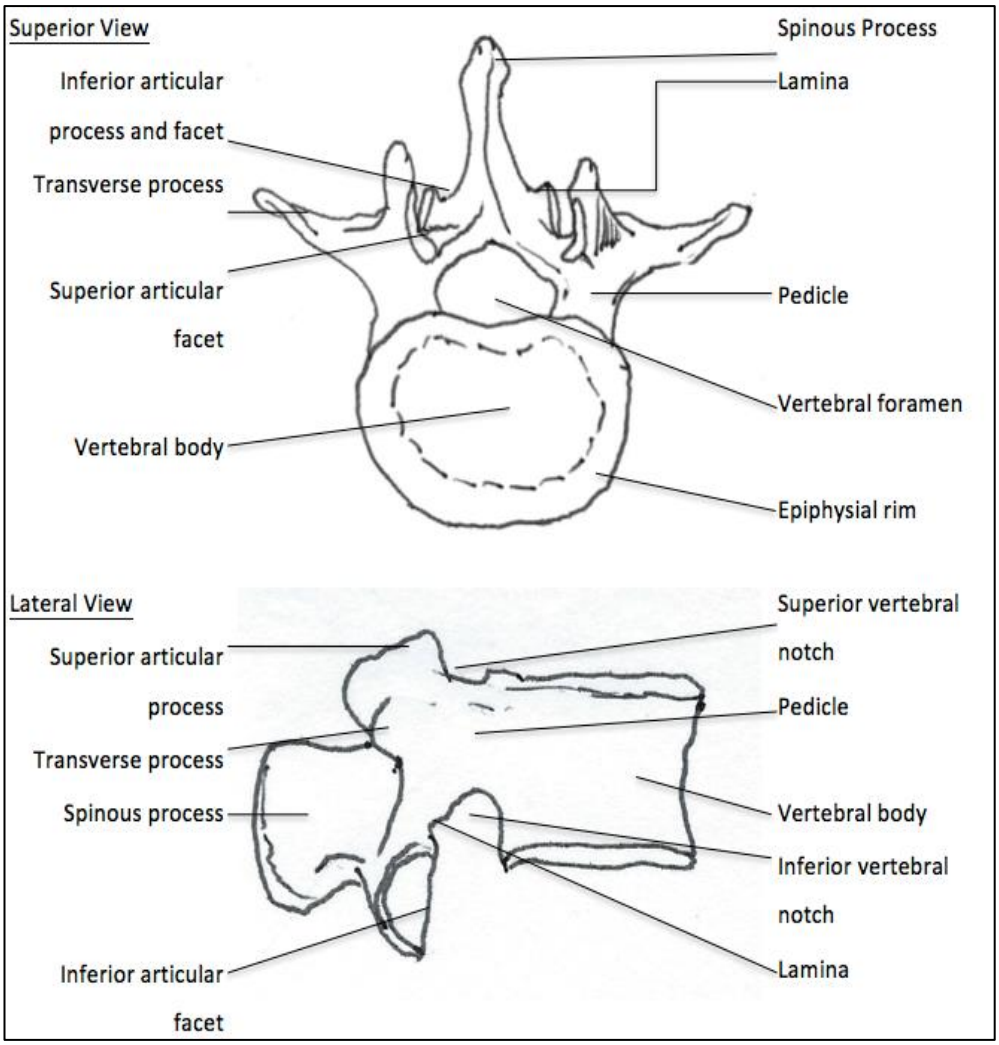


Figure 2-1 Common anatomical features shared by vertebrae (author's image)

2.2.1 Mesenchymal stage

Two weeks after conception, the embryo forms three distinct layers (see Figure 2-2.) (overleaf);

1) The ectoderm (forms the dermis and the central and peripheral nervous system) (Moore and Persaud, 2003:51). It is in contact with the amniotic fluid surrounding the embryo and foetus during gestation

2) The mesoderm (forms the connective tissues, organ linings and blood related organs) (Vernon-Roberts, 1988)

3) The endoderm (forms primitive soft tissue, notochord, lungs and digestive system) (Moore and Persaud, 2003). The notochord is an embryonic midline structure arising in the endoderm and forming the longitudinal midline axis, around which the vertebral bodies are organised (Snell, 2004:951). The notochord contains a central canal (see Figure 2-3) (overleaf).

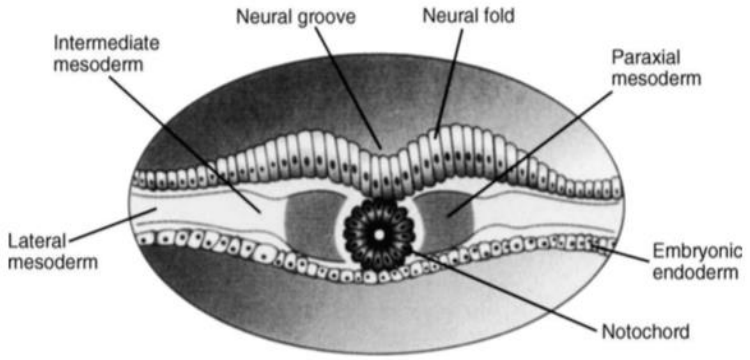


Figure 2-2 The three primordial growth layers (Moore and Persaud, 2003)

In the mesenchymal stage, the mesoderm differentiates into three main areas; paraxial, intermediate and lateral mesoderm (Moore and Persaud, 2003). The vertebral column centres on the notochord and originates from two rods of paraxial mesoderm that form around the notochord as it extends below the base of the skull (Barnes, 2012)

The paraxial mesoderm segments into 42-44 pairs of somites (blocks of tissue) by the 5th week after conception (Rawls and Fisher, 2010). They develop in a craniocaudal fashion and will eventually be instrumental in the formation of the bones of the head, vertebrae and other bony structures of the thorax and associated musculature. The somites are transient structures that differentiate into a ventro-medial part (sclerotome) and a dorso-lateral part (dermomyotome) (Snell, 2004). The sclerotomal cells are responsible for the formation of the spine and the dermomyotomes form the muscle cells and overlying dermis of the skin (O'Rahilly, 1996).

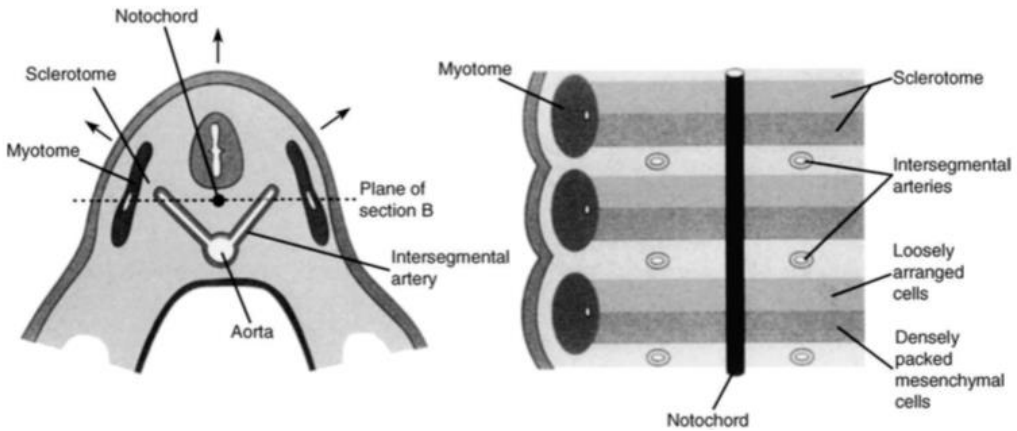


Figure 2-3 Somite differentiation into sclerotome (Moore and Persaud, 2003)

In the 4th week of gestation, the cells of the sclerotome compartment of the somites migrate ventro-medially to surround the notochord (Figure 2-3), increasing in cell number, density and expression of extracellular matrix proteins which cause the mesenchyme to condense into a mesenchymal core and become the centrum of the vertebral body (Tam and Trainor, 1994). The

body of the vertebra develops from the caudal part of one sclerotome and the cranial part of the next sclerotome (Rawls and Fisher, 2010). Dorsal and lateral outgrowths from the mesenchymal vertebral body lead to the formation of the rest of the vertebra (Oliver and Middleditch, 1999) and the mesenchymal cells between the vertebral bodies become the intervertebral discs (Vernon-Roberts, 1988). The cells that initially migrated to adjacent to the neural tube, rather than the notochord, develop into neural arches, which serve to protect the spinal cord, vessels and nerve roots (Moore and Persaud, 2003). The neural arch consists of two pedicles and left and right halves of the laminae (Snell, 2004). The other processes associated with the posterior vertebral arch include the spinous process, transverse processes and articular processes, including facet joints) (Oliver and Middleditch, 1999).

2.2.2 Cartilaginous phase

This is a short phase and occurs at about the sixth week of development when two centres of chondrification appear in the centrum of each vertebral body and one in each of the lamellae of the neural arch (Scheuer and Black, 2004:188). The chondrification centres in the neural arches expand to complete neural arches posteriorly and a spinous process develops at the point of arch completion (Oliver and Middleditch, 1999). These chondrification centres also expand laterally to form the transverse processes and anteriorly to join with the centrum (Rawls and Fisher, 2010).

2.2.3 Ossification phase

Primary ossification centres form from about the 9th week of development after blood vessels grow into the developing vertebrae (Scheuer and Black, 2004). Ossification begins at T12, shifting cranially, and L1, shifting caudally (Schmorl and Junghanns, 1971:3). It occurs in the centrum and on each side of the vertebral arch (Moore and Persaud, 2003). By the seventh month of gestation, primary ossification centres can be seen in all areas (Oliver and Middleditch, 1999). Intervertebral discs form from the notochord and surrounding sclerotomes and the notochord begins to disintegrate (Vernon Roberts, 1988).

Secondary ossification centres appear during adolescence (Snell, 2004). They first appear in the cartilage covering the superior and inferior endplates of the vertebral bodies and form the epiphyseal end plates (Rawls and Fisher, 2010). Secondary ossification centres also appear at the tip of each transverse process and spinous process and ossification progresses until by the 25th year of life, the secondary ossification centres have fused with the rest of the vertebra (Snell, 2004)

2.3 Anatomy of the adult vertebral column

The spine is a segmented flexible structure extending from the cranium to the pelvis and consists of a series of 33 vertebrae that are divided into sections generally comprising seven cervical, twelve thoracic, five lumbar, five fused sacral and four fused coccygeal bones (Schwartz, 1995; Oliver and Middleditch, 1991; Levangie and Norkin, 2005; White et al., 2012). Figure 2-4 illustrates a lateral view of the spinal regions showing the anatomical regions and direction of curvature. There is disagreement on the number of individuals showing variation in the relative number of vertebrae. White et al.(2012) and Barnes (2012) consider it occurs in 10% of individuals and O'Rahilly (1986) in 5-12%. None of these papers commented on the sample profile from which their data was obtained.

The spine has a number of functions:

1) Protects the spinal cord and spinal nerves (Moore and Dalley, 2006; White et al., 2012)
2) Supports the weight of the body superior to the pelvis (Steele and Bramblett, 1988; Oliver and Middleditch, 1991)
3) Provides a point of articulation for the ribs and supports the thoracic cage (Tucker, 1990; Schwartz, 1995; Snell, 2004).
4) Has flexibility to allow movement and support locomotion (Levangie and Norkin, 2005; Adams et al., 2006)
5) Is a site for muscle and ligament attachment (Gunn, 1992; Trew and Everett, 2005)
6) Has elasticity to enable it to act as a shock absorber (Tucker, 1990; Oliver and Middleditch, 1991; Moore and Dalley, 2006).

The living adult is reported to have a mean length of the vertebral column of 72-75 cm with approximately a quarter of that length formed by the intervertebral discs (Schwartz, 1995; Snell, 2004; White et al, 2012). Vertebrae generally display common anatomical features with regional variations that are related to function (serial homology) (Moore and Petty, 2005).

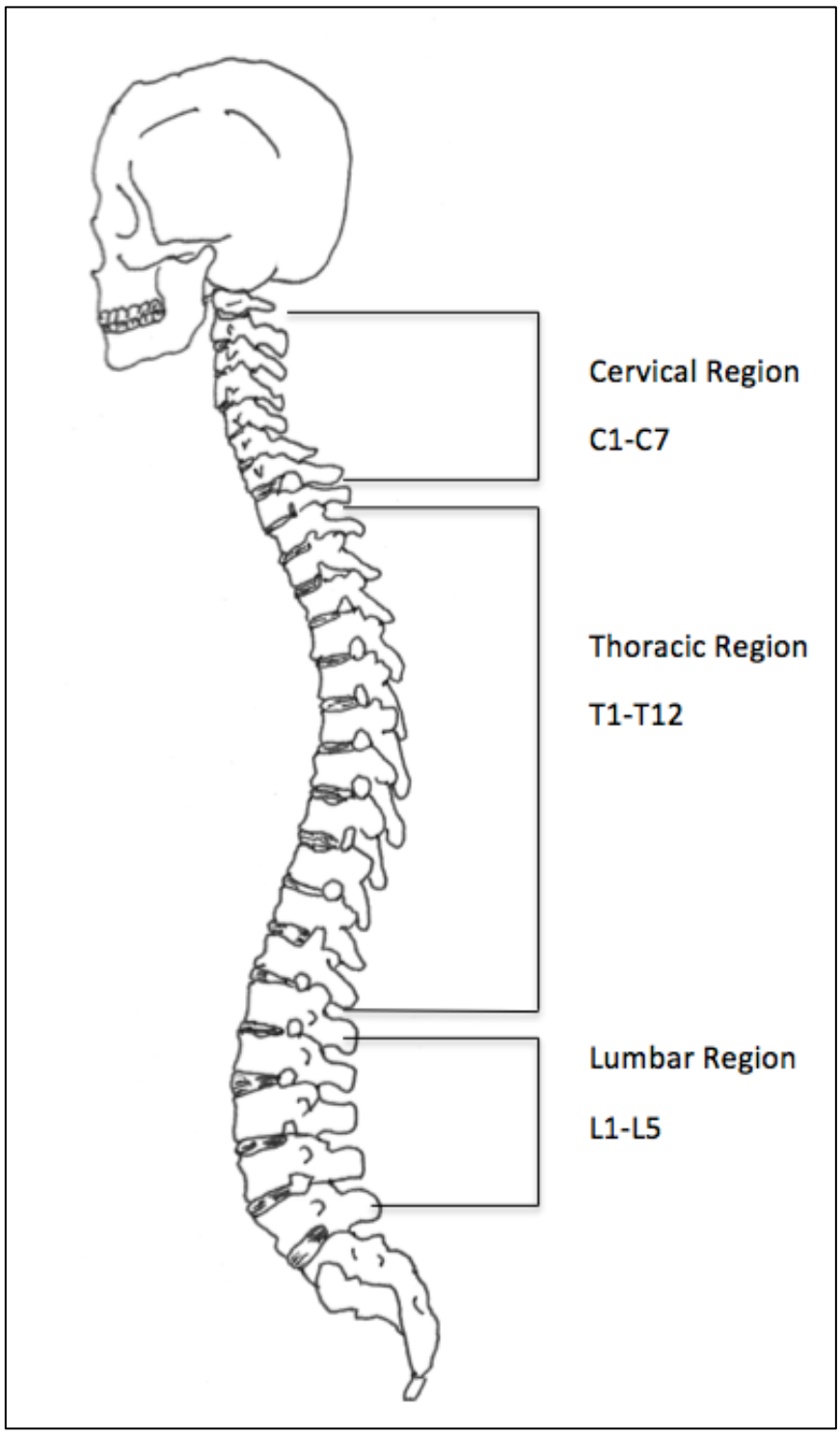


Figure 2-4 Lateral view of curvatures of the spine (author's image)

The next three sections will discuss the spinal regions and the vertebral anatomy specific to that region.

2.3.1 Cervical region

There are generally seven vertebrae in the cervical region. C1 (atlas) and C2 (axis) and C7 are considered atypical vertebrae whereas C3-C6 are typical for the region (Figure 2-5) (Gosling et al., 1996; Snell, 2004).

The bodies of typical cervical vertebrae are roughly rectangular, wider in the medio-lateral aspect when compared with the antero-posterior aspect (Moore and Dalley, 2006). Joints of Luschka (uncovertebral joints) are found at the anterior periphery of the body by small uncinate processes and are formed between the uncinate process inferiorly and uncovertebral articulation superiorly (Williams, 2000). The pedicles project postero-laterally and are short and round whilst the laminae are long and thin (Moore and Petty, 2005; Adams et al., 2006). These combine with the body to form a large, triangular vertebral foramen (McMinn et al., 1993; Snell, 2004).

The superior articular facets face posteriorly and the inferior facets face anteriorly (Oliver and Middleditch, 1999). The facets are small and angled at approximately 45^0 from the horizontal plane (Manaster and Osborne, 1987). Anterior and posterior tubercles can be found on the transverse process, which also contains the transverse foramen allowing the passage of the vertebral artery (Schwartz, 1995; White et al., 2012). The spinous processes are short (C3-C5) and bifid (C3-C6). The spinous process of C7 is long and prominent (Moore and Dalley, 2006).

C1 is an atypical vertebra as it does not have a body or spinous process (McMinn et al., 1993; Snell, 2004) but exists as a bony ring comprised of two wedge shaped lateral masses connected by anterior and posterior arches (Schwartz, 1995; Gosling et al., 1996, Oliver and Middleditch, 1996). The atlas vertebra articulates with the occiput superiorly (atlanto-occipital joint) and axis inferiorly (atlanto-axial joint) via articular surfaces on the superior and inferior aspects (Gunn, 1992; Williams, 2000). The superior articular facet of C1 can vary in its structure and may consist of a single oval facet or two discrete facets (Donlon, 2000).

C2 is also an atypical cervical vertebra. Unlike C1, this vertebra has a body and spinous process, however the superior surface of the body is represented by a projection from the anterior surface of the vertebra (the odontoid peg or dens). This represents the body of C1 when the two vertebrae articulate (Snell, 2004; White et al., 2012).

C7 is also considered to be an atypical cervical vertebra due to the presence of a long non-bifid spinous process making it easily identifiable as the *vertebra prominens* (Gosling et al., 1996; Gunn, 1992; Levangie and Norkin, 2005). The vertebral foramen is smaller, and the transverse processes are larger than in C3-C6 (Snell, 2004; Moore and Dalley, 2006).

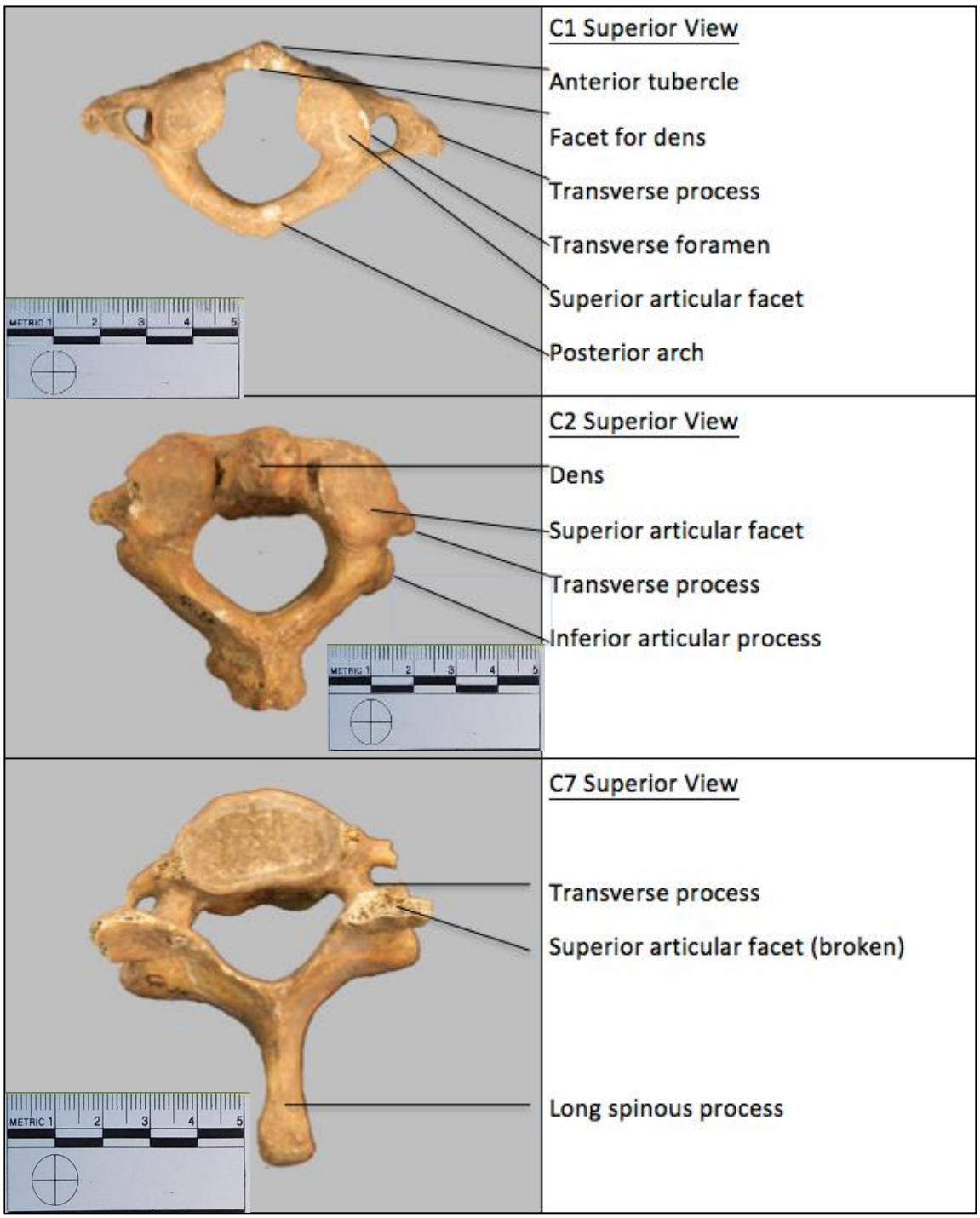


Figure 2-5 Cervical Vertebrae (author's image)

2.3.3 Thoracic region

The twelve thoracic vertebrae increase in size from cranial to caudal (William, 2000). The bodies are heart shaped (Steele and Bramblett, 1988; Moore and Dalley, 2006) and have short, posteriorly facing pedicles with short laminae (Williams, 2000). The vertebral foramen is smaller than those of the cervical and lumbar vertebrae and is circular in shape (Gunn, 1992; Williams, 2000). The superior facets are thin, flat and face posteriorly and laterally, whilst the inferior joints

face anteriorly, superiorly and medially, with the exception of the twelfth thoracic vertebra where the inferior facets face laterally in the transition to lumbar vertebrae (Snell, 2004; Moore and Dalley, 2006). The plane of the facets lies on an arc centred on the vertebral body (Oliver and Middleditch, 1999; Levangie and Norkin, 2005). In the thoracic region, the left superior facets are generally longer, narrower and more sagitally orientated than the right (Masharawi et al., 2008). Vertebral asymmetry is discussed in section 5.7.7.2. The transverse processes are thick, strong and extend postero-laterally. Their length shortens from T1-T12 (Schwartz, 1995; Moore and Dalley, 2006) The spinous processes are long and slope postero-inferiorly (Steele and Bramblett, 1988; White et al., 2012). T1-T12 have costal facets on the vertebral bodies, which articulate with the head of the rib (McMinn et al., 1993; Gosling et al., 1996). They manifest as demi-facets with the superior component at the root of the pedicle (Williams, 2000) and the inferior demi-facet at the lower border of the vertebral body (Williams, 2000). This pattern is seen on mid- thoracic vertebrae with variation at the upper and lower vertebrae.

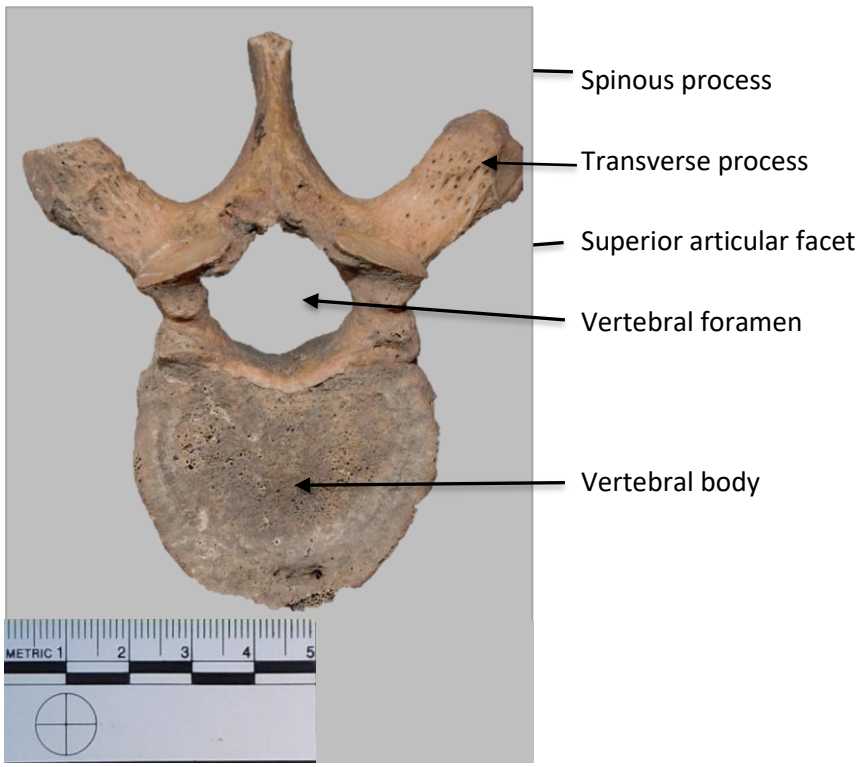


Figure 2-6 Typical thoracic vertebra (T9 from GC81) (author's image)

T1 has a complete costal facet inferior to the superior margin of the body and also a demi-facet at the perimeter of the inferior margin of the body (Schwartz, 1995; Snell, 2004). There is also a "butting facet" associated with the superior facet and located on the laminae which serves to limit the downward displacement of the inferior articular surface of C2 (Levangie and Norkin, 2005; Moore and Petty, 2005). T10-T12 (and sometimes T9) also have complete costal facets on the sides of the vertebral body but unlike T1, do not have a demi-facet at the inferior margin of

the body (McMinn et al., 1993; Scheuer and Black, 2000; Moore and Dalley, 2006). The transition from the thoracic type-vertebra to the lumbar-type can occur anywhere between T10/11 and T12/L1 (Pal and Routal, 1999). Transition at T11/12 is the more frequently seen than at T12/L1. This occurs when there has been a cranial shift at the thoraco-lumbar junction and the transitional facets seen usually on T12 can be seen on T10 or T11 (Pal and Routal, 1999; Barnes, 2012). It is more common for there to be a slow transition (gradual change over a number of levels) from thoracic to lumbar facet with 93% of forty-one spinal columns from skeletons of Indian origin, demonstrating this trend, in contrast with 7% of the spines examined demonstrating an abrupt shift (Pal and Routal, 1999). Cranial shifts at the thoraco-lumbar junction can also lead to small or absent rib facets on T12 due to hypoplasia or agenesis of the ribs (Barnes 2012).

2.3.4 Lumbar vertebrae

A typical lumbar vertebra has a massive body when compared to the thoracic and cervical regions. When viewed from above, the body appears kidney shaped (Snell, 2004; Moore and Dalley, 2006). The pedicles are short, thick and are directed in a posterior direction to join with short, thick and inferiorly directed laminae (Steele and Bramblett, 1988, McMinn et al., 1993; White et al., 2012). The vertebral foramen is triangular in shape being smaller than in the cervical and larger than in the thoracic regions (Gosling et al., 1996; Snell, 2004). The superior facets face medially and posteriorly and have mamillary processes on the posterior surfaces (Moore and Dalley, 2006; Adams et al., 2006). The inferior articular facets are directed antero-laterally (or laterally) (Gunn, 1992; Snell, 2004; White et al., 2012). The transverse processes are long and slender with an accessory process on the posterior surface of the base of each transverse process (Steele and Bramblett, 1988; Moore and Dalley, 2006). In contrast, the spinous processes are short and sturdy, quadrangular in shape and project posteriorly (Gosling et al., 1996; Snell, 2004).

The fifth lumbar vertebra articulates with the first sacral vertebra. Anomalies can occur here when there is a cranial shift of the lumbo-sacral border (Barnes, 2012). L5 can be assimilated into the sacrum (sacralisation) (Pal and Routal, 1999). The inverse can also be seen in the case of a caudal shift, where the first sacral segment shows lumbar characteristics, which can, in severe cases lead to non-fusion of the first to second sacral segment (Barnes, 2012). These lumbar transition vertebrae are reported to be a common occurrence with prevalence varying between 4% -30% (Elster, 1989; Bron et al., 2007).

The information above is an anatomic description. When considering the morphology of vertebrae, it should be remembered that there is considerable variation between individuals. Some individuals have vertebrae that are nearer the ancestral end of the range of shape variation, i.e. they bear a closer resemblance to chimpanzee and orang-utan vertebrae than typically

anatomically modern humans which predisposes the individual to intervertebral disc herniation and the formation of Schmorl's nodes (Plomp, 2015).

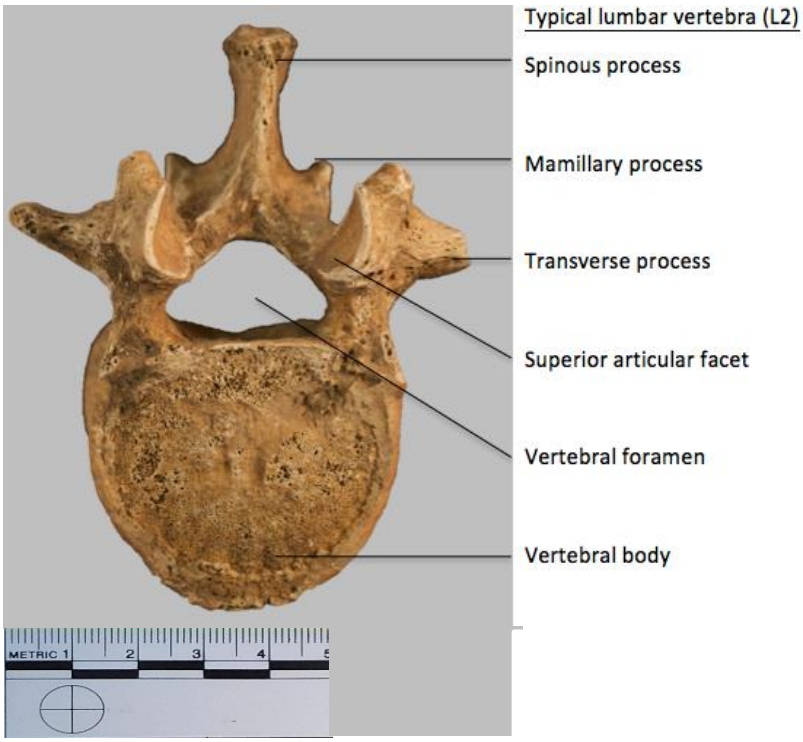


Figure 2-7 Typical lumbar vertebra (L2 from GC81) (author's image)

2.3.5 Intervertebral joints

The vertebrae articulate with each other by means of cartilaginous joints between the bodies and synovial joints between the articular processes (Levangie and Norkin, 2005).

2.3.5.1 Joints of the vertebral bodies (interbody joints)

These cartilaginous joints (symphyses) are formed between the hyaline covered vertebral end plates of two adjacent vertebrae and a fibrocartilaginous intervertebral disc joined by ligaments (Snell, 2005; Moore and Dalley, 2006). There are no intervertebral discs between the first two cervical vertebrae or between the fused bones of the sacrum and coccyx (Snell, 2004). The interbody joints of the lower cervical region are saddle joints thereby allowing motion in only two planes (Levangie and Norkin, 2005).

The anterior and posterior longitudinal ligaments act to hold the vertebrae firmly together, whilst allowing movement to take place (Snell, 2004; Levangie and Norkin 2005). The flexible nature of the intervertebral discs allows movement of the vertebral bodies with a range of movements taking place at the interbody joints which include: gliding (anterior to posterior), allowing the bodies to move during flexion and extension of the spine; distraction and compression, where the

bodies can move apart of closer together and rotation (anterior to posterior and laterally) (Oliver and Middleditch, 1991).

The intervertebral disc and anterior part of the vertebrae (i.e. the vertebral body and intervertebral disc) act as load bearing structures whilst the zygapophyseal joints provide posterior load support (Benoist, 2003).

2.3.5.2 Joints of the vertebral arches

These joints are termed the zygapophyseal joint (and commonly referred to as facet joints) (Moore and Dalley, 2006). The major function of the facet joint is to protect the discs from shear forces and/or excessive flexion and axial rotation whilst facilitating controlled movements in order to prevent damage to the discs (Adams and Hutton, 1980).

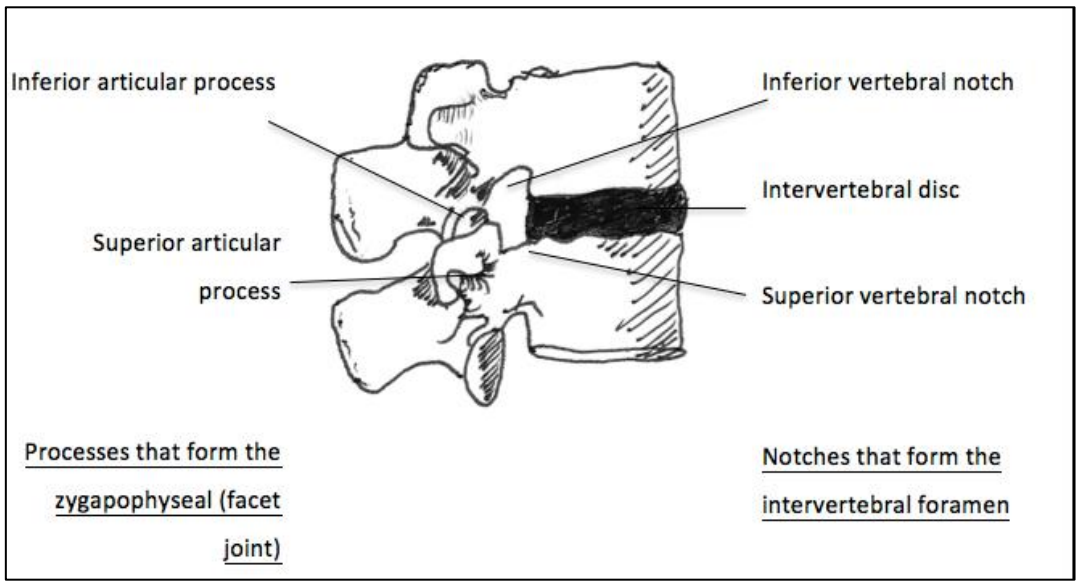


Figure 2-8 Zygapophyseal (facet) joint (author's image)

Facet joints are diarthrodial (synovial) joints, which are free moving articulations found in the axial and appendicular skeleton. They differ from synarthrodial joints (e.g. coronal sutures, symphysis pubis) in that there is no connective soft tissue that directly connects adjacent bony surfaces; instead, they are connected to one another by means of a joint capsule that encloses the joint, allowing flexibility of movement (Levangie and Norkin, 2005). All diarthrodial joints are constructed in a similar way and have a joint capsule that is composed of two layers, a joint cavity enclosed by the joint capsule, synovial tissue that lines the inner surface of the capsule, synovial fluid within the joint cavity and hyaline cartilage that lines the surface of the enclosed bones (Allan, 1998). Figure 2-9 illustrates a typical synovial joint.

The synovial zygapophyseal joints are formed between the superior and inferior articular processes of the vertebrae (Moore and Petty, 2005). In the living, the articular surfaces are covered in hyaline cartilage and surrounded by capsular ligament (Kalichman and Hunter, 2007). The joints are supported and stabilized by the supraspinous, interspinous, intertransverse ligaments, ligamentum flavum and ligamentum nuchae (McMinn et al., 1993; Moore and Dalley, 2005).

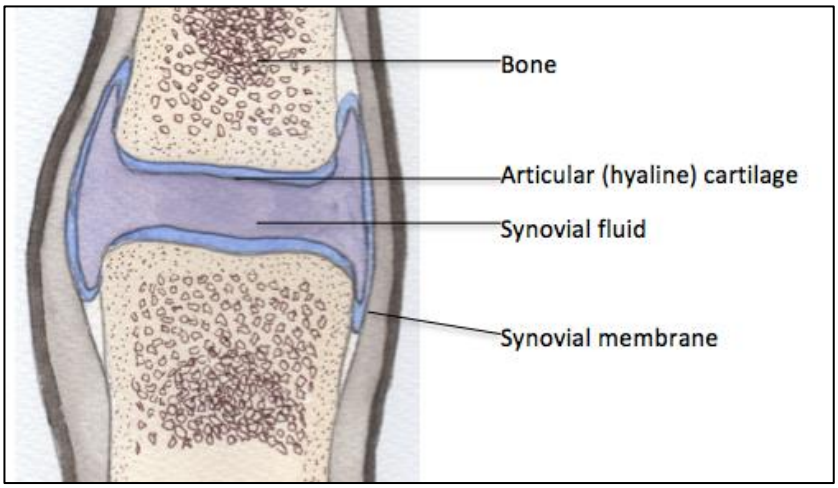


Figure 2-9 Schematic diagram of a typical synovial joint (author's image)

The cervical facet joints are true synovial joints with lax joint capsules that allow for a large range of movement but act as a limiter at the end of the available range (Levangie and Norkin, 2005). The joints contain fibroadipose meniscoids (Oliver and Middleditch, 1999), which are firmly attached to the fibrous capsule surrounding the joint (Mercer and Bogduk, 1993; Bogduk, 1997). These inclusions are thought to protect the joint surfaces during flexion and extension by evening out the undulations of the articular surface and increasing surface area for load transmission (Trew and Everett, 2005). Uhrenholt et al. (2008) identified the presence of folds in the synovial membrane of cervical facet joints that have a protective and lubricative function and compared their function with that of menisci.

Rotation of up to 40^0 is possible in the lower cervical spine due to the approximately 45^0 angle of the facet joints to the horizontal plane (Manaster and Osborn, 1987; Panjabi et al., 1993). The angle of the facet joints acts to limit rotation in the cervical spine in order to prevent over-rotation and potential injury to the spinal cord (Oliver and Middleditch (1999). Yogandan et al. (2003) made an anatomic study of cervical spine facet morphology using data collected from 6 cadavers. It was reported that facet morphology varied with vertebral level, with differences seen between the upper and lower cervical spine and between males and females, in particular females had a thinner layer of articular cartilage covering the surface of the articulation than males. This could lead to exposure of the underlying subchondral bone during mechanical stress.

This is an important issue for this study as levels of degenerative change on the facet surfaces are recorded. The reduced degree of articular cartilage may account for higher levels of degeneration in female cervical spines, as the variation in morphology would alter the biomechanical behaviour of the spine when subject to external loading. Yogandan et al. (2003) also noted that the cervical facet joint surfaces were more planar than in the thoracic region, this is in contrast with Oliver and Middleditch (1999) who report the opposite, describing the thoracic region joints as plane synovial joints. Other sources also describe the thoracic joints as planar (Snell, 2004; Moore and Dalley, 2006). Planar joints are a type of synovial gliding joint between two articular surfaces that are flat or nearly flat, permitting the joint surfaces to glide over each other in the direction of the plane of the joint (Moore and Dalley, 2006).

Thoracic region facet joints also have fibroadipose meniscoids present (Oliver and Middleditch, 1999) and the joint capsules are tauter than in the cervical and lumbar regions limiting the range of movement (Levangie and Norkin, 2005; Moore and Petty, 2005). Flexion and extension are limited by the shape and orientation of the thoracolumbar facets, whilst adding additional stability on flexion (Holdsworth, 1972). In the upper thoracic spine, the angle between the planes of the joints and the horizontal is approximately 60^0. In the mid thoracic region, the angles become closer to vertical and the lower thoracic segments the joints lie more in the sagittal plane (Oliver and Middleditch, 1999).

The facet joints of the lumbar region are true synovial joints with fibroadipose meniscoids present (Levangie and Norkin, 2005). The superior facet shape approximates between a ‘C’ and a ‘J’ shape, which is thought to offer protection against forward displacement of the superior vertebra (Bogduk, 1997). This morphology also causes the lumbar vertebrae to sustain considerable amounts of load when the spine is in extension (Adams and Hutton, 1981). The joint capsules are laxer than in the thoracic region but more taut than in the cervical region (Moore and Petty, 2005). The articular surfaces are almost vertical in the upper lumbar spine, becoming more oblique at L4/5 and L5/S1 enabling the lower joints to resist more force (Yang and King, 1984).

The changes in angle of the plane and shape of the joint surface in each region of the spine are related to the biomechanical requirements of the joint (movement and weight bearing). Figure 2-10 presents examples of facet orientation in the cervical, thoracic and lumbar regions. The changes in angle and orientation can be clearly seen when the vertebrae are observed superiorly.

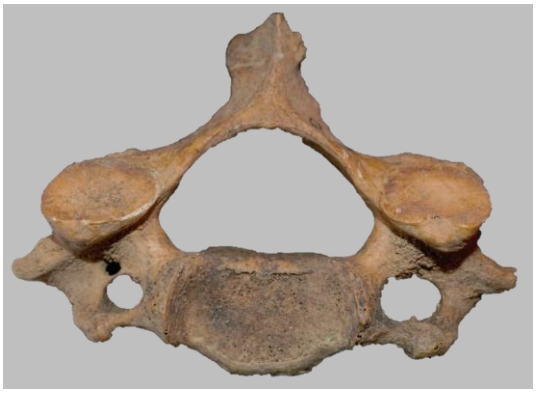
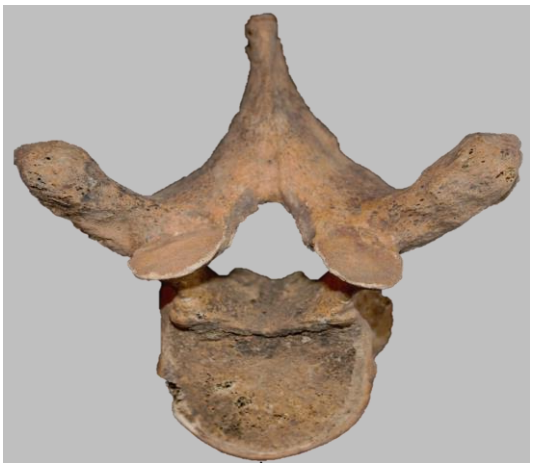
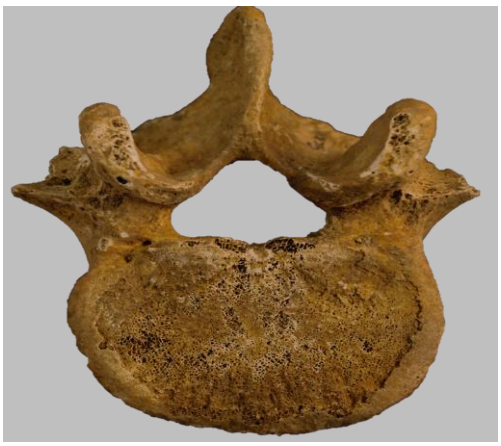
Vertebra	Facet Orientation
	C4 Superior facets face superiorly and medially whilst inferior joints face anteriorly and laterally (Panjabi et al., 1993).
	T4 Superior facets face posteriorly, superiorly and laterally whilst inferior facets face anteriorly, superiorly and medially (Moore and Dalley, 2006).
	L4 Superior facets face postero-medially whilst inferior facets face postero-laterally (Masharawi et al., 2008)

Figure 2-10 Shape and orientation of superior facets demonstrating regional change (from GC100) (author's image)

2.3.6 Curvatures of the spinal column

A lateral view of the curvatures of the adult spine can be seen in Figure 2-11. The curves of the spinal column can be described as primary or secondary. The thoracic and sacral curves are primary i.e. developed *in utero* due to the flexed foetal position (Moore and Petty, 2005). The

primary curve of the foetal vertebral column in the foetus is concave posteriorly (Levangie and Norkin, 2005). These curves are retained through life due to height differences between the anterior and posterior parts of the vertebrae (Moore and Dalley, 2006). The secondary curves in the cervical and lumbar regions develop in infancy as a result of extension from the flexed foetal position (Oliver and Middleditch, 1999).

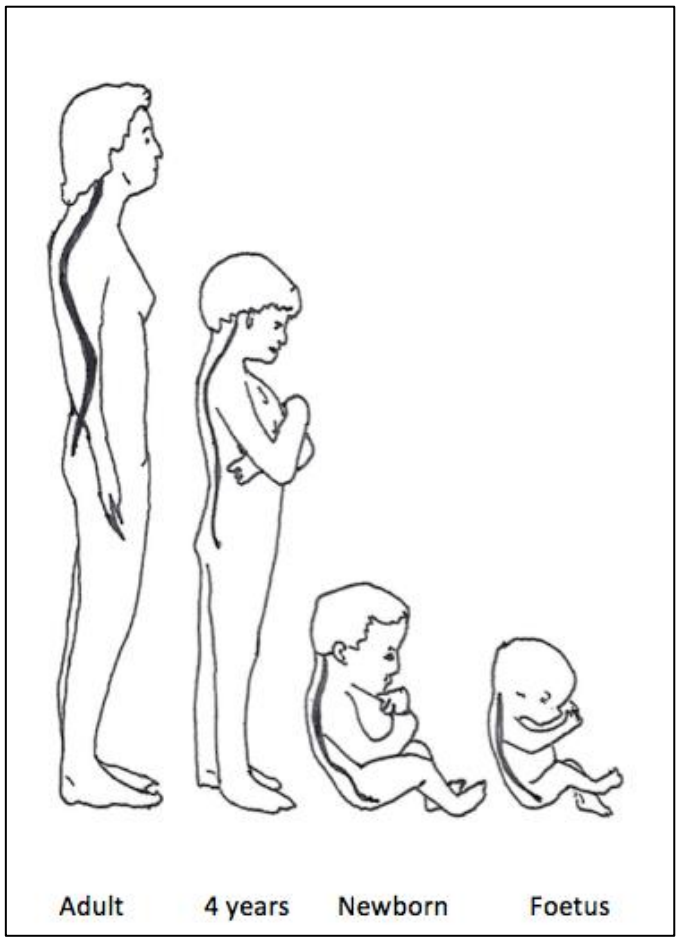


Figure 2-11 Developmental curvatures of the spine (modified from Moore and Dalley, 2006:514)

A cervical lordosis develops when the child begins to hold its head upright, usually beginning at the end of pregnancy and becoming more pronounced at about three to four months of age (Comin et al., 1995; Snell, 2004) and the lumbar lordosis occurs at about 12-18 months of age when the child gains the ability to support itself in the upright position and begins to walk (Moore and Dalley, 2006). The lumbar curvature does not fully develop until the child is about two years old and fully ambulatory (Steele and Bramblett, 1988).

In the adult (See Figure 2-11), four curves are clearly visible in the normal spine. The cervical and lumbar curves are convex anteriorly (lordotic) (Gosling et al., 1996; Steele and Bramblett, 1988; Snell, 2004), whilst those of the thoracic and sacral regions are concave anteriorly (kyphotic) (Gosling et al., 1996; Steele and Bramblett, 1988; Snell, 2004).

The degree of kyphosis in the sacral region is less pronounced in females than males, causing less projection of the coccyx into the pelvic outlet leading to larger size of the birth canal (Oliver and Middleditch, 1999; Snell, 2004; Moore and Dalley, 2006). Degeneration of the intervertebral discs in the elderly leads to reduction of lordosis in the cervical and lumbar regions and the C-shaped curve seen *in utero* become apparent again (Snell, 2004; Levangie and Norkin, 2005). Disc degeneration causes approximation of the vertebral bodies at the anterior margin due to reduced disc height; this in turn reduces the degree of lordosis (Oliver and Middleditch, 1999).

The kyphosis seen in the thoracic region may be caused by vertebral body morphology (Panjabi et al., 1991). In order to investigate the contribution of the intervertebral discs to the shape of the thoracic spine, Goh et al. (1999) measured the Cobb Angle (Figure 2-12) of 93 individuals (35 female and 58 male) using data collected from lateral spine radiographs and mid-sagittal CT films. The Cobb angle is the preferred clinical measure of sagittal deformity and can be defined as the angle formed at the point of intersection between a line drawn parallel to the superior endplate of the vertebra at the top of the curve to be measured and a line drawn parallel to the inferior endplate of the vertebra at the bottom of the curve (McAlister and Shackleford, 1975).

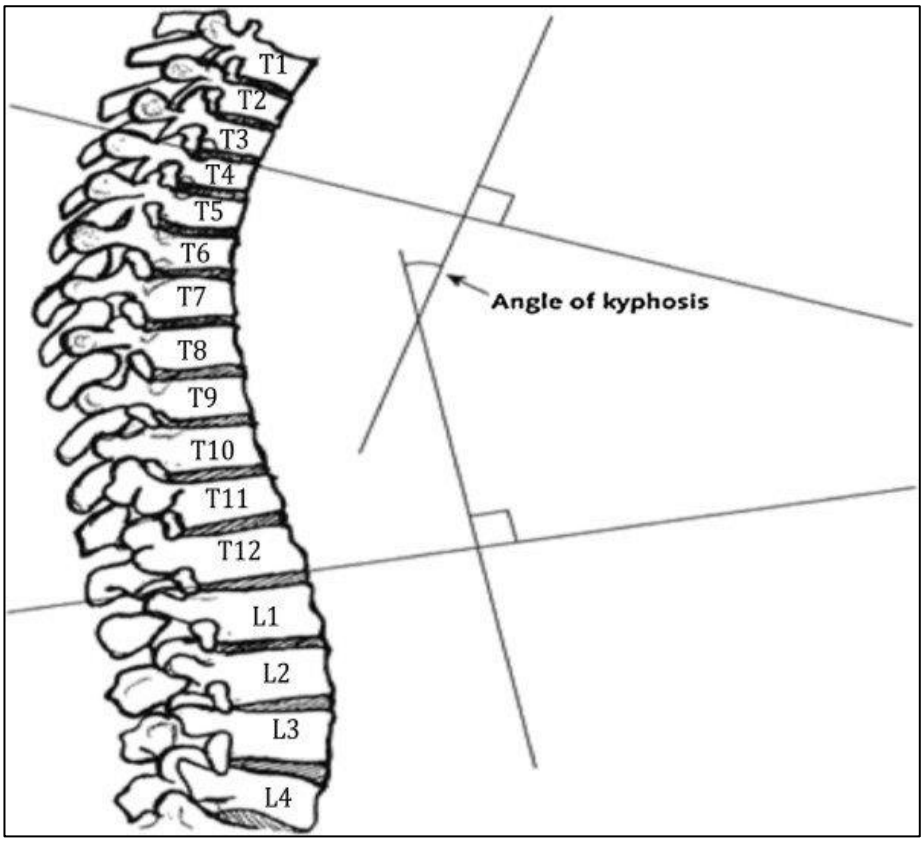


Figure 2-12 Measurement of kyphotic Cobb angle (Moore and Dalley 2006).

Goh et al. (1999) indicate that there is a relationship between degree of kyphosis and the shape of the vertebral bodies but less so for the relationship between kyphosis and the intervertebral

discs. Overall, they noted a trend towards a more noticeable anterior wedging of the vertebral body and intervertebral discs in the mid-thoracic region. The shape of the vertebral bodies and the degree of curvature in the thoracic spine is important because the curved vertebral column is more able to resist compressive loads than an uncurved spine and the curves provide additional flexibility (Levangie and Norkin, 2005). Increased mechanical loading causes passive compression of the intervertebral discs (limited by the zygapophyseal joints and longitudinal ligaments), and dynamic increased curvature (limited by the muscles; erector spinae, multifidus, semispinalis thoracis) that are antagonistic to the movement (Kapanji, 1972).

2.3.7 Cranial and caudal shifts

During development of the vertebrae, most spines are formed with 7 cervical, 12 thoracic and 5 lumbar vertebrae, however, shifts in the differentiating characteristics in the border vertebrae between two regions can occur. Border shifting occurs during development of the sclerotomes as they separate in cranial and caudal halves, with each half joining its neighbouring half (Barnes, 2012). These shifts happen most commonly at the transition zones of the occipito/atlantal, the cervico-thoracic, thoraco-lumbar and lumbosacral junctions.

2.3.7.1 Occipito/atlantal shifts

Cranial shifts occur when the base of the occiput and atlas bones shift upwards (Levangie and Norkin, 2005) leading to fusion of the atlas to the occipital bones. This is a very rare occurrence (0.14 to 0.75% incidence) (Guebert et al., 1987). A cranial shift can also affect development of the dens of the axis leading to presentation as a separate bone, with in extremely rare cases, complete agenesis of the dens (Barnes, 2008).

Caudal shifts in this area are a more common occurrence and can be expressed uni- or bilaterally (Kulkarni and Ramesh, 2012). They can cause the axis to become distorted as it assimilates into the skull base (Moore and Petty, 2005) and can also develop transverse foramina and/or demonstrate a complete anterior arch whilst the posterior arch is often incomplete (Barnes, 2012).

2.3.7.2 Cervico-thoracic shifts

Cranial shifts in this region primarily affect the anterior costal portion of the transverse process of C7 as it is incorporated into the rib-bearing thoracic region (Barnes, 2012). The variations in cervical rib development due to cranial shift can be seen in Figure 2-13. Caudal shifts in this region can lead to the reduction in size of the transverse process and rib of T1 Moore and Petty, 2005).

Cervical ribs are the most common bony anomaly associated with the cervico-thoracic region. They are most commonly seen on C7, although there is evidence that they can extend as high as C4 (Brain et al., 1967; Schmorl and Junghanns, 1971). Barnes (2012) explains this anomaly as the cranial shift of the cervico-thoracic border where the anterior costal portion of the C7 transverse process is incorporated into the rib bearing thoracic region. Cranial and caudal shifts are further described in section 2.2.6. There are different degrees of cervical rib development (see Figure 2-13). The reverse can also happen where there is a caudal shift of the cervico-thoracic junction (Pal and Routal, 1999). This may manifest as shortened abnormally shaped ribs and reduced transverse process size in C7 (Barnes, 2012).

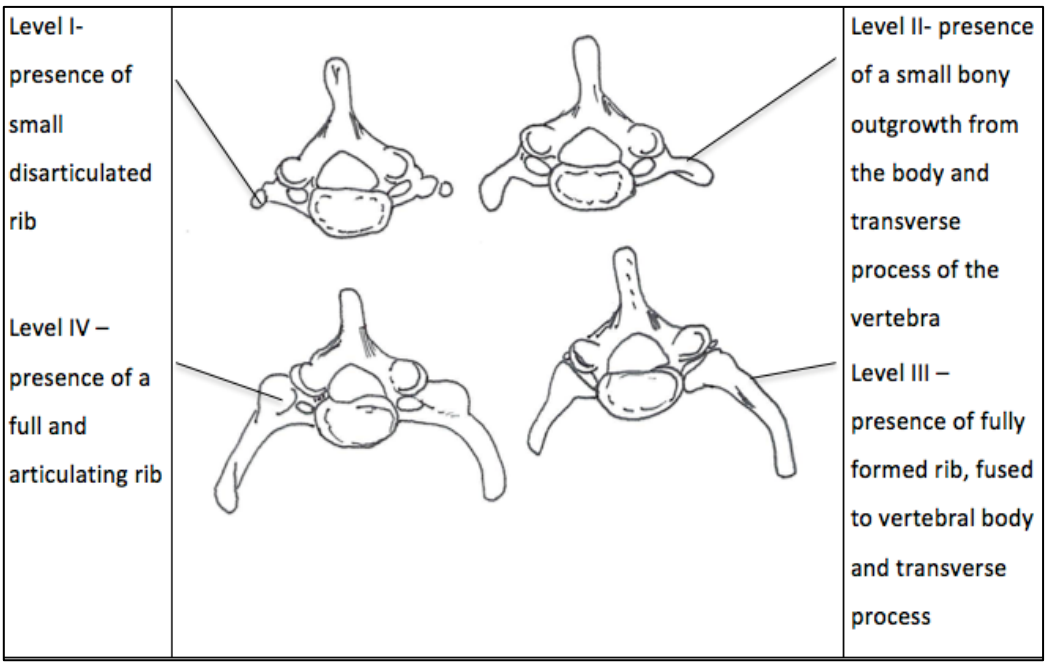


Figure 2-13 Grades of cervical rib (modified from Barnes, 2012:62)

2.3.7.3 Thoraco-lumbar shifts

Cranial shifting in this region leads to a reduction in size or elimination of the 12th rib (Barnes, 2012). The facet joints on T12 are thought to designate the changing border between the thoracic and lumbar section of the spine in many anatomy text books (Snell, 2004; Levangie and Norkin, 2005), however Haeusler et al. (2014) report that between 40%-70% of modern humans are characterised by a change in vertebral articular facet orientation at T11 rather than T12. The broad range of affected modern humans is due to population variation (genetics).

Caudal shifts at the thoraco-lumbar junction can lead to the transverse processes transforming into lumbar ribs, or rib-like projections that are still attached to the vertebrae (Asher et al., 2011). The transitional facets from T12 can shift downwards to L1 (Barnes, 2012).

2.3.7.4 Lumbo-sacral shifts

Cranial shifts in this region can cause L5 to be sacralised and incorporated into the sacrum. This can be complete or incomplete (Bornstein and Peterson, 1966) whereas caudal shifts can cause S1 to take on the characteristics of a lumbar vertebra, sometimes completely separating from the sacrum to manifest as a 6th lumbar vertebra (Asher et al., 2011).

In summary, caudal and cranial shifts can change the characteristics of vertebrae at the regional junctions of the spine. This can cause confusion when identifying vertebrae and create measurements outside the normal range for facet size and angle (Pal and Routal, 1999). Vertebrae that were clearly transitional were excluded from this study.

Figure 2-14 overleaf illustrates the variation seen in rib distribution and also sacralisation and lumbarisation due to cranial and caudal shift.

This chapter has presented the structural, functional and developmental anatomy of the spine. Identification of vertebrae is facilitated by a good knowledge of regional differences in structure but hampered by the effects of cranial and caudal shifts. Vertebrae that were clearly transitional as a result of cranial or caudal shifts were excluded from this study as the variation in facet orientation and size would confound the results. Skeletons with other than normal numbers of vertebrae were also excluded (i.e. 7 cervical, 12 thoracic and 5 lumbar vertebrae).

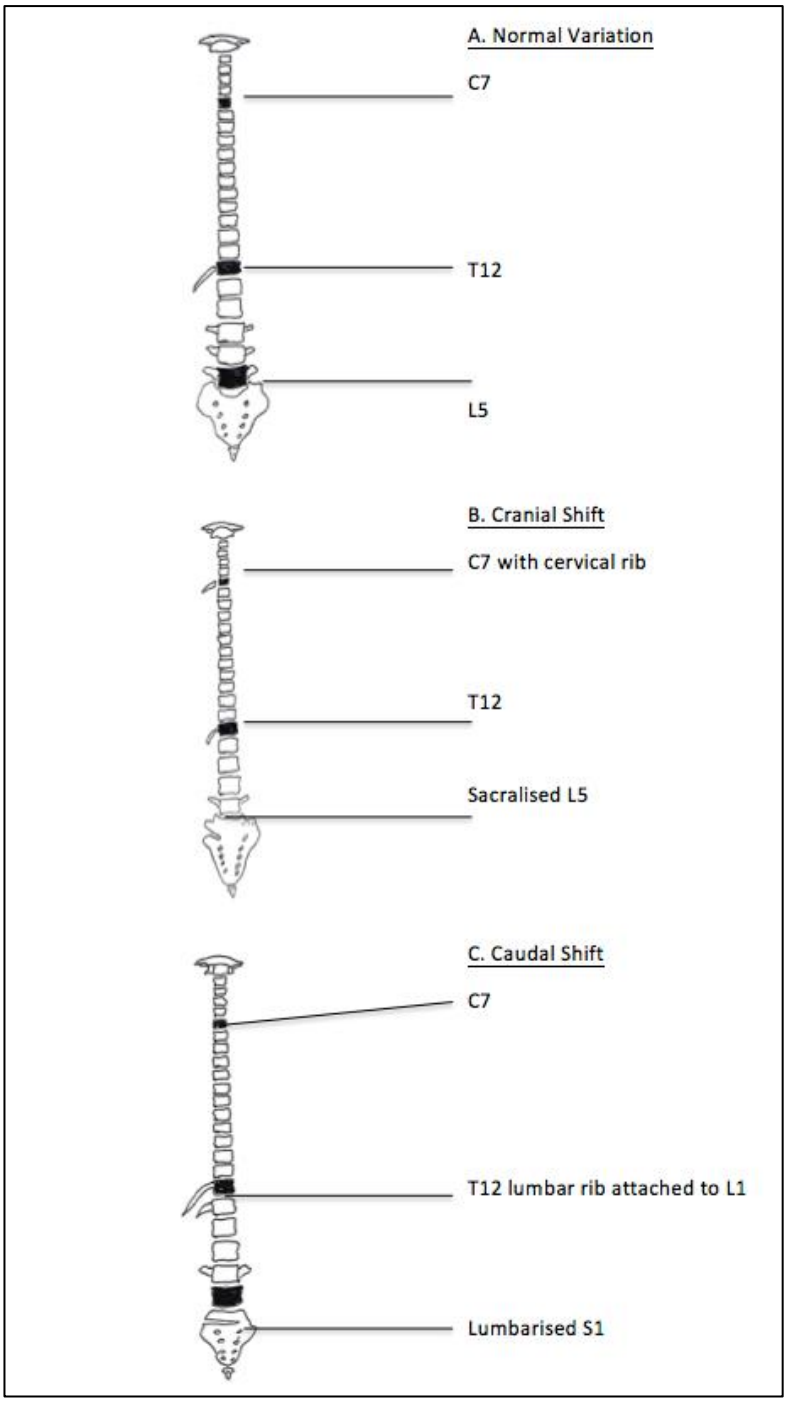


Figure 2-14 Variations in vertebrae and their relationship to ribs (modified from Barnes, 2012)

A) Normal arrangement of vertebrae

B) Demonstrates the effect of a cranial shift with a cervical rib present, that can be seen articulating with C7, a diminished 12th rib articulating with T12 and an incomplete sacralisation of L5

C) An example of a caudal shift, with increased size of the 12th rib and a small lumbar rib. In this situation, it is normal to see larger transverse processes at L4 and smaller than average transverse processes at L5. S1 is partially separated from the sacrum (lumbarisation)

Chapter 3 Sex, Age and Vertebral Morphology

The previous chapter presented an overview of the anatomy and development of the spine from embryo to adult. This chapter builds on that information by considering the relationship between sex, age and changes in vertebral morphology. It includes a review of the literature pertaining to sexual dimorphism of vertebrae from a clinical and archaeological perspective.

3.1 Sex and facet size

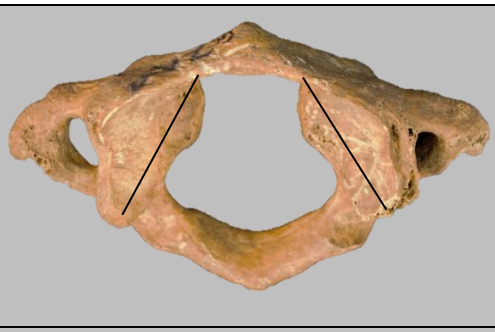
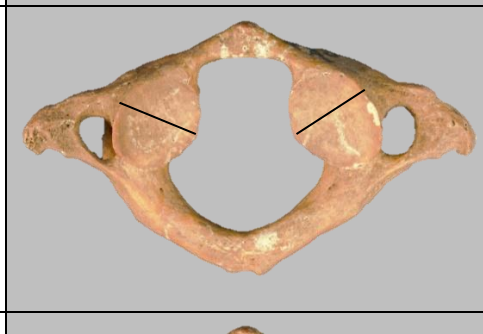
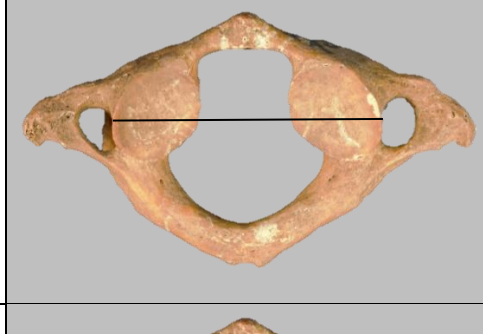
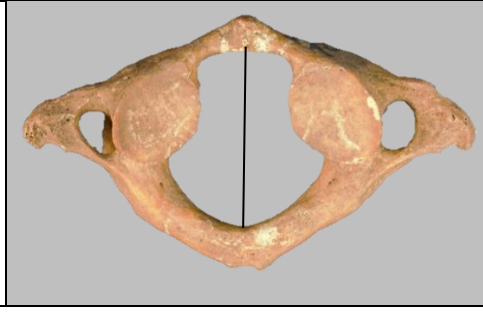
Many osteological elements demonstrate sexual dimorphism in size as well as shape. Sexual dimorphism can be defined as the body size, body shape, behavioural and rate/timing of development differences seen between males and females (Frayer and Wolpoff, 1985; Moore, 2013). It is the result of the complex inter-action of a series of genetic and environmental factors linked to the growth and development of individuals (Cocilovo et al. 2013). It would not be unreasonable to expect to be able to identify sexual dimorphism in the vertebral column given that males generally have larger bodies than females and males tend to develop greater muscle mass leading to increased development of the skeletal system (Cocilovo et al., 2013). However, there have been few clinical and bioarchaeological studies on the suitability of the vertebral column to be used to estimate the sex of a skeleton, possibly because the spine does not carry a sex-specific role.

Early clinical studies of vertebrae were predominantly focussed on comparative measurements without consideration of sexual variation (Aeby, 1879; Anderson, 1883; Cunningham, 1886; Dwight, 1907; Cyriax, 1920; Francis, 1955a) or were descriptive (Putti, 1927; Stewart, 1952; Francis, 1955b). Later studies recognised the possibility of estimating the sex of an individual by assessment of sexual dimorphism in bones and studies of metric variation in the vertebrae were made with varying degrees of success (Marino, 1995; Pastor, 2005). Most studies focussed on a single vertebral level or region of the spine (i.e. cervical, thoracic or lumbar). These studies are reviewed below.

Steele and Bramblett (1988) considered that the C1 vertebra had no previously described anatomical markers that could be considered visually useful as sex or ethnicity indicators, however, Marino (1993) demonstrated that estimation of sex could be reliably determined from C1 (atlas) using metric assessment and discriminant function equations (See Table 3-1, overleaf). He hypothesised that since the superior facets of C1 articulate with the occipital condyles of the cranium and form a load-bearing region, this would manifest as morphological differences between the sexes. He created seven regression and seven discriminant function equations,

concluding that sex could be accurately determined with 60-85% accuracy using data collected from 100 C1 vertebrae from the Terry Collection. When comparing his results with known sex samples from the Hammon-Todd collection, he achieved a success rate of 60-77%.

Table 3-1 Measurements of C1 used by Marino (1995) (author's image)

Measurement	Superior	Inferior
Maximum length of left and right facets		
Maximum width of left and right facets		
Maximum distance between lateral edges of facets		
Maximum vertebral foramen height and width		

Swenson (2013) replicated and expanded Marino's method in an unpublished Master's Thesis. She achieved 75.7-89.1% accuracy for sex estimation. She explained the difference in accuracy as being due to the use of three ancestral groups (Caucasian, African American and Hispanic) whilst Marino used two (Caucasian and African American). She argues that the introduction of a third group into the study led to increased variation and thus greater misclassification particularly of

the Hispanic group. These individuals tend to be more gracile and there was a higher likelihood that males could be identified as females when looking at all three groups. Marino (1997) found that some measurements differed between the two groups and that the overall measurements were slightly greater in Caucasians that in African Americans. However, the outcome supports Marino's hypothesis that C1 can be used to determine the sex of an individual with reasonable accuracy, with the caveat from Marino:

> *"Before any reliance is placed on this technique within forensic applications, more work with larger and more geographically and temporally diverse populations should be conducted"* (Marino, 1995:132).

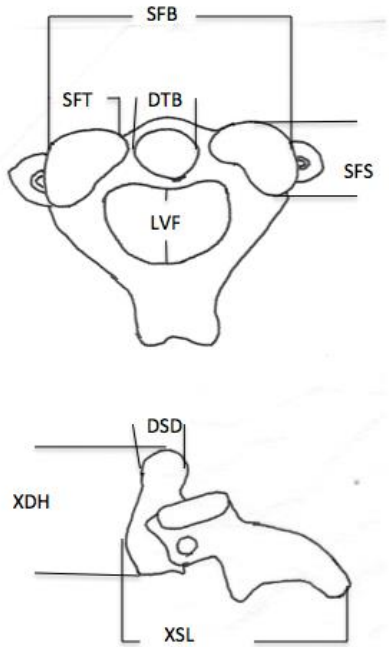
Sexual dimorphism has also been demonstrated in C2 for eight measurements made by Wescott (2000) (Table 3-2 overleaf) He collected his data from a sample of 200 males and 200 females from the Hamman-Todd and Terry anatomical collections and generated five discriminant function equations using a stepwise discriminant analysis that selected the variables that had the greatest amount of discriminating ability. Using a cross validation procedure, it was found that an accuracy of 89% for the "White" sample, 81% for the "Black" sample and a range of 81.7-83.4% accuracy across the whole sample could be achieved depending on the function used. He identified the maximum length of C2, maximum length and width of the superior facet, length of the vertebral foramen and maximum height of C2 to be the most discriminating measurements.

Marlow and Pastor (2011) blind tested Wescott's method to validate its ability to accurately determine the sex of individuals from the Spitalfields collection (of known sex). They were able to validate Wescott's claims that C2 can be accurately used to determine the sex of human skeletal remains however, they noted a decrease in overall classification accuracy when compared to Wescott's results and ascribe this to population variability. They noted that the maximum distance between superior facets was the best discriminating measurement, followed by the maximum length of C2, maximum width of vertebral foramen and odontoid process sagittal diameter.

Schaffler et al. (1992) were also able to demonstrate sexual dimorphism using the dens of C2. Their study was of 120 individuals (males/females, whites and blacks) from the Hamman-Todd collection. They made seven measurements relating specifically to the dens as part of a clinical study. They identified that the height of the dens, the anterior and posterior height of the vertebral body and the antero-posterior diameter of the dens were dimorphic with the relative dimensions consistently skewed towards higher values in males and lower values in females. This research was investigating sex differences in morphology from a clinical viewpoint and not as a

means of estimating the sex of an individual and therefore no measure of accuracy was calculated. The dens was estimated to be 5-10% larger in males than females.

Table 3-2 Measurements of C2 (Wescott, 2000)

Measurement	From (Wescott, 2000)
XSL maximum sagittal length	
XDH maximum height of dens	
DSD maximum antero-posterior diameter of dens	
DTD dens transverse diameter	
LVF length of vertebral foramen	
SFB maximum breadth across superior facets	
SFS maximum sagittal diameter of superior facet	
SFT maximum transverse diameter superior facet	

Medina (2011) took 14 measurements from C2 and achieved a percentage of correct classification of 84.2% using individuals from a Columbian sample. He reported that the sagittal maximum body diameter, the maximum length of the superior facet, the length of the vertebral foramen, the maximum width of the superior facet and the maximum distance between superior facets were the most useful measurements for sex estimation.

Bethard and Seet (2013) published a further validation of Wescott's method. They tested the applicability of the method against a modern American sample and again achieved comparable results, reiterating that C2 is a sexually dimorphic bone and effective predictor of sex. They noted that for their population they achieved a degree of accuracy of 86.7%, this is in contrast with Marlow and Pastor's (2011) results that achieved an accuracy of 77.6% when tested against the Spitalfields population. This supports the need to develop population specific methods of sex estimation as identified by Spradley and Jantz (2011).

Gama et al. (2015) developed Wescott's method further and used 13 dimensions from C2 to develop logistic regression models to estimate sex with a similar degree of accuracy (86.7 to 89.7%) for a Coimbra skeletal sample. They found that the most discriminating variables were the maximum width of C2, the sagittal body diameter, the maximum length of C2 and the maximum width of the right superior facet.

Haugen (1994) focused on the spinous process as part of her study on sex differences in the cervical spine. She used four measurements of the spinous process to assess vertebral sexual dimorphism from C2-C7 (C1 does not have a spinous process). Vertebral body height was also measured. All measurements were found to be sexually dimorphic with a 68-95% accuracy rate in estimation of sex, with slightly higher accuracy for females than males. She noted that female vertebrae were proportionally smaller than male vertebrae.

Several researchers have attempted to identify sexual dimorphism of the vertebral foramen in the cervical spine, with potentially conflicting results. Hashimoto and Tak (1977) and Hukuda and Kojima (2002) failed to identify differences in measurement of the anteroposterior diameter of Japanese male and female vertebral foramina. These results are in contrast with those of Payne and Spillane (1957). They identified small variations in the anteroposterior diameter of the cervical vertebral foramina in a sample of males and female from the U.K. but did not include detail on the statistical significance of the differences, making the significance of the differences difficult to interpret. However, Tatarek (2005) (using African American and Caucasian samples) and Lim and Wong (2004) (using a Chinese sample) demonstrated a statistically significant difference in the anteroposterior diameter of the vertebral foramen and identified the difference as being sexually dimorphic. The data for these studies was collected from different populations, which may have led to the contrasting outcomes. It has been identified that there is a need to identify population specific methods of sex estimation (Spradley and Jantz, 2011). The studies described above demonstrate that different populations may give different results for the same measurement, supporting the argument of Spradley and Jantz (2011). Kajanoja (1966) and Williams (1987) have both reported that discriminant functions for sex determination developed for one population can lead to incorrect sex determination of 32-48% of individuals from a different population.

Amores et al. (2014) investigated sexual dimorphism in C7 and T12 from San Jose cemetery in Granada, Spain using a sample of 121 individuals documented for sex, age and cause of death. The aim of the study was to measure the degree of sexual dimorphism in a southern Spanish population and to establish the accuracy of C7 and T12 for sex estimation. The measurements taken are listed in Figure 3-1. Unlike many of the other studies of sexual dimorphism of the

vertebrae, both right and left measurements were taken. The majority of studies discussed in this section took measurements from the left side only, as this is considered to be the standard side to use during skeletal analysis (Buikstra and Uberlaker, 1994) and measurements are only taken from the right side in the absence of the left. This does not allow for the effects of vertebral asymmetry and the potential effects of hand preference to be taken into account (See section 5.7.7). Amores et al (2014) did not find any significant asymmetry in their measurements but did find significant differences between males and females in terms of size of most measurements with the exception of the length of the superior and inferior facets of C7 and the inferior facets of T12. They identified an accuracy rate of 65.5-70.1% for univariate analysis but this increased to 80% when combined in a multivariate function. They emphasised the need to apply discriminant function equations in populations with similar characteristics.

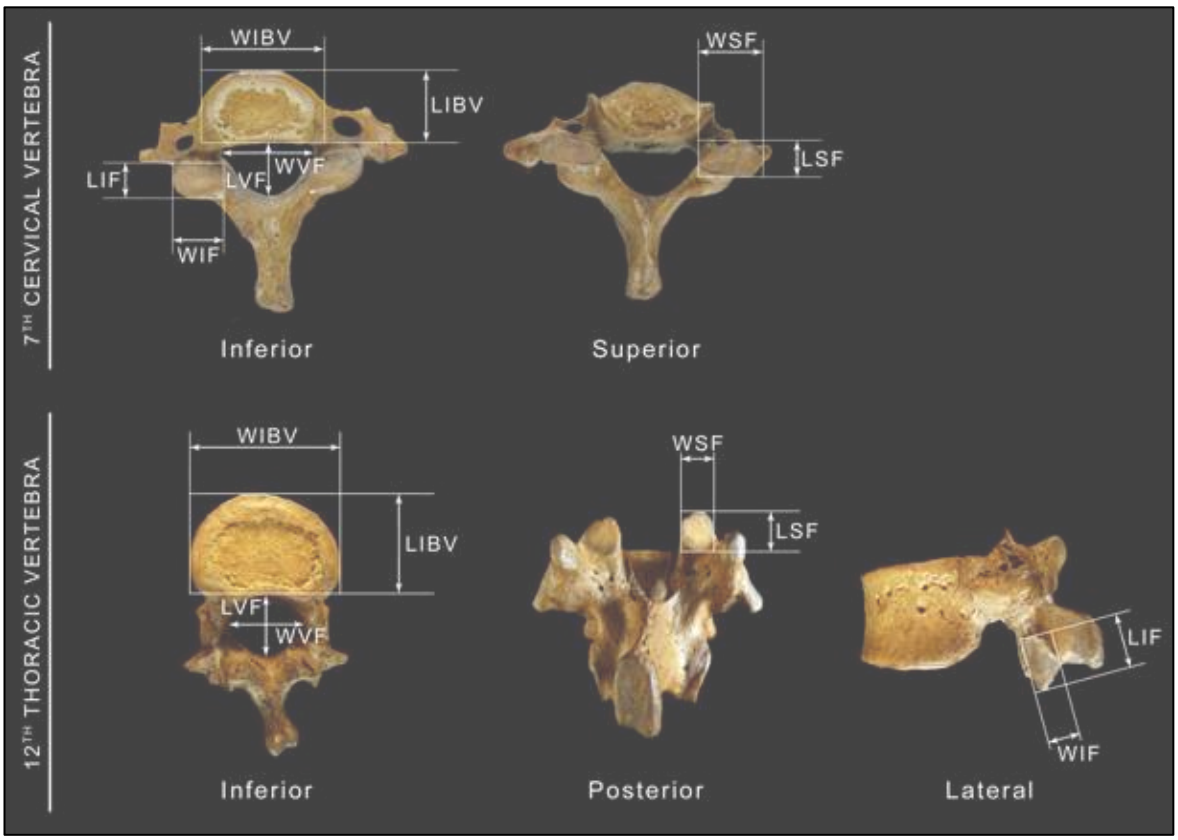


Figure 3-1 Measurements from C7 and T12 (Amores et al., 2014).

Studies of the vertebral body dimensions in the cervical spine have reported differences in vertebral body height and anteroposterior measurements that relate to sex differences (Katz et al., 1973; Liguoro et al., 1994; Kwon, 2004). The sex differences seen in vertebral body measurements can be seen at other levels of the spine as identified below.

Bastir et al. (2014) investigated sexual dimorphism of the thoracic spine in relation to respiratory function using data collected from a skeletal collection curated at the School of Legal Medicine,

Madrid. The sample was of known sex and age at death. They assessed size and shape of the first 10 thoracic vertebrae using 3-D geometric morphometric analysis and identified that there was significant evidence for sexual dimorphism in size and shape of the vertebrae with transverse processes orientated dorsally in males and ventrally in females, the neural canal is relatively larger and more circular in females, the facets for articulation with the rib-tubercles are slightly more superiorly orientated in females leading to greater cranio-caudal inclination of the ribs in females. In the lower thoracic region only, the female spinous processes have a more horizontal (superior) orientation. The difference in regional factors may be related to the greater respiratory capacities seen in males (Bellamare et al., 2003) and the increased lordotic obstetric adaptation in females proposed by Whitcome et al. (2007) and Masharawi et al. (2010).

The posterior transverse diameter, the anteroposterior diameter and the anterior transverse diameter of vertebral bodies of the thoraco-lumbar transition area (T11, T12, L1) from 207 adults from Spitalfields Cemetery in London 18th century was assessed for sexual dimorphism by MacLauglin and Oldale (1992). They were able to demonstrate sexual variation with all measurements achieving a minimum reliability of accuracy of 70% and the anterior transverse measurement of T12 achieving 87% accuracy for correct classification of males and females. Pastor (2005) also investigated T12 and L1 vertebral levels and compared samples from the Spitalfields and Terry collections and demonstrated that out of 12 measurements, 8 showed significant sex variation allowing for accuracy levels in sex prediction of between 76-91%. Eisenstein (1983) achieved similar results in identifying sexual variation of the mid-sagittal and transverse diameters of the vertebral foramen and body. Yu et al. (2008) and Hou et al. (2012) investigated the suitability of T12 for the estimation of sex. Yu et al. (2008) took 33 linear measurements and derived two ratios from 102 T12 vertebrae listed on the Digital Korean database (a collection of 3D models of whole skeletons of Korean individuals created from computed tomography of donated cadavers). They identified 23 sexually dimorphic measurements and were able to predict sex with 62.7-85.3% accuracy using discriminant function equations. They noted that the coronal dimensions of the vertebral body (superior and inferior coronal diameter of endplate and superior and inferior maximum coronal diameter of endplate) were the most sexually dimorphic features of T12. Hou et al. (2012) gathered similar data from the T12 of 141 three dimensionally reconstructed vertebrae. They acknowledged that that metric elements of humans are population specific and their aim was to develop population specific functions for sex determination based on T12 in a contemporary north-eastern Chinese population. Of their 30 linear measurements, 28 were found to be sexually dimorphic. They were able to achieve 56.4-90.1% accuracy in predicting sex when using univariate discriminant function equations and when using four variables (superior maximum sagittal diameter of endplate,

inferior length of whole vertebra, distance between superior articular processes and the ratio of anterior/posterior height of the vertebral body) achieved an accuracy of 94%.

Zheng et al. (2012) identified 23 linear measurements and two ratios that provided a predictive accuracy of 57.1%-86.8% for L1 from a sample of 210 individuals from a Chinese population. Their measurements were from CT images rather than dry bones. They argue that this method is of similar degree of accuracy as from dry bone measurements, citing the work of Reid et al. (2008) who demonstrated that CT is as accurate as callipers and more accurate than computerised radiography. The highest precision of accuracy was calculated from the upper end plate width, the left pedicle height and middle end plate width.

A clinical magnetic resonance imaging (MRI) study of two cohorts of living individuals was used by Oura et al. (2018) to estimate sex using vertebral body measurements of L4 from a Finnish sample. The two cohorts consisted of a younger group (20-30 years) comprising 375 individuals and an older group (46+) comprising 1363 individuals. Data were collected from MRI scans, but individuals with degeneration or osteoporosis were excluded. They were able to achieve accuracies of 86.4% for the younger cohort and 82.8% for the older cohort.

There are a number of clinical studies that provide data relating to average zygapophyseal joint measurements across the whole spine, but they do not differentiate their results in terms of the age and sex of individuals being studied (Panjabi et al., 1993; Mahato, 2011). Masharawi et al. (2005) noted that facet size is greater in males than females, regardless of vertebral level and emphasised the importance of separating the data by sex and age in order to prevent misleading data being collected which increases difficulty in cross study comparisons. None of these studies, however, consider the influence of pregnancy of the size of the facet joints. Whitcombe et al. (2007) report that lumbar spine facet surface area is 14 ± 3% larger relative to vertebral body size in females. They consider that this is due to the redistribution of vertebral load during pregnancy.

In summary, a variety of different measurements have been used in sexual dimorphism studies of the vertebrae, with few focussing on the facet joints and most studies investigating specific spinal regions or vertebral levels. Although there is awareness of the population specificity of discriminant and logistic regression equations, there is less awareness of secular trends. The literature provides good evidence that the sex of an individual can be estimated from vertebrae.

3.1.1 Sex and facet joint orientation

The definition of facet angle is unclear and lacking consistency in the published literature. The literature reveals that measurement of the angle in the sagittal plane is referred to as the angle of

inclination (Tulsi and Hermanis, 1992), disc-facet angle (Boyle et al., 1996), the sagittal angle plane (Panjabi et al., 1993) or the transverse angle (Masharawi et al., 2008).

For the purposes of this study, the sagittal facet angle is defined as the angle between a line drawn across the lateral and medial borders of the facet and a line drawn between the junction of the lamellae and the centrum of the vertebral body i.e. along the sagittal plane (angles A and B in F**igure 3-2**).

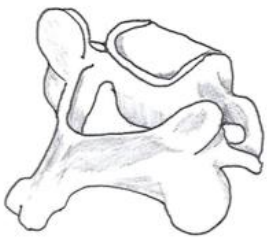
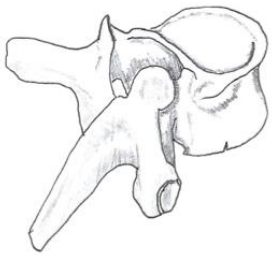
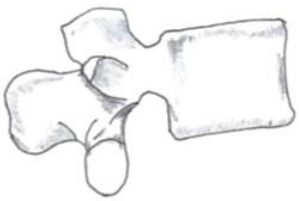
Figure 3-2 Measurement of facet angle (L2 from GC100, author's image)

The orientation of the facets of typical vertebrae for each region is illustrated in Table 3-3 (overleaf). In the cervical region C1 and C2 are atypical, C1 having no vertebral body or spinous process, C2 also having no vertebral body but having an odontoid process.

As can be seen from the diagrams in Table 3-3, there is a change in orientation from the cervical to the lumbar region. The vertebral level of change between the cervical and thoracic region can occur anywhere between C4 and T1 with C6 being the most common site of transition (Pal and Routal, 2001). The level of change in angle between the thoracic and lumbar region usually occurs at T11 but can be T12 or T10 (Davis, 1955; Shinohara, 1997; Singer et al., 1988). Most of differences in transition area can be explained by natural variation ,but rarely there is a caudal or cranial shifts at the cervico-thoracic and thoracolumbar junctions, where the vertebral segment takes on the characteristics of the region above or below it (Barnes 2012). These shifts can lead to

extreme variation e.g. cervical or lumbar vertebrae having ribs attached, or mild variation e.g. mild cranial variation can cause a shift in the facet orientation of the transitional vertebrae giving rise to effects described in section 2.3.7. Spines that clearly demonstrated cranial or caudal shifts were excluded from this study.

Table 3-3 Facet orientation of typical vertebrae (author's image)

General Characteristics of Facet Orientation	Diagram of Typical Vertebra
Cervical Region: superior facets face superiorly and medially whilst inferior joints face anteriorly and laterally (Panjabi et al., 1993).	
Thoracic Region: Superior facets face posteriorly, superiorly and laterally whilst inferior facets face anteriorly, superiorly and medially (Moore and Dalley, 2006).	
Lumbar Region: Superior facets face postero-medially, whilst inferior facets face postero-laterally	

During the 1950's it was noted that there was very little published accurate information about the orientation of the facet joints at all levels of the human spinal column (Stewart, 1952) and indeed very little published on vertebral morphology. Overton and Grossman (1952) examined variations of the articular facets by measuring facet diameter, sagittal and vertical angles between C2 and C3 from 36 specimens. They noted that variations of angle of inclination from the vertical, between left and right sides were not a rare occurrence and also that variation in size between the left and right facets was observed in 44.2% of the specimens. Francis (1955) undertook a systematic study of the facet joints of 284 sets of cervical vertebrae from young adults where age,

sex and ethnicity were known. The data were collected from a documented skeletal collection curated at the Western Reserve University U.S.A. His aim was to record the natural variations that occur. He took various measurements, including largest diameters of the facet joints in planes parallel to the sagittal and frontal planes and described their orientation. His sample excluded vertebrae with signs of pathology such as degeneration. His work can be criticised in that some of the vertebrae used had suffered post-mortem damage and he stated that some of his measurements were approximate. Francis' (1955) research was aimed at identifying variation in cervical facet joints between males and females of American "White" and "Negroid" ethnicity and was not a study of sexual dimorphism. He reported that the facets from male vertebrae were generally bigger than those of females, but the results were based on descriptive statistics and the significance of the results not statistically analysed. This limits the validity of the reported results.

Although clinical studies are interested in collecting data on facet angle for morphometric studies, there are few published papers directly comparing male and female results. Many studies use male skeletons only (Pal and Routal, 2001; Masharawi et al., 2004; Masharawi et al., 2007). The reason for this is not justified within the research but it may be an attempt to control for possible differences in sex.

Boyle et al. (1996) undertook a study of the morphological changes that occur in the cervico-thoracic junction of the spine, to provide information on the morphology of the region and quantify the facet orientation in both the sagittal and transverse planes, in order that anatomical variations and the effects of degeneration and trauma could be identified. Significant differences between the sexes were identified when measuring sagittal facet angles of the cervico-thoracic spine from the disarticulated skeletons of 26 male and 25 female individuals. This result conflicts with results reported by Milne (1991), who found significant differences in linear but not in angular measurements of the cervical spine. Milne hypothesised that the orientation of the facet joints with respect to the disc-facet angle in the cervical spine is greater in the upper cervical region, to allow for different degrees of rotation in the cervical spine. He did not know the age of his samples but obtained separate results for males and females.

Both Milne (1991) and Boyle's (1996) research was carried out on the skeletal collection held at the University of Western Australia. It is not clear whether the same specimens were used. They both used a zygapophyseal endplate protractor to measure the disc facet angle. Milne's (1991) work focussed on the upper cervical spine whereas Boyle (1996) focussed on the lower cervical spine at the cervico-thoracic junction. Neither researcher commented on the age at death of their

samples. There is evidence that facet joints reorientate with age (discussed in section 3-2) and this may account for the conflicting results achieved by these two studies.

There is little published literature on sex differences in facet orientation in the thoracic spine. Masharawi et al. (2004) published a comprehensive database of zygapophyseal joint orientation in the thoraco-lumbar vertebrae using three-dimensional measurement of 240 vertebral columns from the Hammon-Todd Collection. They measured longitudinal and transverse angles in groups classified by age, ethnicity and sex. They found no significant difference between groups in the orientation of the thoraco-lumbar facets but did note that facet size was independent of age and that males had statistically significantly larger facets than females. They did not take body size as a confounding factor into account. The thoracic vertebrae demonstrated asymmetry in orientation but they considered this to be anatomical variation. They noted that the facets at the thoraco-lumbar junction could be antero-posteriorly orientated as seen in the rest of the thoracic spine, or postero-medially orientated as seen in the lumbar spine. They recorded these differences as being natural variation and did not make any comment on thoraco-lumbar shifts as a possible reason for the variation.

Tulsi and Hermanis (1993) found a small but significant statistical difference in the sagittal angle and facet depth of the facets of the lumbar region in a clinically based study of 64 male and 48 female disarticulated spinal columns. They identified asymmetry of less than 10^0 (i.e. considered symmetrical) in 91% of all vertebrae with the exception of L3, where asymmetry was found in 69% of male vertebrae and 71% of female vertebrae. They raised an interesting limitation to their research in that there is little or no information on the thickness or configuration of articular cartilage in living subjects and the effect this may have on the morphology of the facet surface. Archaeological samples do not tend to have articular cartilage remaining. This is advantageous in that the bony surface of the facet can be visibly examined; however, it limits the translation of results from archaeological studies into clinical research.

Whitcombe et al. (2007) report that that facet angles at L2, L3 and L4 are considerably more coronally orientated in females (13 ± 5% when compared to males). Masharawi et al. (2010) also report a similar finding. This allows for increased resistance to shearing forces and increased lumbar lordosis caused by the weight of the developing baby.

A criticism of some of the existing research into facet orientation discussed above is that samples were not always controlled for age. It has been reported that the facets reorientate with age (Adams and Roughly, 2006), however this has been mostly reported in the lumbar region of the spine. A number of studies have identified reorientation of the lumbar facet joints with age (Love et al., 1999; Cohen and Raja, 2007; Wang and Yang, 2009). Difficulties in comparison of cross

study results occur when age has not been factored into the research method and widely different methods of measurement are used. Furthermore, the effects of activity related markers on vertebrae, in particular the relationship between activity, size and angle were not taken into consideration in any of the studies described above. The orientation of the facet surfaces changes according to the functional and mechanical requirement of each vertebral level (Williams, 2000).

3.2 Age and facet size

There is evidence that vertebral morphology varies with age (Kim, 2013). To be able to test the relationship between age and facet size and angle, the age of the individuals must be estimated with a degree of precision. This is not a simple process. This section will review the brief literature related to the relationship between age and facet size and angle. The difficulties of aging an individual and the limitations of using age groups are discussed in section 5.7.3 in Chapter 5.

The literature suggests that the age at which an activity began and ceased, the frequency and intensity, duration of the activity as well as the type of mechanical load applied to the body and the particular bony element under load are all factors that may affect bone morphology in relation to age. There are contrasting reports on the effects of aging on spinal morphology. A number of studies have reported small but significant changes in spinal dimensions when correlated to age; overall shape of the lumbar body, in particular endplate transverse diameter and minimum transverse diameters increasing in size (Erikson, 1976), vertebral body anterior and posterior height and middle body breadth (Jankauskas, 1994), cervical foramen diameter (Humphries et al. 1998), body cross sectional area (Mosekilde and Mosekilde, 1990), lumbar neural canal width (Tatarek, 2001), sagittal and transverse body diameter and pedicle height (Rühli et al. 2005), anterior, middle and posterior vertebral body heights (Whitmarsh et al. 2012) and spinal canal diameter and vertebral body height (Kim, 2013). The results of these studies are in contrast to the study of vertebral heights by Black et al. (1991) who measured vertebral height dimensions from the lateral spinal x-ray of 2992 women aged between 65-70 years of age They compared their results to a similar study of premenopausal women and found that there was no significant difference in dimensions in non-fractured vertebrae.

The influence of age on vertebral facet joint orientation has been a point of debate with contrasting results being published. Wang and Jang (2009) and Jentzsch et al. (2013) identified variation in lumbar facet orientation that was linked to age, with the facets becoming more sagittal in orientation. Wang and Jang (2009) carried out a study of facet orientation with age and identified a negative correlation between coronal orientation in the facets between L4 and L5 and age, with the facets becoming more sagittally orientated. They considered this to place older

individuals at increasing risk of degenerative spondylolisthesis. Their study involved assessing CT scans from 159 men and 141 women divided into 6 age groups (1: <30 years, 2: 31-40 years, 3: 41-50 years, 4: 51-60 years, 5: 61-70 years and 6: >70 years). They did not identify any statistically significant sex-related differences in coronal orientation. Jentzsch et al. (2003) retrospectively analysed CT scan images from 418 males and 202 females in their study of facet orientation and facet joint arthritis in the lumbar spine. Whilst they differentiated between males and females for osteoarthritis prevalence, the data were combined for the sexes for results for facet orientation. They reported increased coronal orientation of the facet joints at L5/S1 in participants ≤ 40 years of age and increased sagittal orientation at the same vertebral level in individuals ≥41 years of age. They did not find any statistically significant changes at other spinal levels in the lumbar spine. In contrast, Masharawi et al. (2004) and Çubuk et al. (2009) found that there was no correlation between age and facet orientation in the lumbar spine. Wang and Yang (2009), Jentzsch et al. (2003), Masharawi et al. (2004) and Çubuk et al. (2009) all collected their data from measurements of CT and x-ray images from clinical experiments on living participants. There are few if any published studies on the effects of age on the cervical and thoracic facet joints. The focus of clinical studies is on the lumbar region due to the links between facet orientation and spondylolisthesis and degenerative joint disease.

3.2.1 Age and osteophytosis

Degenerative change in the form of osteophytosis (osteophytic growth around the perimeter of the vertebral body as a compensation of the effects of degeneration of the intervertebral disc) is the most common general indicator of age in in the vertebrae (Stewart, 1966) It is visible as osteophyte formation around the edge of the articular surface of the vertebral body. Males and females show similar patterns of age-related changes in the development of vertebral body osteophytes but with females showing greater variability (Snodgrass, 2004). Snodgrass (2004) results indicated that the changes, measured on a 0-4 scale after the method described by Stewart (1973), could not be reliably used to estimate age at death, but the presence of extensive osteophytosis could help identify a vertebra from an older individual. Listi and Manheim (2012) expanded on the work done by Snodgrass (2004) to investigate the use of vertebral osteoarthritis and osteophytosis to estimate age at death, scoring the vertebral bodies and facets for degenerative change in 104 individuals from the Bass Collection. They achieved results indicating that the degree of osteophytosis is correlated with age, however the relationship is too weak to enable any more than a general estimate of age at death. Watanabe and Terazawa (2006) disagreed with the results of Snodgrass (2004) and Listi and Mannheim (2012) when they analysed the relationship between osteophyte formation and age in a Japanese population. They

formulated an 'osteophyte formation index' based on grading scores of 0-3 (no osteophyte to large osteophytes) at the anterior and bilateral surfaces of the superior and inferior margins of the vertebral body. They took the maximum score for each spinal level to use in their analysis and averaged the maximum values at each region (cervical, thoracic and lumbar) to define their 'osteophyte formation index'. Their analysis demonstrated a significant correlation between the osteophyte formation index and age at every level of the spine. This method requires data to be collected from the entire spine and therefore would not always be valid as an ageing tool in archaeological samples with poor preservation.

The increased presence of osteophytosis on the vertebral body is related to age and changes the morphology of the vertebral body but would not be accurate tool for the estimation of age at death. The evidence described above indicates that the relationship between osteophyte score and age is weak and would provide a general estimate of age when individual vertebrae are considered. The osteophyte formation index of Watanabe and Terazawa (2006) requires a complete set of data from the spine, something that would be problematic in many archaeologically derived samples.

3.2.2 Summary

In summary, there is plenty of evidence for the existence of sexually dimorphic traits in vertebrae; however, few bioarchaeological studies focus on the zygapophyseal joints in vertebral sexual dimorphism studies. Even fewer consider the sagittal angle of orientation of the facet joint as a potentially dimorphic feature. Whilst it is known that there is sexual dimorphism of angle in the lumbar spine due to the effects of pregnancy, little is known about differences between the sexes, of facet angle in other areas of the spine.

Chapter 4 Bioarchaeology and Activity

The previous chapter reviewed the literature pertaining to vertebral sexual dimorphism and the effects of aging on vertebral dimensions. Whilst it is clear that vertebrae are sexually dimorphic, all the studies reviewed excluded facets that showed signs of degeneration. Degeneration may be used as a marker of differing physical activity. Bones undergo functional adaptation as a result of the stresses and strains they are continuously subjected to. An understanding of the relationship between degree of degeneration with facet size and angle may help to explain inter-sample/population differences in facet size and angle within the samples chosen from this study as they are from differing socio-economic groups and temporal periods, i.e. differing lifestyles and activity patterns. It is therefore useful to describe the biocultural model that is an important bioarchaeological approach to creating an understanding of lifestyle. This discussion is followed by a review of the evidence that biocultural adaptation can be preserved in human bone as physiological stress markers.

This chapter continues with a discussion of bone plasticity, reviewing models of bone functional adaptation before considering biocultural features that can affect bone morphology such as diet, disease and age at death. The final section will review the use of markers of occupational stress in the reconstruction of lifestyle, in particular degenerative changes, and ends with an overview of osteoarthritis including classification, diagnostic criteria, aetiology and the relevance of vertebral osteoarthritis to bioarchaeology. Osteoarthritis of the facet joints is a particularly useful pathology when comparing populations in this study, as differences in distribution may reflect differences in culturally based activities (Jurmain and Kilgore, 1995). Robson Brown et al. (2008) consider that the diagnostic markers for degenerative joint disease are predictors of mechanical loading in life. Therefore, comparison of distribution and degree of severity of osteoarthritis will allow for comparison of physical activity and lifestyle of the samples under study and may be related to bone remodelling of the facet joints

4.1 Bioarchaeology

Bioarchaeology is an interdisciplinary endeavour focused primarily on questions of quality of life, behaviour and lifestyle, biological relatedness and population history through the study of human skeletal remains within their archaeological context. This is achieved by the integration of paleodemography, paleopathology, biological anthropology, archaeological theory and method, medical science and other related disciplines (Larsen, 1997; Knüsel 2000; Pearson and Buikstra, 2006).

The importance of bioarchaeology in the understanding of the past has only been realised in fairly recent times, with the term "bioarchaeology" deriving independently in the United Kingdom and United States in the 1970's. The two derivations had distinct definitions. Clark (1972) first used the word in the title of his study "*Starr Carr: A Case Study in Bioarchaeology"* to describe inferences from the study of faunal remains from archaeological contexts. Clark re-worded the definition in 1973 by describing bioarchaeology as:

> *"The archaeology concerned first and foremost with life"* (p. 464) and
>
> *"The archaeology of how men occupied territories and maintained life"* (p. 466).

After being influenced by the "New Archaeology" proposed by Binford (1962), Jane Buikstra independently invented the term "Bioarchaeology" in 1977 in reference to the merging of physical anthropological methods with archaeology. She describes it simply as:

> *"The contextual analysis of human populations from archaeological sites"* (p. 67).

She identified the need to use this new integrated approach of interdisciplinary and cross-cultural research tools to generate and solve research questions about how past populations lived in contrast to the descriptive skeletal studies previously used that only focused on individuals and the osteological and paleopathological aspects of medical and forensic examination. The fundamental need for an integrated approach is supported in the following quotation:

> *"…. we cannot take an empiricist view and assume that the osteological data speak for themselves…. as the body is simultaneously biological, representational and material". (Sofaer, 2006:11).*

This integrated approach can identify life experiences that affect human biology but may not be apparent in the archaeological or historical evidence (Swedlund and Herring, 2003; Sofaer, 2006). It adds emphasis to the importance of analysing the social process underlying biological variation such as chronological and physical aging, the sexual division of labour and access to adequate nutrition.

The main approach to bioarchaeology is through bioculturalism. The biocultural approach in bioarchaeology is described as problem orientated, examining the interrelationships between humans and their larger social, cultural and physical environments, (i.e. population based) (Buikstra, 2006). It provides a method for cultural comparison and can be applied to individuals and populations throughout time and place (Armelagos, 2008). It is explicit in the emphasis between interaction of humans with their physical, social and cultural environments (Dufour,

2006), with biology and culture being dialectically entwined (Levins and Lewontin, 1895).

Biocultural adaptation is preserved in the composition of the bones as human variability that develops as a function of the body's response to environmental factors and is also recorded in the context of the deposition of the remains (DiGangi and Moore 2013). Recognition of physiological stress marks on the skeleton has been a landmark in biocultural study, becoming an important area for research (Buikstra, 1991). Studying human remains from a biocultural perspective can help to contribute to an understanding of the life and health of that individual in the context of a larger society by the emulation of the real world in order to understand the environmental and cultural context of the population under investigation (Buikstra, 1977:82; Goodman and Leatherman, 1998:228).

There has been much criticism of the biocultural approach and the emphasis it places on the analysis of the social processes that affect biological variation, particularly the "adaptionist" program and the tendency to naturalise social process (Orlove, 1980; Singer, 1996). Segal and Yanagisako (2005) mounted a challenge against bioculturalism, arguing that there should be increased specialisation and separation between the sub disciplines to limit biological and adaptationist interpretation over socioculturalism. Zuckerman and Armelagos (2011) countered their criticism arguing that the separation and individualisation of methods suggested by Segal and Yanagisako is a misinterpretation of the basic principles of the biocultural approach and is a retrograde step in the development of bioarchaeology.

Buikstra (1991) identified that the study of physiological stress marks on the body is important in biocultural studies of archaeological skeletal remains. The next section will discuss evidence left on the skeleton from the effect of the functional adaptation of bone to external stimuli due to their inherent plasticity.

4.2 Bone plasticity and remodelling

This section explores the ability of bone to remodel in response to environmental change. It begins with an overview of the concept of bone plasticity and then reviews models of bone remodelling and ends with discussion of the effect of remodelling on articular surfaces.

4.2.1 Plasticity

Plasticity allows the bones to record the various roles held by an individual during life and provides a link between the osteological study of populations and individual skeletons. The effects of bone plasticity are manifest as the varied overall morphology of skeletons in the archaeological

record and can act as an indicator of skeletal health, disease and life course (Agarwal and Beauchesne, 2013). Levins and Lewontin (1985) viewed human variability as a responsiveness to environmental factors that both mediate and produce each other i.e. biology (genetics) and culture are held as dialectically intertwined. Individuals do not have homogeneity of life from birth to death, but their life course is defined by their sex, status, occupation and environment, all of which will result in variation in the underlying skeleton (Larsen, 1997; Judd and Redfern, 2012).

Numerous non-mechanical factors such as age- or sex-related differences as well as changes elicited by biomechanical demands are thought to have an effect on bones (Meyer et al., 2011; Milella et al. 2012). The most productive studies of human health and disease in the past have examined patterns of pathology "by age, sex and environmental setting" (Armelagos and Gerven, 2003:59). In order to do this, it is necessary to be able to accurately estimate the sex and age at death of individuals. The sex of an individual may predicate on certain behaviours or abilities and may be used to test for social role when reconstructing behaviour (Grauer and Stuart-Macadam, 1998). The effect of life and lifestyle on bone morphology should be considered when estimating the sex of an individual using the non-sex role specific bones (i.e. bones that are not related to physical differentiation relative to reproduction e.g. pelvis) such as the upper and lower limbs, similarly the sex of an individual should be considered when analysing lifestyle. It is thought that differing activity patterns between the sexes can have an effect on sexual dimorphism of bone dimensions. There are a number of studies that have demonstrated significant difference in long bone diaphyseal shape between males and females (Ruff, 1987, 1992, 2000; Bridges, 1989, 1991, 1993; Stock and Pfeiffer, 2001; Weiss, 2003; Wescott, 2006; Carlson et al., 2007; Wanner et al., 2007). Ruff (2000) reported changes in lower limb diaphyseal cross-section through time, as a reflection of differences in physical activity between male and females and used the patterns of sexual dimorphism identified to provide an understanding of the gendered division of labour within populations. Stock and Pfeiffer (2004) identified that sex differences in upper limb robustness and diaphyseal shape could be used as a measure of subsistence patterns and labour intensification. In a study by Pomeroy and Zakrzewski (2009) significant differences in the shape of lower limb diaphyses in a medieval Muslim population from Éjica, Spain were observed which supported documentary and osteological evidence of a marked gender difference in activity. These examples support the understanding that functional adaptation of bone to external stimuli can be used to identify gendered division of labour.

However, Thomas (2014) warns that intra-population sexual dimorphism that has been interpreted as resulting from the gendered division of labour may actually be a reflection of intrinsic dimorphism rather than cultural or population-specific idiosyncrasies. He recommends

that the sample to be analysed should be of assessable sex and age at death and should come from individuals subject to similar environmental influences.

The concept of bone plasticity in relation to activity is fundamental to bioarchaeology (Skerry, 2006). Interest in bone morphology developed due to the realisation that bone is a plastic material that functionally adapts to its environment particularly in response to physical activity. Early definitions of plasticity were based on the concept that human morphology appeared to be malleable during growth and development (Bogin, 1995).

Lasker (1969) redefined the concept of plasticity by separating behavioural, short term-physiological and developmental plasticity from "genetic" adaptation leading to the identification of three modes of adaptation:

1) Natural selection where the selection of genotypes directly influences the genetic constitution of the population, e.g. population differences in height as a result of genetic differences between those populations (Beall and Steegman, 2000).
2) Adaptive plasticity where an individual adapts to the immediate environment in a behavioural response e.g. professional tennis players demonstrate high levels of humeral asymmetry which corresponds with the timing and duration of their participation (Jones et al., 1997).
3) Developmental or ontogenic adaptation. Ontogenetic modification is a plastic response to growth and development that occurs in response to the environment and is not reversible. Baker (1984) considers it to be a "biological or cultural trait which aids the biological functioning of a population in a given environment" e.g. increased lower/upper limb bone length and strength proportions in adult humans occurs as an adaptation to bipedalism (Ruff, 2003b).

The morphology of each individual is formed by a combination of their genetic make-up and variation in development as a result of plasticity as an effect of environment and behaviour (Wells and Stock, 2007).

One of the best-documented effects of adaptive plasticity is the influence of habitual activity on skeletal morphology. Roberts (1995:1) defines adaptive plasticity as "the capability of being moulded" and describes it as a functional adaptation to the environment by both soft tissues and the skeleton, where the environment encompasses natural and cultural phenomena. Sofaer (2006:77) considers that the inherent plasticity of tissue is key to the body's materiality, which is brought into being as the body records the accumulated experience of the life course of skeletal responses to culturally defined activities in conjunction with biological change. Martin (2013) agrees with this and comments that the body is defined by the social and cultural influences that

shape the expression of the physical characteristics and not simply the effects of genes and biology.

The understanding of skeletal response to activity is based on the understanding that bone responds to mechanical stress by stimulating the deposition of new bone in areas of strain caused by mechanical loading. This deposition causes trabecular and cortical bone hypertrophy, which counteracts the loading (Shaw and Stock, 2009).

Functional adaptation is a key theme in this thesis. The next section will review four models of bone remodeling (functional adaptation) to demonstrate the development of theories relating to this subject.

4.2.2 Models of bone functional adaptation

During life, the skeleton is exposed to many continuously recurring loads that lead to changes in morphology (modelling) (Prescher, 1998). The plasticity of bone allows it to adapt to external forces from the mechanical environment acting upon it by modelling and remodelling its internal and external structure in the direction of functional stress as a response to mechanical stimulus (Pearson and Lieberman, 2004; Ruff et al., 2006: Adams et al., 2006). There are various theories used to explain the process of bone functional adaptation which are discussed after a brief description of the concepts of bone modelling and remodelling which are described below.

4.2.2.1 Bone modelling

Bone modelling is a description of the process whereby bones are shaped or reshaped by the independent action of osteoblasts and osteoclasts. In contrast the activities of osteoclasts and osteoblasts are coupled in bone remodelling (Langdahl et al., 2016). Modelling defines skeletal development and growth and is responsible for the shaping of bones with adaptation to strain in adults leading to modelling of bone (Taddei et al., 2009). Physical activity can stimulate bone modelling (Kontilainen et al., 2002). It is also controlled by other factors such as modelling-based bone formation seen in the ribs which are not axially loaded (Ominsky et al., 2015). It is thought that it is controlled by genetic factors in combination with environmental factors such as physical strain and probably hormonal factors as it has been demonstrated that the parathyroid hormone (PTH) and inhibition of sclerostin can stimulate modelling-based bone formation (Lindsay et al. 2006; Ominsky et al. 2014).

4.2.2.2 Bone remodelling

In contrast to bone modelling, remodelling renews the adult skeleton approximately every 10 years (Manolagas, 2000). Remodelling is characterised by four stages:

1) Activation stage – osteoclasts are recruited
2) Resorption phase – osteoclasts resorb bone
3) Reversal phase- osteoclasts undergo apoptosis and osteoblasts are recruited
4) Formation phase – osteoblasts lay down new bone matrix that subsequently mineralizes (Langdahl et al., 2016).

Dempster et al. (2002) define bone remodelling as a process where osteoclasts and osteoblasts work sequentially in the same bone remodelling unit (BMU). It is most prominent on cancellous bone surfaces and 80% of bone remodelling takes place here (cancellous bone only comprises 20% of bone) (Seeman, 2013). Cortical remodelling increases in importance with age as cancellous bone is lost and remodelling activity in both compartments increases with cortical bone remodelling at the periosteal and endocortical surfaces (Bliziotes et al., 2006).

Remodelling has several functions:

1) Replacement of old and damaged bones with new bone. This maintains the mechanical strength of bone however, excessive remodelling and repair poses a risk to bone strength as it destabilizes bone and introduces stress concentrators (Dempster, 1997). Excessive strain on a bone can cause microdamage which can lead to targeted remodelling to remove the damaged bone and increase the volume of the surrounding undamaged tissue leading to a cycle of damage and repair (Allen and Burr, 2008).
2) Calcium homeostasis. Clinical evidence indicates that individuals with low calcium intakes are more prone to adult bone loss as bone acts as a reservoir for calcium (Langdahl et al., 2016).
3) Maintenance of acid/base balance and release of growth factors embedded in bone (Moore and Dalley, 2006).
4) Provides a reservoir of labile mineral (short-term homeostasis) (Dempster, 2006)
5) Only mechanism by which old, dying or dead osteocytes can be replaced (Dempster, 2006).

The next section discusses theories of bone modelling and remodelling.

1**) Wolff's Law**

Wolff's Law states:

"*The form of a bone being given, the bone elements place or displace themselves in the direction of the functional pressure and increase or decrease their mass to reflect the amount of functional pressure"* (Wolff, 1892)

Wolff was a 19th Century German orthopaedic surgeon who applied principles of mechanics to identify this law of transformation and used it to describe the ability of bone to resist stress by its response to mechanical forces acting upon it (modelling). Bone adaptation can take the form of increased or decreased mass depending on whether there is an increase or decrease in stress upon it. If the stress is removed and inactivity occurs, there is resorption of bone until it returns to the original strain levels (Ruff et al., 2006).

Wolff's Law (1892) is comprised of three major tenets: bone must be strong enough for support but light enough for locomotion, the trabeculae in the bone align themselves along the direction of principle strain, and that this is accomplished by self-regulating mechanisms as the bone responds to mechanical loads (Pearson and Lieberman, 2004). Wolff's Law has been widely used within bioarchaeology to explain the adaptation of bone to mechanical stress. However following criticism of unquestioning acceptance of Wolff's Law, the term "functional adaptation" is considered by some to be more appropriate (Bertram and Swartz, 1991; Carter et al., 1991; Cowin, 2004; Pearson and Lieberman, 2004).

There has been considerable criticism of the tenets proposed by Wolff. Pearson and Lieberman (2004) state that Wolff's Law is not a "law" and that it is over simplistic because it fails to consider the multiple processes that occur simultaneously and that these processes should be considered separately. They question the extent of genetic versus environmental influences on bone shape but consider that in the immature skeleton, the primary influence on cortical bone modelling is mechanical strain. This is supported by evidence from other research that has shown that epiphyses and articular surfaces respond to mechanical forces during growth (Frost, 1979, 1994, 1999; Hamrick, 1999; Plochocki and Organ, 2003).

Bertram and Swartz (1991) undertook a critical literature review to provide an analysis of some of the primary evidence to support Wolff's law and its mode of action. They considered that there was lack of control for factors that could potentially affect the outcome of many of the experiments leading to confused interpretation of the results. They identified that it is impossible to determine the extent of mechanical influence on bone form until all other factors are taken

into consideration. To this effect, they highlighted areas of Wolff's Law where other factors may influence the outcome. These are listed in Table 4-1.

Wolff's law is commonly cited in reference to bone modeling as a response to mechanical stimuli. Bertram and Swartz's (1991) critique of Wolff's tenets supports the proposition from many researchers that the phrase '*bone functional adaptation'* is a more accurate representation of the bone modeling process. Wolff's Law applies specific mathematical rules governing the modeling process in bone (where bone is modeled as being a solid, homogenous and isotropic substance subjected to statically applied forces) and is based on the assumption that there is a simple cause and effect sequence between mechanical loading and bone shape. However, this is now identified as being based on engineering and biomechanical misconceptions (Cowin, 2001) and does not accurately reflect or predict bone remodelling and therefore is a less suitable model. There are a number of reasons for it to be a less suitable model e.g. the function of bone is to provide support and protection for the internal structures of the body, it serves to store calcium, it is a site of production of red blood cells as well as being involved in movement (Currey, 1984). The Wolff model can be criticised for not considering these factors or other factors such as the effects of hormones, nutritional status, age and genetics (Lieberman, 1996).

Table 4-1 Summary of Bertram and Swartz response to Wolff's tenets

Wolff's Law	Bertram and Swartz's Response
Trabeculae align themselves along the direction of principle strain	This is true only in growing bone
Bone undergoes a process of self-regulation as it responds to mechanical loads	Sensitivity to bone resorption is dependent on age (in youth, bone resorption can be reversed, with age bone resorption can lead to osteoporosis). Rates of modelling and remodelling are not consistent for all locations within the body with a "load threshold" triggering response. Modelling occurs in areas of bone that are undergoing physical strain whilst remodelling is a balanced process that occurs throughout the skeleton and particularly in areas of microdamage to effect repair of the bone.
Atrophy is the reverse of hypertrophy	This does not account for the systemic bone hypertrophy seen in some individuals. Atrophy is not the reverse of hypertrophy. The localised response of bones in terms of apposition and resorption reflect the biomechanics of the whole bone

2) Frost's mechanostat model

This model is built upon the hypothesis that a negative feedback, homeostatic loop regulates bone modelling (Frost, 1987, 1990a, 1990b, 2003). Frost (1987) considers that the effects of mechanical strain will only induce changes in bone strength when a particular threshold is exceeded and that the range for optimal strain is genetically determined. No bone response will be seen if the mechanical load remains in the range of customary strain. Deposition to strengthen bone occurs when this range is exceeded, increasing the strength of the bone and thereby reducing the level of strain to within the customary range. Conversely, if there is a reduction in strain below the customary strain level, bone resorption occurs, and equilibrium returns. Frost defines this mechanism as the mechanostat. A weakness of Frost's model is that it does not fully consider the modulation effect of non-mechanical factors (including hormones and other humeral agents) on the mechanostat effect.

3) Turner's mechanotransduction model

Turner (1998) refined Frost's mechanostat model to create an understanding of localised responses to loading at a cellular level in bone. He describes a process of mechanotransduction whereby mechanical loads are sensed by osteocytes which release signals that activate or inhibit the action of osteoblasts and/or osteoclasts (Klein-Nulend et al. 2013). This process offers an explanation for structural change at the tissue level (Rauch and Schönau, (2001).

The mechanotransduction model identifies three rules that govern bone regulation (Turner, 1998):

a) Bone responds to dynamic rather than static loads (the magnitude of the loading, the loading frequency and the strain rate are all important factors in the determination of bone remodelling response) (Rubin and Lanyon, 1984; Forwood and Turner, 1995; Turner et al., 1995).

b) Short durations of loading are sufficient to stimulate a response; however, osteocytes can become desensitised to the leading stimulus if the loading duration increases (Rubin and Lanyon, 1994), with mechanosensitivity beginning to decline soon after the stimulus is initiated. Robling et al. (2006) were able to measure a 95% decrease in mechanosensitivity in rats after only 20 loading cycles. Brief resting between cycles of loading allows the osteocytes to recover sensitivity and has been shown to maximise the osteogenic effects of mechanical loading in the rat (Robling et al., 2001). This model may translate to humans.

c) A routine loading pattern reduces osteocyte response. Structural changes occur as a response to abnormal strain and not normal loading.

Turner's (1998) mechanotransduction model presents a good explanation for cellular level response to mechanical loading but does not identify the actual events that convert mechanical stress to a biochemical event. It also fails to identify whether specific stresses (e.g. stretch versus shear) will lead to different responses (Chen, 2008).

4) Carter and Beaupré's mechanical model

Carter and Beaupré (2001) developed the models proposed by Frost (1990a, 1990b) and Turner (1998) by incorporating the influencing effects of developmental factors. Their model identified biological and mechanobiological components in bone growth. Both components are necessary for normal bone formation, but the relative importance of the two factors changes over the course of development. The biological component recognises the intrinsic growth processes controlled by genes, hormones and other metabolic factors, whilst the mechanobiological component factors in the changes that occur in bone as a response to mechanical loading. With increasing age, the importance of the mechanobiological influence increases and the biological response decreases. A weakness of this paradigm is that it was modelled on healthy adults with the assumption that biological influences are constant and that it only represents net changes in bone without consideration of the separate activities of osteoblasts and osteoclasts (Hernandez et al., 2000).

The second to fourth models of bone remodelling presented here all have roots that date back to the work of Wolff. They each add further explanation to the effect that mechanical loading has on tissue formation in bone. Vertebral sexual dimorphism is thought to result in part from population specific activity (Gilsantz et al., 1997). The next section discusses the effect of mechanical loading (physical activity) on bone morphology.

4.2.3 Mechanical stress and bone remodelling

Physical activity is known to influence bone through dynamic biomechanical loading, especially when performed on a regular basis (Turner and Robling, 2003). There are strong links between mechanical stress from physical activity and changes in bone morphology and dimensions leading to increased cross-sectional size and bone density in both long and irregular bones (Mosekilde, 2000; Kontulainen et al., 2003; Martyn-St James and Carroll, 2010; Bolam et al., 2013). The converse effect has also been reported with low levels of physical activity being correlated to diminished vertebral size (Gilsanz et al., 1994). Bones respond to loading in a site-specific manner (Kontulainen et al., 2003). Nilsson et al. (2014) suggest that the morphological mechanisms that occur due to mechanical stress-induced changes in bone size are an increase in cortical bone thickness (prevalent during the growth period) and a decrease in endosteal bone loss (prevalent

in the aging population). Ruff et al. (2006) agree with this and report that increased mechanical loading mainly affects internal bone remodelling, with growth towards the medullary cavity. Ruff (2005) reports that estimation of adult activity from the external dimensions of a long bone is fraught with difficulty unless the internal dimensions of the bone are also considered. Mechanical loading triggers an increase in osteoblastic activity leading to change in morphology (Lieverse et al., 2011). This manifests as changes in robusticity of long bones (defined as the thickness of the shaft to its length (Martin and Saller, 1957) and quantified by cross-sectional cortical geometry (Ruff, 2000). The process of bone adaptation is complicated and not fully understood (Pearson and Lieberman, 2004), however, there is still a considerable body of evidence for a direct link between mechanical loading and the geometric properties of long bone diaphyses (Robling et al., 2000; Daly et al., 2004; Warden et al., 2005; Ruff, et al., 2006) and vertebral size (Gilsanz et al., 1994; Mosekilde and Mosekilde, 1990; Mosekilde, 2000).

The relationship between mechanical loading and functional adaptation of bone has been used to identify changes in behaviour in populations, with an increased robusticity considered to develop as a consequence of strenuous physical activity (Bridges et al., 2000; Steckel and Rose, 2002; Stock and Pfeiffer, 2004), enabling interpretation of patterns of prehistoric behaviour by measuring skeletal robusticity (Stock and Pfeiffer, 2001, 2004; Stock et al., 2011). The effects of bone remodelling on articular surfaces as a result of adaptive plasticity are reviewed in the next section.

4.2.4 Remodelling of articular surfaces

The effect of physical activity on remodeling of the facet joints is a key focus within this thesis as this may relate to the degree of sexual dimorphism seen. This section reviews the effects of remodelling of articular surface areas as a response to physical activity.

Within the context of bioarchaeology, bone remodelling has been considered to be a good indicator of skeletal response to repeated activity-induced stress in humans, with bone plasticity recording the body's response to social and environmental factors as an osteological record of life experiences (Sofaer, 2006:77). Bones respond to physical stress by remodelling their internal and external structure in the direction of the functional stress (Ruff et al., 2006). From a biomechanical perspective, the response of an articular surface to loading can have important behavioural implications in relation to the amount of force a joint undergoes in an individual's lifetime. However, there is conflicting evidence for the argument that activity and loading can affect remodelling and asymmetry in articular surfaces. Ruff (1992) identified that the cross-sectional area of the femoral midshaft from a population from Peco Pueblo increased significantly over time but the size of the femoral head did not follow the same pattern. The femoral head

correlated most closely with the body mass of the individual at age 18, whilst the femoral midshaft measurement correlated most strongly with the mass of the individual at the time of study. This led Ruff (1992) to theorise that articular surfaces are under mechanical constraint and do not demonstrate the same plasticity as long bone diaphyses. This result was confirmed by Lieberman et al. (2001), who investigated the effect of mechanical loading to articular surfaces in the developing skeleton to measure the phenotypic plasticity of the articular surface. He did this by comparing two groups of young sheep. One group was exercised on a treadmill and the others were non-exercised. There were no significant differences in body mass between the two groups.

He failed to find a significant difference in articular surface area once control for body size was undertaken. The exercised sheep demonstrated a significant increase on cross sectional size of the diaphysis with the most pronounced differences occurring in the juvenile group. This study confirmed Ruff's findings that the articular surfaces are highly constrained in their ability to macroscopically remodel.

Plochocki and Organ (2003) were able to offer a contrast to the conclusions drawn by Lieberman et al. (2001) and Ruff (1988) when they found levels of asymmetry on the articular surfaces of humeri, radii, femorae and tibiae from two archaeological sites in Missouri. Their data demonstrated a right-sided dominance in every joint dimension of the upper body except the distal radial articulation. They concluded that limb articular facets are adapted to the mechanical environment and that biomechanical factors are important in the development and maintenance of articular morphology.

Meyer et al. (2011) argued against the method used by Lieberman et al. (2001) saying that sheep do not provide an appropriate model to assess the effect of activity on bone in humans, as unlike humans, sheep are quadruped and use all for limbs for locomotion. They agree with Knüsel et al., (1997) that upper limbs in humans portray a clearer picture of the effects of increased strain on bone when measuring asymmetry due to the effects of differences in recruitment of right and left arms in the performance of occupational activities, as they are free from confounding factors related to locomotion. Bilateral asymmetry of the upper limb (particularly the humerus) can also be used to measure hand preference (Stirland, 1993; Steele and Mays, 1995; Steele, 2000; Blackburn and Knüsel, 2006). The lower limbs show less asymmetry as there is similar recruitment in the act of bipedal locomotion (Auerbach and Ruff, 2006). Bipedalism is also linked to significant increase in the cephalad to caudad size of vertebral bodies and associated facet joints (Nakatsukasa et al., 1994; Whitcombe et al., 2007). The degree to which the adaptation is reflected in facet asymmetry is not clear from the existing literature

The macroscopic effects of bone remodelling and the challenges of interpretation have been identified above. However, not all bone remodelling is macroscopic; the next section reviews the microscopic changes that also occur. Barak et al. (2011) were able to identify microscopic changes in the articular surface within the tarsal joint as a result of remodelling. Their study used a sheep model to test the effects of induced changes in tarsal joint loading on corresponding adjustments in trabecular orientation in the cortical bone of the joints. Their research indicated that trabecular orientation is very sensitive to loading and effects were observed after a short duration of experimentation (34 days), although they comment that their study was subject to limitations of small sample size and duration. This result strongly supports Wolff's hypothesis (discussed in section 4.2.2) that trabecular bone structure can adjust to follow the principle directions of stress caused by the effect of external loads upon a joint.

The relationship between the degree of physical loading (as assessed by the degree of degenerative change undergone by the joint surface, see section 4.3.4) and the size and orientation of the facet will be measured as part of this research to test whether this influences the degree of sexual dimorphism in the facets. If bone alters in response to the loading it undergoes during activity, then the changes undergone by the articular surface area may provide information about the effect that behavioural variations may have on load-induced degeneration of the joints (Bridges, 1991; Spector et al., 1996; Kerrigan et al., 1998). Although Plochocki and Organ (2003) considered that limb articular facets responded to mechanical loading, there is significant evidence is to the contrary. Research has demonstrated that articular loading in adults can have a profound effect on subchondral bone and trabecular orientation inferior to the joint surface but that these changes do not affect the external articular dimensions (Pauwels, 1987; Poss, 1984; Radin et al., 1982, 1984; Rafferty and Ruff, 1994; Ruff, 2000; Barak et al., 2011; DeSilva and Devlin, 2012; Su et al., 2013). From this it could be suggested that different loading patterns will affect the trabecular architecture of zygapophyseal joints at different vertebral levels with varied degrees of orientation. This is an area for further research and beyond the remit for this study.

Although the studies described above all link changing bone morphology with mechanical loading, other factors also need to be taken into account. The relationship between sex, age and bone morphology (focussing specifically on the vertebrae) are factors for consideration within this study.

4.3 Reconstruction of lifestyle using markers of occupational stress

The previous section reviewed literature pertaining to articular surface remodeling and eluded to the use of articular degenerative change as a measure of degree of mechanical loading/physical activity undertaken by an individual. Inter-sample differences in facet size and orientation may be linked to differing activity levels and therefore the use of degenerative changes as a measure of activity may add insight into variations observed. The use of markers of occupational stress (MOS) including the role of degenerative change is reviewed in this section. Each marker is reviewed from a bioarchaeological perspective to demonstrate their use in providing information about physical activity in past populations.

4.3.1 Activity related changes

Knüsel (2000) considered that research into activity-related change is a developing area in human osteology. However, interest in the study of linking skeletal markers to activity is thought to have developed from within the context of study of the impact of occupation on the body (Buikstra and Beck, 2006). Early theories linking disease and occupational stress were considered from as early as the fifteenth century in work by Paracelsus (1493-1541). He identified a link between respiratory disease and occupation in miners (Kennedy, 1989). Ramazzi published the first systematic work on industrial medicine in 1700. He realised that recognition of an individual's occupation was a source for understanding problems of health (Kennedy, 1989). In 1887 William Arbuthnot Lane observed:

> *"When we find a condition of the skeleton differing from the normal and obviously not the result of disease, I think we are justified in concluding that the variation must have come from the performance of some purpose or function in addition to those normally performed during the life of that individual alone" (Lane, 1887: 586).*

The interesting part of this quote is *"in addition to".* Lane is identifying an individual as being different from their contemporaries as a result of the effects of physical activity on their skeleton that are not undertaken by others in the same subset of population.

When attempts have been made to create a theoretical link between physical activity and changes in bone morphology, emphasis has been placed on the plasticity of skeletal material as an adaptive response to the external forces of the mechanical environment acting upon it (Rubin et al., 1990; Goodship and Cunningham, 2001; Preuschoft, 2004). The emphasis on plasticity influenced a number of early anthropologists, including Boas, Martin and Weidenreich (Buikstra and Beck, 2006). It was soon realised that information from the skeleton itself was not enough to

identify specific activities but that combining evidence from archaeological contexts and human remains is an important tool in the reconstruction of general patterns and levels of activity in historic populations. This is still a dominant paradigm today (al-Oumaoui et al., 2004; Molnar, 2010, Cardoso and Henderson 2010).

4.3.2 Markers of occupational stress

Markers of occupational stress (MOS) have been used to explore inter-sample differences in prevalence and severity of stress markers to gain information about the arrival of agriculture (Marchi et al., 2006; Lieverse et al., 2007), sexual division of labour (Sofaer Deverenski, 2000) and economic intensification (Klaus et al., 2009). The successful use of MOS as activity indicators relies on the presumption that there is a close association between repetitive activity and skeletal change. Repetitive activities can lead to bone remodeling as an effect of mechanical loading and this is thought to be a good indicator of lifestyle in archaeological samples (Kennedy, 1989).

A number of different methods and procedures for the assessment of MOS, have been used to study behaviour and lifestyle of past people (Larsen, 1997; Cox and Mays, 2000; Katzenberg and Saunders, 2000; Buikstra and Beck, 2006, Jurmain et al., 2012). One such method is the examination of gross pathological changes in the skeleton, which involves study of bony changes such as enthesophytes, osteoarthritis, spondylolysis, os acromiale and osteochondritis dessicans (Ponce, 2010). These MOS are general indicators of joint use and can document long-term physical stresses, habitual movements and general motions on the body of an individual (Larsen, 1997; Knüsel, 2000).

Jurmain (1990) severely criticized the use of MOS and has questioned their validity, due in part to the difficulty in quantifying alterations in the bones. It is not easy to decide whether changes observed are caused by repeated activity or idiopathic. It is also difficult to identify a primary cause for the changes seen (Jurmain et al., 2012; Weiss et al., 2012). There are a number of confounding factors that can affect the expression of repeated activity on bone. These include trauma and micro trauma, robusticity, age, sex, genetic predisposition or poor manual handling techniques (Jurmain, 1990). Experimental control for the external factors that can affect the prevalence and severity of bone changes leads to improved comparison within and between sample populations increasing the validity of activity-related studies (Ostendorf Smith, 2013). It should be remembered that whilst bioarchaeological analysis can provide a great deal of information about bones, without context this information would be limited (Buikstra and Beck, 2006). Comparative population based descriptive studies have been published in the latter part of the 20th century (Pearson and Buikstra, 2006) but more work on MOS in past and present populations is needed to help identify which activities are responsible for the development of the

features observable in skeletal populations (Buikstra and Beck, 2006) and to identify further MOS that will support or refute existing results. The use of MOS as markers of activity is subject to a number of limitations and these are discussed in section 4.3.3

4.3.3 Limitations in the use of MOS as markers of activity

It should be recognized that there are limitations to the use of MOS in the reconstruction of the activity patterns of past populations:

1) The inconsistent use of scoring systems to record MOS makes cross-study comparison challenging. For example, at least three methods for recording enthesopathies have been recorded. Angel et al. (1987) used a scoring system with stages from "absent" to "showing strong development". Crubézy (1988) measured entheseal change with a four-stage scoring system based on the dimensions of each exostosis at entheseal sites. Vilotte et al. (2010) identified a methodological issue when they noted that entheses could be a useful tool for the identification of occupational stress provided that the correct entheses are measured using appropriate methods. Hawkey (1988) used a classification system that examined ossification exostoses, robusticity markers (where "robusticity" refers to "hypertrophy of the bone in the form of robust muscle attachment" (Hawkey, 1988:324)) and stress lesions. The identification of these methodological and theoretical discrepancies led to the Coimbra Workshop in Musculoskeletal Stress Markers in 2009. A continuously updated website (http://www.us.pt/en/cia/msm/) was established as a result of the workshop. It allows all researchers in musculo-skeletal markers (MSM) to contribute to more uniform and reliable analyses in the reconstruction of past activities (Santos et al., 2011). To further assure conformity of method, an entheseal-scoring workshop using this method was held at University of Sheffield in January 2015.

2) In order for bone morphology to be modified, the bone needs to be put through a series of movements that are energetic and carried out for a long period probably on a daily basis (Molleson, 2007). Many studies on MOS make the assumption that the most commonly assessed bony alterations are a result of habitual occupation. Jurmain (1999) placed emphasis on the point that the many varied activities (habitual and exceptional) that occur during a lifetime need to be considered in MOS studies. Merbs (1983) added to this argument by saying that although bodies are exposed to a variety of activities on a daily basis, there are certain activities that are performed repetitively, especially those linked to survival, e.g. in food preparation and hunting and these would leave the greatest evidence of adaptation in the skeleton. Luttman et al., (1988) identified that, in order to be able to compare activities,

there needs to be greater definition and characterisation of a specific activity, such as the length of time it is performed, the number of times the action is performed within a given time span and also how much overload is placed upon the body and on which part of the body.

3) External factors such as ethnicity, sex, age, diet and genetics may affect the way in which an activity is performed and how the activity affects the body as well as the type, duration and range of activities undertaken. Jurmain (1999) identified a number of questions that should be considered in order to try and understand the effect these external factors may have on activity. These included information on who did what behaviour and for how long; how old was the individual when they started the activity; how much individual variation is there between the participants in a specific activity and finally how was a specific activity undertaken?

4) There is a risk of circular argument in the interpretation of activity patterns from the skeleton. Relating skeletal changes to a "presumed" behavioural cause and then using the changes to support the argument that the behaviour caused the changes is a circular argument. The classic example of this is seen in Angel's (1966) discussion on the existence of "atlatl elbow". Ethnographical evidence demonstrates the existence of atlatls, osteological evidence identified the presence of osteoarthritis in the elbow joints, therefore the assumption has been made that throwing atlatls causes degenerative change in the elbow joint. Jurmain (1999) considers this circular approach to be in part, caused by lack of consideration of available clinical data, which identifies aetiology related to degenerative joint disease onset. Larsen (1997) contrasts this by suggesting that clinical data should be reviewed in bioarchaeological study, but that it is not always possible to make a direct comparison between the two sources of data as clinical data does not always include the nuances of subtle change visible in the dry bone sample. Clinical data does provide a baseline for bioarchaeological research and its usefulness should not be overlooked. Clinical studies can contribute to the general understanding of how habitual occupational or recreational activity causes change in the musculoskeletal system (Bird, 1990), but in clinical research, the emphasis is on soft-tissue damage and pathology, which limits the use this resource can have for bioarchaeologists (Kennedy, 1989).

The use of multiple markers of occupational stress to study activity patterns can diminish the risk of circular argument (Hawkey, 1998; Roberts and Manchester, 2005). Watts (2010) used multiple non-specific indicators of stress to identify which period of growth and maturity was most

affected by the stressor. Al-Oumaoui et al., (2004) used multiple musculoskeletal stress markers to assess activities carried out by populations from the Iberian Peninsula according to their sex, environment and culture and found that their results coincided with the available historical and archaeological data. Sofaer Deverenski, (2000) used the distribution and severity of degenerative change on the zygapophyseal joints and osteophytosis of the vertebral bodies to identify gender specific activities. Jurmain (1999) argued that the use of a single marker or a combination of markers does not give more rigour to the interpretation of activity patterns if the data are insufficient and that greater precision is not achieved by using lots of weak data, highlighting the importance of good and appropriate data collection.

4.3.4 Activity and degenerative joint disease

This section reviews the link between activity and degenerative joint disease. It begins by identifying the problems associated with clinical and archaeological terminology for degenerative joint disease then discusses classification of osteoarthritis and the multifactorial aetiology of the disease. This is followed by an overview of the degeneration cascade and process behind joint degeneration.

4.3.4.1 Definition of degenerative joint disease

There is a lack of consistency in the terminology used in clinical and archaeological literature when discussing degenerative joint disease and osteoarthritis. Clinically, osteoarthritis is defined as a "non-inflammatory degenerative joint disease occurring mostly in older persons" (Taylor, 1988:1197). Berkow (1992) adds to this definition by describing the condition as being characterised by "degeneration of the articular cartilage, hypertrophy of the bone at the margins and changes in the synovial membrane" Jurmain (1999) presents the archaeological nomenclature of osteoarthritis to the debate by discussing the arguments for naming the condition either osteoarthritis or degenerative joint disease; "osteoarthritis" is thought to imply an inflammatory condition (Hough, 1993) and degenerative joint disease is considered to imply a manifest, passive process associated with old age (Dieppe, 1987). Lozada (2011) considers that term degenerative joint disease used as a descriptive name for osteoarthritis to be inappropriate because secondary non-specific inflammatory changes may also affect joints as well as the effects of "wear and tear". The terms degenerative arthrosis, degenerative arthritis or osteoarthrosis are also commonly found in the clinical literature but are not commonly seen in the paleopathological literature (Resnick, 2002). Waldron (2012) considers that osteoarthritis should not be considered a degenerative condition because it is a disease of joint articular cartilage and the changes that can be seen in bones are secondary to articular cartilage breakdown. However, Bick (1948)

identified that neither term was more significant than the other, but it was important that there was consensus of agreement on which term to use. The term osteoarthritis (OA) will be used in this study as it is commonly used in clinical and bioarchaeological literature.

The next section presents classification into primary and secondary OA as a means of differentiating type of OA and the process of degeneration in the spine. It continues with a discussion of causation factors.

4.3.4.2 Primary and secondary osteoarthritis

The classification scheme of Mitchell and Cruess (1977) is frequently used to classify osteoarthritis as either primary (idiopathic, developing in previously undamaged joints in the absence of an apparent triggering event) or secondary (some known causative factor, disease or predisposing state, such as anatomic abnormalities, trauma and inflammatory and metabolic disorders) (Berkow, 1992; Arden and Nevitt, 2006). However, the spectrum of joint involvement and severity, and the etiological factors involved are considered to be too complex to be involved in two simple divisions (Doherty et al., 1983). Doherty et al.'s (1983) research into the role of primary OA in the hands of a patient having an effect on the onset and severity of secondary OA in knees of elderly patients invalidates the clear distinction between the two subsets and adds emphasis to the multifactorial aetiology of OA.

From a clinical perspective, primary osteoarthritis is seen typically in middle-aged females and is described in the clinical literature as being symmetrical and polyarticular, affecting the main weight-bearing joints and axial skeleton (Fergusson, 1987). Joints displaying degenerative change are considered to have primary OA when it occurs in the absence of any underlying predisposing factor (Moskowitz, 1993). It can be seen in the distal (Heberden's nodes) and proximal interphalangeal joints (Bouchard's nodes), the first metacarpal joint, cervical and lumbar spine, first metatarso-phalangeal joint, hip, knee, intervertebral discs and facet joints of the spine (Berkow, 1992; Kellgren and Moore, 1952).

Secondary osteoarthritis refers to degenerative disease in a synovial joint resulting from a predisposing factor, e.g. trauma that causes damage to the articular cartilage and may or may not also have caused damage to the underlying subchondral bone. It can occur in relatively young individuals (Sharma, 2001). Secondary osteoarthritis can develop following a number of pre-existing disorders. These include, for example, metabolic causes such as acromegaly and ochronosis, anatomic anomalies such as congenital hip dislocation, leg length inequality and hypermobility syndromes, traumatic events such as major joint trauma, joint fracture and chronic injury due to occupation or activity or inflammatory disorders such as septic arthritis (Arden and

Nevitt, 2006; Wright, 1990). Some of these disorders, e.g. ochronosis (hyperpigmentation) would not be visible in an osteoarchaeological sample due to the lack of preservation of the soft tissues.

4.3.4.3 The process of degeneration in the spine

It is thought that there are three phases in the spinal degenerative cascade that are linked to the process of degeneration in the spine (Kirkaldy-Willis, 1985). The first phase is when changes in the anterior vertebral elements (e.g. decreased height of the intervertebral disc) cause reduced stability between vertebrae and the disco-ligamentous structures become less supportive leading to degenerative changes (eburnation) in the vertebral body and facet joints (Figure 4-1). This progresses to the second phase, decrease in disc height continues and the vertebral segments become less stable, leading to loosening of the facet capsule and ligaments with a greater degree of degenerative change occurring. The third phase is identified by further degeneration and restabilisation of the spine by the formation of osteophytes and fibrosis (Suri et al, 2010).

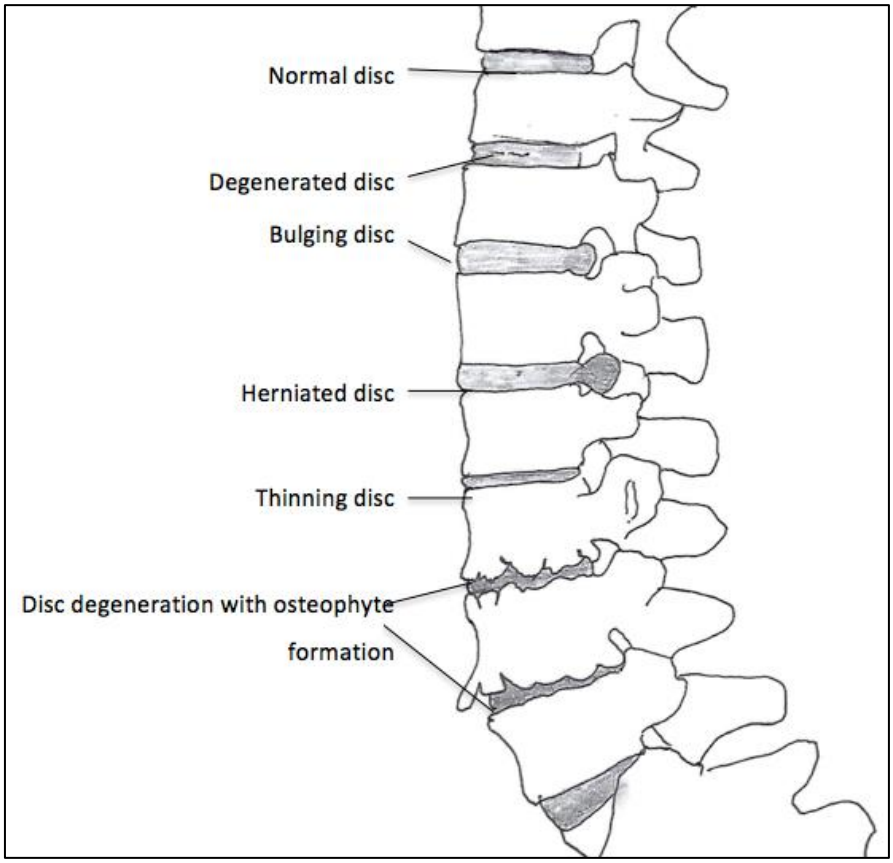


Figure 4-1 Range of degenerative processes in the spine (author's image)

4.3.4.4 Causes of osteoarthritis

The exact aetiology of OA is yet to be determined (Greenberg et al., 2006; Berenbaum, 2013). One possible cause is the failure of one or more factors in the interaction of mechanical, biologic,

biochemical and enzymatic feedback loops which can lead to the development of OA in a joint (Berkow 1992). OA can be considered to be a multifactorial condition due to many mechanisms that can initiate the cellular changes leading to the development of OA representing a sustained imbalance between cartilage synthesis and degradation (Moskowitz et al, 2004), leading to disruption of the integrity of the articular cartilage (Rogers et al., 1987). OA aetiology is a combination of intrinsic factors found in cartilage and extrinsic factors such as age, sex, hormonal changes, obesity, genetic predisposition, ethnicity, mechanical factors, physical activity and occupation (Merbs, 1983, 2001; Waldron, 1997; Sofaer Deverenski, 2000; Kahl and Smith, 2000, Solano, 2002; Weiss, 2005a, 2005b; Weiss and Jurmain, 2007). In summary, there is no one direct cause for OA. Mechanical influences are implicated as predisposing factors, and these are discussed next from a clinical and archaeological perspective.

Whilst moderate mechanical loading through a joint appears to be necessary for the maintenance of healthy cartilage (matrix synthesis), abnormal loading is thought to increase the risk of developing OA (Griffin and Guilak, 2005) and the mechanical environment caused by strenuous physical activity is considered to be a primary causal factor in the development of OA (Larsen, 1997); however, the development of OA is a lengthy process and can take 15-20 years (Poole, 1999). The clinical literature suggests that there are a number of mechanical factors such as gross malalignment or abnormal geometry within the joints, which can increase the risk of abnormal loading (Goodfellow and Mitsou, 1977; Bullough, 1981) as can the lack of proprioceptive and nociceptive receptors (Jordan et al., 2000). (Proprioception is joint position sense and nociception is the ability to sense pain.) Malalignment can occur when there is excessive valgus or varus strain through a joint (e.g. the knee). The strain increases local stresses inside the joint and causes OA progression due to a cycle of further damage to cartilage and bone in the compartment subjected to increased loading (Sharma, 1995; Sharma et al., 2001; Felson, 2004).

Another cause of malalignment is hypermobility (caused by ligamentous laxity) within a joint (Bird et al., 1978; Fergusson, 1987). Reduced muscle strength or muscle fatigue has also been recorded as a factor in joint malalignment leading to cartilage degeneration and OA (Fisher and Prendergast, 1997; Thorstensson et al., 2004). Conflicting studies have shown that both weaker and increased quadriceps strength in the setting of knee joint malalignment can be associated with increased risk of deterioration in a joint with OA. Baker et al. (2004) identified that patients diagnosed using radiography as having knee OA demonstrated significantly weaker quadriceps strength than patients without OA. In contrast, Sharma et al. (2003) found that patients with greater quadriceps strength are at greater risk of existing knee progression within the context of joint malalignment and ligamentous laxity. Reduced motor power (e.g. caused by poliomyelitis) appears to reduce the risk of OA onset even though the joint can be moved passively and may be

unstable (Glynn et al., 1966). Muscle fatigue caused by repetitive movements can increase the vulnerability of a joint to OA. This situation can be seen an occupational risk for workers using joints repeatedly for hours (Nuki, 1999). Abnormal geometry can be caused by congenital abnormality (e.g. congenital hip dysplasia (Tanzer and Noiseux, 2004), leg length anomalies (Golightly et al., 2008), joint injury earlier in life such as a meniscal tear in the knee or rupture of an anterior cruciate ligament (Englund and Lohmander, 2004) or tear of the hip labrum (Tanzer and Noiseux, 2004). Joints are subject to a process of continual remodeling throughout life (Johnson, 1962) (See section 4.2.3). This can change the profile of the joint surfaces allowing the two articular areas to become more congruent. However, this may cause loading in areas that already maximally bearing strain (Bullough, 1981). It has been hypothesized that abnormalities in the remodeling process may be involved in the development and progression of OA and is thought that this risk is increased in the abnormal joint (Bullough and Jagannath, 1983).

The effects of age, weight and mechanical loading have been discussed as causes of OA in the bioarchaeological literature (Merbs, 1983, 2001; Waldron, 1997; Sofaer Deverenski, 2000; Kahl and Smith, 2000; Solano, 2002; Weiss, 2005a, 2005b). The role of heavy mechanical loading as a cause of OA is an area that has been subject to intense scrutiny and has led to the conclusion that severe OA scores on joints are the result of continued use of specific muscles and joints in daily and repetitive tasks (Weiss and Jurmain, 2007) and as such has led some researchers to consider that this condition is ideal for the reconstruction of activity patterns. It is extremely difficult to link patterns of OA distribution in the body to specific activities, however, OA can be considered to be a general indicator of joint loading and can be used to identify joints under long-term stress or used for habitual movements (Knüsel, 2000). Some paleopathologists (Waldron, 1994; Jurmain, 2012) consider that research in this area is limited due to the lack of consideration of external factors (such as environmentally associated stress) reflected by variable lifestyles that can affect the onset of OA. Waldron (1994) argued that until the role of all non-mechanical influences (e.g. nutrition, hormones, age, genetics, disease) and biomechanical responses (e.g. magnitude of stress, rate of stress, stress interval etc.) in bone remodeling are fully understood, patterns of activity cannot be satisfactorily quantified. Martin et al. (2013) also encourage researchers to incorporate as much contextual information as possible when comparing activity related differences between sexes and populations to increase the validity of the results, rather than just identifying significant differences in order to try to create an understanding of why the differences occur

The relationship between repetitive physical activity and OA is of particular interest to this study. Movement is the essential prerequisite for the development of OA; joints that do not move do not develop OA (Waldron, 2012). As discussed above, there are also a number of other important

factors that can precipitate the onset of OA (age, sex, hormone levels, obesity, genetic predisposition and mechanical factors). There have been many studies investigating the effect of occupationally related repetitive movements in relation to the development of OA. Weiss and Jurmain's (2007) review of general studies of occupation/epidemiological data and studies relating to specific activities data failed to demonstrate a definitive relationship between increased levels of activity and prevalence of OA. However, 22 of the 41 studies reviewed did show a significant relationship between movement and prevalence of OA. The studies chosen for inclusion in their review were selected based on content, rather than a representative sample of the available literature. The selected studies looked at individuals in specific risk groups relating to mechanically stressful activities. Their review predominantly included studies that examined prevalence of OA in relation to activity but did not consider the severity and extent of OA present. This pattern has continued in activity-related/OA research, e.g. eburnation was scored simply as absent or present in Molnar et al. (2011). Other studies have scored the individual diagnostic criteria for OA (pitting, eburnation, osteophytic growth) (Sofaer Deverenski, 2000). The inclusion of a high level of discrimination in recording of the individual criteria for OA allows for potential distinction in aetiology between samples under investigation.

4.3.4.5 Physical activity and OA

Waldron (2009) considers that after dental disease, osteoarthritis is the most frequently seen skeletal pathological condition. Macroscopically, it can be diagnosed on dry bone using the method described in section 5.7.6. The primary value of OA in bioarchaeological study relies upon the assumption that there is a relationship between the distribution and severity of OA and movement of the joints caused by repetitive mechanically loaded activities which allows for differentiation of lifestyle amongst and between populations (Ostendorf Smith, 2013).

The field of bioarchaeology has held an interest in the relationship between physical activity and patterns of OA distribution in the body as a source of information about behaviour since the 1960's when Angel (1966) first used the term "atlatl elbow" to explain patterns of OA seen in the radio-humeral joints of skeletons from Early Horizon burials at Tranquillity, California. Angel's work was one of the first to identify the potential link between osteoarthritis and specific behaviour when he attributed the distinct pattern of OA to throwing actions related to the use of the atlatl (a spear thrower) in males. This link between an activity and pathology was influential in the paleopathological study of activity markers. Bioarchaeologists have built upon this background by examining alterations in skeletal morphology as a response to habitual and repetitive physical activity (Havelkova et al., 2010; Lessa, 2011) with many bioarchaeologists believing that the presence of OA indicates patterns of use or "overuse" of the joints of a skeleton

due to heavy workload and demanding physical activities (Angel, 1966; Jurmain, 1977; Merbs, 1983; Bridges, 1991; Bridges, 1992; Larsen et al., 1995; Jurmain, 1999; Sofaer Deverenski, 2000). However, Jurmain (1999) urges caution when using OA as an activity marker. Angel's sample was very small (13 elbows). The small sample size did not allow for assessment of differences between age groups; the individuals' onset of OA is age related and Angel did not control for this factor. The term "Atlatl elbow" to describe a pattern of degenerative change (eburnation) of the capitulum of the humerus is actually based upon limited evidence. The distribution pattern of OA is not a clear link to specific physical activity. Whilst greater severity and extent of OA can infer a more physical lifestyle, it is difficult to interpret OA distribution patterns and link them to a specific activity due to its inherent multifactorial aetiology leading researchers to question the reliability of using OA as a marker of activity (Weiss, 2005; Weiss and Jurmain, 2007; Waldron, 2009). Jurmain (1977) was a keen supporter of using OA as an MOS, however further research and understanding of the complexity of OA caused him to become much less certain as to its validity. Jurmain (1999) identified that mechanical loading plays only a small part in the development of OA and other factors must be considered. Archaeological and ethnographical evidence as used by Angel (1966) to support the theory behind activity based MOS is not always valid. The evidence does not provide detail on the frequency or duration that a specific activity was performed by an individual. This evidence also generally fails to document the age that an individual began to undertake tasks that involved mechanical loading. This lack of supporting evidence makes it unlikely that general or specific activities can be inferred from MOS (Jurmain, 1999:138-9). In summary, Jurmain emphasised that there is not a straightforward relationship between OA and activity and many other factors need to be taken into consideration. Larsen (1997:164) states:

> "*…although articular pathology relating to activity offers important insight into behavioural characteristics of human populations in a general sense, the identification of specific activities or occupations from individual remains may not always be possible".*

4.3.4.6 Specific activity and OA

There have been many clinical studies relating to the study of occupation/sporting activity and OA in modern populations, which identify areas of the body at risk from certain repetitive movements. Occupations that require fine finger movements and pincer grip increase the risk of hand OA (Hadler et al., 1978); those that require repetitive movements involving kneeling, knee bending, squatting or the carrying of heavy loads increase the risk of development of knee and hip OA (Thelin, 1990; Felson et al., 1991; Croft et al., 1992; Cooper et al., 1994; Coggon et al., 2000). Miners perform repeated kneeling and squatting actions and carry heavy weights, thereby

predisposing them to OA of the knee (McMillan and Williams, 2005). Farmers and farm workers appear to be predisposed to a higher frequency of OA of the hip than the general population due to their work requiring them to perform activities that involve carrying heavy weights (which can involve a flexed trunk when manoeuvring animals), digging and shovelling (Schouten et al., 2002). Sporting activities, such as running that involve moderate activity do not appear to increase the risk of hip or knee OA (Buckwalter and Lane, 1997). Vignon et al., (2006) systematically reviewed OA of the hip and knee and the relationship with sport and concluded that all sport could present a risk for the development of OA in the hip and knee even if moderately performed, but this risk is related to training intensity, duration of training, pre-existing trauma to the hip or knee and increased body mass index for each individual. Elite and professional sports participants are considered to be at much higher risk of the development of OA due to the effect of impact forces and torsional forces to the joints (Vingard et al., 1993; Kujala et al., 1994; Kujala et al., 1995; Spector et al., 1996). The number of hours of exposure to intense sporting activity and long-term exposure over years of high intensity activity is considered to be a high risk factor for OA (Vingard et al., 1993).

Early osteological emphasis when considering OA focussed on the spine. Elliot-Smith and Wood-Jones (1910) reported the presence of "spondylitis" as being a common occurrence in the spines of Ancient Nubians. Dorland's Medical Dictionary (Taylor, 1988) defines spondylitis as inflammation of the vertebrae. When one or more vertebrae are involved, it is termed spondylo-arthritis. This term covers the arthritic complaints including rheumatoid and osteoarthritis. It is likely that Elliot-Smith and Wood-Jones were reporting on OA changes in the spines of the human remains they were studying. There was no attempt to link the findings to activity. The identification of osteoarthritic changes within the spine was a precursor to study of activity related change.

Pre-1970, many studies continued to focus on the spine and mostly looked at patterns of distribution of vertebral osteophytosis (Hooton, 1930; Stewart, 1947; Anderson, 1963; Bourke, 1967; Chapman, 1972; Swedborg, 1974). Swedborg's study used 1126 spines from a Polish medieval population and is notable for the rigour with which analysis of vertebral osteophytosis and facet joint OA was performed. The main aim of these studies was the recording of degenerative changes within the spine rather than attempting to link them to activity.

Post-1970, the bioarchaeological focus altered and the emphasis shifted towards identifying activities that could be linked to OA distribution. Merbs (1983) used data collected from a Canadian Inuit population (41 males and 50 females) to explore the relationship between known or inferred specific activities (obtained from ethnographical resources) performed by the Inuit and

selected pathological changes seen in their skeletons. He identified 20 activity patterns that had the potential to leave MOS. Some of these activities were common to all populations (e.g. bipedalism), but some were Inuit specific. He identified that female Inuits have a distinctive pattern of distribution of OA in the lower thoracic spine and linked this to the carrying of heavy objects on their backs. In addition, Merbs linked high levels of vertebral osteophytosis in males to sledding accidents. He noted the importance of sex and side differences. An interesting outcome of this study was the unexpected linking of elements of an activity with particular patterns of distribution of MOS. His data were derived from a Canadian Inuit population and he correlated OA found in the shoulder, elbow, wrist, hand, spine, ribs, hip, knee, ankle, foot and temporomandibular joint with specific activities identified from ethnographic sources e.g. paddling a kayak and throwing a harpoon placed stress upon the shoulders and elbows; the action of sewing or hammering, flaking and splitting hard materials such as bone or stone was compatible with OA seen in the hands and fingers; using teeth to soften skins and boots with the teeth could be manifest as OA in the temporomandibular joint. Although Merbs supported his findings with information provided by ethnographic evidence, caution should be applied regarding the activities and occupations suggested from the archaeological evidence of a small sample.

Lai and Lovell (1992) carried out a similar study using three male skeletons from Alberta, Canada, dating to the Fur Trade Period. They acknowledge the difficulties identified by Jurmain in linking specific activities to skeletal characteristics but argue that their sample met the criteria for the study of MOS due to the presence of OA, muscle insertion robusticity, enthesophytes and accessory articular facets. They found OA in the cervical spines of the skeletons and attributed the patterns of degenerative change seen to the use of tumplines to carry heavy loads. Although Merbs (1983) and Lai and Lovell (1992) were able to support their results with evidence gleaned from ethnographic and historical accounts, the sample size used in their research was moderate in the case of Merb's (1983) and small in Lau and Lovell's (1992) study and therefore caution should be used when considering activity MOS and the activities relating to them within these contexts.

Bridges (1994) also found similar results in the lower vertebrae of remains from the Pickwick Basin area of north-western Alabama (USA). Bridges suggested that the changes observed might be attributable to the extra strain placed on the spine by using a tumpline around the forehead or a body band around the upper torso.

The study by Sofaer Deverenski (2000) is a further example of degenerative changes in the spine being linked to the carrying of heavy weights. She analysed the spines from individuals from Ensay

and Wharram Percy in the UK and was able to demonstrate a correlation between degrees of arthritic change and activity, with differences being seen between sexes and samples. Her results were supported by ethnographical and historical documents that identified a gendered division of labour. The Ensay women carried large heavy creels strapped across their chests, with the weight of the creel resting on the low back. This was thought to cause a distinctive pattern of degeneration in the spine not seen in the males from Ensay nor the Wharram Percy population. She also noted that articular facet remodeling could be correlated to the age at death, the sex and population of the sample, whereas the presence of osteophytes and pitting could be considered to be the product of different causes e.g. different physical stresses placed upon the body due to differences in lifestyle.. This study identifies the importance of considering the diagnostic criteria for OA (eburnation, pitting, osteophytes) separately as not all are implicated in changes caused by repeated activity.

Stirland (1991) further questioned the interpretation of activity from skeletal remains using ethnographic and historic accounts but realised the benefit to population study, if some occupations or repetitive activities can be identified using MOS. The skeletons retrieved from Henry VIII's flagship, the Mary Rose offered an exceptional opportunity for research into activity related markers. There was documentary evidence for this population and they were controlled for environment (in that they were all crew members of one ship) and time period, which makes them ideal for this type of study. Although there was no crew list from the ship, (apart from three crew members that were known by name), there was a list of the occupations performed by the crew. Thus, the human remains from the Mary Rose fit Merb's (1983) criteria for activity related research, as there are a limited number of known specialised occupations; there is good skeletal preservation and also a known date of death. Analysis of the remains showed that the area of the body showing most pathological change was the vertebral column. The presence of symptoms indicative of high levels of stress in young men from the gun deck was attributed to hauling cannons into and out of the gun ports. This was further supported when Stirland and Waldron (1997) compared the pathological changes seen in the vertebrae from comingled remains of young men from the Mary Rose with those of the spines of mature or older adults from a medieval cemetery (St Mary Fybridgegate, Norwich). They noted that the spines of the younger men from the Mary Rose differed less than would be expected from the older men from Norwich. Stirland and Waldron question whether this lack of differential implies that there were accelerated ageing changes in the Mary Rose spines due to the occupations of the crew that would have involved much heavy work.

Rojas-Sepulveda et al. (2008) observed a high prevalence of vertebral OA in a Pre-Columbian Muisca series from Columbia. They examined vertebrae from 83 individuals and found that 83%

of individuals and 32% of vertebrae had at least one of the manifestations of OA (lipping, osteophytes, eburnation, pitting). Changes could be seen in the youngest cohort (15-30 years). This evidence was used to conclude that high levels of activity began in childhood and that this may have accelerated the aging process seen on the spines.

The previous studies refer to prevalence or distribution of OA in relation to activity. The prevalence of facet joint OA in a population is dependent upon the age and sex of the population being studied (Srikanth, 2005), however these categories are not always included in the information given in published literature. Most studies on vertebral OA focus on osteophytosis of the vertebral body (VOS). Regular patterning of involvement of VOS (with highest levels being seen in the lumbar region and lowest levels of involvement in the thoracic region) is considered to be highly relevant in the study of spinal OA (Jurmain, 1999). This patterning is supported by a number of studies (Bridges, 1992, 1994; Lovell, 1994). Stewart (1966) explained the patterning as being due to increased stress being placed upon certain intervertebral discs as a result of curvature of the spine caused by bipedalism. Facet OA follows similar distribution patterns as VOS with highest levels being reported at C2-C5, C7/T1, T9/T10 and L5/S1 (Inglemark et al., 1959; Kilgore, 1984; Bridges, 1994; Knüsel et al., 1997). These observations were made across different populations. Inglemark et al. (1959) collected their data from 215 skeletons from a medieval cemetery at Aebelholt in Denmark; Kilgore (1984) used a medieval Nubian population; Bridges (1994) analysed individuals from prehistoric South Eastern United States and Knüsel et al. (1994) remains from a Medieval monastic cemetery of the Gilbertine Priory of St Andrew, Fishergate. They all recorded that the changes became more pronounced with advancing age. The prevalence of OA increases with age in both clinical (Felson et al., 1995; Jordan et al., 2000; Loeser and Shakoor, 2003; Zukowski et al., 2012) and archaeological samples (Waldron, 1992; Jurmain, 1977). However, it is not possible to establish a relationship between age of onset and degree of joint destruction because many joints can remain unaffected in very old individuals (Bullough, 2004).

It is difficult to make categorical statements about the differences in prevalence of OA in males and females without taking age into consideration. Generally speaking, clinical evidence indicates that older women are more likely to have OA than men and have greater severity of the disease (Srikanth et al., 2005), however, prior to the age of 50 men tend to have a higher prevalence (Felson, 2004). The literature suggests that females have a higher incidence of knee and certain types of hand OA (Olivieria et al., 1995; Felson and Zhang, 1998; Sowers, 2001; Wilder et al. 2006) and males over 50 are more at risk of developing cervical spine OA (Srikanth, 2005). The age-related rise in OA prevalence in post-menopausal women suggests a possible link with sex hormone levels, particularly oestrogen deficiency (Arden and Nevitt, 2006).

Waldron (1996) studied the distribution of OA in the hands of subjects from archaeological sites across England (including Allington Avenue, Ashtead, Brighton Hill south, Farringdon Street, Great Chesterford, Kellington, Merton Priory, Red Cross Way, Royal Mint, Southgate Street, Spitalfields and Ulwell). The samples were categorised as medieval or post-medieval in period. Individuals were only included if a complete set of hand bones was present. A positive diagnosis of OA was made when eburnation was observed on a joint surface. This study also identified differences between males and females, with males having predominantly unifocal disease, whereas it was predominantly multifocal in females, and 64% of females and 58% of males having at least one joint showing eburnation. Waldron (1996) identified a potential source of bias in this study in that although OA was identified on the hands of many skeletons, these individuals had to be excluded from the study as their hands were incomplete. Waldron (1991) also conducted a similar study on the Georgian and Early Victorian population interred in the crypts of Christ Church Spitalfields in East London (1729-1869) and again found that when considering the finger joints, women were more likely to be affected than men (16% of females v 9% of males).

The archaeological literature identifies that the prevalence of OA can fluctuate with males usually having a higher prevalence than females for weight bearing joints in the under 50's, with the converse being seen as women become over 50 (Bridges, 1992). The association between sex, age and OA means that age profiles must always be considered when examining differences in OA in archaeological populations

In the past, the sex differences that occur in the distribution and prevalence of OA have been considered to be related to activity patterns (Jurmain, 1977). However, it should not be assumed that sex differences are cultural and hormones, body size, genetic predisposition and joint structure should also be taken into consideration (Weiss and Jurmain, 2007).

This section is concluded with reference to Bridges' (1992) bibliographic review of prehistoric OA in Pre-Columbian America. She observed that the knee demonstrated the highest prevalence of OA followed by the elbow. Furthermore, no correlation of specific pattern of OA with any particular subsistence economy was found because prehistoric groups activities range from hunter/gatherer to agriculture and fishing and all demonstrate a high prevalence of knee and elbow OA. Thus, it is not possible to infer specific activities from the presence or absence of OA in a joint, however, it is possible to infer different levels of activity. The above examples show that, although the validity of using OA as a marker of occupational stress has been questioned, it is still used to measure or compare activity levels between populations. Differences in distribution and severity of OA in the spine can be a useful tool when comparing activity levels between

individuals or populations. Although some studies (e.g. Merbs, 1983) were successful in linking OA distribution to specific activities, it is generally concluded that this is not ideal practice.

4.3.4.7 Limitations to the use of OA as a marker of physical activity

The extent to which OA can be used as an indicator of activity has been subjected to debate (Jurmain, 1999; Waldron, 1991). This is in part due to the realization that it is an age-related disease (Rogers et al., 1987) with other factors such as sex, ancestry, weight and movement being involved in its aetiology (Waldron, 1994). Knüsel et al. (1997) attempted to use the distribution and severity of degenerative joint disease in the spine to identify differing activity patterns between two known populations from a 13th-14th century medieval priory cemetery at St Andrew, Fishergate, York. They were unable to identify any significant differences and concluded that the vertebral column is not the best focus of study for occupational markers in skeletal collections due to the fact that biological constraints (curvature of the spine in response to bipedalism) obscure the expression of the markers. However, their study was a comparative analysis of the pattern and severity of OA at the facet joints and vertebral bodies and remodelling was scored as complementary to osteophytic growth and not separately. In contrast Sofaer Deverenski (2000) was able to identify intra-and inter-site differences in the frequency and distribution of identifiable changes in the spine in respect of OA of the facets and osteophytosis of the vertebral bodies. In her study remodelling was separately defined from the presence of osteophytes.

There is some evidence that degenerative change can be seen in younger adults (18-25 years of age) when they have been subjected to the stress of repeated loads upon the joints (Bridges, 1991). These are atypical degenerative changes as the pattern of degeneration occurs much earlier in life than expected. OA found in only one location in a younger adult is possibly related to an old healed traumatic injury to that joint, but activity related degenerative change is seen in multiple locations (Martin, 2013). Given that evidence of OA in relation to repetitive physical activity, can be seen across age groups (young adult to old adult), it is worthy of continued use as a marker of occupational stress.

On reviewing the literature, it is noticeable that there is great variation in the definition, diagnosis and recording of OA between researchers. Bridges (1992) identified areas of concern, including non-standard data-recording protocols and absence of statistical testing. This limits the use of OA as a marker of occupational stress in bioarchaeological studies as the lack of methodological consistency limits cross-study comparison and reduces the academic benefit of existing studies. It is difficult to apply clinical studies of risk factors to bioarchaeological studies of OA as clinicians use factors such as pain and swelling in the affected joints, crepitus, joint space narrowing, marginal osteophytes and sclerosis (seen on radiographs) to define OA, whereas

paleopathologists use marginal osteophytes and eburnation to make their diagnosis (Waldron, 2009).

There are inherent difficulties in comparing population prevalence rates for OA within the literature from different data sets as varying methods of diagnosis are used and data is presented differently (Roberts and Manchester, 2005). The lack of a systematic scoring system for OA within the bioarchaeological context is a major limitation to research. This leads to extreme difficulty in comparing studies and consequently differences in prevalence of OA between similar populations may not accurately reflect population-specific patterns of distribution and severity. Inter-study comparison may highlight the diversity of classification and scoring method used rather than a true comparison of prevalence.

Jurmain (1999) noted that there was a lack of a single diagnostic and scoring system for OA in bioarchaeology and that eburnation should be used as the diagnostic criteria for the presence of OA. Waldron (2009) recommended that, in order to make a diagnosis of OA on a joint surface, eburnation or at least two other features such as marginal osteophytes, sclerosis, pitting or changes in joint contour must be present. The need for a standardised data collection method was recognised and lead to Buikstra and Ubelaker (1994) producing the Data Collection Standards Manual. This standardizes the recording of the presence and degree of severity of lipping, pitting and eburnation for all joint surfaces.

Another attempt to standardise diagnosis and recording is the Global History of Health Project (http://global.sbs.ohio-state.edu/). The aim of the project is to assess global levels of health from human remains using standardised methods. This method relies on vertebral body osteophytosis as a diagnostic for OA of the spine (Steckel and Rose, 2002) and is therefore lacking the specificity of diagnosis recommended by Waldron (2009).

There has been scepticism of the adoption of standardised methods of recording and diagnosis. Cohen and Crane-Kramer (2007) consider that it would be impossible to get all bioarchaeologists to work from the same standardised methods. Their opinion is that it would be better to get researchers from similar areas to adopt the same methods in order to reduce the risk of error from environmental, genetic and inter-observer error. They do not feel that this would work globally.

In conclusion, until there is a standardised method for diagnosing and recording OA in human remains, inter-site comparison will always be problematic. Further research could be directed towards methodological standardisation.

This section has reviewed the use of MOS in the comparison of differing activity levels between samples. The role of OA as a MOS has been given special attention as the degree of severity and distribution of OA throughout the spine is measurable and can provide information about the degree of but not type of activity undertaken by the samples under investigation in this study.

In summary, this chapter has identified the difficulties in using OA as a marker of occupational stress. OA has been used to compare degrees of physical activity between populations but cannot be used to infer a specific activity. Inter-sample variation of the degree and severity of OA (as scored using the methods described in Section 5.7.9) will be used to assess the degree of physical activity undertaken. This information will help to redress Ruff's (1987) criticism of sexual dimorphism studies in that there has been great focus on statistical techniques for differentiating sexes but little consideration of functional aspects. By considering the relationship between OA score and facet morphology and structure and function are explored.

Chapter 5 Methods

This chapter discusses the human skeletal sample used in this study and the methods used to resolve the research questions introduced in Chapter 1. The Materials section will provide detail about the archaeological sample used in this study with detail about the context of the cemetery and the sample composition, whilst in the Methods section, the processes to estimate sex, age, measure facet angle and size, degree of osteoarthritis, lower limb robusticity and humeral directional asymmetry (previously linked to asymmetry of distribution of degenerative disease in the spine: Stirland and Waldron, 1997) are described.

Studies have indicated populational variation in sexual dimorphism of the vertebra (Zheng et al., 2012; Hou et al., 2012; Amores et al., 2014). To reduce the effect of this confounding factor, all archaeologically derived cemetery populations chosen for this study came from the southeast of England (see Figure 5-1). The aim of this strategy for was to minimise inter-sample differences in sexual dimorphism. However it is unlikely that activity patterns were uniform across the populations sampled and that there may be considerable differences in activity and diet between temporally dispersed samples. The differing activity and diet patterns will be controlled for by individual analysis of each sample followed by inter-sample comparison.

The skeletal samples chosen for this study were selected because they were recorded in the site report as having a significant number of well-preserved adult burials of both sexes that represented a wide age range and were available for macroscopic analysis. The study will examine the sexual dimorphism of each vertebral level, which allowed for inclusion of skeletons with an incomplete complement of cervical, thoracic and lumbar vertebrae.

The Great Chesterford collection was used for the pilot study to test for intra-rater reliability of the method. The skeletons from this site were initially analysed in 2013 to test the method used to measure the facets and for the author to gain experience in vertebral level recognition and measuring techniques. The collection was re-measured in 2014 and 2015 providing data to test for intra observer reliability.

Figure 5-1 Map of southern England showing cemetery locations (author's image)

5.1 Great Chesterford

5.1.1 Historical background of Great Chesterford

Great Chesterford (TL 501435) is located in Essex. The town lies south of Cambridge, on the east bank of the River Cam and was a strategically important site, straddling the entrance to the Fens through a gap in the low chalk hills as well as a number of significant route ways and the Iron Age tribal boundary between the Trinovantes and the Catuvellauni (Evison, 1994). The actual position of the Anglo-Saxon settlement in Great Chesterford is unknown. The town had its origins in the late Iron Age and the site of the Roman town in can be identified from traces in field boundaries, from earlier records and excavations (Brinson, 1963). The site of the Roman town and its environs are scheduled as an Ancient Monument.

5.1.2 Archaeological background of Great Chesterford

Commercial gravel extraction in the county produced firm evidence of an Anglo-Saxon cemetery near the Roman town of Great Chesterford in 1952, although recorded discoveries (notably a cruciform brooch) from as early as 1819 suggested that there was a cemetery in this area (Jones, 1980). Smith (1903) commented that cemeteries of the Anglo-Saxon period are rare in Essex. Jones (1980) considered that this statement was still true 80 years later.

Excavation of the cemetery was carried out over several seasons between 1953 and 1955 on behalf of the Inspectorate of Ancient Monuments and reported by Evison (1994). The area permitted for excavation was extremely limited for each season due to the need to keep the ground level for the convenience of the gravel extraction contractors. To date, only the west and south limits of the cemetery have been found. The excavation area is thought to be a section cut through the centre of the cemetery. A total of 161 inhumation graves, 33 cremation graves, 2 horse graves and 2 dog burials were disinterred. It is thought that this only represents a fraction of the number of burials at this site. It is thought that further graves have been destroyed as a result of gravel digging, deep ploughing and the routing of the M11 motorway through the northern part of the cemetery in 1977 (Evison, 1994).

The skeletons were fairly well preserved with 88 adults and 83 sub-adults (42 males, 63 females and 66 not assigned a sex). A group of males were buried, some without weapons and some without grave goods. Evison (1994) suggests that these may be the burials of non-local merchants (buried without weapons) and slaves (buried without goods). It is thought that most of the excavated graves date from the 6th Century, however, it is considered probable that 5th and 7th Century graves were in the destroyed areas (Evison, 1994). The remains are curated at the University of Southampton

5.1.3 Taphonomic alterations at Great Chesterford

Waldron (1994b) noted that the remains from Great Chesterford had been stored badly, with boxes containing multiple elements rather than discrete skeletons. There was evidence of post-mortem breakage of a substantial number of bones with two or more parts of the broken bones being stored in separate boxes. The bones were reconstructed into discrete skeletons when the inhumation numbers were visible.

5.2 Buckland Cemetery

5.2.1 Historical background to Buckland Cemetery

Buckland (TR310430) can be found in Kent. The cemetery is situated on Long Hill on the east bank of the river Dour and is separated from Castle Hill by the Dour Valley. Buckland is in close proximity to the Roman port of *Portus dubris*, built at the mouth of the river Dour, the only significant break in almost 20km of chalk cliffs. There is widespread evidence of Roman settlement in the countryside around Dover and also native settlements and associated cemeteries (Philp, 1989; Parfitt, 2002:394).

5.2.2 Archaeological background to Buckland

There have been two major campaigns of archaeological excavation at Buckland (see Figure 5-2). The first campaign was undertaken between 1951 and 1953 led by Vera Evison. It is thought that the cemetery was first disturbed by the building of the Dover-Deal railway and Evison found evidence of grave disturbance during her excavations. The building of a new housing estate at Long Hill led to the further discovery of a number of graves containing human remains and the Inspectorate of Ancient Monuments mounted a rescue excavation. In total, 171 graves from AD 475-750 were excavated. These remains are curated at the Natural History Museum.

In 1994 development of another housing development at Castle Hill was planned. This estate was situated on the slopes below the original cemetery and separated from it by the Dover-Deal railway cutting. The proximity of this site to the important Anglo-Saxon cemetery excavated by Evison led to a one-day evaluation by South-Eastern Archaeological Services on behalf of the Heritage Conservation Group of Kent County Council to check for the presence of outlying graves. Twelve graves were identified during this evaluation necessitating more extensive excavations to locate, record and remove any further graves before the site was destroyed by construction activities. Canterbury Archaeological Trust performed the excavations in July 1994, leading to the discovery of a total of 244 graves. The remains from this campaign are curated at the offices of the Canterbury Archaeological Trust in Kent and were used in this study. The site is now fully developed as a housing estate.

5.2.3 Taphonomic alterations at Buckland

Trevor Anderson evaluated the lower Buckland cemetery remains (Anderson, 2012). His report does not contain details of the methods used to identify sex and age group, although he does write that the analysis was based on osteological evidence, rather than by considering the grave goods. Bone preservation is very poor in this cemetery limiting the number of spines available to this study. This is a common finding in Anglo-Saxon cemeteries (Anderson, 1990; Hirst, 1985; Philp, 1973; Waldron, 1994).

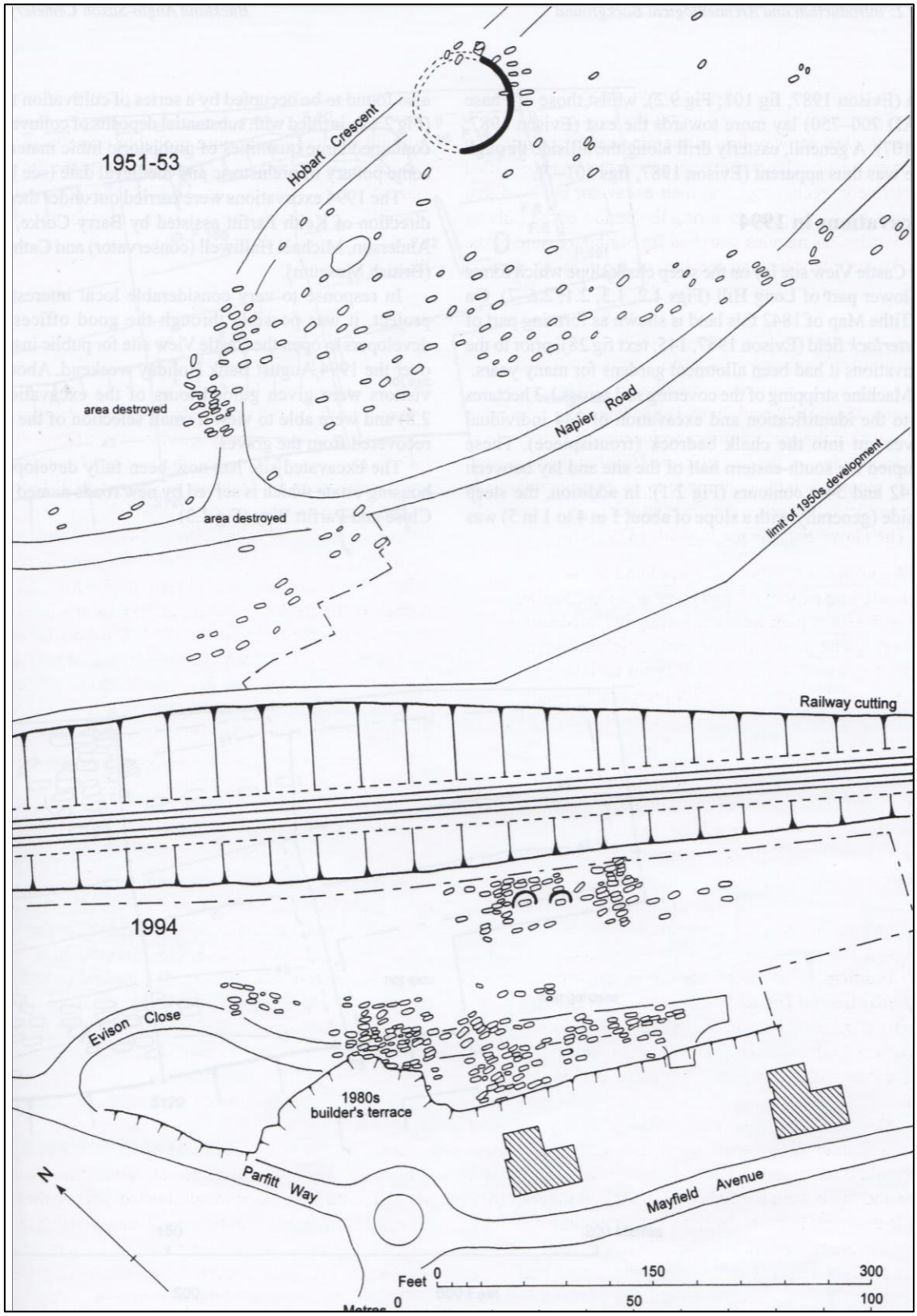


Figure 5-2 Overall plan of Buckland (Long Hill) Anglo-Saxon cemetery showing areas excavated in 1951-3 and 1994: from Parfitt and Anderson (2012)

5.3 St Anne's Road

5.3.1 Historical background to St Anne's Road

St Anne's Road cemetery is sited in Upperton, (OV603603) a suburb of Eastbourne East Sussex. St Anne's is a multi-period site on the upper southwest-facing slope of St Anne's Hill facing the river Bourne and the Bourne valley. The site lies on the margins of the South Downs adjacent to a trackway across the hill ridge.

5.3.2 Archaeological background to St Anne's Road.

This area has been subject to archaeological study since the Victorian Period with numerous excavation campaigns taking place. There is evidence of settlement from the Bronze Age onwards with a Bronze Age Barrow ditch being identified during excavations by Spurrell (1882) and evidence of Iron Age settlement and field systems. The first evidence for the presence of an Anglo-Saxon cemetery was unearthed at the end of the 19th Century during the construction of a school (Spurrell, 1882). In 1991 a series of archaeological trial trenching was carried out prior to redevelopment of the site as a housing estate. This fieldwork confirmed the existence of an important and extensive Anglo-Saxon cemetery with 27 inhumations and three cremations being excavated. East Sussex County Council requested further excavation in 1992 in an area south of the 1991 excavation area intended as a new college annex. A further 42 graves were identified but not examined intrusively. The college decided not to proceed with the extension scheme as extensive excavation works would have been required and the trench was refilled.

A further series of excavations were carried out in 1997 and 1998 by Archaeology South East, which led to the site being scheduled under the Ancient Monuments and Archaeological Areas Act, 1979 in recognition of the importance of the site. It is thought that there are still a large number of undisturbed graves in the area.

5.3.3 Taphonomic alterations at St Ann's Road

The preservation of the skeletal remains is poor with skeletal elements being fragmentary or degraded, although most skeletal elements are represented. After excavation in 1991, the remains were stored in poor conditions in a garage, which led to further deterioration. Of the 192 excavated individuals, 150 were adult and 42 were infant or juvenile. The remains are curated at Eastbourne Town Hall

5.4 St Bride's Crypt and St Brides Lower Cemetery

5.4.1 Historical background to St Bride's Crypt and Lower Cemetery

St Brides Church is situated in Fleet Street, London and is one of the oldest in the city. The church is built on the site of a Roman building which is thought to be the remains of a small mausoleum in a late Roman cemetery (Grimes, 1968). Christian worship took place at the site as early as the 7th Century. The church was destroyed in the Great Fire of London in 1666 and rebuilt by Sir Christopher Wren on top of the previous 6 churches that had stood on this site. It is still an active church today.

The Church sustained bomb damage during the Second World War, which led to excavations in the 1950s by Professor Grimes. The excavation revealed a large number of skeletal remains from a medieval charnel house and individuals interred in the crypt. It is thought that the charnel house contained the remains of as many as 7000 individuals. The crypt contains the remains of middle-class Londoners interred in the late 18th to early 19th century. 227 of these were interred in coffins with metal plates associated with each internment. These metal plates were inscribed with the name, age at death and date of death (Scheuer and Bowman, 1995). In 1854 the crypts were sealed by an Act of Parliament and left undisturbed until damaged in the Second World War.

St Bride's Lower Cemetery was founded in response to overcrowding in the St Bride's Churchyard and the burials are thought to date from AD 1770-1849 (Miles and Conheeney, 2005). It is situated at 75-82 Farringdon Street, London EC4. St Bride's Fleet Street and Lower St Bride's Churchyard are part of the same parish population but represent different echelons of society. It is thought that this population contained individuals from Bridewell workhouse and Fleet prison as well as other individuals of low socioeconomic status. The parish records contain detailed information about these individuals but as they were of low status, they were not buried with coffin plates making individual identification impossible.

5.4.2 Archaeological background to St Bride's Crypt and Lower Cemetery

Post War excavations of St Bride's church in the 1950's by Professor W. F. Grimes led to the identification of a crypt as part of the Chapel. This excavation was at the behest of the then curate Rev C.M. Armitage (Milne and Reynolds, 1994). The remains of the 227 individuals from the crypt were analysed and recorded by the Centre for Human Bioarchaeology. The remains are curated at the Church. The excavations at St Bride's Lower Cemetery led to the recovery of 606 individuals, of which 544 were analysed by the Centre for Human Bioarchaeology based at the Museum of London. The remains are curated at the Museum.

5.4.3 Taphonomic alterations at St Bride's Crypt and Lower Cemetery

Generally, bone preservation is good in both sets of remains with high levels of skeletal completeness.

5.5 Inclusion criteria

Adult skeletons only are included in this study as the estimation of sex in a non-adult is complex (Mays and Cox, 2000). Skeletons from the cohorts without known age at death were classified as adult when they exhibited epiphyseal fusion of the long bones (with the exception of the medial clavicle which fuses in the early twenties, (Langley-Shirley and Jantz, 2010)) , closure of the spheno-occipital synchondrosis, Ascádi and Nemeskéri (1970), dental wear and antemortem loss (Miles, 1963; Brothwell, 1981), altered morphology of the pubic symphysis (Todd, 1920; Brooks and Suchey, 1990) and morphological change in the auricular surface (Lovejoy et al 1985),

An important inclusion criterion is the state of preservation of the skeletal material. The bones needed to be in a good state of preservation for estimation of sex, age, asymmetry and measurement of zygapophyseal angle and size to be undertaken. Table 5-1 summarises the numbers of skeletons from each cemetery that are suitable for inclusion in this study.

Table 5-1 Summary table of skeletal remains included in this study

Cemetery	No of skeletons excavated	No of skeletons with sufficient preservation to be included in the study
Great Chesterford	167	20
Buckland	244	8
St Anne's	192	25
St Bride's Crypt	224	67
St Bride's Lower	544	60

5.6 Exclusion criteria

Skeletal material was excluded from this study if on examination, it was deemed to be from a non-adult, if there was insufficient preservation of the bones necessary to collect the appropriate data and also if there was evidence of a pathology that would affect normal activity e.g. fracture, amputation of a limb, diseases affecting the spine e.g. tuberculosis, diffuse idiopathic skeletal

hyperostosis, scoliosis (idiopathic or acquired) or other pathology that would affect the normal functioning of the body. Transitional vertebrae (see section 2.3.7) were also excluded to limit the natural variation of the data.

5.7 Method

This section describes and discusses the methods used to collect and analyse the data. The difficulties of estimating sex and age using morphological and metric methods are identified. The methods chosen for use in this study are presented in detail. Observational and metric methods were used to estimate the sex and age at death of individuals without coffin plates. Robusticity, asymmetry, the presence of osteophytosis and the severity and extent of OA of the zygapophyseal joints are all estimated using standard osteological techniques which are discussed within the text.

5.7.1 Methods of analysis

This data were collected from Great Chesterford Cemetery Essex, Buckland Cemetery Kent, St Anne's Cemetery, East Sussex and St Bride's Church, Fleet Street, London. The sex, age and in some cases occupation was known for the individuals from St Bride's Church crypt. This is of great value in this study as age related/occupational changes can be accurately measured and provide a reference sample. Bocquet-Appel and Masset (1982) identified the importance of using reference sample for age related studies. They identified that no one reference collection is ideal but must have several characteristics, i.e. the sex and age-at death of the individuals are known, and that the collection contains a good representation of the population of interest. There is no Anglo-Saxon reference collection with this information available and therefore the St Bride's sample will be used in this study.

All the data collected from each sample was initially recorded on paper forms that were specifically designed for this study. No standard recording form exists for recording morphological changes in vertebrae and therefore an appropriate form was designed for recording information related to OA score, sagittal vertebral facet angle, facet height and width. The form also included sections for recording of data relating to sex, age and osteometrics (see Appendix E). The recording form section for estimating sex, age and long bone measurements was designed around the template from pre-existing recording standards sheets (Buikstra and Ubelaker, 1994; Brickley and McKinley, 2004) and the section of the recording form for facet measurement and OA scoring was designed specifically for this project. Macroscopic examination was used to collect data from the skeletons. Current bioarchaeological methods as described in the following sections were

chosen for sexing and aging techniques because they are commonly used in British research and would create a data set that would be comparable with other studies. Hard copy data was transferred to Excel spreadsheets and imported into SPSS for data analysis. The statistical methods used are described in 5.7.8.

5.7.2 Demographic data - sex

The majority of the individuals from the cemeteries used in this study had sex and age estimated as part of the post-excavation process, however, it was decided to reassess these data by applying the same standard sex and age methods to all of the skeletons from undocumented burials (i.e. age at death and sex not discernible from coffin plate) with the aim of preventing inter-observer error.

5.7.2.1 Estimation of sex from archaeologically derived samples

The difficulties in correctly estimating sex and the various methods that can be used are described in this section. The sex of an individual can be inferred using morphological and/or metric techniques. Spradley and Jantz (2011) emphasise the distinction between assessment of sex using subjective visual analysis of morphological features and estimation of sex using metric data and recommend the use of metric sex estimation (supported by evidence of a greater number of recently published papers using discriminant function analysis of metric data when compared to the number of papers using visual assessment techniques). However, Stewart (1979) recommends combining methods and using metric data to validate visual analysis. Adams and Byrd (2002) support this concept but warn that visual sex assessment is affected by subjectivity and has higher inter- and intra-observer errors than metric methods (Adams and Byrd, 2002). In contrast, Milner and Boldsen (2012a) consider that, in relatively complete skeletons, an experienced osteologist would be as accurate using morphological as metric methods but add the caveat that quantitative methods are more certain and it should be remembered that not all bone dimensions are equally sexually dimorphic. Thus, discrimination should be used when deciding what measurements are appropriate for each element. Morphological and metric variation can best be seen in structures related to reproduction. The zygapophyseal joints have no reproductive specific role and therefore may lack dichotomous variation. The differences that may be observed may be due to females being generally smaller than males. The effect of physical activity in particular the sexual division of labour may also play a part in differential zygapophyseal joint size.

The next two sections will discuss morphological and metric variation in more detail.

5.7.2.2 Morphological variation in skeletal structure

When using morphological variation to assess the sex of a skeleton, some bones are more sexually dimorphic than others, particularly the pelvis and skull. Pelvic shape differences are related to parturition and locomotion and are thought to be the most reliable features for sex determination (Brothwell, 1981) with females having a wider pelvic inlet, wider sub-pubic cavity and wider greater sciatic notch than males. High levels of accuracy have been reported when assessing morphological analysis of the pelvis using known sex reference collections; Bruzek (2002) reported a 95% success rate when using the Paris and Coimbra collections. His method utilized eleven pelvic traits from the pre-auricular surface, greater sciatic notch, the composite arch between the sciatic notch and auricular surface, the inferior pelvis and ischiopubic proportions. His results showed that there was considerable variation in the contribution of each trait towards a correct assessment of sex but using multiple variables a greater level of accuracy could be achieved.

Morphological variation in the skull using sex indicators outlined in Buikstra and Ubelaker (1994), i.e. nuchal crest, mastoid process, supra-orbital margin, supra-orbital ridge and mental eminence, tend to be less accurate than pelvic features when estimating sex. Williams and Rogers (2006) achieved an 80-90% accuracy rate using the dimorphic features of the skull. Generally, the skull indicators are larger and more robust in males but in some populations this can be problematic as ancestry can affect some cranial traits making sex estimation more difficult (Garvin et al., 2014). Increased robustness in females in certain populations can lead to misidentification (Walrath et al., 2004; Walker, 2008). The subjective nature of morphological analysis can also lead to errors of classification. Buikstra and Uberlaker (1994:16) state:

> *"Estimates of sex therefore can be difficult if the observer is not familiar with the overall pattern of variability within the population from which the sample is drawn".*

The methods used to estimate the sex of an individual recognise, to a degree, the morphological variation that can occur in different samples by providing a continuum from male to female by including the classifications; typical male, probable male, unknown, probable female, typical female (Sofaer, 2006). This classification system allows recognition that there can be considerable variation within a given trait and an increased dispersion of measurements in both sexes produces an increase in the overlap of corresponding distributions and hence a lower degree of dimorphism leading to greater difficulty in dichotomous characterisation (Marini et al., 1999).

5.7.2.3 Metric variation in skeletal structure

Incomplete, fragmented or commingled remains are frequently encountered in bioarchaeological contexts and the typical anatomically dimorphic features of the pelvis or skull may be absent or damaged making qualitative methods for sex estimation problematic. As an alternative, the quantitative assessment of metric traits can be used. Metric estimation of sex is based on differences in size and/or shape in male and female bones and is based on taking measurements of various dimensions of skeletal material.

There are several strengths in the use of metric methods. The methods rely on standard osteometric points and are considered by some to be more repeatable than the reliance on subjective judgement against a scale of expression for the less sexually dimorphic bones leading to lower intra- and inter- observer error (Adams and Byrd, 2002; Spradley and Jantz, 2011). McKeown and Schmidt (2013) emphasise the importance of fully understanding the parameters of the measurement to be taken and the need for accuracy of observation, as minor errors in data collecting can lead to a significant effect on the validity of the results calculated. Konigsberg and Hens (1998) consider that metric variables have higher levels of simplicity and consistency in their recording and as continuous variables can be analysed using powerful statistical methods. However, there is conflicting argument on the validity of metric methods over morphologic al methods. Ramsthaler et al. (2007) compared metric and morphological methods for the determination of sex from the crania of reference collections from Frankfurt and Mainz (Germany). They used Fordisc software (discussed in the section below) to estimate the sex from the metric data and found that the average accuracy for both sexes was 86% (metric) vs. 94% (morphological). They explain their discrepancy as a weakness of Fordisc because their sample may not match the software reference sample drawn from the US American forensic database for ancestry, age distribution and socio-economic status.

Sexual dimorphism in size can be estimated in a number of different ways.

a) Single measurements: Single measurements capture variation in size and some measurements (e.g. humeral or femoral head diameters) can identify a reasonable separation of the sexes (Milner and Boldsen, 2012a). Unlike multiple measurements, single measurements do not capture a sense of shape, only size. There are practical reasons for using single measurement methods for sex estimation; the data are quick and easy to collect, they can be a reasonable estimator of sex and are suitable for fragmented or incomplete skeletons where the number of measurable options is reduced. One of the key issues is that, if there is an overrepresentation of one sex in the skeletal sample with one sex dominating the other, the probability that a bone of a certain size is male or female can be affected (Milner and Boldsen, 2011). In summary, the single measurement

method is suitable for a speedy estimation of sex, particularly in fragmented remains in populations that have an even distribution of males and females.

b) Simple ratios: These represent bone shape in contrast to single measurements described above that represent bone size. In comparative studies of sexual size dimorphism, simple ratios can be transformed into indices to reduce the bias that can occur when size alone is used as an indicator of sex (Arsuaga and Carretero, 1994) e.g. sexual dimorphism index (SDI). This index is usually calculated as a ratio of mean values of a specific measurement from males and females (see section 5.7.7.3). However, there has been some criticism of the use of indices:

i). Ratios do not tend to have normal distribution and therefore violate the assumption of normality required for parametric statistical tests (Atchley et al., 1976),

ii). Ratios do not remove the effects of size and require the assumption that the numerator and denominator are collinear with an intercept of zero (Jackson et al., 1990).

iii). Ratios increase problems related to measurement error leading to wide confidence intervals (Sokal and Rohlf, 1995).

Smith (1999) summarised the issues relating to the use of ratios/indices in comparative studies relating to sexual size dimorphism (SSD) and compared 25 data sets from the literature to duplicate a number of statistical procedures commonly used. He concluded that there was no compelling reason for ratios not to be used in the analysis of SSD and that the logarithmic ratio of male/female and linear scale ratios are equally appropriate for use in sexual dimorphism studies. In summary, ratios can be of limited use when estimating the sex of a skeleton, as a set of indices generated from a sample will not indicate which individuals do not fit into the expected range.

c) Complex multivariate analyses; within-group differences can be maximised using statistical tests such as discriminant function analysis (DFA) or logistic regression. These statistical processes classify the sex of unknown individuals and calculate the probability that they can be ascribed to a group e.g. sex or ancestry, by examining variability between all groups. They can be performed using statistical software. Studies have indicated that DFA equations are population specific (Introna et al., 1998; Slaus et al., 2003; Sumati and Phatak, 2010). Thieme and Schull (1957) noted that the applicability of DFA was dependent on the degree of sexual dimorphism between populations and the degree to which sexual dimorphism is the same within populations. They reported that inter-population differences within a single sex is often more pronounced than intra-population differences. This led to the development of population-specific discriminant functions for sex estimation among various populations (Murphy, 2002; Spradley et al., 2008)

DFA is considered to be an objective statistical technique for sex determination (Hsiao et al., 1996). The method selects the minimum number of traits that yield maximum discriminant effectiveness (Isçan and Helmer, 1993) and uses posterior probability and typicality probability to calculate the classification probabilities (Albanese et al., 2008). It can only be used to place continuous variables into two categories (e.g. males and females) and is suitable for analysis of facet size and angle. DFA assumes that the sample is normally distributed for the trait under examination (Field, 2013). It is a commonly used statistic in studies of skeletal sexual dimorphism. However, many of the studies make no comment on the normality of distribution of the data used.

Logistic regression is robust against violations of normality and homoscedasticity and has fewer restrictive assumptions (Field 2013). It allocates an individual of unknown sex to a set of *a priori* defined groups (male or female) and generates posterior probabilities of group membership. It can be used to place continuous and categorical variables into defined groups. It is therefore useful to use logistic regression for all data that is not amenable to DFA.

One of the most noted examples of multivariate analyses can be seen in the computer program FORDISC (Jantz and Ousley, 2005). This program is able to provide the probability that an individual is male of female or belongs to a particular demographic group by comparing standard cranial and postcranial measurements from an unknown individual against a large database of known individuals. The database is compiled from measurements collected from individuals of known ethnic origin and sex that were born after 1900 from the US American Forensic Database. The error risk due to population specificity is reduced with this program because data was collected from a broad geographic sample; however, there are limitations to its use. As with all statistical programs, data can only be placed into the categories available from the software (Simmons and Haglund, 2005). Ramsthaler et al. (2007) identified that Fordisc cannot be used as a single method for the estimation of sex of recent skeletal remains from Europe as the database is not compatible. Milner and Boldsen (2012) advise that the study skeletons should come from the same population as the reference population for there to be any validity in sex estimation. FORDISC 3.0 has been programmed so that classification will not be allowed if the post probability is too low, reducing the risk of misclassification (Morris, 2010).

Probabilistic Sex Diagnosis (DSP) is another computer program that can be used to determine the sex of an individual. The database consists of os coxae metric data collected from 2040 adult specimens from 12 different reference populations (Murail et al., 2005). The authors claim close to 100% accuracy in sex estimation. The sample populations are of known age at death and sex from different areas of the world (Europe, Africa, North America and Asia). They date from the

18th to early 20th century. This database is used in this study as the sample populations are more closely matched to the study population for location but do not match closely for period. In order to reduce error, multiple methods of sex estimation including DSP are used in the study.

There are limitations to the use of bioarchaeological databases because the reliability of sexing methods decreases when unrelated population samples are compared (Van Gerven and Oakland, 1973; Calcagno, 1981). Secular changes and differential activity patterns are thought to lead to variation in skeletal metric and non-metric features and hence differences in sexually dimorphic features in different populations (Işcan, 2005; Case and Ross, 2007).

A number of manuals defining the most utilised methods for the estimation of sex and age at death have been published (Ascadi and Nemeskeri, 1970; Bass, 1995; Buikstra and Ubelaker, 1994; Krogman and Işcan, 1986). However, these methods do not account for population specific variation in human skeletal remains. This has led to many regional studies relating to these variables, leading to better intra- and inter-populational variability comparisons e.g. Hanihara, 1952; Konigsberg and Frankenberg, 1992; Plato et al., 1994; Jackes, 2000; Hoppa and Vaupel, 2002; Hou et al., 2012; Nikita, 2012.

5.7.2.4 Methods used to estimate sex.

Good bone preservation is necessary for accurate sex estimation in adults (Milner and Boldsen, 2012). Typical accuracy for sex estimation in adults from morphological traits is 90-95% when using the pelvis and 80% when using the skull (Krogman and Işcan, 1986). In this study, a multifactorial approach was adopted when assessing the sex of an individual, with pelvic morphology being given the highest priority (Cox, 2000). Data for sex determination was recorded using the macroscopic assessment methods of Buikstra and Ubelaker (1994) and derived from the sexually dimorphic features of the skull, pelvis and femoral head. In order to reduce the risk of error between populations, all features were seriated before final assessment of the sex of an individual was made to increase accuracy when estimating the sex of an individual (White et al., 2012). Table 5-2 overleaf lists the features used in this study to ascribe a sex to an individual

Table 5-2 Cranial, pelvic and femoral features used to determine adult sex

Skeletal Element	Morphological/metric feature	Reference
Skull	Nuchal crest	Ascadi and Nemeskéri (1970)
	Mastoid process	
	Supra-orbital margin	
	Supra-orbital ridge	
	Mental eminence	
Pelvis	Ventral arc	Phenice (1970)
	Sub pubic cavity	
	Ischiopubic ramus bridge	
	Greater sciatic notch	Walker (2005)
Femur	Femoral head diameter	Stewart (1974)

Ubelaker and Volt (2002) identified Phenice's method to be the most accurate method for sex estimation and therefore this method was given the highest priority. In the absence of the pubic bones, the morphology of the sciatic notch was given the next priority level (Walker, 2005). In the absence of a pelvic girdle, cranial morphology or morphometrics were used to assess sex. High levels of accuracy (92.5-99%) can be achieved using skeletal measurements (Giles, 1970; Cox, 2000). The measurements taken can indicate a male or female individual depending on the robustness or gracility of the bones being measured (Bass, 1995). Many factors can affect skeletal robusticity (genetics, environment, nutrition, maturation rate, physical activity and health) and females could display male attributes or vice versa (Wolfe and Gray, 1982). In this study, Stewart's (1974) method in respect of femoral head diameter, was used to sex bones from individuals where bones with sexually dimorphic features were absent or unrecordable due to poor bone preservation. He identified that individuals with femoral head dimensions between 44 and 46 mm could not be sexed with any accuracy but measurements below 43 mm and above 47 mm can be identified as females and males respectively with 90% accuracy. This method was used to assign sex to Buckland B282B and B309.

Table 5-3 Use of femoral head diameter to estimate sex

Measurement	Males	Females	Reference
Femoral proximal/distal head diameter	>48 mm	<43 mm	Stewart (1974)

When using morphometric data to assess the sex of an individual, age was taken into account as older post-menopausal women can develop "male" cranial features which could potentially lead them to being identified as male (Walker, 1995).

To further increase the probability that sex has been estimated correctly, pelvic measurements were taken and assessed using the Probabilistic Sex diagnosis database [DSP] (Murail et al. 2005). This tool uses discriminant function analysis to calculate the individual probability that an individual is either male or female by comparing innominate measurements against a global reference sample. A minimum of four measurements is required for probability calculation. The measurements are listed in Table 5-4. The excel spreadsheet and measurement details are available from: http://www.paceau.u-bordeaux1.fr/publication/dsvp1/html. The pelvic evidence is considered to be more accurate in cases where the skull and pelvis provide conflicting diagnostic signs (Cox, 2000).

Individuals that were not sex distinctive due to anomalous features or absent diagnostic bones were excluded from this study. In the event of an anomalous assessment (probably male, probably female or unknown) the overall picture for that individual were reviewed from all the features analysed in conjunction with the position of the feature in the seriation rank. If it is still problematic to ascribe a sex to that individual, they were excluded from this study.

In order to be able to fully consider the effects of sexual dimorphism, this study includes data from 180 individual skeletons analysed by the author or of known sex.

Table 5-4 Probabilistic sex diagnosis database (DSP) measurement description

Variable	Brief Definition	Reference
PUM	Minimum distance from the superior and medial point of the pubic symphysis and nearest point of acetabular rim at lunate surface	Bräuer 1988
SPU	Pubic breadth between the most lateral acetabular point and the medial aspect of the pubis. The measurement should be perpendicular to the major axis of the os pubis	Gaillard 1960
DCOX	Maximum height of os coxae measured from the inferior border of the os coxae to the most superior margin of os coxae	Bräuer 1988
IIMT	Distance from the posterior inferior iliac spine to the anterior border of the greater sciatic notch. The axis of measurement should be perpendicular to the anterior border	Bräuer 1988
ISMM	Distance from the most anterior inferior point of the ischial tuberosity to the furthest point on the acetabular border	Schulter-Ellis et al. 1983
SCOX	Distance between the anterior superior iliac spine and the posterior superior iliac spine	Bräuer 1988
SS	Distance between the anterior inferior iliac spine and the deepest point on the sciatic notch	Gaillard 1960
SA	Distance between the anterior inferior iliac spine and the auricular point (defined as the intersection between the arcuate line with the auricular surface)	Gaillard 1960
SIS	Distance between the lateral border of the acetabulum and the mid point of the anterior portion of the sciatic notch	Bräuer 1988
VEAC	Maximum vertical diameter of the acetabulum	Bräuer 1988

5.7.3 Demographic data- age

5.7.3.1 Age estimation from archaeologically derived samples

Knowing the age at death of a particular individual is essential when assessing the biological profile of a subject and to enable valid comment to be made about human characteristics that are subject to age-related change e.g. activity, genetics, health and overall lifestyle (Calce, 2012). Chronological age does not have external factors affecting it; it is purely a measure of time that has passed. In contrast, physiological age refers to the aging processes that occur in the body (growth, development and the effects of aging). Physiological changes are not synchronous and

can vary from individual to individual (e.g. menarche and menopause) (Gerdhem and Obrant, 2004). Over time, the effects of environment and activity cause a divergence in physiological and chronological age increasing error into age calculations particularly in the assessment of old individuals (Uhl, 2013). Low reliability in age estimation methods can result from the fact that chronological age and physiological age only rarely coincide (Campanacho et al., 2012). Age at death estimates assess the physiological age not the chronological age of an individual and broad age ranges are required for each age-related change in order to account for external factors (Santos, 1996).

There is considerable criticism about estimate accuracy, precision and reliability when ascribing an age at death to an individual with little consensus amongst osteologists as to which ageing method is the least unreliable (Hoppa and Vaupel, 2002; Milner, 2008). Mays, (1998: 50) stated

> *"At present, the lack of a wholly satisfactory technique for estimating age at death in adult skeletons from archaeological sites is one of the most thorny problems facing human osteoarchaeology."*

The use of multiple methods for assessment of age of death are recommended to address the issues identified by Mays, (1998) (Buikstra, 2006). Lovejoy et al., (1985) developed the original multifactorial method. Milner and Boldsen (2012) use this method to enable a more accurate assessment of age at death using a Transition Analysis system. They used the pubic symphysis, sacro-iliac joint and cranial sutures in their procedure and found that the three areas did not perform equally well when evaluated against 252 known-age modern males and females. The cranial suture assessment performed least accurately and from this result Milner and Boldsen stated:

"*It is hardly worth bothering with sutures as their positive effect is, at best, negligible, and their inclusion often worsens estimates". (p. 107).*

In contrast, the use of changes in the pubic symphysis worked best when estimating age, however, there is a consistently low reliability in results, particularly when the methods are applied to a different population than the population used to develop the method (Santos, 1996). Occupation and/or physical activity can both be a factor in the degenerative changes seen in the os pubis (Scheuer, 2002) and may be a factor in the variation seen in rate of ageing in this bone. Heavy mechanical loading can lead to increased degeneration and apparent ageing of the bone. Scheuer's study (2002) captures a general sense of a population's age-at death distribution but is not particularly sensitive to estimate an individual's age.

Age estimation is more problematic for adult skeletons than for juvenile remains because juvenile ageing methods rely on more highly constrained developmental processes, whereas adult age estimates are derived from degenerative characteristics that accompany the aging process, e.g. changes in the pubic symphysis and sacro-iliac joint may occur at different ages in individuals and are only weakly associated with age (Milner and Boldsen, 2012). Degenerative changes that accompany advancing age can be seen as changes in the pelvis and these variations are used in the methods of Suchey-Brooks (Brook and Suchey, 1990), Todd (1920) and Lovejoy et al. (1985). There are many factors that impact upon the degeneration that is observed with increasing physiological age (e.g. nutrition, activity, diet, disease, stress) (Roberts and Manchester, 2005).

Any estimation of age is in effect a probability statement of accuracy and precision as there is no simple method to define age. Different methods give different determinations of age (White and Folkens, 2005). The multifactorial method for aging adult skeletons outlined by Buikstra and Ubelaker (1994) as appropriate for a British population was used in this study, as there is no one definitive method for estimation of age. The use of commonly used methods allows for cross study comparison. Lovejoy et al. (1985) recommend the seriation of skeletons for each indicator in the sample under investigation to maximise the information from biological age and to reduce observer error, however, Konigsberg and Frankenberg (2002) consider that seriation creates a problem of lack of independence and can complicate decision making when transitioning from one age to another. In order to increase the reliability of age at death assessment in this study, each population was considered separately, and all remains were seriated by the skeletal part being assessed (e.g. pubic symphysis). After seriation, the individual remains were placed in the age interval they most closely resembled according to the seriation sequence for each age interval after the method of Bedford et al. (1993).

Early researchers such as Hrdlička thought that it was sufficient for an anthropologist to place a skeleton into sub-adult, adult or senile categories by using observation of multiple features associated with ageing, such as pelvic auricular surfaces and cranial suture closure, however despite continued use of such an approach, there are limitations associated with this. The use of age categories can be problematic as it is necessary to assume that all individual age estimates have the same degree of error (Boldsen et al., 2002). A possible solution to this problem is to use broad categories that encompass considerable morphological variation although this carries a risk of blending age information.

5.7.3.2 Methods used to assess age

In this study, multiple aging methods were used to estimate age at death, which individuals being placed into three categories (young adult, middle adult and old adult). The methods used are described overleaf.

Buikstra and Ubelaker (1994) identified use of the multifactorial methods listed below as being appropriate for a British population: the minimum and maximum age at death for each individual from undocumented populations was estimated for each of the methods listed in Table 5-5. Lovejoy et al. (1985) recommended the use of seriation series for each indicator under investigation to maximise the information that could be gathered about biological age at death and to reduce observer error. A seriation sequence was established for each indicator of skeletal age at death by comparing the degrees of variation of each indicator and arranging the samples in ascending age order.

Table 5-5 Age at death estimation methods used in this study

Skeletal element	Morphological/metric feature	Source
Skull	Dental Wear	Miles (1963) and Brothwell (1981)
Pelvis	Pubic symphysis	Brooks and Suchey (1990)
	Auricular surfaces	Lovejoy et al (1985)

Once the maximum and minimum age determined for each individual was determined, the individual was included into a broad age category (Table 5-6) as described by Buikstra and Ubelaker (1994). The use of broad age range categories is recommended due to the difficulties of accurately estimating the age at death from skeletal material to less than a 15-year range (Cox, 2000).

A random sample from the documented St Bride's population was also assessed for age. (A random number generator computer program was used to identify the individuals to be assessed) and the accuracy of estimated age and actual age compared.

The dental wear methods of Miles (1963) and Brothwell (1981) were used for this study. The decision to use dental wear methods was supported by Mays (1988) who considers that these are one of the most accurate methods for ageing adult material.

Schwartz (1995:195) lists a number of methods that have been developed to assess age from the symphysis pubis, however, the majority of published research rely on the Todd and Suchey-

Brooks methods (McKern and Stewart, 1957; Gilbert and Kern, 1973; Meindl et al., 1985). Testing of these methods against reference populations has indicated that they are capable of producing accurate results with the Suchey-Brooks method (Brooks and Suchey, 1990) showing greater accuracy than the Todd method (Mays, 2010). The Suchey-Brooks method uses separate scoring systems for males and females making it appropriate to use for this study.

One of the advantages of using Lovejoy et al. (1985) method for estimating age at death using the auricular surface of the ilium is that it has been demonstrated to discriminate well between the middle adult and old adult age groups (Bedford et al., 1993). This discrimination is important, as the samples under study need to be allocated to an appropriate age range group with as much accuracy as possible.

Table 5-6 Age categories used to divide the population into life phases
(After Buikstra and Ubelaker, 1994; Cox, 2000).

Category	Age Range (Years)
Young Adults	21-35
Middle Adult	36-45
Old Adult	46+

The age range was recorded in the SPSS database as an independent variable. Population demographic profiles were drawn from the age range (Chamberlain, 2006). The age ranges were used to test for age-related variability in facet orientation and size both within and between age cohorts (Roberts and Connell, 2004).In order to be able to fully consider age related changes, this study only includes data from skeletal material aged by the author and from known age individuals.

5.7.4 Data collection methods for facet size and angle

5.7.4.1 Facet size

Facet joint articular surfaces may undergo functional adaptation as a response to use which may be correlated with the amount of stress placed upon it (Dhall, 1984). Panjabi et al. (1993) and Patel et al. (2007) used width and height measurements and width/height ratios to compare facets size at different vertebral levels. They assumed the facet surface area was circular and used the formula :

$$\text{AREA (A)} = \pi \times (width \times height) \div 4$$

Their calculation did not take facet depth into account and assumes that the surface of the facet is flat. Facet shape varies widely with vertebral level, therefore the use of simplistic mathematical formulae to calculate area would not be appropriate for accurate area comparison. The assumption that the facet is flat is also assumed by Buikstra and Ubelaker (1994). They multiplied facet height measurement with facet width. This method was used in this study facets are more rectangular/oval than circular in shape and it was considered that this calculation would allow for greater accuracy of analysis. The calculation is not a true measure of surface area as the facet depth is not included, but does provide a basis for comparison between the facets.

The definition of the facet edge varied between vertebrae as illustrated in Figure 5-3. Clearly defined facet edges (as seen on the left facet) were used where possible to take measurements. In the absence of a defined facet margin, (as seen on the right facet), measurements were taken from the surface area that appeared to be involved in articulation (outlined in Figure 5-4). As all data was collected by one observer the same criteria were applied to all measurements minimising error.

Figure 5-3 Variation in facet border definition T10, B282B

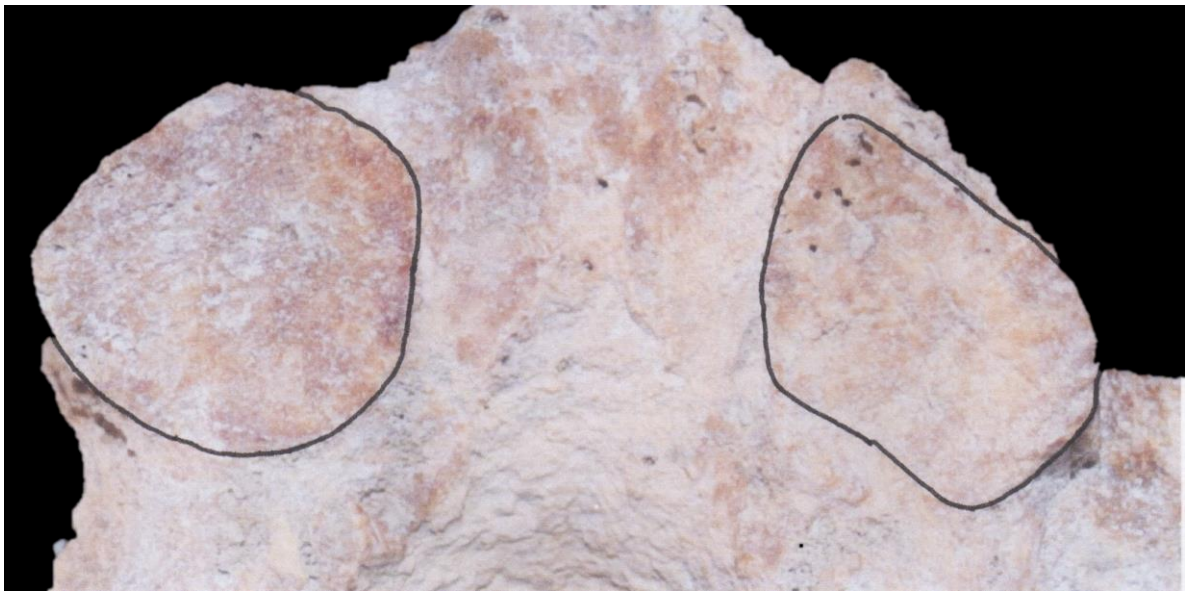


Figure 5-4 Margins of facet border for measurement T10 B282B

A Mitutoyo digital caliper (calibrated to 0.01 mm, measurement taken to 0.1 mm) was used to take width and height measurements from each of the four facets on each vertebra after the method of Patel et al. (2007). The two measurements were taken at right angles to each other at the greatest point in each direction. Figure 5-5 illustrates the measurements taken to assess the height and width of the right inferior facet of C5 from GC14. Each facet was recorded separately as it is not uncommon for be variance in size to be seen. This anomaly is illustrated seen in Figure 5-6, which illustrates the differences between the inferior facets of C6 from GC14.

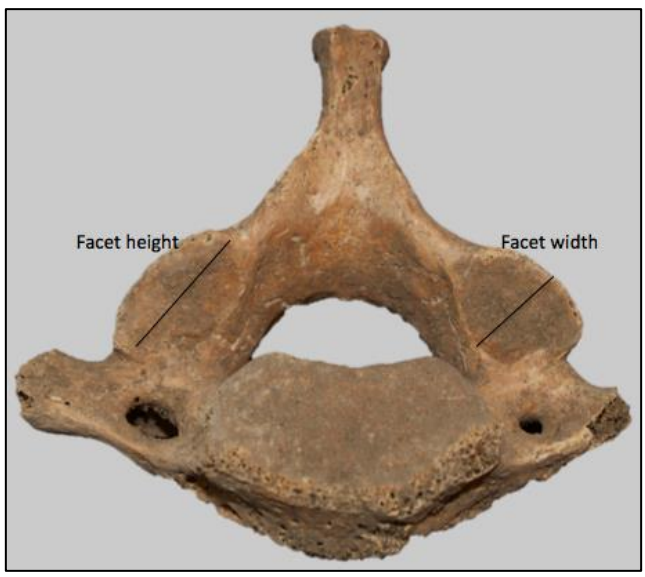


Figure 5-5 Illustration of position of facet height and width measurements(C6 from GC9 (author's image)

Figure 5-6 Differences between C5 left and right inferior facet size (C5 from GC100 (author's image)

5.7.4.2 Facet angle

The link between facet joint orientation and OA has been a focus of clinical research (Fujiwara et al., 2001, Kalichman and Hunter, 2007; Kalichman et al., 2009; Çubuk et al., 2009; Wang and Yang, 2009). Fujiwara et al. (2001) demonstrated a significant association between sagittal orientation and OA in the lumbar facet joints. Resnick and Niwayama (1981) consider that the remodeling process of OA in the lumbar region of the spine alters the morphological features of the facet joint resulting in sagittal orientation.

Most clinical research has focused on the lumbar spine, as this area is responsible for many episodes of back pain. In many studies, simple covariates such as age, sex and body mass index (BMI) have not been examined and the relationship between facet orientation and OA, whilst adjusting for these covariates, has not been clearly defined (Kalichman, 2009). The majority of the clinical studies have used CT or MRI imaging from in vivo studies to assess the extent and severity of OA. Jurmain (1999) considers the presence of eburnation to be pathognomic for OA. Eburnation is not visible in medical scans and so the diagnosis of OA is different in clinical and archaeological samples. The use of dry bone archaeological samples facilitates the study of articular surfaces and the measurement of size and angle that is not possible in the living subject.

The use of goniometers or modified protractors is one of the main methods used by other studies to measure the sagittal facet angle (Mahato, 2011; Ebraheim et al., 2008; Patel et al., 2004; Boyle et al., 1996). A transparent finger goniometer was used to measure the sagittal angle. The vertical arm of the goniometer is lined up with two points, on the vertebra: 1) the junction between the two laminae and 2) the midpoint of the vertebral body (which is found by marking the midpoint between the widest, and deepest measurements of the vertebral body). The angle subtending

this line is found by looking through the goniometer and lining up the calibration line on the moveable arm with the lateral and medial edges of the facet being examined (See Figure 5-7).The sagittal angle for each facet is recorded separately as it is not uncommon for asymmetries to exist in the vertebrae (Van Roy et al., 1997) and facet tropism can occur with variable angles between the facets (Putti, 1927). This method can be time consuming but with practice produces good intra-rater reliability (See Section 5.8.1).

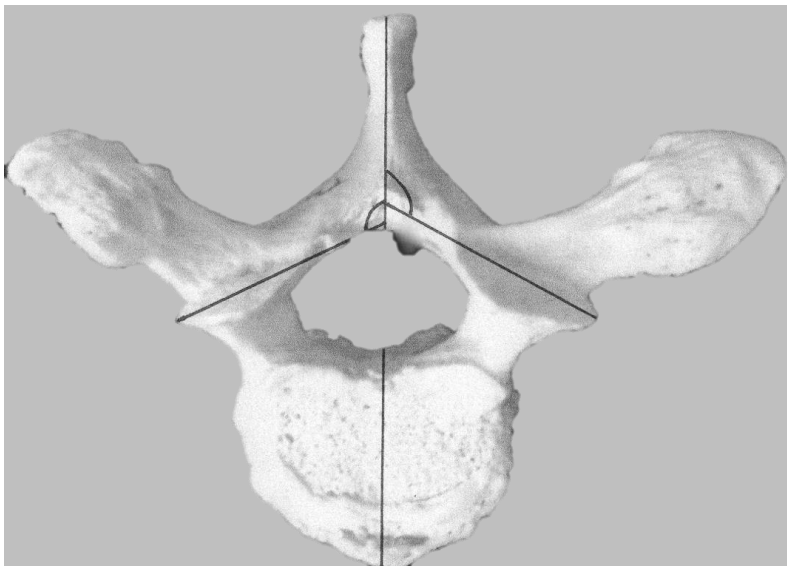


Figure 5-7 Measurement of facet sagittal angle

5.7.5 Osteoarthritis

5.7.6 Diagnostic criteria

Joint space narrowing (thought to be caused by loss of articular cartilage), marginal osteophyte formation and the presence of subchondral cysts and sclerosis are considered to be important indicators of the presence of OA in joints examined by clinical radiography (Rogers et al., 1990). Paleopathological diagnostic criteria for OA in dry bone samples have been selectively derived from clinical radiographical methods (Mays, 2002).

Bourke (1967), Rogers et al. (1987), Jurmain and Kilgore (1995) and Weiss and Jurmain (2007) consider that the most reliable diagnostic criteria for the paleopathological determination of OA, in a dry bone sample, is by the consideration of changes to the joint margin (i.e. the development of osteophytes) in conjunction with changes to the articular surface of the joint (pitting and eburnation) (See Figure 5-8). The more severe osseous changes (pitting, eburnation and osteophyte formation) are more readily identifiable rather than the subtle manifestations of initial pathogenic changes within the joint leading Sokoloff (1987:8) to state,

"It seems sensible to bypass the initial event and recognize the disintegration of the osteoarticular surface as the distinctive feature of OA".

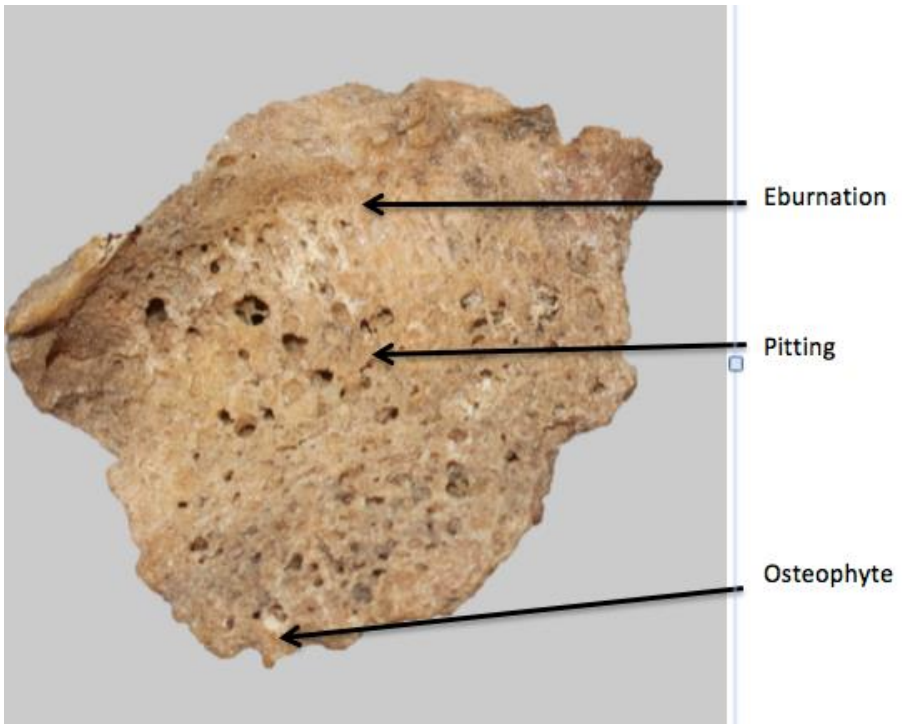


Figure 5-8 Facet surface degenerative changes of the left superior facet of T6 from FAO901454 (author's image)

There was no evidence of hyaline cartilage on the facet surfaces in all samples, therefore examination of the bones for evidence and extent of osteoarthritic change was limited to macroscopic examination of the subchondral surface.

Each facet was scored for the absence or degree of presence and severity of eburnation, pitting and osteophytes to maximize the degree of discrimination between all the facets. For each of the scoring methods the superior and inferior facet surfaces were assessed separately. One observer examined the vertebrae. The observer was blind as to the sex and age of the individual being examined in order to reduce potential bias.

Rogers and Waldron (1995) describe the progression of osteoarthritis as beginning with osteophytic growth then the development of subchondral porosity and finally eburnation of the joint surface occurs. There is lack of consensus as to which observations definitively indicate OA (Duncan, 1979; Jurmain, 1999), however, eburnation is often considered to be the definitive indicator of degeneration of a joint surface and is thus considered to be the determinant of the diagnosis of OA (Rogers and Waldron, 1995; Arcini, 1999; Molnar et al., 2011).

Brickley and McKinley (2004) recommend that presence of porosity, osteophytes and eburnation should be recorded separately as an increase in the extent of one feature may not necessarily be paralleled by an increase in the extent of another (Atkinson, 1985). They suggest using the grading system of Säger (1969) to record the presence of each change and that the system of Buikstra and Ubelaker (1994:123) should be used to record the severity of the changes by considering the area of the facet surface affected by the change. The presence of eburnation is considered to be firm evidence of OA with pitting and osteophytes considered diagnostic when manifest at the same time in the absence of eburnation (Rogers and Waldron 1995). Rogers and Waldron's (1995) methodology was considered to be the most appropriate for this study as it covers a range of bony changes, which are indicative of OA. The prevalence of OA in each facet was calculated following the method described in 5.7.6.5

5.7.6.1 Eburnation

Eburnation is considered to be pathognomic of degenerative joint disease and is synonymous with sclerosis (Rogers et al., 1987; Bridges, 1992). Rogers and Waldron (1995:44) wrote:

> *"In practice little will be lost by restricting the diagnosis to include only those joints with eburnation".*

Many researchers use this parameter since this criterion is consistently used and frequently referenced in bioarchaeological literature. Bridges (1996) disagrees with this approach and recommends the use of a more evaluative approach using multiple diagnostic features for OA. For the purposes of this study, eburnation, pitting and osteophytes were recorded. Joint surface was recorded as positive for OA in the presence of eburnation or when there is a combination of pitting and osteophytes. The presence of pitting or osteophytes on their own was not considered positive (See sections 4.4.3.2 and 5.7.6.3 for a description of the diagnostic criteria for pitting and osteophytes).

During the degenerative process, the articular cartilage covering the joint surface can break down. Lajeunesse (2002) identified three physiological phases in this process, whereby normal cell metabolism and signalling to promote cartilage repair and loss are affected by alterations to the cartilage biochemistry. As the cartilage begins to erode the subchondral bone is gradually exposed. Continued compressive use of this degenerating surface causes bone on bone contact to occur and the surfaces become polished (eburnation) (Ortner, 2003). Further use of the joint leads to the development of indentations or grooves parallel to the line of motion of the joint being formed (Jurmain, 1999). Eburnation indicates that a joint was still moving even though the articular cartilage had worn away (Rogers et al., 1987; Rogers and Waldron, 1995).

Eburnation can be seen when the surface of the bone is converted to a dense smooth layer as a result of bone-to-bone contact. It is considered to be the most reliable pathognomic criterion for diagnosing the presence of OA (Jurmain, 1999). Eburnation can be difficult to observe. It was found that shining a bright light obliquely across the surface of the joint increased the visibility of any eburnation present especially when used in conjunction with a hand lens.

The severity is scored on a 4-point scale from 0-3. The extent of eburnation coverage of the total facet surface is scored on a 4-point scale (see Table 5-7). The scores used do not represent exact measurements but represent a ranked order of extent and severity of the OA criteria being assessed due to the difficulty in quantitatively measuring changes due to OA (Robb, 1998).

Table 5-7 Eburnation scores

Eburnation Severity	**Score**
Absence of eburnation	0
Eburnation barely visible	1
Polished surface visible	2
Eburnation visible as polished surface with grooves	3
Eburnation extent	**Score**
No eburnation	0
<1/3 of surface area affected	1
1/3-2/3 surface area affected	2
>2/3 surface area affected	3

(Severity Score after Säger (1969) and Extent Score after Buikstra and Ubelaker (1994:123))

5.7.6.2 Pitting

In dry bone samples, pitting appears as multiple, irregularly shaped holes with sharp edges (Jurmain, 1999). Jurmain (1999) states that, although pitting is a frequently used criterion in the assessment of OA, the actual process is poorly defined and inconsistently applied in osteological research. In a controlled study, Rothschild (1997) demonstrated that there is no correlation between pitting and eburnation or also pitting and osteoarthritis and that porosity should not be considered a diagnostic feature of osteoarthritis. Woods (1995) recommends that the scoring of

pitting should be kept separate during the assessment of OA as its distribution on a joint surface is not concordant with that of eburnation and occurs in areas of least contact between the joint surfaces. He considers that the pores seen in pitting may occur as a result of defects in the articular cartilage or poor nutritional supply to the bone; in this case, pitting may not directly contribute to severe OA. Milgram (1983) identifies the pits as holes seen in the thinnest part of the bone as the subchondral bone is eroded. He describes them histologically as tiny cysts filled with reparative cartilage cells that can vary in size and cluster pattern. Milgram (1983) describes the pits as being part of a pathological process and although present in conjunction with degenerative disease are not necessarily part of the same disease process. Rogers and Waldron (1995) and Waldron (1995) have used the presence of pitting in combination with osteophytes or changes in joint contour as part of their diagnostic criteria for OA. The lack of clarity of the diagnostic suitability of pitting means that, for this study, although pitting will be assessed separately, it will not be considered suitable for differential diagnosis of OA unless it is in combination with osteophytes or joint contour change.

Pitting is defined as small perforations on the surface of the bone where there is erosion of the subchondral layer, exposing the trabeculae below (Waldron, 2009). It is scored on a five-point scale from 0-4. The score was applied to the largest pit visible. The extent of pitting over the total facet surface is scored on a 4-point scale (see Table 5-8). The scores used do not represent exact measurements but represent a ranked order of extent and severity of the OA criteria being assessed due to the difficulty in quantitatively measuring changes due to OA (Robb, 1998).

Table 5-8 Pitting scores

Pitting Severity	**Score**
Absence of pitting	0
Small pits <0.5 mm in diameter	1
Medium pits 0.5-1.0 mm in diameter	2
Large pits >1.0 and ≤ 1.5mm in diameter	3
Craters ≥ 1.5 mm in diameter	4
Pitting Extent	**Score**
No pitting	0
<1/3 of surface area affected	1
1/3-2/3 surface area affected	2
1/3-2/3 surface area affected	3

5.7.6.3 Osteophytes

The restabilisation process of the third phase in the degeneration cascade (described in Section 4.3.4.3) is the probable cause of marginal osteophyte formation (Rogers and Waldron, 1995). Marginal osteophytes develop around the margins of joints and are frequently seen close to the attachment of the joint capsule (Jurmain, 1999). Their presence can also be age related (Rogers and Waldron, 1995). Although there is lack of agreement between the use of individual diagnostic criteria for OA, it is recommended that the presence, absence and degree of eburnation, pitting and osteophyte development is used in the scoring of OA in osteological specimens (Bourke, 1967; Rogers et al.1987; Jurmain and Kilgore 1995; Weiss and Jurmain, 2007.

Osteophytic growth is defined as being new bone on or around the joint surface (Jurmain, 1999). The severity was scored following the Säger (1969) system with a 5-point scale. In practice the highest score of 4 was not used as no fusion of facets was observed in the samples studied. The extent of the edge of the facet that was affected by osteophytic growth was scored using a 4-point scale (see Table 5-9). The scores used do not represent exact measurements but represent a ranked order of extent and severity of the OA criteria being assessed due to the difficulty in quantitatively measuring changes due to OA (Robb, 1998). Missing data were scored as unobserved and not included into any calculations of frequency

Table 5-9 Osteophyte scores

Osteophyte Severity	**Score**
Absence of osteophytes	0
One or two small osteophytes around facet	1
Multiple small osteophytes	2
Multiple large osteophytes	3
Fusion of facets	4
Osteophyte extent	**Score**
No osteophytes	0
<1/3 facet edge affected	1
1/3-2/3 facet edge affected	2
>2/3 facet edge affected	3

(After Säger (1969)

5.7.6.4 Vertebral body osteophytosis

Vertebral osteophytosis (VOS) results from degeneration of the intervertebral disc (Maat et al., 1995). It manifests as osteophytic growth around the perimeter of the vertebral body. There is argument about the order in which the two degenerative processes occur with Butler et al. (1989) reporting that discs degenerate before facets and Eubanks et al. (2007) reported the opposite, facet OA precedes vertebral osteophytosis. Therefore, the presence of VOS was considered as a potential confounder for this study. Osteophytosis of the vertebral body was scored following Säger (1969).

Table 5-10 Osteophytosis scores (Säger, 1969)

Osteophytosis Severity	Score
Absence of osteophytes	0
Mild arthrosis with up to 50% vertebral margin affected	1
Moderate arthrosis with 50-100% of vertebral margin affected	2
Severe arthrosis with 100% of vertebral margin affected and presence of hypertrophic osteophytes bridging joint space	3
Complete ankylosis	4

5.7.6.5 Prevalence rates

Prevalence rate calculations were performed for each of the scores achieved for eburnation, pitting and osteophytes, as a combined score of their grade and extent, following the method described by Waldron (2007). It was also calculated for vertebral osteophytosis (see section 5.7.6.4) and presence/absence of osteoarthritis (OA).

The true prevalence rate (TPR) was calculated following Roberts and Cox, (2003) and Waldron (2007), using the formula:

$$TPR = \frac{\text{Number of facets affected}}{\text{Number of facets}} \times 100\%$$

The crude prevalence rate (CPR) was calculated as described by Mays et al. (2004:7) using the formula:

$$CPR = \frac{\text{Number of individuals with condition}}{\text{Number of individuals sampled}} \times 100\%$$

It is useful to record true and crude prevalence rates in order to facilitate comparison with other studies (Waldron, 2007). However, Mays et al. (2004:7) recommend that, when comparing results

within and between samples, it is appropriate to use the crude prevalence rate value as "observations on several bones or teeth from a given individual cannot be considered independent for statistical purposes".

Crude prevalence rates can under-represent or over-represent the true prevalence (Roberts and Cox, 2003:41), because this method assumes that all bones of all skeletons are equally preserved. This is unlikely to be the case in archaeological samples. True prevalence rates identify the number of facets available for observation and provide a clearer picture of prevalence. This study calculated the true and crude prevalence rates for each age group in turn with the *a priori* assumption that the prevalence of OA indicators increased with age to minimise merging of data between age groups (Waldron, 2007). Crude prevalence rates were compared within and between samples by sex. Prevalence rates were compared for inter-sample differences using a Kruskal-Wallace test with Mann-Whitney post hoc to differentiate between pairs of samples.

5.7.7 Extrinsic factors

Lovejoy et al. (1982) have criticised the use of linear measurements and indices alone when using bone dimensions to estimate sex arguing that there should be a greater emphasis on the use of functional correlates and consideration of the relevance of findings to biological adaptation. While sex differences in vertebral shape and size have been noted, there has been no attempt to provide a functional interpretation for these differences. This is addressed in the current study whereby the relationship between facet size and angle are correlated with markers of occupational stress (femoral robusticity, humeral directional asymmetry, eburnation, pitting, osteophyte formation around the perimeter of the facet joint, osteophytosis (osteophyte formation around the perimeter of the vertebral body) and the presence/absence of OA) was assessed. This also enabled comparison of degree of physical activity between samples. The statistical modelling used to control these factors is discussed in section 5.7.8

5.7.7.1 Femoral robusticity

The term robusticity refers to the study and quantification of variation in skeletal size and shape (Stock and Shaw, 2007). Bone strengthens by the addition of new tissue in response to loading placed upon it (Ruff et al., 2006) (See section 4.2.3). The relationship between mechanical loading and functional adaptation of bone has been used to identify changes in behaviour in populations, with an increased robusticity considered to develop as a consequence of strenuous physical activity (Bridges et al., 2000; Steckel and Rose, 2002; Stock and Pfeiffer, 2004) (See section 4.3.2). This study examined the facet joints for changes that may occur as a response to mechanical loading. Robusticity measures of long bones may help to provide a more complete picture of the

lifestyle of an individual in respect of their activity levels and mechanical loading undertaken by the body. The use of long bone external dimensions standardized to bone length (Bräuer, 1988; Wescott, 2002; Ruff et al., 2003) and cross-sectional geometry (Lovejoy et al., 1976; Trinkaus et al., 1994, Larsen, 1997; Stock, 2006) are the most commonly used methods to estimate robusticity.

Cross-sectional geometry of the bone diaphysis by application of beam theory relies on accurate determination of periosteal and endosteal contours of the bone (Lovejoy et al., 1976). This method was not appropriate for this thesis as it is a destructive method that involves sectioning of the bone under study. Non-invasive methods of contour determination involve the use of computed tomography (Jungers and Minns, 1979) or silicone moulds used in conjunction with biplanar radiographs (Stock, 2002). Neither of these two methods was suitable due to the cost and difficulty of imaging samples from a number of locations, thus the use of external long bone dimensions was more appropriate for this study. Stock and Shaw, (2007) reviewed the external methods used to estimate robusticity and identified that, if direct sectioning and CT scanning was not available then the measurement of total sub-periosteal area provided the best externally based method of evaluating robusticity.

To estimate bone strength of the femur, total sub-periosteal area, (TA) was calculated from the antero-posterior and medio-lateral diameters of the femoral midshaft. The mid-shaft was chosen for measurement as this represents the true size of the diaphysis. These measurements can be standardized to body size in order to interpret the measure of robusticity because body size is a primary influence on skeletal mass (Stock and Shaw, 2007). Bräuer (1988) standardized the bone external dimensions against bone length. Trinkaus et al. (1994) proposed standardization of second moments of area by dividing them by the bone length raised by the power of 2.33. (Second moments of area are a measure of the resistance to bending of a loaded section (Lieberman et al., 2004)). Ruff (2008) identified that using bone length raised to the power of 5.33 standardizes second moments to body size and bone length. Bone length is strongly correlated with stature and less strongly correlated with body mass; however body mass has a more significant influence on mechanical loading and long bone dimensions (Ruff et al., 1993). Femoral head diameter can also be used to estimate body mass (Ruff, 2002), Wescott (2006) standardized the external dimensions of the femoral diaphysis to the femoral head diameter.

The anteroposterior (AP) midshaft diameter of the femur was measured at the midpoint of the diaphysis in a sagittal orientation at the highest point of the linea aspera, perpendicular to the bone surface The mediolateral (ML) midshaft diameter was measured in a transverse orientation at the midpoint of the diaphysis, perpendicular to the antero-posterior diameter. Both

measurements were made using a Mitutoyo digital caliper (calibrated to 0.01mm, measured to 0.1mm) and recorded in millimetres. Both femoral diaphyses were measured if present and TA calculated for both if present in order to assess for laterality of mechanical loading.

The standardized total sub-periosteal area (TA) was calculated using the equation:

$$TA = \frac{[\pi\left(\frac{\mathrm{AP}}{2}\right)\left(\frac{\mathrm{ML}}{2}\right)]}{\mathrm{Max\ length}^3}$$ (Ruff et al., 2002; Auerbach and Ruff, 2004a).

5.7.7.2 Directional asymmetry

When examining an East London population from Spitalfields, Waldron (1991) noted that there was a change in laterality of distribution of OA in the facet joint in different regions of the spine, with OA being more common on the left in the cervical region, in the right in the thoracic region and with mostly bilateral distribution in the lumbar region. He theorized that the bilaterality observed in the lumbar spine was due to mobility or forces acting through the spine, but that movement was not the complete answer to this patterning. Merbs (1983), Bridges (1994) and Sofaer Deverenski (2000) also reported similar pattern of distribution. There are a number of suggested causes for this pattern, both anatomical and functional.

Nathan (1962) considered that the position of the aorta on the left of the upper thoracic spine caused inhibition of osteophyte formation on the vertebral body, but the extrapolation of this argument for the formation of degenerative change on the zygapophyseal joints is not clear. Research has shown that although the spine is generally considered to be straight in the coronal plane a lateral curvature is frequently observed (Tallroth et al., 2009). This slight thoracic scoliotic curvature usually occurs in the mid to lower thoracic region, convex to the right (Taylor, 1983; Taylor, 1986; De Smet, 1985; Goldberg et al., 1990). It is considered to be the normally occurring alignment and not related to handedness (Williams, 2000).

Merbs (1983) and Bridges (1994) suggest that asymmetries of OA distribution and severity in the facet joints may be due to the influence of handedness in individuals due to the origin points on the spine of muscles that insert into the upper arm (trapezius and superior and inferior rhomboid muscles). The predominance of right-handedness within the general population (90% across all groups studied (Marchant et al., 1995)) may support this theory, as this would affect the upper thoracic region which is the area of greatest asymmetry (Bridges, 1994), There is a lack of clinical evidence to support this theory. Bridges (1994) tested this hypothesis by comparing the results of OA distribution analysis in North American prehistoric groups and concluded that the asymmetrical patterns of distribution of OA were caused by a wide variety of different activities that involved use of the right arm, rather than a specific activity. In contrast, Wilczak and Kennedy

(1998) consider that side differences in OA distribution represent the effects of specific physical activities rather than age-related changes.

In order to examine the potential confounding effect of hand preference on asymmetry patterns of facet morphology and OA distribution found in the spine, it was necessary to try and identify the dominant hand in each of the skeletons analysed for this research. Identification of hand preference is traditionally based upon the assumption that the dominant hand is used most in habitual activity and this leads to a directional bilateral asymmetry in the upper limbs through mechanical driven bone growth and remodelling as an adaptive response (Steele, 2000; Shaw and Stock, 2009a; Shaw and Stock, 2009b; Shaw, 2011). This assumption has been supported by in-vivo studies of self-reported handedness and measurement of skeletal asymmetries (Lazenby, 2002; Medland et al., 2004; Shaw, 2011). Several studies have highlighted the fact that there are variable degrees of asymmetry in different skeletal elements from the same individual (Stock and Pfeiffer, 2004; Auerbach and Ruff, 2006; Auerbach and Raxter, 2008). The humerus has been identified as a suitable element in studies of bilateral asymmetry (Stirland, 1993; Steele and Mays, 1995; Steele, 2000; Blackburn and Knüsel, 2006). The lateral asymmetries in length of the humerus and in the humerus + radius have been used to deduce handedness (Steele and Mays, 1995; Lazenby, 2002; Shaw, 2011). Auerbach and Ruff (2006) identified that in the humerus, the average diaphyseal breadths demonstrate the greatest absolute and directional asymmetry. For this reason, diaphyseal breadth was used in this study to assess handedness in each individual. The anteroposterior (AP) midshaft diameter of the humerus was measured at the midpoint of the diaphysis in a sagittal orientation at the maximum diameter; perpendicular to the bone surface. The medio-lateral (ML) midshaft diameter was measured in a transverse orientation at the midpoint of the diaphysis, perpendicular to the antero-posterior diameter at the minimum diameter. Both measurements were made using a Mitutoyo digital caliper (calibrated to 0.01mm, measured to 0.1 mm) and recorded in millimetres.

Directional asymmetry (DA) is a measure of the effects of lateralized behaviour in the human skeleton (Stirland, 1993; Mays, 2002). Differences in the magnitude of DA can be attributed to differential mechanical loading during bone growth (Auerbach and Ruff, 2006; Auerbach and Raxter, 2008; Özener, 2010). Directional asymmetry for the facet joints was calculated based on the facet size as described in section 5.7.4.1 and the asymmetry equation calculated using right and left facet sizes.

Percentage directional asymmetry (%DA) (the difference between the left and right sides) was calculated using the formula: $\%DA = \frac{(Right-Left)/(Right+Left)}{2} \text{X}100.$

(Mays et al., 1999; Auerbach and Raxter, 2008)

Positive values indicate a right biased asymmetry and negative values a left biased asymmetry. This provided information about the predominant directional bias and a measure of the magnitude of asymmetry for the humerus and facets.

5.7.7.3 Sexual dimorphism index (SDI)

A sexual dimorphic index (SDI) provides definition of the degree of difference between the sexes and calculates the magnitude of sexual dimorphism between males and females. There are three main assumptions when calculating an SDI (Reno et al., 2003):

1) Both sexes are present within the sample (documentary evidence to support this for St Bride's Crypt and morphological examination as described in section 5.7.2 to estimate the sex of individuals from St Brides' Lower and the Anglo-Saxon sample)
2) Any individual has an equal prior probability of being male or female
3) When 2 individuals are of different sex, the larger is male.

Smith (1999) summarised a number of methods to calculate this index, including ratios and regression formulae. Regression analysis has not been shown to be any more accurate than ratio calculations (Smith, 1999) and therefore a sexual dimorphism index (SDI) for facet size and angle was calculated using the formula:

(Male mean measurement/female mean measurement) x 100 (Smith, 1999)

Results greater than 100% indicate that the male measurement is greater than that for the female, however this does not clearly differentiate between ambiguous individuals. In this study, SDI values were allocated to categories relating to sexual identity as described in Buikstra and Ubelaker (1994) as follows: female (<90), probably female (90-99) ambiguous sex (100), probably male (101-110) male >110). This allowed for strongly sexually dimorphic individuals to be clearly identified.

5.7.8 Data management and statistical analysis

All data was recorded on Excel Spread sheets and exported into SPSS (v 24, IBM, Chicago).

5.7.8.1 Missing data

Missing data due to poor skeletal preservation and outlying data due to the wide range of natural variation limited the choices of statistical analysis for this study. Whilst there are statistical tests that would interrogate and analyse the data in a more efficient manner, the data from this study was not robust enough to undergo these types of analysis.

5.7.8.2 Descriptive statistics

Descriptive statistics using SPSS v 24 (mean, maximum, minimum and standard deviation) of the size of the facet surfaces and the sagittal angle for each vertebra were calculated, to identify any outliers. The normality of frequency distribution for the continuous values was found. The descriptive statistics results are summarised in Appendix B and C. The variables used in statistical analysis are listed in Table 5-11.

5.7.8.3 Bonferroni adjustment

Abelson (1995) postulated that if enough measurements were taken, a number of significant relationships would be found that could be attributed to chance or random processes. Therefore, a Bonferroni correction was applied to most of the sets of analyses to reduce the risk of Type I errors. The Bonferroni correction was calculated by dividing the alpha value (typically 0.05) by the number of statistical tests and the value of the correction applied is identified with each individual set of results. However, a problem associated with using Bonferroni adjustment is that it dramatically lowers the chance of detecting a real difference if one exists (Kim and Bang, 2016). Greenland et al. (2016) recommend designating a primary hypothesis and answering this with adjusted p values and to present adjusted and unadjusted p-values together as secondary information. Pergener (1998) does not recommend using the Bonferroni adjustment because it can be a bad fit to the real significance (expectation) increasing the risk of Type II errors and therefore to balance this, results with Bonferroni adjustment ($p<0.0005$) and $p<0.05$ are included in results tables. Significant p values for $p<0.05$ and Bonferroni adjusted values are highlighted in bold in the appendices.

5.7.8.4 Statistical analysis of the relationship between sex, facet size and angle

Although the data were normally distributed, a number of outlier values were identified and therefore a non-parametric test (Mann-Whitney U) was used with a Bonferroni adjustment ($\alpha = 0.0005$) to test for differences between the two independent groups (male and female) on a continuous measurement (facet size/angle).

5.7.8.5 Correlation analysis

A correlation is simply defined as the relationship between two or more variables and correlation analysis is used to identify if there is a connection between variables (Field, 2013). For correlation studies in this research, the strength of the association as indicated by the correlation coefficient in terms of: no relationship ($r_s < 0.01$), weak relationship ($r_s = 0.1$-0.29), medium ($r_s = 0.3$-0.49) and strong ($r_s = 0.5$-0.1) was recorded after the method described by Cohen (1998: 79-81). Pallant

(2013) recommends focussing on the strength of the relationship as the significance (p value) can be influenced by the size of the sample and the test of strength of a relationship is independent of significance testing. For this study, both significance value and correlation strength are reported.

5.7.8.6 Age groups v actual age

Facet size and actual age are continuous data, whereas age group is categorical data. In order to check for loss of resolution the relationship between aggregated data (age group) and facet size is compared with the correlational relationship between disaggregated data (actual age at death) and facet size.

5.7.9 Assessment of the roles of predictor variables in assessing sex

This section describes the methods used to test the degree of accuracy with which the sex of an individual can be estimated from facet size and angle using discriminant function analysis. Discriminant function is frequently used to derive equations for sex estimation (Schwartz, 2008). A summary table of predictor variables that summarise statistically significant analyses of all the data in relation to sex differences and facet size and angle was created to clarify results.

5.7.9.1 Discriminant function analysis

Discriminant function analysis was used to classify vertebrae into dichotomous groups based on the male/female variable based on a linear combination of interval predictor variables. In the first instance the variables will be facet size for all four facets, secondly facet angle for all four facets and finally a combination of predictor variables. The advantage of using discriminant function analysis in skeletal measurements is that it reduces the level of subjectivity that can occur when morphology is used to determine sex and is reported to be an effective tool on sex identification (Isçan, 1988).

SPSS was used to select and weight variables to create discriminant functions for each vertebral level using a stepwise process. Variable preservation of the skeletons sampled led to a number of missing values and for the purpose of analysis; the missing values were replaced with mean values calculated by SPSS. Discriminant analysis is highly sensitive to outliers and therefore these were removed from the data and treated as missing values. Cross-validated classification was used to assess the accuracy of the discriminant equations for each vertebra.

The discriminant function used was:

$F(n) = C + U1X1 + U2X2 + U3X3 + U4X4$ (Field, 2013).

Where F is the discriminant function total, (n) is the discriminant function equation number (1,2 or 3), U1, U2, U3 and U4 are the unstandardized coefficients of X1 (left superior facet), X2 (right superior facet), X3 (left inferior facet) and X4 (right superior facet).

Application of the discriminant function to the mean measurements for each facet for males and females created the group centroids (Zm and Zf), representing males (Zm) and females (Zf). The demarcation point (Z_0) was calculated by taking the weighted means of values at the group centroids for males and females using the following formula (Xavier, 2003):

$$Z_0 = \frac{(Zm*Nf)+(Zf*Nm)}{(Nm+Nf)}$$

The discriminant scores were calculated separately for each individual of known sex from St Bride's crypt by calculating the discriminant function for each of the vertebral levels. The score was compared against the demarcation point. Scores above the demarcation point were deemed to be male and those below were female. The outcome was compared against the known sex of the individual and the percentage accuracy of correct grouping was noted. This was repeated for the St Bride's Lower and Anglo-Saxon populations. Population specificity of the discriminant functions was tested by substituting the data from for St Bride's Lower and Anglo-Saxon into the functions for St Bride's Crypt and comparing the percentage accuracy of correct grouping.

Table 5-11 Definition of variables

Variable and Section Reference	How Used in Analysis	Type of Data / logistic Code
Sex 5.7.2.4	Categorised into 2 groups	Categorical 0=Male 1= Female
Age 5.7.3.2	Categorised into 3 age groups	Categorical 1 = 21-34 2 = 35-45 3 = 46+
Facet Size 5.7.4.1	Area = π(*width x height*) ÷ 4	Continuous
Facet Angle 5.7.4.2	Superior angles for left and right Inferior angles for left and right	Continuous
Eburnation 5.7.6.1	Score for extent and severity added together	Continuous
Pitting 5.7.6.2	Score for extent and severity added together	Continuous
Osteophytes 5.7.6.3	Score for extent and severity added together	Continuous
Prevalence rate 5.7.6.5	Calculated as: Total prevalence rate = $\frac{Number\ of\ facets\ affected}{Number\ of\ facets}$ *X100%* Crude prevalence rate = $\frac{Number\ of\ individuals\ with\ condition}{Number\ of\ individuals\ sampled}$ *X100%* Calculated separately for combined severity and extent scores for eburnation, pitting and osteophytes, osteophytosis and presence/absence OA	Continuous

Table 5-11 Definition of variables continued

Variable and Section Reference	How Used in Analysis	Type of Data / logistic Code
Femoral robusticity 5.7.7.1	Sub periosteal area = $[\pi(AP/2)(ML/2)]/max\ length^3$	Continuous
Vertebral osteophytosis 5.7.6.4	Score for superior and inferior margins added together	Continuous ordinal
Vertebral asymmetry 5.7.7.2	Difference between right and left sides for facet angle and size Directional asymmetry %DA = (Right-Left)/(Right + Left)/2 X100	Continuous
Humeral directional asymmetry 5.7.7.2	Humeral directional asymmetry %DA = (Right-Left)/(Right + Left)/2 X100	Continuous
Sexual Dimorphism Index 5.7.7.3	(Male mean measurement/female mean measurement) x 100	Continuous
Population sample 5.1.3	Cemetery	Categorical 1 = St Bride's Crypt 2 = St Bride's Lower 3 = Anglo-Saxon
Time Period	Categorised into groups	1 = Anglo-Saxon 2 = St Bride's

5.8 Pilot Study

A pilot study of the methods used in this study was carried out on individuals from a Great Chesterford (N = 20); an Anglo-Saxon cemetery in Essex. The analysis of the Great Chesterford sample took place at the University of Southampton. The use of standard methods across all populations under study ensured that there was consistent recording of the data required to test the hypothesis for this research. The methods used in this study were assessed for intra-observer reliability. The researcher took all repeat measurements. The results are discussed in section 5.8.1.

Limited preservation of the bones led to a relatively small sample being available for the pilot study of analysis of individuals from Great Chesterford (N=20). It was not possible to randomly sample from this cemetery due to the varied preservation of the bones. Limited access to samples other than Great Chesterford meant that this sample only was available to test for intra-rater reliability. Initial data collecting by the author occurred in 2012 and was repeated without reference to the original data in 2014 and 2015.

Table 5-12 Great Chesterford demographic

Age Group	Males (% total number)	Females (% total number)
21-34	5 (56)	3 (27)
35-45	4 (44)	7 (64)
46+	0	1 (9)

5.8.1 Analysis of intra-observer reliability

This section discusses the analysis of intra -observer reliability. Observer error analysis is an important part of any scientific study as it confirms the reliability of the methods used for data collection. For a method to be considered reliable, the data collected must be replicable. The reliability of this study was tested using intra-observer error studies by repeated analysis of the pilot study material (Great Chesterford).

5.8.1.1 Intra-observer error

Intra-observer error analyses were performed using Fleiss' kappa statistic for categorical data and One-Way Repeated Measures of Analysis of Variance (ANOVA) for continuous data.

Fleiss's kappa statistic is a well-known index for assessing the reliability of agreement between raters (Falotico and Quatto, 2014). This method is an adaptation of Cohen's Kappa and is applicable to three or more observations (Sim and Wright, 2005). The goal of the assessment of

intra- and inter-observer error is to assess the rate of agreement and thus this statistical test is appropriate. The following criteria were used to measure levels of agreement between observations: $\kappa = +1.00$ (perfect agreement) and $\kappa = -1.00$ (no agreement), as κ approaches 0 it is more likely that the agreement is a chance event (Pallant, 2013). Peat (2001) considers that a $\kappa = 0.5$ to be representative of a moderate agreement, $\kappa < 0.7$ a good agreement and $\kappa < 0.8$ a very good agreement. Landis and Koch (1977) further classify the strength of agreement using the following descriptors: poor (<0.00), slight (0.00-0.20), fair (0.21-0.4), moderate (0.41-0.60), substantial (0.61-0.80) and almost perfect (0.81-1.00). The classification system of Landis and Koch (1977) will be used in this study as it has more specific definition between the levels of agreement than the one used by Peat (2001). The results of the intra-observer error for categorical data are reported in Appendix A and summarised in Table 5—13.

The majority of repeated categorical scores demonstrated high levels of agreement. The highest agreement was observed in vertebral levels where the feature was mostly absent. The lowest level of agreement with 3 observations overall was moderate. The reproducibility of the results indicate that the method chosen for this study was appropriate.

Table 5-13 Fleiss' kappa level of agreement for intra-observer error

Criterion	Section of Spine	Level of Agreement (Landis and Koch, 1977)	Count of All Facets at Level of Agreement	Percentage of Facets at Same Level of Agreement per area
Eburnation	Cervical	Perfect	40	71%
		Almost Perfect	16	29%
		Substantial	0	0%
		Moderate	0	0%
	Thoracic	Perfect	43	45%
		Almost Perfect	48	50%
		Substantial	4	4%
		Moderate	1	1%
	Lumbar	Perfect	7	17%
		Almost Perfect	33	83%
		Substantial	0	0%
		Moderate	0	0%
Pitting	Cervical	Perfect	6	11%
		Almost Perfect	47	83%
		Substantial	2	4%
		Moderate	1	2%
	Thoracic	Perfect	14	15%
		Almost Perfect	81	84%
		Substantial	1	1%
		Moderate	0	0%
	Lumbar	Perfect	5	13%
		Almost Perfect	35	87%
		Substantial	0	0%
		Moderate	0	0%
Osteophytes	Cervical	Perfect	39	71%
		Almost Perfect	16	29%
		Substantial	0	0%
		Moderate	0	0%
	Thoracic	Perfect	43	45%
		Almost Perfect	48	50%
		Substantial	4	4%
		Moderate	1	1%
	Lumbar	Perfect	7	17%
		Almost Perfect	33	83%
		Substantial	0	0%
		Moderate	0	0%

5.8.1.2 Continuous data

One-way repeated measures analysis of variance (ANOVA) is a statistical method used to test for significant differences in multiple repeated measures between groups (Pallant, 2013). This is an appropriate statistical method for comparison of the repeated measurements of facet size and sagittal angle. The Wilks' Lambda value and probability value p are reported. A significant p value of <0.05 for the differences in repeat measurements indicates that differences between the measurements are unlikely to be due to chance and that there was a change in confidence score across the three repeated measures (Field, 2013).

One-way repeated measures ANOVA was performed to compare repeated measurements of the width, height and sagittal angle of the facets as the data set consisted of continuous variables that were of normal distribution. The data was collected in 2009, 2013 and 2016 from the Great Chesterford sample. The overall results tables can be found in Appendix A and are summarised in Table 5-14.

Table 5-14 Summary of count of facets showing significant difference in repeated measures

Spinal Region	**Criterion**	**Count of Facets with Significant Difference Between Repeated Measurement (p<0.05)**	**Percentage of Facets with Significant Difference in Repeated Measure per Region**
Cervical	Facet Width	2	7%
	Facet Height	0	0%
	Facet Angle	1	4%
Thoracic	Facet Width	3	6%
	Facet Height	4	8%
	Facet Angle	6	12%
Cervical	Facet Width	1	5%
	Facet Height	0	0%
	Facet Angle	4	2%

The results show that for the majority of facet levels, there is no significant difference between all three repeated measurements for facet width, height and angle when $p<0.05$. Overall 10% of the facet width, 3% of the facet height measurement and 10% of the facet angle measurements showed statistically significant differences in the repeated measures. This could be due to lack of operator experience in determining measurement points in the first data set collection. The overall results indicate that the methods used are appropriate and reproducible.

Chapter 6 Results

This chapter presents the results of data analysis to answer the key questions identified in Chapter 1. It will begin by reviewing the demographic data of the samples under study and then will present the results of the statistical analyses. Facet size, facet angle and inter-sample analyses of predictor variables will be presented separately for clarity. The main tables of results can be found in the attached appendices (Appendix B-E) with summaries of the significant or important results being presented in this chapter. The reported results are arbitrarily divided into cervical, thoracic and lumbar regions, based on characteristics and function. Transitional vertebrae between spinal regions (see Section 2.3.7) were excluded from the analyses.

6.1 Sample demography

The total number of individuals used in this study is summarised in Table 6-1. These numbers are not representative of the cemetery population as a whole but are a sample of the individuals that are interred. Only skeletons with sufficient preservation to allow for adequate data analysis were included in this study.

The St Bride's Crypt context is described in detail in section 5.4.1, St Bride's Lower cemetery in section 5.4.2 and the Anglo-Saxon cemetery contexts in sections 5.1, 5.2 and 5.3. Due to the small number of individuals from the Anglo-Saxon cemeteries, the data from the three cemeteries were amalgamated.

As the relationship between age, facet size and angle was explored in this study, there was a risk that imbalances in proportion of age and sex categories would skew the results of comparisons between groups. To check for this, the individuals were placed into approximate age groups (Young Adult, 21-34 years; Middle Adult, 35-45 years and Old Adult, 46+) based upon their estimated age at death (see 5.7.3). The number of males and females in each age group are summarised in Table 6-1 overleaf. Fisher's exact test was used to test for imbalances in age group membership and revealed that there was no significant difference in the number of males and females in each age group ($\chi^2_{(2, n=180)}$ =0.487, p=0.784, phi = 0.052).

Table 6-1 Summary of cemetery origin and age distribution of skeletons used in this study

Cemetery	Sex	Number of Individuals	Young Adult	Middle Adult	Old Adult
Great Chesterford	Male	8	3	5	0
	Female	12	6	6	0
Buckland	Male	4	3	0	1
	Female	4	3	1	0
St Anne's	Male	17	11	6	0
	Female	8	1	5	2
St Bride's Crypt	Male	26	6	6	14
	Female	41	13	11	17
St Bride's Lower	Male	35	3	17	15
	Female	24	7	6	11

6.2 Inter-sample comparison of predictor variables

Prior to presenting the results of analysis of facet size and angle by sample, the results of analysis of inter-sample variation between the predictor variables and prevalence of eburnation, pitting, osteophytes and vertebral osteophytosis are reported.

6.2.1 Inter-sample comparison of femoral robusticity

Femoral robusticity data for males and females were tested for statistically significant differences between the samples.

Kruskal-Wallace tests did not demonstrate any statistically significant difference between left or right femoral robusticity across three samples.

Left femoral robusticity: males – (SBC, n=13: SBL, n=26: AS, n=19). X^2 (2, n=58) =0.83, p=0.66

Left femoral robusticity: females – (SBC, n=23: SBL, n=15: AS, n=23). X^2 (2, n=49) =0.08, p=0.96

Right femoral robusticity: males – (SBC, n=12: SBL, n=26: AS, n=23). X^2 (2, n=61) =0.14, p=0.99

Right femoral robusticity: females – (SBC, n=19: SBL, n=13: AS, n=14). X^2 (2, n=46) =0.81, p=0.67).

These results demonstrate that there is no statistically significant inter-sample difference in femoral robusticity

6.2.2 Inter-sample comparison of humeral directional asymmetry

Kruskal-Wallis tests did not demonstrate any statistically significant difference between humeral directional asymmetry across the three samples.

Humeral asymmetry: males – (SBC, n=18: SBL, n=27: AS, n=12). X^2 (2, n=57) =1.354, p=0.51

Humeral asymmetry: females – (SBC, n=31: SBL, n=21: AS, n=5). X^2 (2, n=57) =0.835, p=0.66).

These results demonstrate that there is no statistically significant inter-sample difference in humeral directional asymmetry between the three samples.

6.2.3 Inter-sample comparison of prevalence rates

6.2.3.1 Crude prevalence rates

Crude prevalence rates were calculated as described in section 5.7.6.5. The results are presented in Table 6-2 and illustrated in Figure 6-1. The crude prevalence rate is a ratio between the number of individuals with a condition and the number of individuals in a sample and presented as a percentage. It measures the number of individuals in a study with the characteristic of interest. This method is limited in scope as it divides the samples into afflicted/not-afflicted categories. Whilst it is useful to be able to visualise the number of individuals in each sample with the particular characteristic it does not differentiate the degree with which it occurs.

Table 6-2 Percentage crude prevalence rates for eburnation, pitting, osteophytes and osteophytosis

Sample	Sex	Crude prevalence rate eburnation	Crude prevalence rate pitting	Crude prevalence rate osteophytes	Crude prevalence rate osteophytosis
SBC	Female	88	90	100	39
	Male	96	96	100	54
SBL	Female	63	100	100	54
	Male	71	100	100	60
AS	Female	63	88	63	63
	Male	52	100	97	31

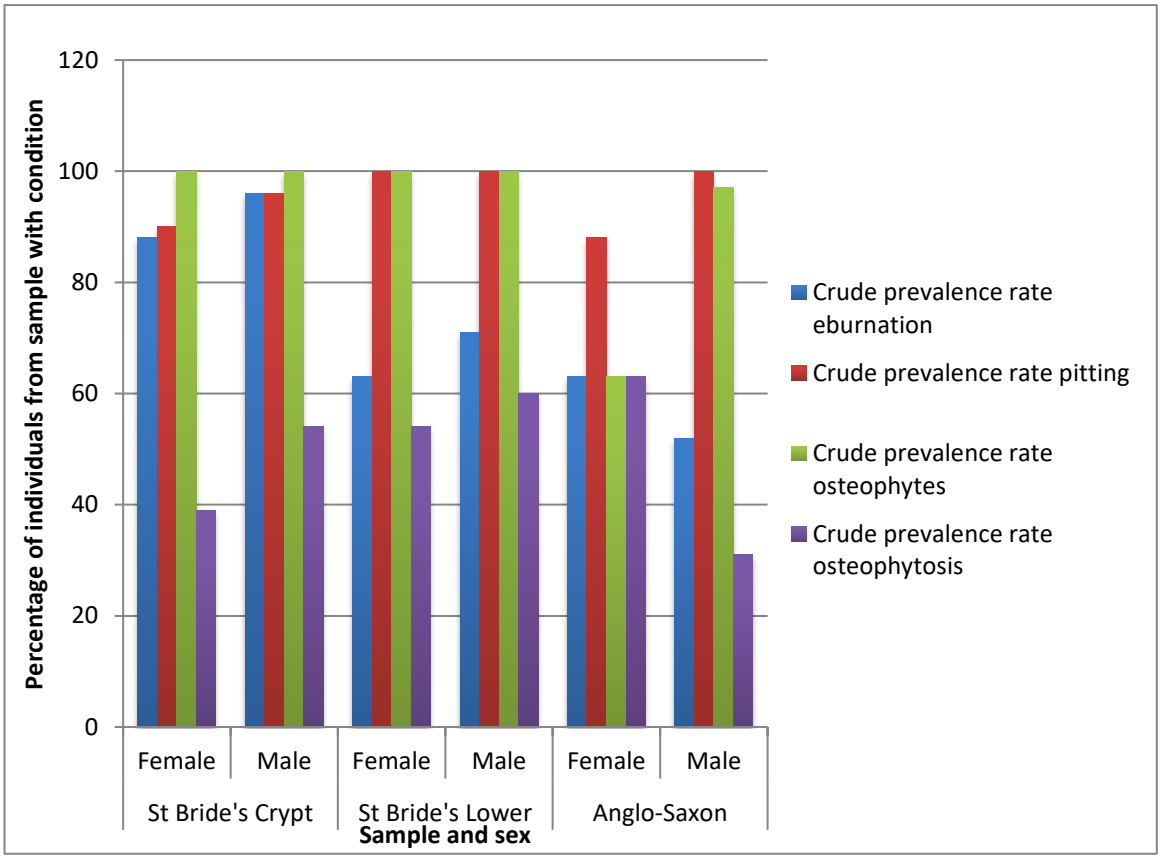


Figure 6-1 Inter-sample crude prevalence rates

6.2.3.2 True prevalence rates

True prevalence rates identify the number of facets available for observation and provide a clearer picture of the characteristic being investigated. Appendix D-1 presents the true prevalence rates as a percentage for eburnation, pitting, osteophytes and vertebral osteophytosis by individual. These values are represented graphically in Figure 6-2,6-3,6-4 and 6-5. The values represent a count of the facets at each vertebral level with the characteristic as a percentage of the facets present. This allows for the management of missing data due to poor preservation.

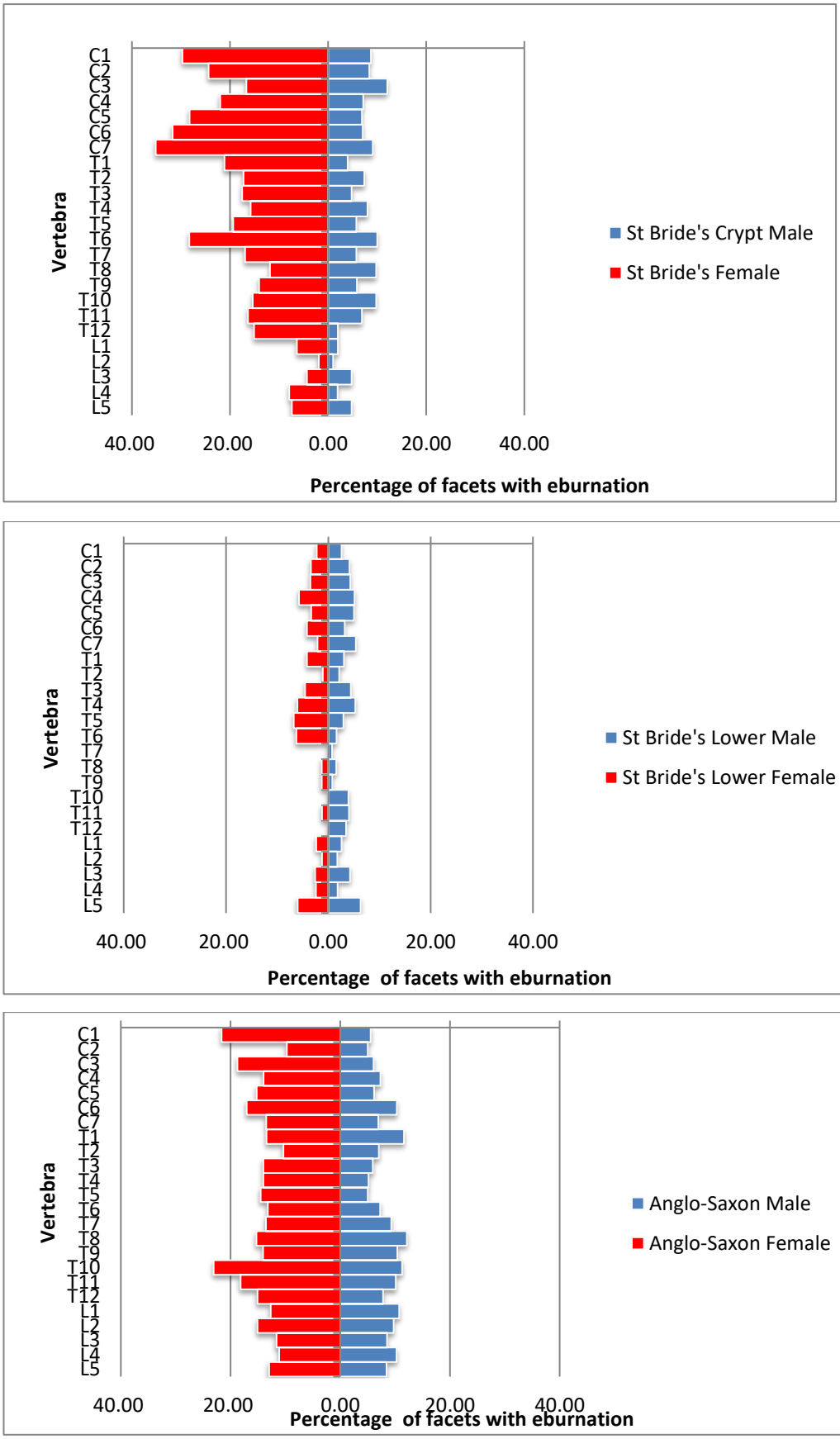


Figure 6-2 Inter-sample variation in the percentage of facets with eburnation

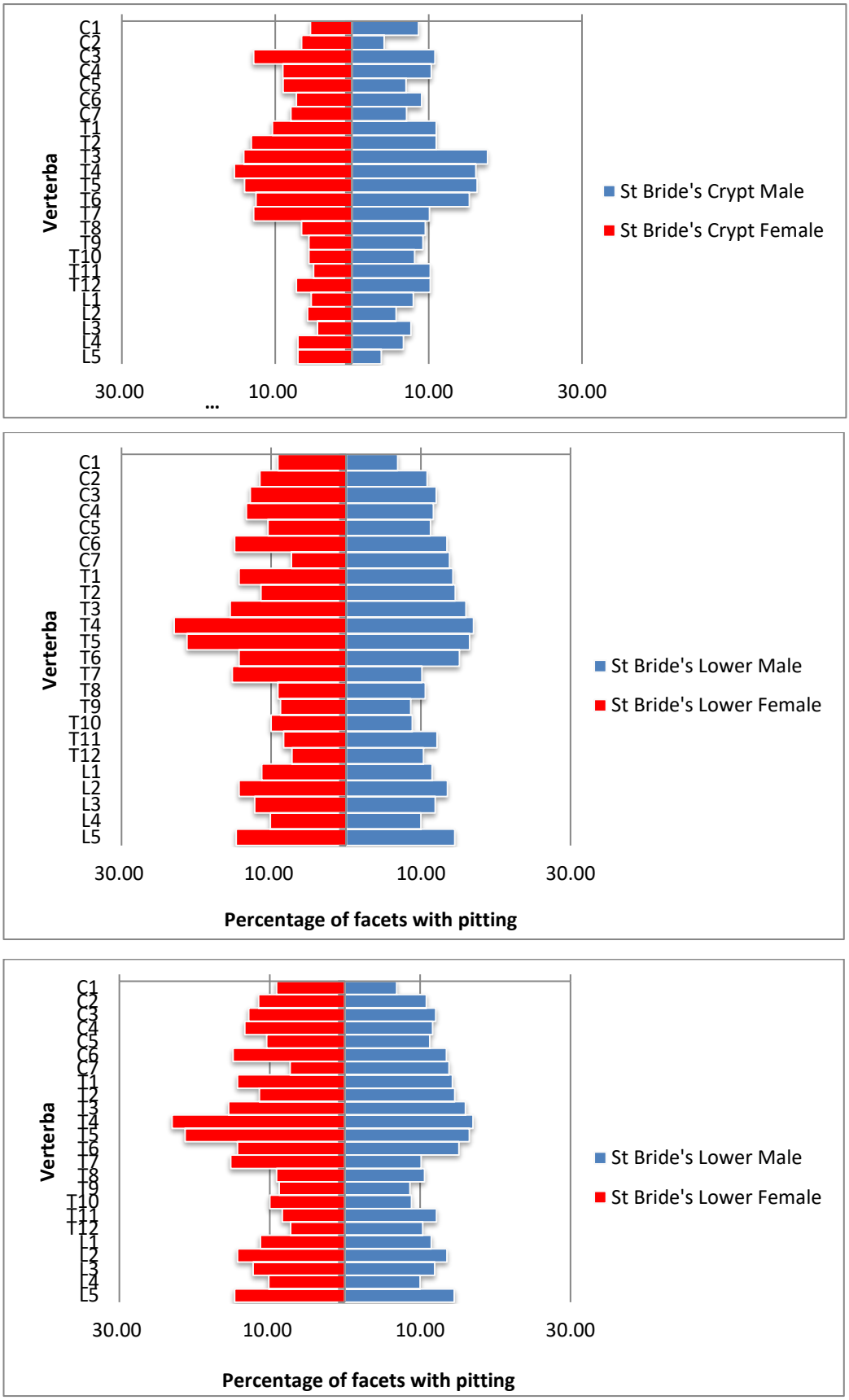
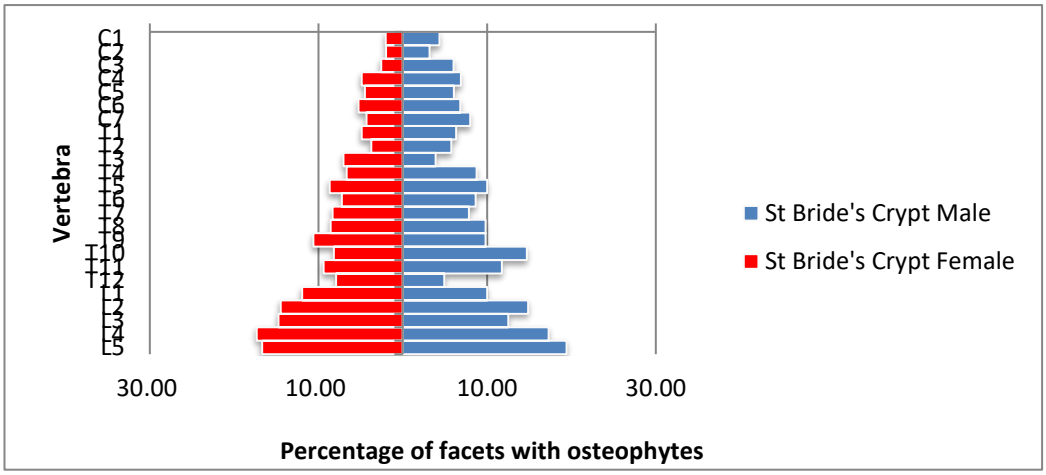
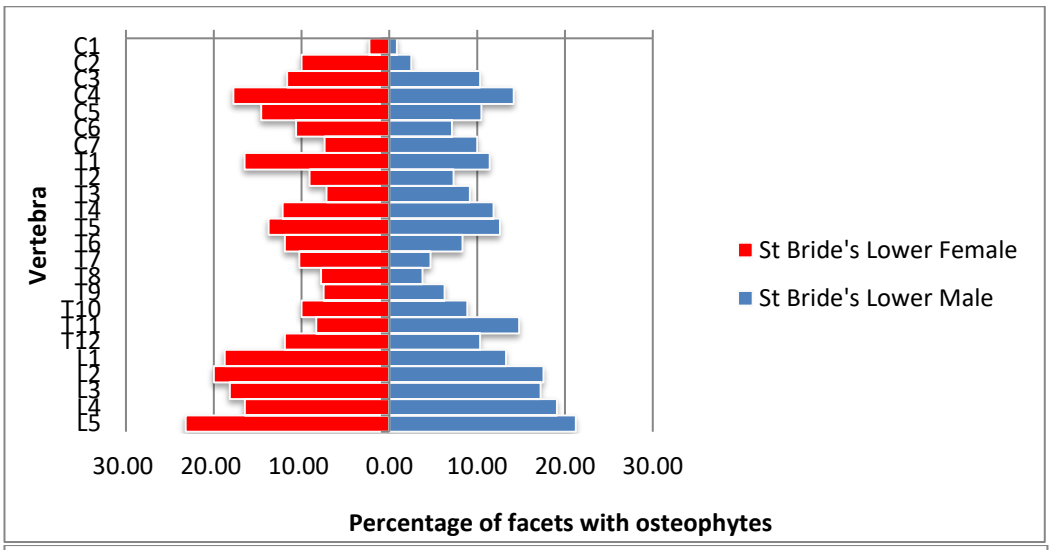


Figure 6-3 Inter-sample variation in the percentage of facets with pitting





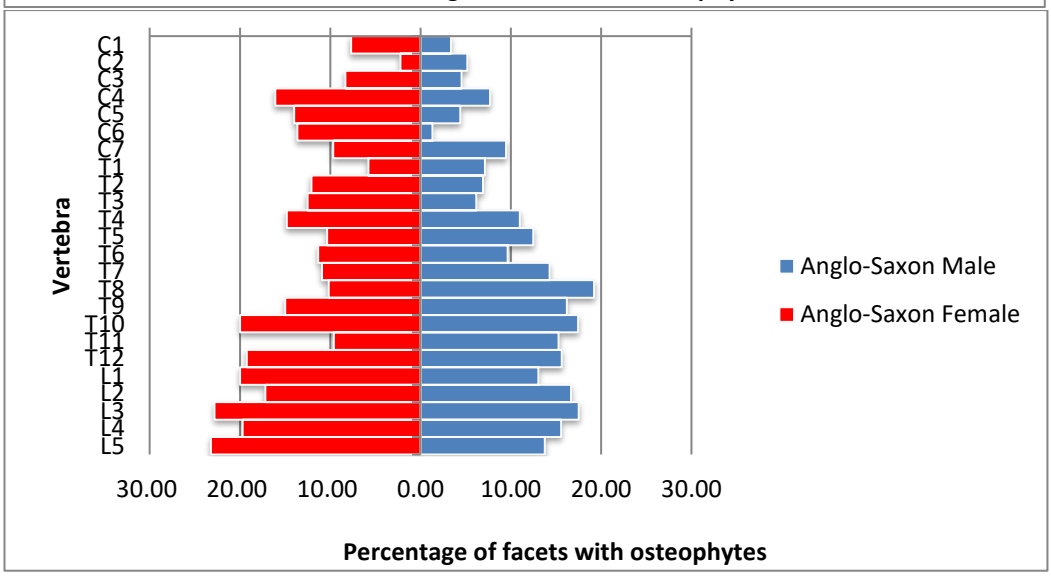
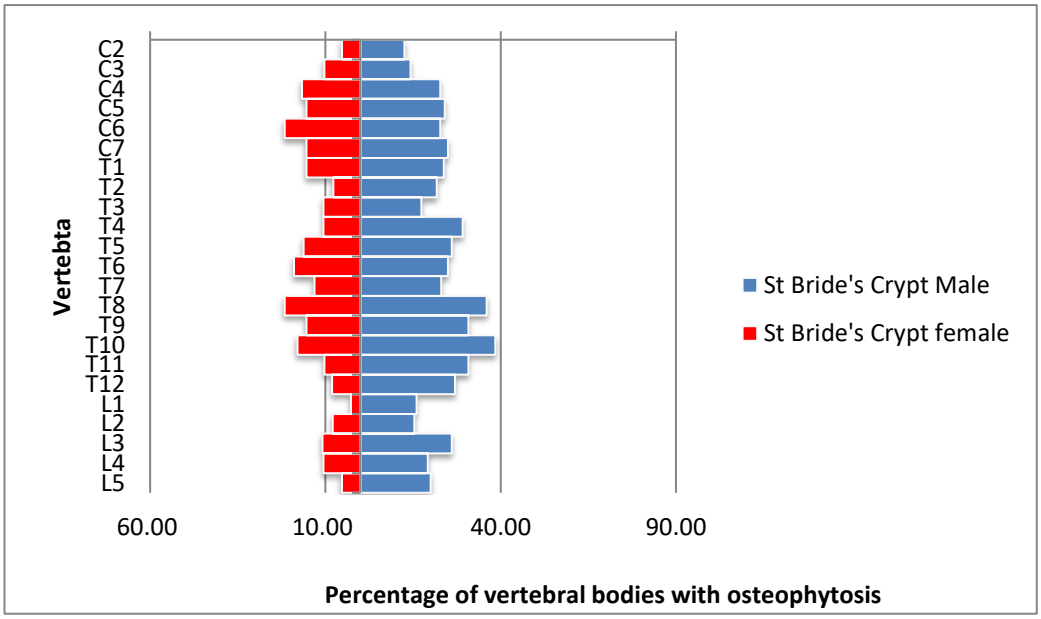
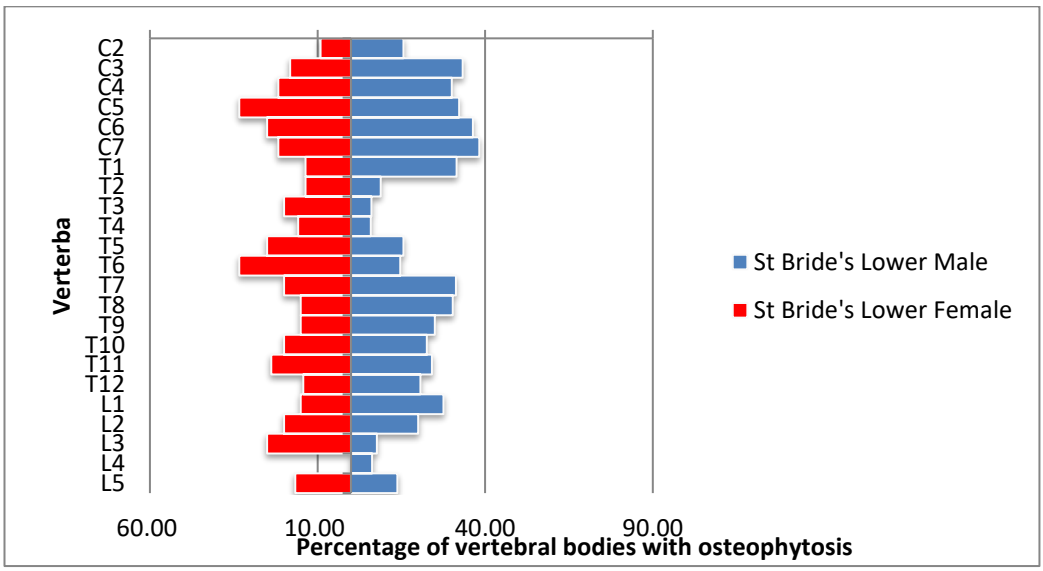


Figure 6-4 Inter-sample variation in percentage of facets with osteophytes





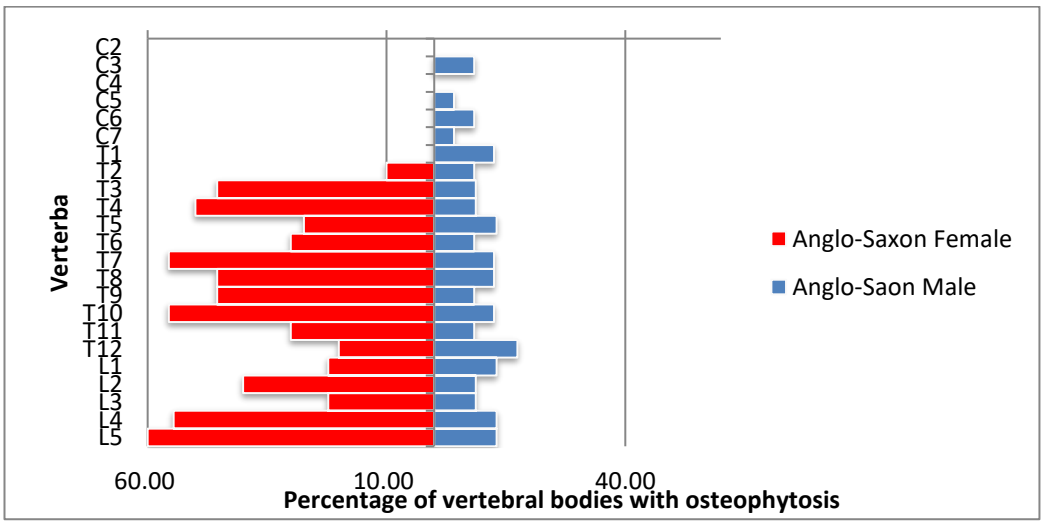


Figure 6-5 Inter-sample variation in the percentage of vertebral bodies with osteophytosis

Kruskal-Wallis tests with Bonferroni adjustment (α=0.0002) show statistically significant

differences in percentage true prevalence for pitting on both males and females across the three samples. Table 6-3 summarises the results of the Kruskal Wallis test. The true prevalence rates for pitting show statistically significant inter-sample differences (p value highlighted). However, it is not possible to differentiate between the samples and therefore a series of Mann-Whitney U tests between pairs of samples for pitting score of all vertebrae were performed to make the differentiation. The results of this analysis can be seen in Table 6-4. After Bonferroni adjustment, (α=0.0002) statistically significant differences in true prevalence of pitting can be seen between the Anglo-Saxon sample and St Bride's Crypt and St Bride's Lower (p value highlighted). Table 6-5 presents the combined median scores for true prevalence of pitting for each sample at all vertebral levels and clearly demonstrates that the true prevalence of pitting is much higher for males and females from the Anglo-Saxon sample.

Table 6-3 Summary of Kruskal-Wallace analysis of inter-sample differences in true prevalence of eburnation, pitting, osteophytes and osteophytosis

Variable	Sample	Sex	n	df	N	X^2	p
Eburnation	SBC	Male	26	2	94	6.786	0.034
	SBC		35				
	AS		33				
	SBC	Female	41	2	86	8.576	0.014
	SBC		35				
	AS		33				
Pitting	SBC	Male	26	2	94	19.784	**0.0001**
	SBC		35				
	AS		33				
	SBC	Female	44	2	86	37.859	**0.0001**
	SBC		24				
	AS		21				
Osteophytes	SBC	Male	26	2	94	2.566	0.277
	SBC		35				
	AS		33				
	SBC	Female	41	2	86	10.32	0.006
	SBC		24				
	AS		21				
VOS	SBC	Male	26	2	94	5.795	0.005
	SBC		35				
	AS		33				
	SBC	Female	44	2	86	2.113	0.348
	SBC		21				
	AS		24				

Table 6-4 Summary of Mann-Whitney U test for differences in true prevalence between sample pairs

Predictor Variable True Prevalence	Sex	Sample Comparison	Z	r (Effect size)	N	p
Eburnation	Male	SBC/SBL	-2.911	-0.373	61	0.004
		SBC/AS	-1.549	-0.202	59	0.121
		SBL/AS	-0.095	-0.012	68	0.924
	Female	SBC/SBL	-1.694	-0.21	65	0.09
		SBC/AS	-1.991	-0.253	62	0.046
		SBL/AS	-2.643	-0.394	45	0.008
Pitting	Male	SBC/SBL	-1.327	-0.17	61	0.184
		SBC/AS	-3.855	-0.502	59	**0.0001**
		SBL/AS	-3.595	-0.436	68	**0.0001**
	Female	SBC/SBL	-1.543	-0.191	65	0.123
		SBC/AS	-5.697	-0.724	62	**0.0001**
		SBL/AS	-4.937	-0.736	45	**0.0001**
Osteophytes	Male	SBC/SBL	-1.838	-0.235	61	0.066
		SBC/AS	-0.382	-0.05	59	0.703
		SBL/AS	-0.743	-0.09	68	0.458
	Female	SBC/SBL	-0.2603	-0.032	65	0.009
		SBC/AS	-2.67	-0.339	62	0.008
		SBL/AS	-0.182	-0.027	45	0.856
Vertebral Osteophytosis	Male	SBC/SBL	-0.387	-0.05	61	0.699
		SBC/AS	-1.742	-0.227	59	0.081
		SBL/AS	-2.351	-0.285	68	0.19
	Female	SBC/SBL	-1.425	-0.177	65	0.154
		SBC/AS	-1.12	-0.142	62	0.901
		SBL/AS	-0.975	-0.145	45	0.33

Table 6-5 Median scores for true prevalence of male and female pitting scores

Sample	Male True Prevalence Pitting Median	Female True Prevalence Pitting Median
SBC	15.61	17.7
SBL	18.39	23.98
AS	56.84	78.43

6.2.4 Prevalence rates of osteoarthritis.

Osteoarthritis (OA) is diagnosed as described in 5.2.4. Eburnation alone or pitting and osteophytes co-occurring are considered diagnostic of OA. To further clarify inter-sample differences in eburnation, pitting and osteophytes, the crude and true prevalence rates of OA were calculated for each sample (5.7.6.5).

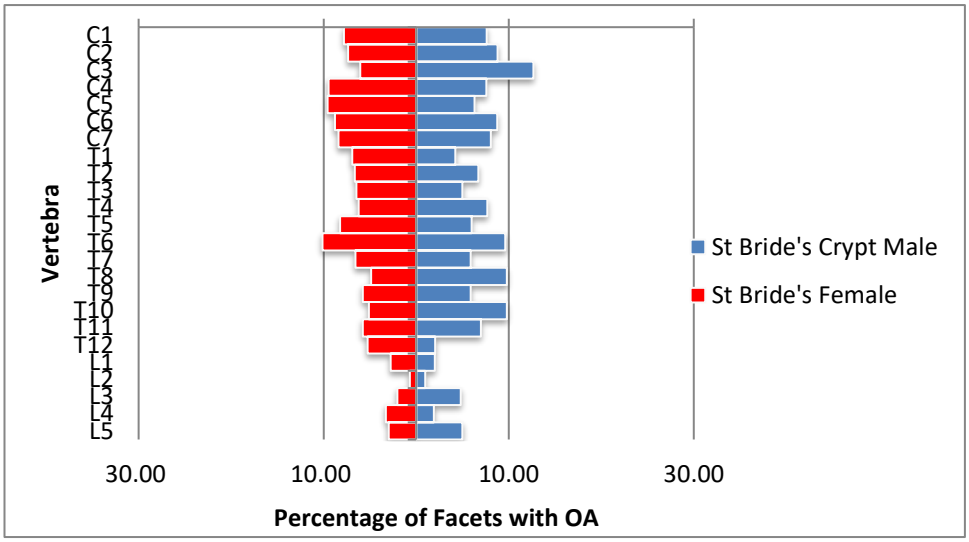
6.2.5 Inter-sample comparison of OA prevalence rates.

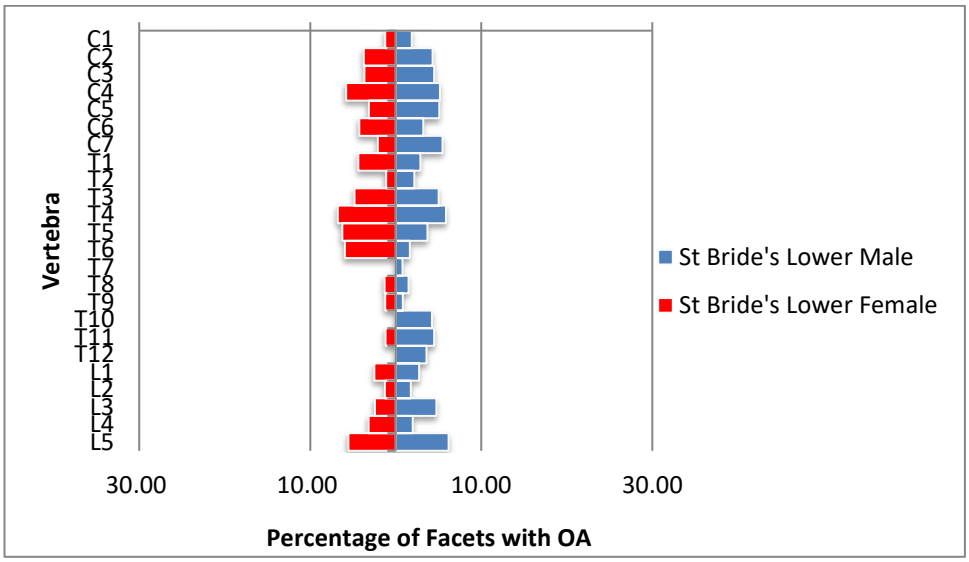
Crude prevalence rates were calculated as described in section 5.7.6.5. The results are presented in Table 6-6. In males, the highest crude prevalence rate for OA (88%) was seen in the St Bride's Crypt sample, closely followed by the Anglo-Saxon Males at 83%. In females, the Anglo-Saxon sample have the highest crude prevalence rate for OA at 100%, i.e. all females in this group showed OA on at least one facet level in their spines.

Table 6-6 Crude prevalence rates for osteoarthritis

Sample	Sex	Crude prevalence rate OA
SBC	Female	56%
	Male	88%
SBL	Female	58%
	Male	66%
AS	Female	100%
	Male	83%

True prevalence rates (see section 5.7.6.5) identify the number of facets available for observation and provide a clearer picture of prevalence. Appendix D-2 presents the true prevalence rates as a percentage for OA by individual. Kruskal-Wallis test with Bonferroni adjustment (p=0.0002) (Table 6-7) showed a statistically significant difference in percentage true prevalence for OA for females across the three samples (significant values highlighted).





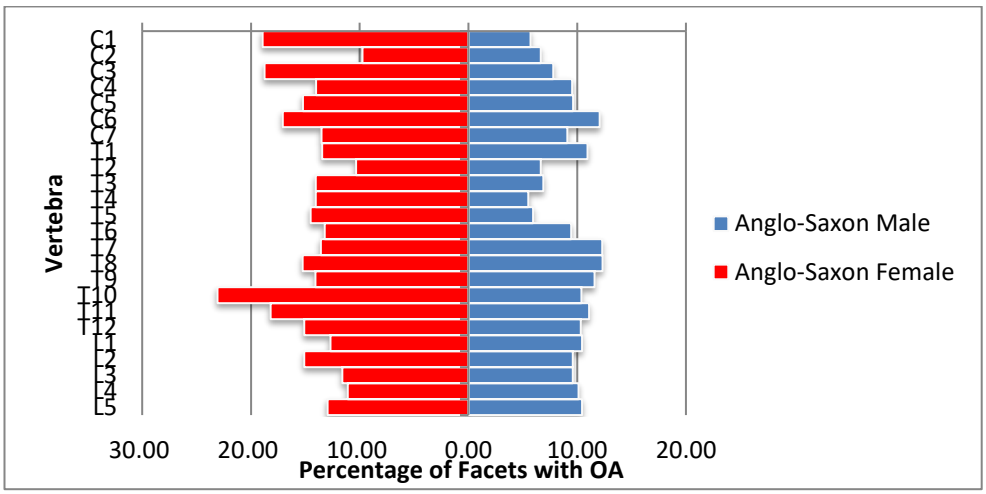


Figure 6-6 Inter-sample variation in true prevalence of OA

Table 6-7 Kruskal-Wallace test for inter-sample variation in true prevalence rates of OA

Variable	Sample	Sex	n	df	N	X^2	p
OA	SBC	Male	26	2	93	13.976	0.001
	SBC		35				
	AS		32				
	SBC	Female	39	2	85	24.735	**<0.0001**
	SBC		24				
	AS		22				

The results summarised in Table 6-7 indicate that there is a sample difference in true prevalence rates for OA between the three samples under study but does not identify which of the samples is statistically significantly different from one another, therefore a series of Mann-Whitney U tests between pairs of samples were performed allowing for differentiation. The results of this analysis can be seen in Table 6-8. After Bonferroni adjustment (α=0.0001) statistically significant differences in true prevalence of OA can be seen between the female Anglo-Saxon sample and St Bride's Crypt and St Bride's Lower with strong effect size (using Cohen, 1988 criteria of 0.1 = weak effect, 0.3 = medium effect and 0.5 = strong effect) and also between the male Anglo-Saxon sample and St Bride's Lower. Table 6-9 presents the median scores for true prevalence of OA for each sample and clearly demonstrates that the true prevalence of OA is much higher for males and females from the Anglo-Saxon sample.

Table 6-8 Mann-Whitney U Test for inter-sample variation in true prevalence

Predictor Variable True Prevalence	Sex	Sample Comparison	Z	r (Effect size)	N	p
OA	Male	SBC/SBL	-1.947	0.25 (Weak)	61	0.052
		SBC/AS	-2.043	0.27(Weak)	58	0.041
		SBL/AS	-3.531	0.43 (Medium)	67	**<0.0001**
	Female	SBC/SBL	-0.103	0.01 (None)	63	0.918
		SBC/AS	-4.60	**0.95 (Strong)**	61	**<0.0001**
		SBL/AS	-4.089	**0.6 (Strong)**	46	**<0.0001**

Table 6-9 Median scores for male and female true prevalence OA

Sample	Male True Prevalence OA Median	Female True Prevalence OA Median
SBC	5.44	2.41
SBL	1.64	1.91
AS	13.23	20.21

In order to further clarify the above results, Mann-Witney U tests were performed to identify differences in true prevalence of OA between males and females from each sample. Bonferroni adjustment was not applied to this analysis due to the small number of comparisons. Table 6-10 presents the results of inter-sex comparison by sample. Males and females from St Bride's Crypt show a statistically significant difference in true prevalence rate of OA between males and females. This observation was not seen in St Bride's Lower and the Anglo-Saxon individuals.

Table 6-10 Mann-Whitney U test for inter-sex differences in true prevalence of OA.

Sample	N	N	Total N	R (Effect size)	Z	p
SBC	Males	26	65	0.27 (Weak effect)	-2.217	**0.027**
	Females	39				
SBL	Males	35	59	0.04 (No effect)	-0.301	0.763
	Females	24				
AS	Males	32	54	0.14 (Weak effect)	-1.021	0.307
	Females	22				

This section investigated inter-sample differences of the predictor variables used in this study. The most significant variations seen were the true prevalence rate of pitting and OA in the Anglo-Saxon sample.

6.3 Facet size

This section presents the results generated by analysis of sexual dimorphism and the relationship between facet size with age, femoral robusticity, humeral directional asymmetry, facet eburnation, pitting, osteophyte scores and vertebral body osteophytosis. Facet size was calculated by multiplying the height and width of each facet (see Section 5.7.4).

6.3.1 Facet Size metric analysis

Each facet was analysed separately in this analysis (i.e. left and right superior and inferior facets for each vertebral level).The number of facets analysed for each sample is summarised in Table 6-11. The Anglo-Saxon sample was poorly preserved and had fewer intact facets available for study.

Table 6-11 summary of number of facets analysed for each sample

Sample	Number of Facets used for Analysis
St Bride's Crypt	5808
St Bride's Lower	4791
Anglo-Saxon	2997

A number of outlying values were observed and are reported for each spinal region and sample in Table 6-12. These values are due to natural variation in facet size. Many statistical techniques are sensitive to outliers, with correlation studies being particularly affected and although the majority of the data was of normal distribution, non-parametric methods were used to reduce the effect of the outlying data.

Table 6-12 Count of data outliers by spinal region and sample

Spinal Region	Number of Outliers for Facet Size		
	St Bride's Crypt	St Bride's Lower	Anglo-Saxon
Cervical	78 (13%)	42 (5%)	21 (4%)
Thoracic	116 (10%)	82 (6%)	48 (5%)
Lumbar	31 (6%)	26 (5%)	9 (2%)

Descriptive statistics for facet size for each sample using age combined, sex-divided groups are reported in Appendix B-1. This section is focussed on differences in size between males and females and not the effect of age on facet size (reported in Section 6.3.5) and therefore the age groups were amalgamated.

There is a wide range of standard deviation for facet size means across all facets for both sexes. This represents the wide variation in size that can be seen in the same facets from different individuals. The extremes of standard variation results and the facet levels at which they occurred at are summarised in Table 6-14.

Table 6-13 Maximum and minimum standard deviation values for facet size

	St Bride's Crypt		St Bride's Lower		Anglo-Saxon	
	Male	Female	Male	Female	Male	Female
Minimum Standard Deviation	12.65 T7RI	14.58 T8LtS	13.35 C7RI	12.71 T8LtS	14.11 C4RI	12.41 L4LtS
Maximum Standard Deviation	72.59 C2LtS	56.61 L4RS	70.2 T9LtS	79.35 L5LtS	77.23 L3RS	66.6 L4LtS

Key: C=cervical, T=thoracic, L=lumbar, R=right, Lt=left, S=superior, I=inferior

6.3.2 Facet size sexual dimorphism index

This section presents the results of calculation of the sexual dimorphic index (SDI) for each sample. The indices were generated from the average facet size calculated for each individual facet (i.e. left and right superior and inferior) (See section 5.7.4.1). The SDI demonstrates the presence or absence of differences in size between males and females and is a quick method to check for sexual dimorphism. However, it does not indicate the statistical significance of any

differences observed and therefore further analysis was performed to test for this and reported in this section

Table 6-14 summarises the results of SDI analysis presented in Appendix B-1. The results show the count of facets for each region at "SDI >110" (male), "< 90" (female) or "unclassified" (SDI values between 109 and 91). Male indices were greater than female and unclassified individuals in 85% (82/96) of facets from the St Bride's Crypt sample, and the St Bride's Lower (i.e. male facets were larger than female). This decreases to 47% (45/96) from the Anglo-Saxon sample (indicating that there was less difference in facet size between males and females); the left inferior facet of C2 for this sample had an SDI value of 89.24 indicating that the female index value was greater that the male mean and was the only facet to show this. There was a greater number of facets from the Anglo-Saxon sample that fell into the range between classification levels set for males and females indicating that there was much less sexual dimorphism in this sample. The results of statistical analysis to test if this difference is significant are presented in the next section.

Table 6-14 Count of sexual dimorphism index (SDI) results by sample

Sample	Spinal Region	SDI>110	SDI<90	Unclassified
St Bride's Crypt	Cervical	22	0	6
	Thoracic	41	0	7
	Lumbar	19	0	1
St Bride's Lower	Cervical	19	0	9
	Thoracic	44	0	4
	Lumbar	19	0	1
Anglo-Saxon	Cervical	12	1	15
	Thoracic	26	0	22
	Lumbar	7	0	13

Figure 6.7 illustrates the comparison in SDI values between the three samples by facet level. It can be seen that for St Bride's Crypt and the Anglo-Saxon samples the SDI values for facet size were evenly distributed throughout the vertebral column with no region having consistently high scores, however for St Bride's Crypt, the higher values (demonstrating bigger male values) were distributed throughout the lower half of the vertebral column.

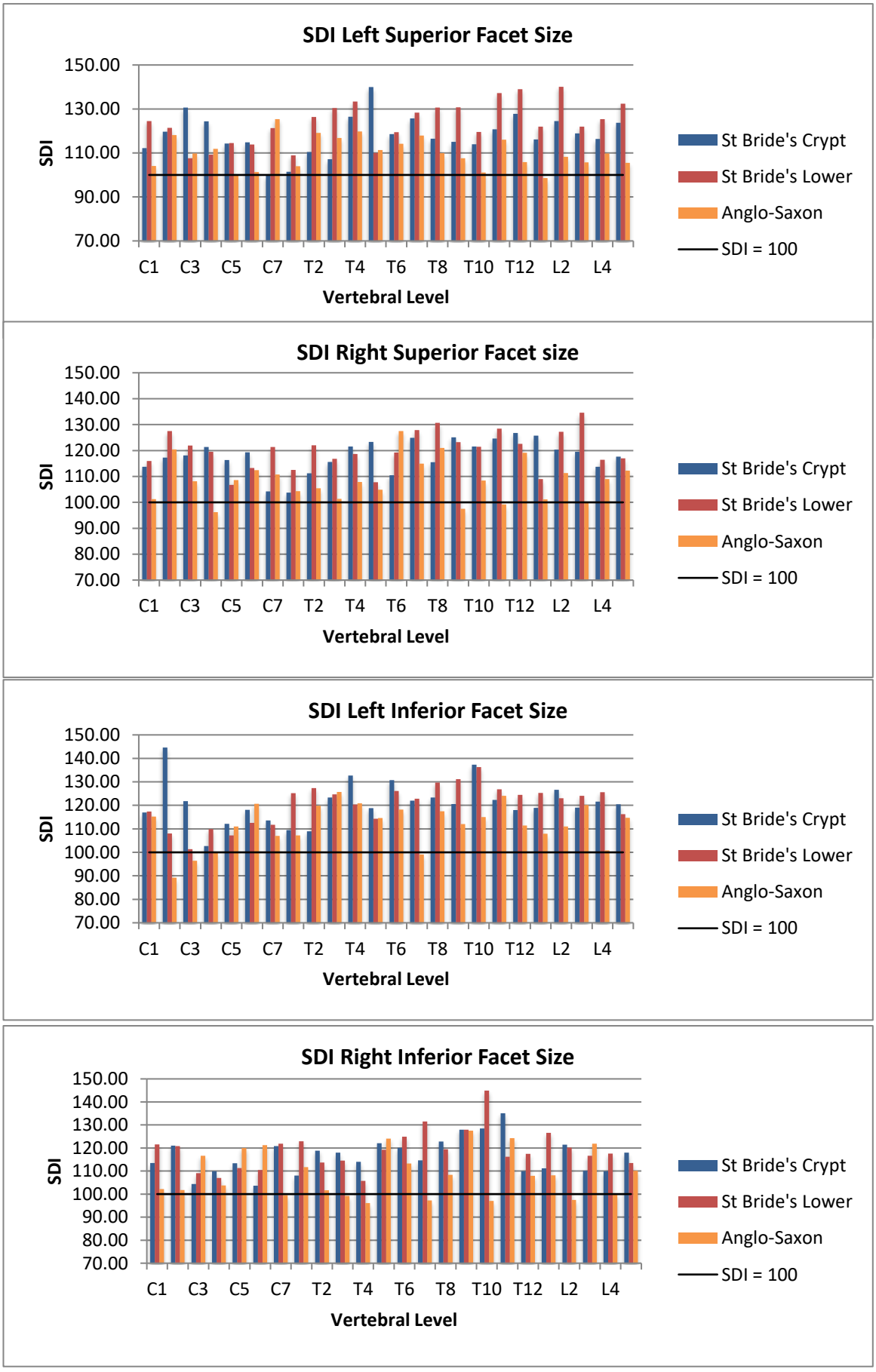


Figure 6-7 Sexual dimorphism index scores for facet size

6.3.3 Statistical analysis of the relationship between sex and facet size

The previous section has identified that there is a pattern of sexual dimorphism in facet size. Statistical significance of differences in facet size between males and females are reported in this section. Mann-Witney U test with Bonferroni adjustment (α=0.0005) was used to test for differences between the two independent groups (male and female) on a continuous measurement (facet size).The full results for these analyses can be seen in Appendix B-2. The percentage frequency of facets showing significant results are summarised by region in Table 6-15 and are represented graphically in Figure 6-8.

Table 6-15 Percentage frequency of facets with statistically significant differences in facet size between sexes

Spinal Region	Sample	Percentage significant at p<0.0005	Percentage significant at p<0.05
Cervical	SBC	18	46
	SBL	18	50
	AS	0	1
Thoracic	SBC	54	83
	SBL	5	77
	AS	4	21
Lumbar	SBC	40	85
	SBL	20	95
	AS	0	10

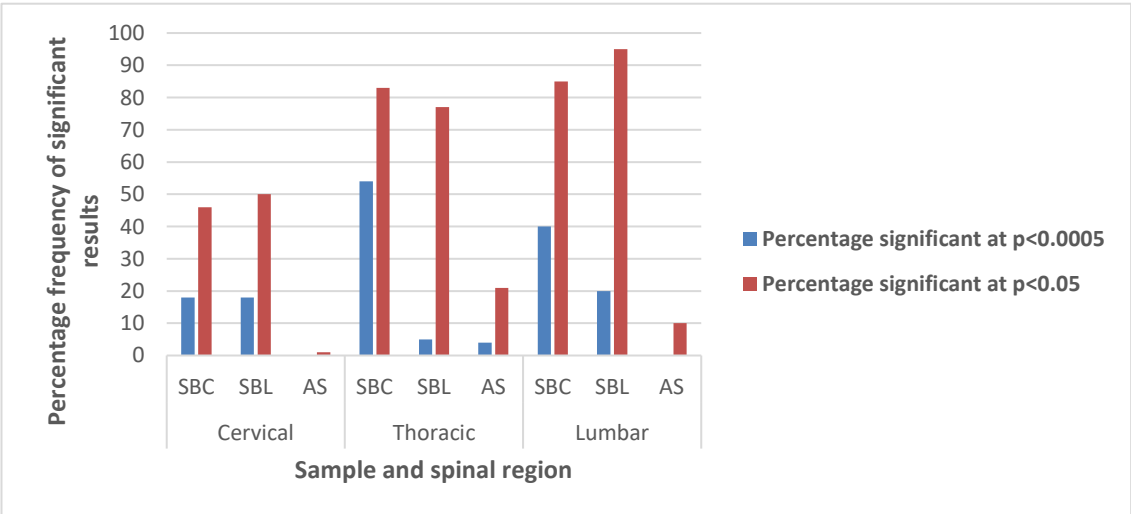


Figure 6-8 Percentage frequency of significant differences in facet size by sample and spinal region

The Bonferroni correction reduced the significant p value to p<0.0005, but despite this, statistically significant differences in facet size between the sexes were identified.

The null hypothesis tested in this section (See Chapter 1) is that there will be no measurable sexual dimorphism of facet joint size. This null hypothesis can be rejected for all three samples, but it should be noted that the degree of difference on facet size between males and females is less pronounced in the Anglo-Saxon samples studied.

6.3.4 Stepwise discriminant function analysis of facet size.

The previous section has identified that there are measurable differences in facet joint size between males and females and therefore this parameter may be of use in estimating the sex of an individual. The degree of difference between facet sizes is variable and the weighted importance of each value is not known. Discriminant function analysis is a statistical procedure that is frequently used to classify an individual into dichotomous groups based on the male/female variable (see Section 5.8.2.1). SPSS v24 was used to select and weight variables to create discriminant functions for each vertebral level, selecting the variables that best discriminated between the two groups. The mean facet size measurements for each facet were entered into the discriminant function equations and the group centroids for males and females (Zm and Zf) were noted. The demarcation point (Z_0) was calculated from the weighted means of values at the group centroids for males and females (see section 5.8.2.1 for further details). Size measurements above the demarcation point are deemed to indicate a male individual and those below the demarcation point are deemed to indicate a female individual. The number of males and females identified for each vertebral level (Nm and Nf) were also recorded. Discriminant function analysis then compared this value to the sex recorded for that individual and the probability of correct allocation into the appropriate group was also recorded as a percentage (calculated by SPSS).

Stepwise discriminant function analysis was performed as described in 5.8.2.1 for each sample, as discriminant function equations are population specific. The results can be seen in Table 6-16. The p value result is from Wilks' Lambda test for goodness of fit for the model, and tests for significant differences between the male and female groups. In this analysis, the p value was set at 0.0006 (with Bonferroni correction). Results for each sample are included in the table. This analysis generated discriminant functions to identify the sex of an individual based on the size of the facets at each vertebral level. In the event of little or no difference in facet size between the sexes, no variables qualified for inclusion in the equation.

The total percentage accuracy of correct classification listed in this table will be used to compare accuracy against the use of predictor variables in deriving discriminant function equations in Table 6-64.

Abbreviation Key:

C = cervical,

T = thoracic,

L = lumbar

Numbers represent the vertebral level

Lt = left,

R = right,

S =superior,

I = inferior

E.g. C1LtSA = facet size for C1, left superior facet and C1LS = facet angle for C1 left superior facet

SBC = St Bride's Crypt,

SBL = St Bride's Lower,

AS = Anglo-Saxon,

Zm = male group centroid,

Zf = female group centroid,

Nm = number of males identified,

Nf= number of females identified,

Z_0= demarcation point.

Table 6-16 Stepwise discriminant function analysis for facet size

Vertebral Level	Sample	p	F(n)	Zm	Zf	Nm	Nf	Z0	% Accuracy		
									M	F	Total
C1	SBC	<0.001	F=(-6.74)+(0.03)C1LtISize	0.62	-0.45	14	25	0.09	61	78	71
	SBL	<0.001	F=(-8.348)+(0.02)C1LtISize +(0.02)C2RSSize	0.75	-0.94	20	17	-0.11	77	85	80
	AS		No qualifying variables								
C2	SBC	<0.001	F=(-5.73)+(0.03)C2LtSSize	0.73	-0.44	9	30	0.15	39	86	67
	SBL	<0.001	F=(-6.45)+(0.03)C2LtSSize	0.62	-0.9	25	16	-0.14	86	80	84
	AS		No qualifying variables								
C3	SBC	0.042	F=(-3.33)+(0.29)C3LtISize	0.38	-0.23	6	30	0.07	30	97	71
	SBL	0.024	F=(-3.11)+(0.03)C3LtSSize	0.29	-0.39	22	10	-0.05	79	48	65
	AS	0.062	F=(-5.43)+(0.04)C3RISize	0.58	-0.44	10	5	-0.048	67	64	65
C4	SBC	0.006	F=(-3.59)+(0.03)C4LtSSize	0.53	-0.34	6	25	0.095	32	89	66
	SBL	0.025	F=(-3.33)+(0.03)C4LtSSize	0.28	-0.38	24	9	-0.053	83	41	65
	AS		No qualifying variables								
C5	SBC		No qualifying variables								
	SBL		No qualifying variables								
	AS		No qualifying variables								
C6	SBC	0.004	F=(-2.99)+(0.07)C6LtISize-(0.05)C6RISize	0.63	-0.34	9	32	0.146	45	87	72
	SBL		No qualifying variables								
	AS		No qualifying variables								
C7	SBC	0.003	F=(-3.86)+(0.03)C7RISize	0.5	-0.3	8	35	0.1	32	68	67
	SBL	0.008	F=(-3.96)+(0.04)C7RSSize	0.34	-0.42	24	16	-0.042	75	67	71
	AS		No qualifying variables								

Table 6—16 Stepwise discriminant function analysis for facet size continued

Vertebral Level	Sample	p	F(n)	Zm	Zf	Nm	Nf	Z0	% Accuracy		
									M	F	Total
T1	SBC	0.006	F=(-3.93)+(0.04)T1RISize	0.31	-0.48	29	11	-0.08	83	48	69
	SBL		No qualifying variables								
	AS		No qualifying variables								
T2	SBC	0.002	F=(-4.82)+(0.05)T2RISize	0.5	-0.34	13	33	0.08	50	87	72
	SBL	0.001	F=(-4.09)+(0.04)T2LtSSize	0.38	-0.56	23	13	-0.094	68	59	64
	AS		No qualifying variables								
T3	SBC	<0.001	F=(-4.92)+(0.05)T3LtISize	0.64	-0.41	12	31	0.12	48	80	67
	SBL	0.005	F=(-3.27)+(0.03)T3LtSSize	0.36	-0.49	26	13	-0.068	90	62	78
	AS	0.01	F=(-5.07)+(0.05)T3LtISize	0.41	-0.62	21	6	-0.01	96	50	79
T4	SBC	<0.001	F=(-4.59)+(0.02)T4LtISize +(0.03)T4LSSize	0.67	-0.64	15	32	0.01	58	89	76
	SBL	0.003	F=(-0.35)+(0.04)T4LtSSize	0.46	-0.73	24	15	-0.13	80	79	80
	AS	0.001	F=(-7.96)+(0.08)T4RSsize	0.64	-0.97	17	11	-0.162	74	26	72
T5	SBC	<0.001	F=(-3.32)+(0.038)T5LtSSize	0.65	-0.47	13	34	0.09	52	92	76
	SBL		No qualifying variables								
	AS	0.023	F=(-3.48)+(0.03)T5RISize	-0.36	-0.49	14	10	-0.42	70	71	71
T6	SBC	<0.001	F=(-4.45)+(0.05)T6LtISize	0.7	-0.51	16	33	0.1	62	87	77
	SBL	<0.001	F=(-5.03)+(0.06)T6RISize	0.49	-0.63	22	14	-0.07	79	67	74
	AS	0.034	F=(-4.15)+(0.04)T6RSSize	0.42	-0.45	13	8	-0.02	72	62	68

Table 6-16 Stepwise discriminant function analysis for facet size continued

Vertebral Level	Sample	p	F(n)	Zm	Zf	Nm	Nf	Z0	% Accuracy		
									M	F	Total
T7	SBC	<0.001	F=(-5.61)+(0.04)T7LtSSize +(0.03)T7RSSize	0.74	-0.49	12	33	0.13	46	87	70
	SBL	<0.001	F+(-5.97)+(0.08)T7RISize	0.56	-0.85	28	14	-0.15	90	70	82
	AS		No qualifying variables								
T8	SBC	0.004	F=(-5.09)+(0.02)T8LtISize +(0.2)T8RSSize	0.54	-0.38	12	29	0.08	48	81	67
	SBL	<0.001	F=(-5.5)+(0.07)T8LtSSize	0.53	-0.97	29	12	-0.22	88	60	77
	AS	0.23	F=(-4.62)+(0.02)T8RSSize	0.41	-0.47	11	8	-0.03	65	53	59
T9	SBC	<0.001	F=(-4.2)+(0.05)T9TISize	0.64	-0.42	14	35	0.11	56	92	78
	SBL	<0.001	F=(-4.16)+(0.05)T9LtSSize	0.46	-0.67	23	15	-0.1	74	75	75
	AS	0.019	F=(-4.02)+(0.04)T9RISize	0.43	-0.49	11	9	-0.03	69	64	67
T10	SBC	<0.001	F=(-3.22)+(0.03)T10tLISize	0.61	-0.39	13	35	0.11	50	90	74
	SBL	<0.001	F=(-3.12)+(0.03)T10RISize	0.45	-0.65	24	12	-0.1	80	60	72
	AS		No qualifying variables								
T11	SBC	<0.001	F=(-4.09)+(0.02)T11RISize +(0.03)T11RSSize	0.66	-0.423	11	32	0.1185	44	82	67
	SBL	0.001	F=(-3.39)+(0.03)T11LtSSize	0.44	-0.6	21	14	-0.08	75	70	73
	AS	0.054	F=(-3.14)+(0.03)T11LtISize	0.36	-0.46	12	7	-0.05	67	54	61
T12	SBC	0.004	F=(-3.16)+(0.03)T12LtSSize	0.48	-0.31	7	32	0.085	29	87	64
	SBL	0.006	F=(-2.63)+(0.03)T12LtSSize	0.36	-0.479	21	14	-0.06	75	67	71
	AS		No qualifying variables								

Table 6—16 Stepwise discriminant function analysis for facet size continued

Vertebral Level	Sample	p	F(n)	Zm	Zf	Nm	Nf	Z0	% Accuracy		
									M	F	Total
L1	SBC	0.005	F=(-3.09)+(0.02)L1RSSize	0.44	-0.33	12	26	0.59	48	74	63
	SBL	0.005	F=(-3.88)+(0.03)L1RISize	0.37	-0.5	21	12	0.25	75	60	69
	AS		No qualifying variables								
L2	SBC	<0.001	F=(-4.56)+(0.03)L2LtISize	0.63	-0.46	14	30	0.09	54	83	71
	SBL	0.004	F=(-3.17)+(0.02)L2LtSSize	0.35	-0.6	23	12	-0.12	79	60	71
	AS		No qualifying variables								
L3	SBC	0.005	F=(-4.17)+(0.02)L3RSSize	0.43	-0.32	13	27	0.06	50	77	66
	SBL	0.003	F=(-4.71)+(0.03)L3LtISize	0.47	-0.55	22	15	-0.04	82	71	77
	AS		No qualifying variables								
L4	SBC	0.003	F=(-3.94)+(0.02)L4LtISize	0.46	-0.32	11	33	0.07	42	87	69
	SBL	0.004	F=(-04.84)+(0.02)L4LtSSize	0.37	-0.66	23	8	-0.15	92	53	78
	AS		No qualifying variables								
L5	SBC	0.002	F=(-4.17)+(0.02)L5LtSSize	0.49	-0.39	12	31	0.05	48	91	73
	SBL	<0.001	F=(-4.45)+(0.02)L5LtSSize	0.51	-0.73	22	12	-0.11	76	63	71
	AS		No qualifying variables								

6.3.5 Relationship between facet size and age.

This section presents the results of analysis of the relationship between facet size with age. There is conflicting evidence in the literature about the influence of age on vertebral morphology (see Section 4.1).

Samples were divided into age group categories as described in section 5.7.3. Kruskal Wallace one-way between–groups analysis of variance with Bonferroni correction ($p<0.0005$) was used to identify any significant differences between facet size across the three age groups. (See Table 6-1 for sample size). Males and females were analysed separately to reduce the influence on facet size due to sexual dimorphism and also by sample to examine each group individually. The full results can be seen in Appendix B-3. Table 6-17 summarises the results of the Kruskal Wallace analysis of variation of facet size with age group. With $p < 0.0005$ there was no statistically

significant difference in facet size with age across all samples for either males or females. When $p<0.05$ is considered small significant differences were identified as reported in the table below.

Table 6-17 Percentage frequency of statistically significant results for facet size with age group analysis

Spinal Region	Sample	Percentage significant at p<0.0005		Percentage significant at p<0.05	
		Male	Female	Male	Female
Cervical	SBC	0	0	7	0
	SBL	0	0	0	12
	AS	0	0	0	7
Thoracic	SBC	0	0	2	13
	SBL	0	0	2	2
	AS	0	0	2	2
Lumbar	SBC	0	0	0	0
	SBL	0	0	0	20
	AS	0	0	5	0

These results indicate that age at death is not a significant variable affecting facet size for males and females for all three samples. The null hypothesis tested in this section was that there would be no difference in facet size with age group. This null hypothesis cannot be rejected. The results here suggest that increasing age at death is associated with small difference in facet size when $p<0.05$.

6.3.6 Age groups v actual age

This section presents the results of testing aggregated and disaggregated data from St Bride's Crypt to test changes in facet size with age. The sex and age of the individuals from St Bride's Crypt is documented and provides a control sample, providing the perfect opportunity to test the hypothesis that there is loss of resolution of the archaeological record when broad age ranges are used to define the age at death of a sample.

In the previous section, the relationship between facet size and age at death using age groups for the St Bride's Crypt sample was explored using Kruskal-Wallis one-way between groups analysis of variance with Bonferroni adjustment ($p=0.0005$). The results showed that there were no statistically significant relationships between facet size and age group for both males and females. (See Table 6-17).

Spearman's Rho correlational analysis with Bonferroni correction ($p<0.0005$) was used to test the interrelationship between facet size and age at death of males and females (disaggregated data) from St Bride's Crypt. The strength of correlation was derived as described in the introduction to this chapter. The results can be seen in Appendix B--4.The results are summarised by spinal region in Table 6-18. Both males and females demonstrated facets with negative correlation for size with age (n =13, 14% of facets for males and n = 40, 42% for females). This implies that for certain vertebral levels, facet size decreases with advancing age. Table 6-19 presents the correlation results by spinal region. Strong correlations were seen in the male cervical and lumbar regions and female thoracic region after Bonferroni adjustment was applied. These results show that the ascribing an individual to an age group can "dilute" the relationship between facet size and age such that strong relationships could be overlooked.

Table 6-18 Percentage frequency of correlation classifications between facet size and actual age at death

Sex	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)	Negative Correlation	P<0.0005
Male	28	40	20	2	13	0
Female	52	39	8	1	40	0

Table 6-19 Percentage frequency of correlation classifications between facet size and actual age at death by spinal region

Spinal Region	Sex	Negative correlation	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)
Cervical	Male	14	28	39	29	4
	Female	50	50	39	11	0
Thoracic	Male	13	29	50	21	0
	Female	42	55	33	12	2
Lumbar	Male	5	25	65	10	5
	Female	30	55	35	10	0

6.3.7 Relationship between facet size and sample and temporal patterning

The accuracy of discriminant functions used to estimate sex relies on similarity between the individual/group being tested and the sample population on which the function was originally derived. This section tests the null hypothesis was that there would be no difference in facet size between the populations.

The previous results indicate that facet size sexual dimorphism exists in the samples under study and it was observed that there was less difference in facet size between male and females in the Anglo-Saxon group. The next step was to explore inter-sample difference in facet size. Kruskal-Wallace tests were used to identify statistically significant differences in facet size between all three samples for males and females, ($p<0.0005$ with Bonferroni adjustment). This was followed by a post-hoc Mann-Whitney U test to identify which groups show a statistically significant difference from each other. Kruskal-Wallis tests were performed on all facet levels for the three samples and the percentage frequency of facets showing significant differences are summarised in Table 6-20. (The full table of results can be seen in Appendix B-5).

The results show that with Bonferroni adjustment, there is 1 cervical facet showing a significant difference between samples in facet size for males and 1 cervical and 8 thoracic facets for females. However, if Perneger's (1998) recommendation with regard to $p<0.05$ is applied, a number of differences between the samples become apparent with 19 male facets and 58 female facets showing significant size difference between samples in facet size.

Table 6-20 Percentage frequency of significant inter-sample differences in facet size using Kruskal-Wallace test

Spinal Region	Male		Female	
	p<0.0005	p<0.05	p<0.0005	p<0.05
Cervical	4	32	4	57
Thoracic	0	21	17	67
Lumbar	0	0	0	50

The next step was to perform a Mann-Witney U test to identify which groups are statistically different from each other. The results are summarised in Table 6--21 (the full table of results is available in Appendix B-6).

Table 6-21 Percentage frequency of significant Mann-Whitney U test results for facet size between sample groups by spinal region

Spinal Region	Inter-sample Comparison	P<0.0005		p<0.05	
		Number of facets		Number of facets	
		Male	Female	Male	Female
Cervical	St Bride's Crypt/St Bride's Lower	0	0	7	4
	St Bride's Crypt /Anglo-Saxon	0	39	29	50
	St Bride's Lower/Anglo-Saxon	39	4	50	75
Thoracic	St Bride's Crypt/St Bride's Lower	0	0	0	6
	St Bride's Crypt /Anglo-Saxon	0	23	21	71
	St Bride's Lower/Anglo-Saxon	23	19	71	65
Lumbar	St Bride's Crypt/St Bride's Lower	0	0	0	0
	St Bride's Crypt /Anglo-Saxon	0	5	5	75
	St Bride's Lower/Anglo-Saxon	5	0	75	80

For males, 23 facets show significant difference between St Bride's Lower and Anglo-Saxon samples and for females, 23 facets between St Bride's Crypt and Anglo-Saxon and 10 facets between St Bride's Lower and Anglo-Saxon samples when $p<0.0005$. There is no difference between St Bride's Crypt and St Bride's Lower for males and females at this significance.

These results indicate that direct comparison in facet size cannot be made between the different samples used in this study, particularly when considering females due to population differences. The null hypothesis that there is no difference in facet size between samples cannot be rejected between St Bride's Crypt and St Bride's Lower but can be rejected between St Bride's Crypt and Anglo-Saxon and St Bride's Lower and Anglo-Saxon.

6.3.8 Effect of sample and temporal variation on the accuracy of sex estimation using DFA equations

To date, there has been little comparative research exploring differences in basal dimensions between samples and how significant any variation might be in terms of the accuracy of discriminant functions used for estimating sex. The discriminant function equations derived for facet size from St Bride's Lower and the Anglo-Saxon samples were used in turn as a test of probability for correct allocation sex of the St Bride's Crypt group as a way of testing the effect of size variation between the three samples identified in the previous section. The equations

were substituted with the St Bride's Crypt data as this is from a documented sample and the actual sex of each individual is known. Table 6-22 summarises the results of the substitutions. Although some St Bride's Lower/St Bride's Crypt percentage accuracies are similar in value, the degree of accuracy is higher in C1, T7, T11, T12 and L1, the same at C2, T8, L5 and reduces for all the other vertebral levels where the degree of accuracy could be calculated (C3, C4, C7, T2, T3, T9, T10, L3, L4). The Anglo-Saxon equations produced lower degrees of accuracy of classification when applied to St Bride's Crypt data across all vertebral levels where substitution was possible. One-way repeated-measures ANOVA was conducted to compare the percentage probability scores when discriminant functions were substituted with the St Bride's Crypt data. There was a statistically significant difference between the results with strong effect size, Wilks' Lambda = 0.136, F (2,5) = 15.81, p = 0.007, multivariate eta squared = 0.864.

Table 6-22 Percentage accuracy of correct classification achieved after discriminant function substitution (vertebral levels for which discriminant functions could not be calculated as a result of missing data or lack of sexual dimorphism are left blank)

Vertebral Level	St Bride's Crypt with St Bride's Crypt data	St Bride's Lower with St Bride's Crypt data	Anglo Saxon with St Bride's Crypt data
C1	71	73	0
C2	67	67	0
C3	71	67	64
C4	66	61	0
C5	0	0	0
C6	72	0	0
C7	67	51	0
T1	69	0	0
T2	72	63	0
T3	67	63	51
T4	76	45	55
T5	76	0	55
T6	77	70	60
T7	68	69	0
T8	67	67	60
T9	78	64	57
T10	74	67	0
T11	67	72	6
T12	64	67	0
L1	63	66	0
L2	71	72	0
L3	66	63	0
L4	69	67	0
L5	73	73	0

The aim of this section was to test whether discriminant functions based on facet size could accurately estimate sex in other samples. The results so far have demonstrated that significant variation exists in the dimensions of facet size between the three samples and that these differences can affect the accuracy of discriminant functions when applied to a different sample. The hypothesis that discriminant function equations are not interchangeable between samples cannot be rejected.

Many factors may be responsible for the differences between the groups and the relationship between predictor variables and facet size are analysed and reported in the next section.

6.3.9 Relationship between facet size and predictor variables

This section presents the results of analyses of predictor variables identified in Section 5.7.7. Each variable was analysed separately. Percentage frequencies of strong correlations for each predictor variable by facet level are summarised in table and graph form in this section, whilst the complete tables of results can be found in the attached appendices.

6.3.9.1 Correlation between femoral robusticity and facet size

The femoral robusticity measure was calculated for the right and left femora present using the method described in section 5.7.7.1. The number of individuals and femora used in this correlation study are summarised in Table 6-23. Some individuals had damaged or incomplete femora which meant that both could not be included in the analysis.

Table 6-23 Summary of femora available for correlation study

Cemetery	Male			Female		
	N (Individuals)	N (Right)	N (Left)	N (Individuals)	N (Right)	N (Left)
St Bride's Crypt	25	13	12	42	23	19
St Bride's Lower	35	26	26	24	15	13
Anglo-Saxon	29	22	15	24	24	18

Correlation analysis was performed between the results from the femoral robusticity calculations (described in 5.7.7.1) and facet size. The Spearman Ranked Order correlation coefficient (r) was calculated ($p<0.0005$ after Bonferroni adjustment). This method determines correlation between continuous variables and provides a measure of how the two variables are associated (Pallant 2013).

The results of the correlation analysis were classified according to the method of Cohen (1998) (described in the introduction to this chapter) and presented in Table 6-24. The overall results and two-tailed significance values were also reported in Appendix B-7, column p.

Table 6-24 presents the results of the correlation analysis. The numbers in the table represent the percentage frequency of each facet with the attribute. Both males and females showed negative correlation. Negative correlation was distributed throughout the spinal regions and indicates that as femoral robusticity increases facet size decreases. It is not clear why males should have much higher levels of negative correlation than females in the St Bride's Crypt and Anglo-Saxon populations, whilst the converse is seen In the St Bride's Lower population where females have much higher levels of negative correlation than males for the right side facet joints.

Table 6-24 Percentage frequency of correlation classifications between femoral robusticity and facet size

Sex	Sample	No Correlation (r_s<0.01)		Weak Correlation (r_s=0.1-0.29)		Medium Correlation (r_s=0.3-0.49)		Strong Correlation (r_s=0.5-1.0)		Negative Correlation		P<0.0005	
		Lt	R	Lt	R	Lt	R	Lt	R	Lt	R	Lt	R
Male	SBC	32	34	51	60	18	30	0	1	65	86	0	0
	SBL	38	53	60	46	9	5	0	0	20	60	0	0
	AS	21	25	46	47	28	29	6	3	67	60	0	0
Female	SBC	34	27	43	46	15	25	1	2	38	44	0	0
	SBL	32	21	49	63	12	19	8	2	36	89	0	0

Table 6-25 summarises correlation strength by spinal region. In the St Bride's Crypt group, a strong correlation was seen between right femoral robusticity and the right superior facet of T5, the left superior facet of T7, the right superior facets of T8 and T9, the right inferior facet of T12, and the left superior facet of L3 in males and the right superior facet of C5, the right superior facet of T2 and the right inferior facet of T4 in females. A strong correlation was found between left femoral robusticity and the right inferior facet of C4 and left and right superior facets of T7.

No strong correlations were found between femoral robusticity and facet size in males from the St Bride's Lower Group. In females, a strong correlation was found between left femoral robusticity and the left inferior facet of C4, the right inferior facet of T2, the left and right superior and right inferior facets of T3, the right superior facet of T4, the left superior facet of T5, the left superior facet of T12 and all facets of L4 and also between right femoral robusticity and the right inferior facet of T4 and right superior facet of T11.

In the Anglo-Saxon samples, a strong correlation between facet size and left femoral robusticity was found in the male spine at the right inferior facets of C4, T4 and T5, the right superior facet of T6, and the left inferior facet of L2 and L3. In the female spine, a strong correlation was found

between the right inferior facet of C2, the right superior facet of C3, the left superior and right inferior facet of C4, the left and right superior facets of C6, the left and right superior and left inferior facets of C7, the right inferior facet of T4, the left inferior facet of T12. A strong correlation was also found between right femoral robusticity and the right inferior facet of C2, the left and right superior facets of C3, the left superior facet of C4, the left and right inferior facets of C6, the left and right superior and left inferior facet of C7, the right inferior facet of T4 and the left inferior facet of T12.

There was a higher percentage frequency of correlations between facet size and femoral robusticity in the Anglo-Saxon sample than in the other two samples, however no clear pattern of correlation can be seen for individual facets. Overall, femoral robusticity does not demonstrate a linear relationship with facet size for most vertebral levels.

Table 6-25 Percentage frequency of correlation classifications between femoral robusticity and facet size by spinal region

Spinal Region	Sex	Sample	No Correlation (r_s<0.01)		Weak Correlation (r_s=0.1-0.29)		Medium Correlation (r_s=0.3-0.49)		Strong Correlation (r_s=0.5-1.0)	
			Lt	R	Lt	R	Lt	R	Lt	R
Cervical	Male	SBC	36	50	46	39	18	11	0	0
		SBL	21	64	64	36	14	0	0	0
		AS	36	32	28	36	32	29	4	4
	Female	SBC	43	18	39	43	14	36	4	4
		SBL	36	29	50	50	11	21	4	0
		AS	7	7	28	32	25	25	39	36
Thoracic	Male	SBC	36	25	50	27	15	36	0	10
		SBL	21	42	67	58	10	8	0	0
		AS	17	25	50	52	27	27	6	0
	Female	SBC	33	31	42	39	19	27	4	4
		SBL	27	10	54	75	15	21	15	4
		AS	35	42	42	48	13	13	4	4
Lumbar	Male	SBC	15	25	60	25	25	40	0	5
		SBL	60	65	40	30	0	5	0	0
		AS	15	15	60	50	25	35	10	10
	Female	SBC	25	30	50	65	5	5	0	0
		SBL	35	35	35	55	10	10	20	0
		AS	356	45	40	35	25	20	0	0

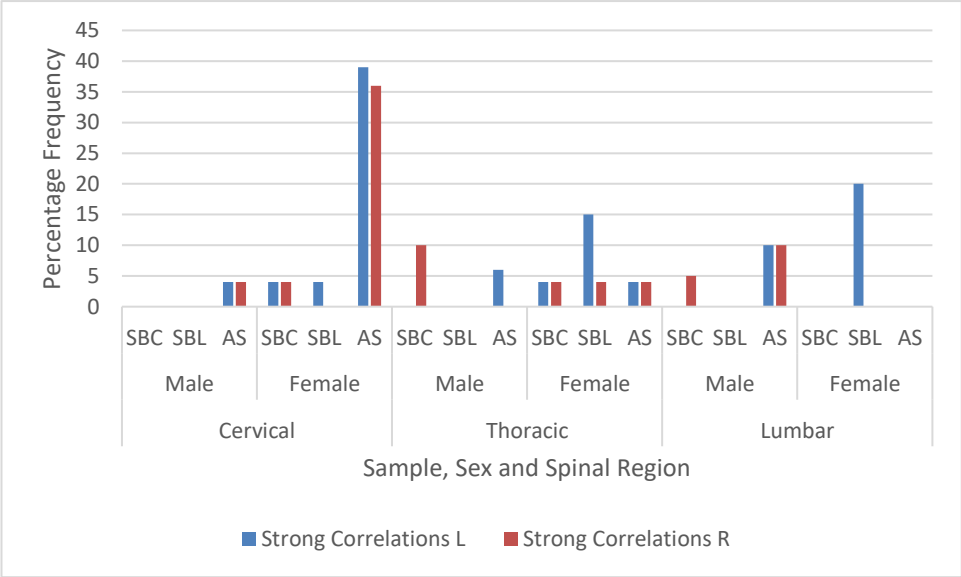


Figure 6-9 Percentage frequency of strong correlations between femoral robusticity and facet size

The previous results identify strong correlation between femoral robusticity and individual facets. The next section compares the correlation classifications between superior and inferior facets on the same side of a vertebra to give an overall picture of lateral agreement and allows testing for loss of resolution if the results are amalgamated by side, rather than each facet reported separately. Table 6-26 presents the results achieved when the correlation classification of the left superior/inferior and right superior/inferior facets are compared. The numbers represent the percentage frequency of pairs of facets from the same vertebra with the same classification. This tests for loss of resolution when facet data is amalgamated. The results demonstrate a loss of resolution and indicate that greater accuracy is achieved when the percentage frequency of correlation classification for each facet is reported.

Table 6-26 Percentage frequency of superior and inferior facets with matching correlation classification

Spinal Region	Sex	Sample	No Match		No Correlation (r_s<0.01)		Weak Correlation (r_s=0.1-0.29)		Medium Correlation (r_s=0.3-0.49)		Strong Correlation (r_s=0.5-1.0)	
			L	R	L	R	L	R	L	R	L	R
Cervical	Male	SBC	25	25	7	14	14	11	4	0	0	0
		SBL	25	21	4	18	21	11	0	0	0	0
		AS	25	28	14	7	4	7	7	7	0	0
	Female	SBC	28	32	14	4	7	14	0	0	0	0
		SBL	32	28	7	4	11	14	0	4	0	0
		AS	39	36	0	28	7	4	0	7	4	4
Thoracic	Male	SBC	35	21	4	17	10	10	0	2	0	0
		SBL	27	25	6	21	17	4	0	0	0	0
		AS	38	35	0	4	8	6	4	4	0	0
	Female	SBC	42	38	4	2	4	6	0	4	0	0
		SBL	31	33	2	6	13	8	0	2	4	0
		AS	31	27	10	6	2	13	0	0	6	4
Lumbar	Male	SBC	35	25	10	15	0	5	0	0	0	0
		SBL	20	30	5	5	25	15	0	0	0	0
		AS	30	25	0	0	5	15	10	10	5	0
	Female	SBC	30	25	0	5	15	5	0	10	0	0
		SBL	40	25	5	0	0	25	0	0	5	0
		AS	40	45	10	0	0	5	0	0	0	10

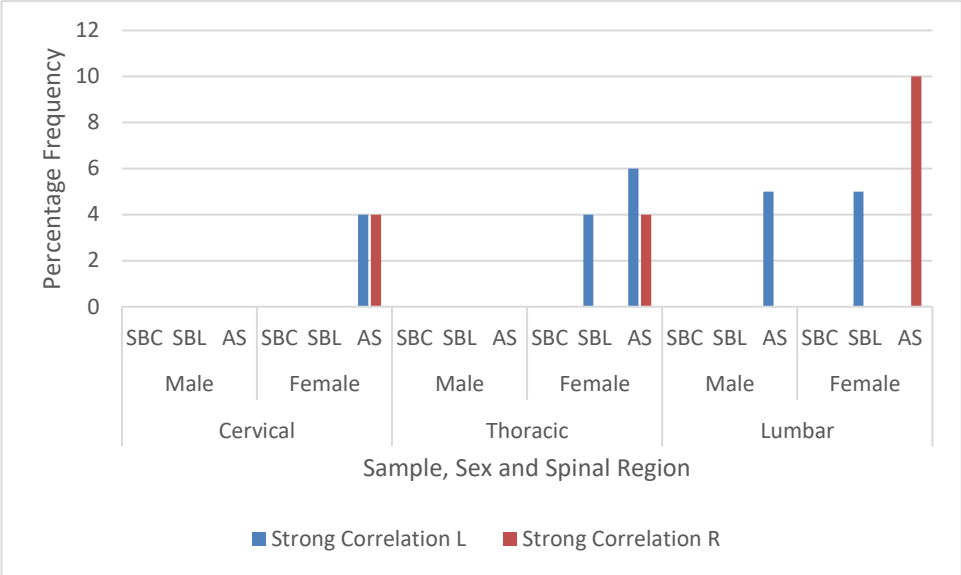


Figure 6-10 Percentage frequency of matching strong correlations between femoral robusticity and facet size in left and right superior and inferior facets

The correlation classifications between right leg and right facet relative to left facet and right leg and similarly for the left side were compared and the number of facets with matching correlations for ipsilateral and contralateral leg and facets are reported in Table 6-27. The numbers represent the percentage frequency of facets that have the same correlation classification for each comparison. Lt represents the count of facets with the same correlation classification between left facet, left leg and left facet right leg. R represents the count of same correlation classification for the right side.

Table 6-27 Percentage frequency of ipsilateral and contralateral matching correlations femoral robusticity and facet size

Spinal Region	St Bride's Crypt				St Bride's Lower				Anglo-Saxon			
	Male		Female		Male		Female		Male		Female	
	Lt	R	Lt	R	Lt	R	Lt	R	Lt	R	Lt	R
Cervical	57	25	29	18	21	14	21	11	36	29	21	32
Thoracic	17	13	25	18	13	10	25	13	33	27	13	23
Lumbar	20	10	25	25	35	20	15	20	20	30	35	30

These results indicate that for correlation of femoral robusticity and facet size, although there is a degree of symmetry, apart from Anglo-Saxon males, less than 50% of facets show relative differences.

6.3.9.2 Correlation between humeral and facet size directional asymmetry.

Poor preservation restricted the number of humeri available for analysis and the total number used for each population is listed in Table 6-28. Correlation analyses were limited for some facet levels due to lack of suitable data.

Table 6-28 Number of humeri included in correlation

Cemetery	Male		Female	
	N left humeri	N right humeri	N left humeri	N right humeri
St Bride's Crypt	10	8	19	21
St Bride's Lower	5	22	13	8
Anglo-Saxon	8	4	2	3

The directional asymmetry between right and left upper limb and right and left superior and inferior facet size was calculated using the method described in 5.7.7.2. The correlation between the two directional asymmetries was then analysed using a 2 x 2 table with Yates' continuity correction used to compensate for over estimation of the Chi-squared value ($p<0.001$ with Bonferroni correction). The full results are presented in Appendix B-8 and summarised in Table 6-29 and Table 6-30. The phi coefficient was used to measure the degree of association between the two directional asymmetries and classified according to Cohen's (1988) criteria as described in the introduction to this chapter.

Table 6-29 presents the results of the correlation analysis. No correlations showed statistical significance but strong correlations between humeral and facet size asymmetry were noted in the superior and inferior facets of L2 in males and the inferior facets of T9 and the superior facets of L3 in females from St Bride's Crypt; the superior facets of C4 and inferior facets of T2 in females from St Bride's Lower; the superior facets of C4, C7, T10, T11, T12, L2 and L3, inferior facets of C5, T11, L1, and L4 in males and the superior facets of T5, T6, T12, L2, L3, L4 and inferior facets of T2, T6, T7, T9, L3 and L4 in females from the Anglo-Saxon sample.

Table 6-30 summarises the results of correlation analysis by spinal region. The numbers represent the percentage frequency of paired (left and right superior and left and right inferior) facets showing the same correlation classification. It can be seen that the association between humeral and facet size directional asymmetry is non-existent or weak in the majority of vertebral levels for St Bride's Crypt, with the highest count of facets with medium strength associations occurring in the thoracic spine (females having 7 levels both superior and inferior and males 5 facets). Counts of paired facets with strong associations were noted at the superior facet of C4 and the inferior facet of T3 in females from St Bride's Lower, with the highest count of medium strength associations occurred in the thoracic spine (females, 5 and males 3 facets). Strong correlations

were also noted in the Anglo-Saxon group (11 male and 12 female) at the superior facets of C4, C7, T10, T11, T12, L2 and L3 and inferior facets of C5, T11, L1 and L4 in males and the superior facets of T5, T6, T12, L2, L3 and L4 and inferior facets of T2, T6, T7, T9, L3, and L4 in females.

Table 6-29 Percentage frequency of correlation classifications between humeral and facet size directional asymmetry

Sex	Cemetery	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)	Negative Correlation	P<0.001
Male	SBC	29	17	9	2	21	0
	SBL	18	27	4	0	23	0
	AS	9	15	14	11	21	0
Female	SBC	20	16	11	2	26	0
	SBL	10	27	9	2	17	0
	AS	0	11	8	13	17	0

illustrates the results reported in Table 6-30 and demonstrates the difference in percentage frequency of strong correlations between the samples. Humeral directional asymmetry shows limited use as a predictor of facet size asymmetry in the St Bride's Crypt and St Bride's Lower samples. However there is a greater relationship between these two measures particularly in the male thoracic region and female thoracic and lumbar regions in the Anglo-Saxon sample.

Table 6-30 Percentage frequency of correlation classification between humeral and facet size asymmetry by spinal region

Spinal Region	Sex	Sample	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)
Cervical	Male	SBC	18	18	11	0
		SBL	14	10	0	0
		AS	14	11	11	11
	Female	SBC	21	25	4	0
		SBL	14	18	14	4
		AS	0	18	0	0
Thoracic	Male	SBC	19	19	10	0
		SBL	21	21	6	0
		AS	8	17	17	8
	Female	SBC	21	10	17	2
		SBL	6	29	10	2
		AS	0	6	15	15
Lumbar	Male	SBC	20	10	5	10
		SBL	15	30	5	0
		AS	5	15	10	20
	Female	SBC	15	15	15	5
		SBL	15	35	0	0
		AS	0	15	5	25

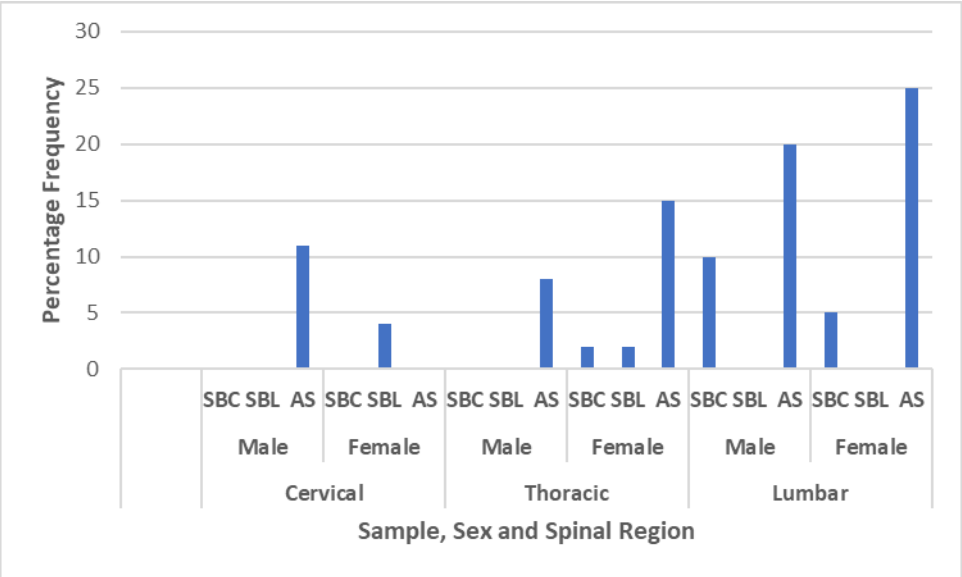


Figure 6-11 Percentage frequency of strong correlations between humeral and facet size directional asymmetry

These results indicate that humeral facet directional and facet size asymmetry show more strong correlations in the Anglo-Saxon sample than the St Bride's Samples.

6.3.9.3 Diagnostic criteria for osteoarthritis as predictor variables

The next three sections will consider the effects of eburnation, pitting and osteophytes as predictor variables before assessing correlation of the presence/absence of osteoarthritis as a predictor variable for facet size and angle.

6.3.9.4 Correlation between eburnation score and facet size.

The presence or absence and severity of eburnation seen on each facet were recorded using the method described in 5.7.6.1. The scores for severity and extent were summed to create a new variable called ebtot. The scores represent a ranked order of extent and severity.

The correlation between ebtot and facet size was analysed using Spearman's Ranked Order Correlation with $p<0.001$ with Bonferroni adjustment. The correlation coefficient was used to measure the degree of association between ebtot and facet size and classified according to Cohen's (1988) criteria as described in 6.2.13.

The full results are presented in Appendix B-9 and summarised below in Table 6-31 and Table 6-32.

Table 6-31 Percentage frequency of correlation classifications between ebtot (total eburnation score) and facet size

Sex	Sample	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)	Negative Correlation	P<0.001	P<0.05
Male	SBC	20	30	10	3	34	0	2
	SBL	19	42	8	2	40	0	4
	AS	28	41	9	10	70	0	8
Female	SBC	30	32	7	0	42	0	0
	SBL	21	18	9	3	34	0	1
	AS	13	45	10	16	48	0	5

The numbers on the table represent the percentage frequency of facets showing the same correlation classification. Negative correlation was noted in 33 (34%) of male and 40 (42%) of female facets from St Bride's Crypt, 39 (40%) of males and 33 (34%) of female facets from St Bride's Lower and 67 (70%) of male and 46 (48%) of female facets from the Anglo-Saxon sample. This indicates that in these facets, increased ebtot was correlated with smaller facet size. No correlations showed a statistical significance at p<0.0001, however, 14 males and 6 female facets showed significant correlation across all categories at p<0.05. Strong correlations were noted in the male lumbar region for St Bride's Crypt, male thoracic region for St Bride's Lower and thoracic and lumbar for males and all three regions for females from the Anglo-Saxon samples. Degree of OA is known to be related to age. The samples could not be divided into age groups to control for this confounding factor as some groups were too small for analysis.

Table 6-32 summarises the results of the correlation analysis by spinal region. The percentage frequency of facets without eburnation is identified in the "No Eburnation" column and is represented by blank cells in Appendix B-9. For St Bride's Crypt, males and females have similar numbers of facets without eburnation in the cervical region (21% of facets each). This changes in the thoracic region, where males have 42% of facets without eburnation and females have 8%. A similar pattern is seen in the lumbar region where males have 15% and females have 10% of facets without eburnation. The association between eburnation score and facet size is non-existent or weak in the majority of facets with strong correlations between eburnation and facet size seen in the left superior facet of T1, the right superior facet of T3 and the left superior facet of T4 in males, with no strong correlations seen in female spines.

For St Bride's Lower, females have a higher number of facets without eburnation in the cervical region (males 4%, females, 21%). In contrast, in the thoracic region males and females have similar numbers of facets without eburnation (males 40%, females 42%). The lumbar region

pattern reverses that seen in the cervical region with males having 45% and females 25% of facets without eburnation. The association between eburnation score and facet size in non-existent or weak in the majority of facets with strong correlations between eburnation and facet size seen in the right superior facet of C6 and the right superior facets of C3 and C7 and the left superior facet of L5 in females.

For the Anglo-Saxon sample, females have more facets without eburnation in the cervical region than males (14% females, 0% males). In the thoracic and lumbar regions all facets included in this analysis have some eburnation. Strong correlations between eburnation and facet size were seen in the left inferior facet of T1, the right inferior facet of T5, the left inferior facet of T2, the left and right inferior facets of T11, the right and left inferior facets of T12, the left inferior facet of L1 and L2, the left superior facet of L3 in males and in the left and right inferior facets of C2, the left and right superior facets of C3, the right superior facet of C4, the right superior and left and right inferior facets of C5, the right superior and left inferior facets of T11 and the left superior facet of L1 in the female spine.

Figure 6-12 illustrates the results listed in Table 6-32 and clearly identifies that the highest count of strong correlations can be seen in the cervical region of Anglo-Saxon females and thoracic region of Anglo-Saxon males.

The results indicate that ebtot shows the highest count for strong correlation with facet size for the Anglo-Saxon sample and thus has the potential to be a predictor for facet size in this sample. This is not the case for the St Bride's samples.

Table 6-32 Percentage frequency of correlations between ebtot (total eburnation score) and facet size by spinal region

Spinal Region	Sex	Sample	No Eburnation	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)
Cervical	Male	SBC	21	21	32	25	0
		SBL	4	14	61	18	4
		AS	0	43	43	18	0
	Female	SBC	21	18	43	18	0
		SBL	21	21	25	29	8
		AS	14	11	21	14	39
Thoracic	Male	SBC	42	19	43	8	6
		SBL	40	23	38	0	0
		AS	100	25	46	0	25
	Female	SBC	8	46	38	8	0
		SBL	42	19	21	0	0
		AS	100	13	56	0	6
Lumbar	Male	SBC	15	25	40	15	0
		SBL	45	15	25	15	0
		AS	100	40	25	20	15
	Female	SBC	75	10	5	10	0
		SBL	65	25	0	5	5
		AS	100	15	50	30	5

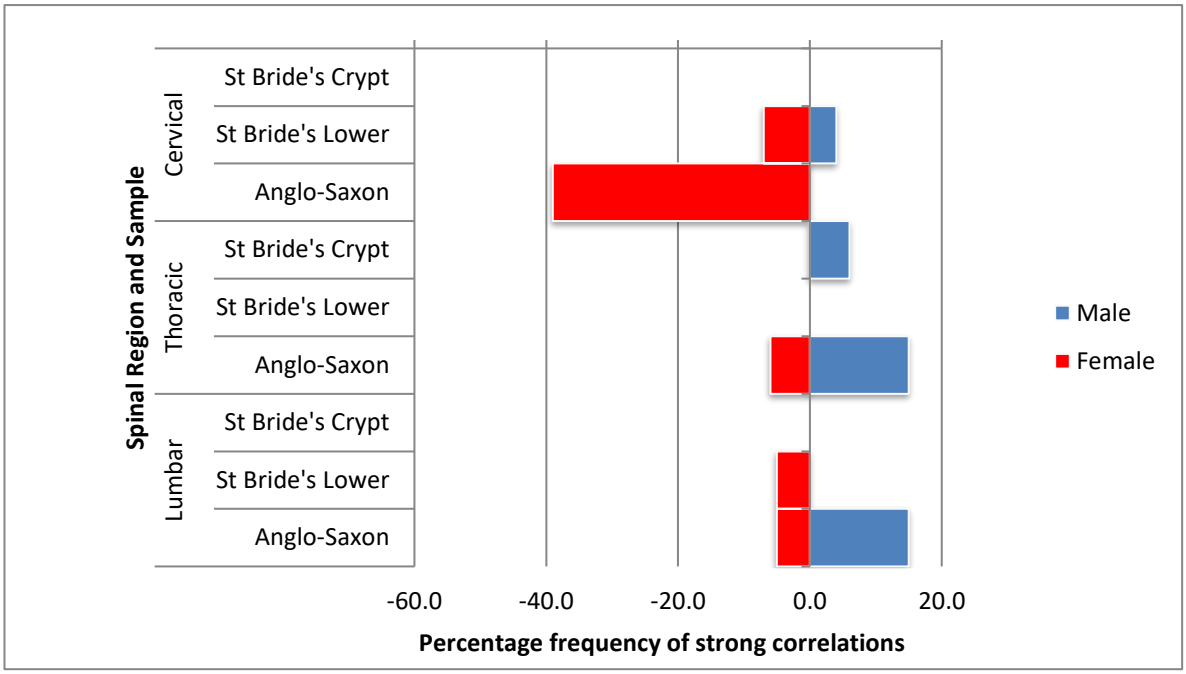


Figure 6-12 Percentage frequency of strong correlations between ebtot (total eburnation score) and facet size

6.3.9.5 Correlation between pitting score and facet size

The presence or absence and severity of pitting seen on each facet were recorded using the method described in 5.7.6.2. As with eburnation scores, the pitting scores for severity and extent were added together to create a new variable (pitot). Statistical analysis was performed as for eburnation (see Section 6.3.9.4).

The full results are presented in Appendix B-10 and summarised below in Table 6-33 and Table 6-34.

Table 6-33 Percentage frequency of correlation classifications between pitot and facet size

Sex	Sample	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)	Negative Correlation	P<0.001
Male	SBC	22	53	23	2	51	0
	SBL	47	39	8	2	36	0
	AS	25	46	13	6	66	0
Female	SBC	38	46	14	1	45	0
	SBL	23	41	13	5	45	0
	AS	40	33	10	21	45	0

Negative correlation was noted in 51% of male and 45% of female facets from St Bride's Crypt; 36% of males and 45% of female facets from St Bride's Lower and 66% of male and 45% of female

facets from the Anglo-Saxon sample. This indicates that in these facets, increased pitot score was correlated with smaller facet size. Although no correlations showed a statistical significance, strong correlations were noted in the thoracic and lumbar region in males and the thoracic region for females from St Bride's Crypt, male cervical and thoracic region, female thoracic and lumbar regions for St Bride's Lower and all three regions for males and females from the Anglo-Saxon samples.

Table 6-34 summarises the percentage frequency of facets with each correlation classification by spinal region. The number facets without pitting is identified in the "No Pitting" column and are represented by blank cells in Appendix B-10 The results are illustrated in Figure 6-13

Table 6-34 Percentage frequency of correlation classifications between pitot and facet size by spinal region

Spinal Region	Sex	Sample	No pitting	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)
Cervical	Male	SBC	0	21	57	21	0
		SBL	0	32	50	14	4
		AS	0	25	50	18	8
	Female	SBC	0	29	61	11	0
		SBL	4	39	39	18	0
		AS	0	21	21	18	43
Thoracic	Male	SBC	0	23	44	31	2
		SBL	0	54	38	0	2
		AS	0	21	52	0	6
	Female	SBC	0	35	44	18	2
		SBL	15	19	46	0	2
		AS	0	38	38	0	10
Lumbar	Male	SBC	0	20	70	5	5
		SBL	0	50	25	20	0
		AS	0	35	25	35	5
	Female	SBC	0	60	30	10	0
		SBL	5	10	30	35	20
		AS	0	20	40	25	15

For St Bride's Crypt, all facet levels have a degree of pitting. The association between pitot and facet size is non-existent or weak in the majority of the facets with some medium strength

associations occurring in all spinal regions. Strong correlations between pitting and facet size were seen in the left inferior facet of T3 and the left superior facet of T2 in males.

For St Bride's Lower, males have pitting in all regions of the spine whereas females have low numbers of facets without pitting in the cervical (4%) and lumbar regions (5%) and a higher number of facets (15%) without pitting in the thoracic region. It can be seen that the association between pitot and facet size is non-existent or weak in the majority of the facets with most medium strength associations occurring in the cervical and lumbar regions for males and females. Strong correlation between pitot and facet size was seen at the right superior facets of C6 and T9 in males and the left inferior facet of T4 in the female spine.

For the Anglo-Saxon sample, all facet levels had a degree of pitting. It can be seen that the association between pitot and facet size is non-existent or weak in the majority of facets with most medium strength associations occurring in the cervical and lumbar regions for males and females. Strong correlations between pitot and facet size were seen in the right inferior facet of C4, the right superior facet of C5 and T2, the left inferior facet of T7 and T8 and the left superior facet of L3 in male spines and the right and left inferior facets of C1, the left and right superior and inferior facets of C2, the right superior facet of C3, the left and right superior facets of C4, the right superior, left and right superior facets of C5, the left superior facet of C6, the right inferior facet of T7, the left inferior facet of T12, the right inferior facet of L1, the left inferior facet of L4 and L5 in the female spine.

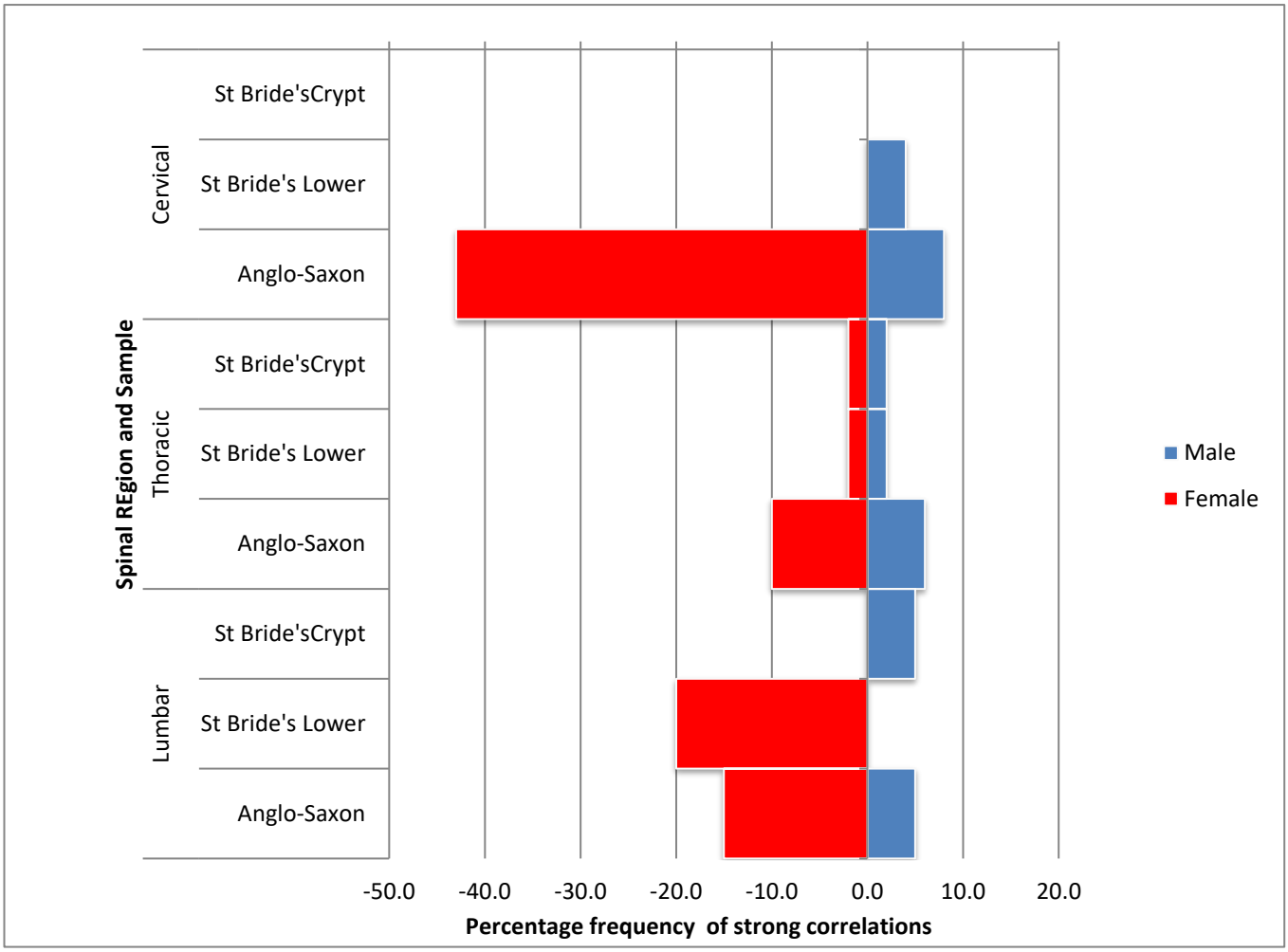


Figure 6-13 Percentage frequency of strong correlations between pitot (total pitting score) and facet size

The results indicate that the highest scores for strong correlation classification between pitot and facet size can be seen in the female Anglo-Saxon sample for all spinal regions and in the lumbar region for St Bride's Lower females. These results combined with the low levels of correlation seen in the males indicate that the relationship between pitot and facet size is sample and sex specific.

6.3.9.6 Correlation between osteophyte score and facet size

The method and statistical analysis for correlation between osteophyte score and facet size are the same as used for eburnation (see section 6.3.9.4), creating the new variable ostot. The full results are presented in Appendix B-11 and summarised below in Table 6-35 and Table 6-36.

Table 6-35 Percentage frequency of correlation classifications between ostot (total osteophyte score) and facet size

Sex	Sample	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)	Negative Correlation	P<0.001
Male	SBC	28	46	11	4	55	0
	SBL	22	46	7	0	50	0
	AS	22	29	10	5	44	0
Female	SBC	41	48	7	1	41	0
	SBL	31	38	10	4	36	0
	AS	21	34	11	8	42	0

Negative correlation was noted in 55% of male and 41% of female facets from St Bride's Crypt, 50% of males and 36% of female facets from St Bride's Lower and 44% of male and 42% of female facets from the Anglo-Saxon sample. This indicates that in these facets increased ostot was correlated with smaller facet size. Although no correlations showed a statistical significance, strong correlations were noted in all regions of the spine in males and the cervical region for females from St Bride's Crypt, female thoracic and lumbar regions for St Bride's Lower and all three regions for males and females from the Anglo-Saxon samples.

Table 6-36 summarises the percentage frequency of correlations by spinal region. The number of facets without osteophytes is identified in the "No Osteophytes" column, and represented by blank cells in Appendix B-11 Figure 6-14 illustrates the results presented in Table 6-36.

For St Bride's Crypt, there are a number of facet levels without osteophytes in the male cervical (14%) and thoracic (13%) regions and female cervical (11%) region. It can be seen that the association between ostot and facet size is non-existent or weak in the majority of the facets with some medium strength associations occurring in all spinal regions with the exception of the male lumbar spine. Strong correlation between ostot and facet size was seen in the left inferior facet of C5, the left superior facet of T5, the right superior facet of T12, and the right superior facet of L4 in males and the right superior facet of C4 in females.

Table 6-36 Summary of count of correlation classification between ostot (total osteophyte score) and facet size by spinal region

Spinal Region	Sex	Sample	No Osteophytes	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)
Cervical	Male	SBC	14	25	50	7	4
		SBL	7	11	57	25	0
		AS	36	4	36	21	4
	Female	SBC	11	36	46	4	4
		SBL	21	39	32	11	0
		AS	36	11	25	25	7
Thoracic	Male	SBC	13	31	33	19	4
		SBL	17	23	52	0	0
		AS	25	27	23	0	6
	Female	SBC	0	38	54	8	0
		SBL	8	25	46	0	6
		AS	2	19	40	0	10
Lumbar	Male	SBC	0	25	70	0	5
		SBL	0	35	65	0	0
		AS	5	35	35	20	5
	Female	SBC	0	55	35	10	0
		SBL	0	35	25	35	5
		AS	0	40	35	20	5

For St Bride's Lower, females have more facets without osteophytes in the cervical region (males 7%, females 21%). This pattern is reversed in the thoracic region (males 17%, females 8%) and no facets are without osteophytes in the male and female lumbar regions. It can be seen that the association between ostot and facet size is non-existent or weak in the majority of the facets with medium strength associations occurring in the cervical region for males and the cervical and lumbar regions for females. Strong correlation between ostot and facet size was seen at the left superior facet of T2, the left and right inferior facets of T4 and the left inferior facet of L4 in females.

For the Anglo-Saxon sample, 36% of facets do not have osteophytes in the cervical region for males both males and females. In the thoracic region it is mainly male facets that do not have osteophytes (males 25%, females 2%) and in the lumbar region only 1 male facet (5%) does not have osteophytes. It can be seen that the association between ostot and facet size is non-existent

or weak in the majority of the facets with most medium strength associations occurring in the cervical and lumbar regions for males and females. Strong correlation between ostot and facet size was seen in the left superior facet of C2 and C4, the left and right superior facets of T8 and the right inferior facet of L1 in males and the right superior facet of C3, the left inferior facets of C7 and T1, the left superior facet of T8, the right superior facet of T10, the right superior and left inferior facets of T11 and the left inferior facet of L4 in females.

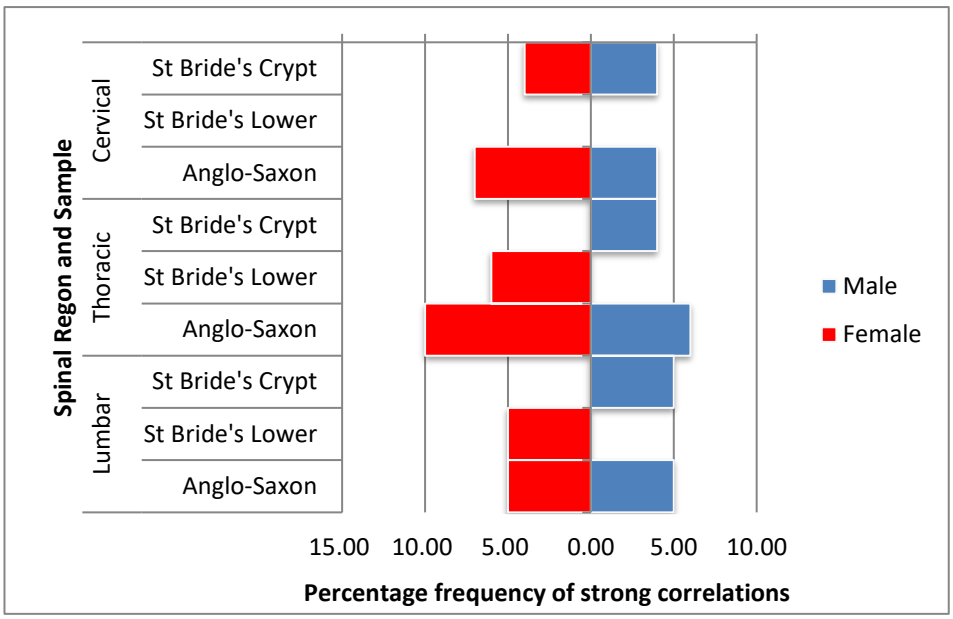


Figure 6-14 Percentage frequency of strong correlation classifications between ostot (total osteophyte score) and facet size

Overall, the count of strong correlations is low, although the highest score was once again seen in the Anglo-Saxon sample (thoracic region). This indicates that there is a poor relationship between ostot and size.

6.3.9.7 Correlation between vertebral osteophytosis score and facet size

The presence of vertebral osteophytosis was scored as described in 5.7.6.4. The score for the superior and inferior margins of the vertebral body were added together, creating the new variable, cvostot. The statistical analysis details can be seen in Section 6.3.9.4. C1 does not have a vertebral body and is therefore excluded from this analysis.

The full results are presented in Appendix B-12 and summarised below in Table 6-37and Table 6-38.

Table 6-37 Count of correlation classification between cvostot (total score for vertebral osteophytosis) and facet size

Sex	Sample	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)	Negative Correlation	P<0.001
Male	SBC	20	51	19	6	28	0
	SBL	51	36	7	1	35	0
	AS	20	40	13	14	38	0
Female	SBC	45	39	11	1	38	0
	SBL	32	40	14	4	45	0
	AS	11	27	11	17	31	0

Negative correlation was noted in 28% of male and 38% of female facets from St Bride's Crypt, 35% of males and 45% of female facets from St Bride's Lower and 38% of male and 31% of female facets from the Anglo-Saxon sample. This indicates that in these facets, increased cvostot was correlated with smaller facet size. Although no correlations showed a statistical significance, strong correlations were noted in the cervical region in males and the cervical region for females from St Bride's Crypt, the cervical region in males and all three regions in females from St Bride's Lower and all three regions for males and thoracic and lumbar regions in females from the Anglo-Saxon samples. There were no intact female cervical vertebral bodies from the Anglo-Saxon population under study and therefore no conclusions could be drawn about this region.

Table 6-38 summarises the results of the correlation analysis by spinal region. Vertebral bodies that were missing are listed in the "No Vertebral Body" column. This limited the number of analyses that could be performed and is represented by blank cells in Appendix B-12. The shaded area in the appendix table represents the lack of vertebral bodies for C1. No correlation could be drawn for this vertebral level of the spine. Figure 6-15 illustrates the results presented in Table 6-38.

For St Bride's Crypt, it can be seen that the association between cvostot and facet size is non-existent or weak in the majority of the facets with some medium strength associations occurring in all spinal regions for both sexes. Strong correlation between cvostot and facet size was seen in the left inferior facet of C6, the left inferior facet of T2, the right inferior facet of T3, the left inferior facet of T7, the right and left inferior facets of L4 in males and the right superior facet of T5 in females.

Table 6-38 Percentage frequency of correlations between cvostot and facet size by spinal region

Spinal Region	Sex	Sample	No Vertebral bodies	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)
Cervical	Male	SBC	0	25	57	4	4
		SBL	0	54	25	4	4
		AS	4	11	14	11	25
	Female	SBC	0	29	46	14	0
		SBL	0	32	50	4	4
		AS	21				
Thoracic	Male	SBC	0	15	54	48	6
		SBL	0	42	50	8	0
		AS	0	31	56	13	2
	Female	SBC	0	50	35	13	2
		SBL	0	35	38	23	2
		AS	2	19	38	17	21
Lumbar	Male	SBC	0	25	35	25	10
		SBL	0	70	20	5	0
		AS	0	10	45	15	25
	Female	SBC	0	55	35	5	0
		SBL	5	25	35	5	10
		AS	0	10	40	15	30

For St Bride's Lower, it can be seen that the association between cvostot and facet size is non-existent or weak in the majority of the facets with medium strength associations occurring in all spinal regions for both sexes. Strong correlation between cvostot and facet size was seen at the right inferior facet of C5 in males and the left superior facet of C5, the right superior facet of T12 and the left and right inferior facets of L5 in females.

For the Anglo-Saxon sample, no female cervical vertebral bodies were sufficiently preserved for data collection. It can be seen that the association between cvostot and facet size is none-existent or weak in the majority of the facets with most medium strength associations occurring in all observable spinal regions for males and females. Strong correlation between cvostot and facet size was seen in the right superior and right inferior facets of C5, all facets of C6, the left superior facet of C7, the left superior facet of T5, the left inferior facet of L2 and L3, the right superior and left inferior facet of L4, the right inferior facet of L5 in males and the right and left inferior facets of T4, the left inferior facet of T6, the left superior and left inferior facets of T7, the left and right

inferior facets of T9, the left and right superior facets of L4 and the right superior and right inferior facets of L5 in females.

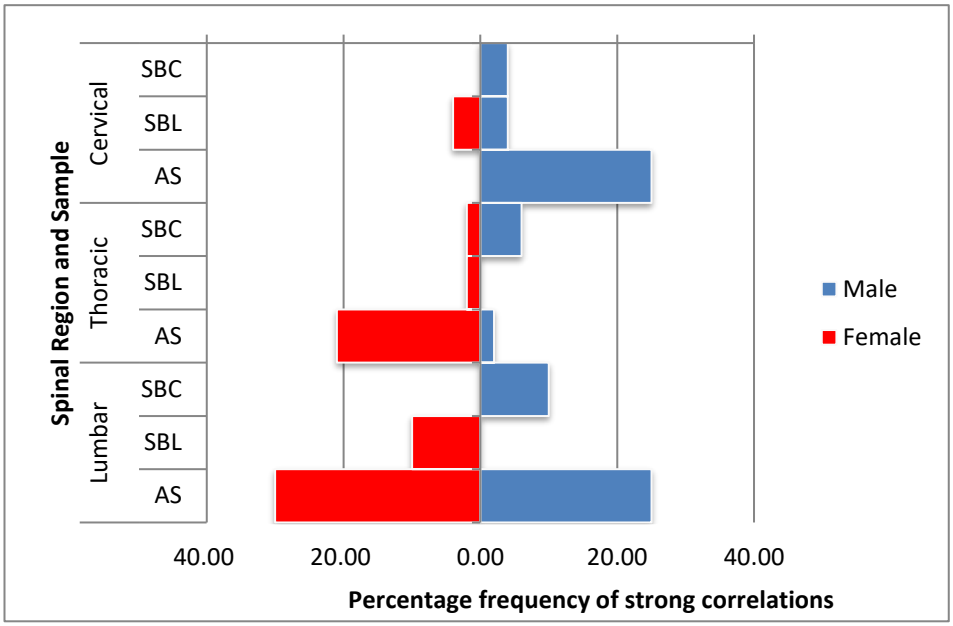


Figure 6-15 Percentage frequency of strong correlations between CVOS (total vertebral body osteophytosis score) and facet size

The highest percentage frequency is seen in the thoracic region of Anglo-Saxon females and the cervical region of Anglo-Saxon males. The limited preservation of the Anglo-Saxon female cervical vertebral bodies limits the conclusions that can be drawn from this analysis.

6.4 Facet Angle

This section presents the results generated by analysis of sexual dimorphism of and the relationship between facet angle with age, femoral robusticity, humeral directional asymmetry, facet eburnation, pitting, osteophyte scores and vertebral body osteophytosis.

6.4.1 Facet angle metric analysis

The number of facets analysed for each sample is summarised in Table 6-11. Descriptive statistics for facet angle for each sample using age combined, sex-divided groups are reported in Appendix C-1. As with facet size, a number of outlying values were observed (see Table 6-39). Non-parametric statistical methods were used to reduce the effect of the outlying data (see 6.3.1)

Table 6-39 Percentage of data outliers by spinal region and sample

Spinal region	Facet angle		
	St Bride's Crypt	St Bride's Lower	Anglo-Saxon
Cervical	2	3	2
Thoracic	3	3	2
Lumbar	2	3	2

The maximum and minimum standard deviation values and the facet levels they occurred at are summarised in Table 6-40. The range represents the natural variation in angle that can be seen at the same facet levels from different individuals.

Table 6-40 Maximum and minimum standard deviation values for facet angle

	St Bride's Crypt		St Bride's Lower		Anglo-Saxon	
	Male	Female	Male	Female	Male	Female
Minimum Standard Deviation	3.02 LtST6	2.98 LtST6	2.67 RST4	2.28 LtSC1	3.4 RST9	3.82 LtST4
Maximum Standard Deviation	30.76 RIT11	29.37 LtST12	27.57 LtST12	24.19 LtIT12	33.94 LtIT2	37.11 RIT2

Key: C=cervical, T=thoracic, L=lumbar, R=right, Lt=left, S=superior, I=inferior

6.4.2 Sexual dimorphism index for facet angle

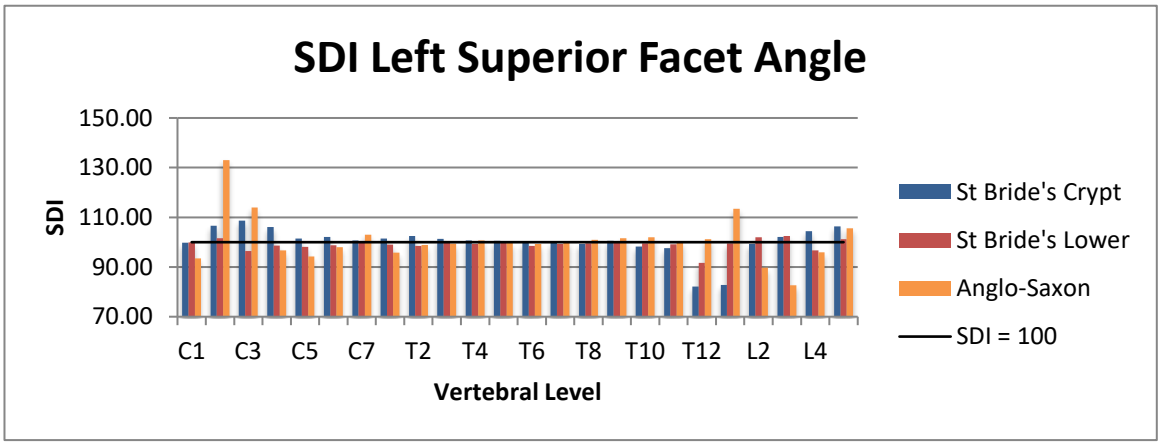
A sexual dimorphism index (SDI) was used to ascertain the degree of sexual dimorphism in size in facet angle measurements. As in Section 6.2.2, differentiation between the sexes was considered to have occurred at an index value of 110 or above or 90 and below. Values between these figures do not differentiate between the sexes with any certainty.

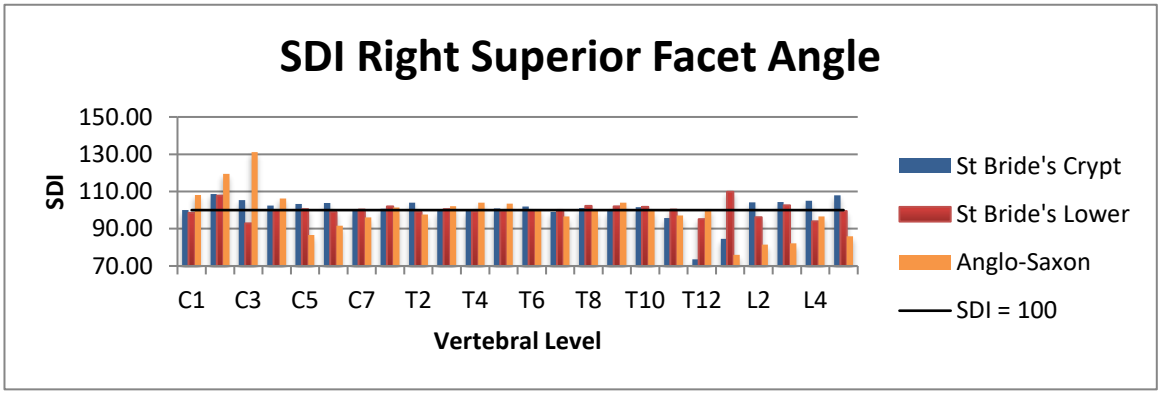
Table 6-41 summarises the results of SDI analysis presented in Appendix C-1. The SDI results show that the SDI is unable to clearly differentiate between sexes in 85% of cases for St Bride's Crypt, 76% for St Bride's Lower and 73% for the Anglo-Saxon sample. This indicates that there is a low level of sexual dimorphism in facet angle for the St Bride's samples and less so for the Anglo-Saxons. The SDI showed greatest degree of difference in the lumbar region in the St Bride's Crypt and Anglo-Saxon samples.

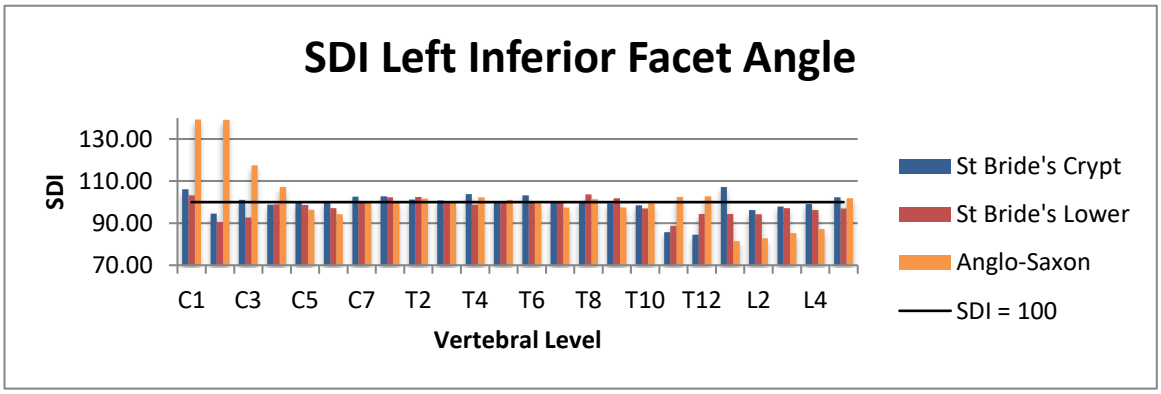
Figure 6-16 overleaf illustrates the comparison in SDI values for facet angle across the three samples by facet level.

Table 6-41 Count of Sexual Dimorphism Index (SDI) results by sample

Sample	Spinal Region	SDI>110	SDI<90	Unclassified
St Bride's Crypt	Cervical	1	0	27
	Thoracic	0	5	43
	Lumbar	0	8	12
St Bride's Lower	Cervical	0	1	27
	Thoracic	0	1	47
	Lumbar	0	1	19
Anglo-Saxon	Cervical	10	1	17
	Thoracic	2	0	46
	Lumbar	1	12	7







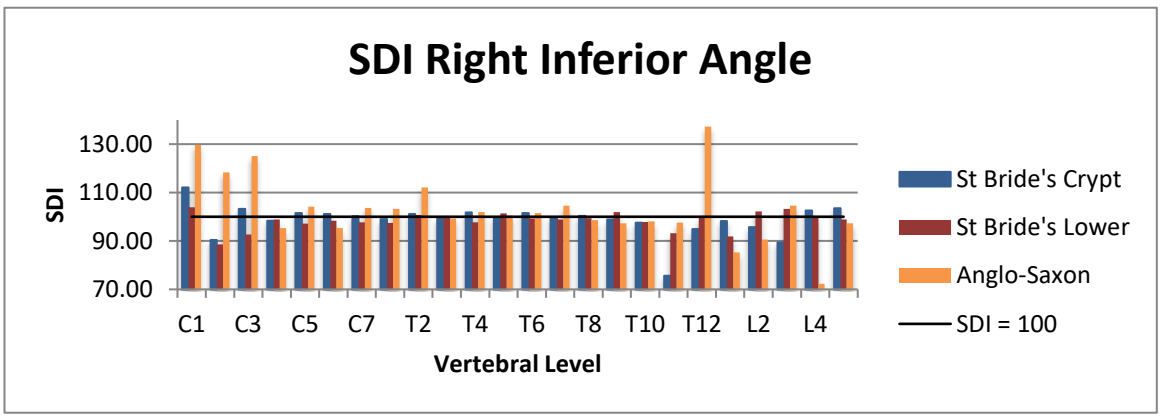


Figure 6-16 Sexual dimorphism index scores for facet angle

6.4.3 Statistical analysis of the relationship between sex and facet angle

There is a less obvious pattern of sexual dimorphism in facet angle when compared to facet size. Mann-Whitney U with Bonferroni correction ($\alpha = 0.0005$) was used to determine the statistical significance of differences in facet angle between males and females. The full results for these analyses can be seen Appendix C-2. The significant results are summarised by region in Table 6-42 and illustrated in Figure 6-17.

Table 6-42 Percentage frequency of statistically significant results, facet angle with sex

Spinal Region	Population	Percentage significant at $p<0.0005$	Percentage significant at $p<0.05$
Cervical	SBC	0	7
	SBL	0	11
	AS	0	40
Thoracic	SBC	2	2
	SBL	0	4
	AS	0	4
Lumbar	SBC	0	5
	SBL	0	0
	AS	5	0

The Bonferroni correction reduced the significant p value to $p<0.0005$ meaning few statistically significant differences in facet angle between the sexes were identified; 1 for St Bride's Crypt in the thoracic region and 1 for Anglo-Saxon in the lumbar region representing 2% and 5% of facets respectively.

The null hypothesis tested in this section (See Chapter 1) is that there will be no measurable difference in sexual dimorphism in facet joint sagittal orientation. This null hypothesis cannot be rejected for all three samples for most facet levels with degree of orientation being statistically insignificant between males and females.

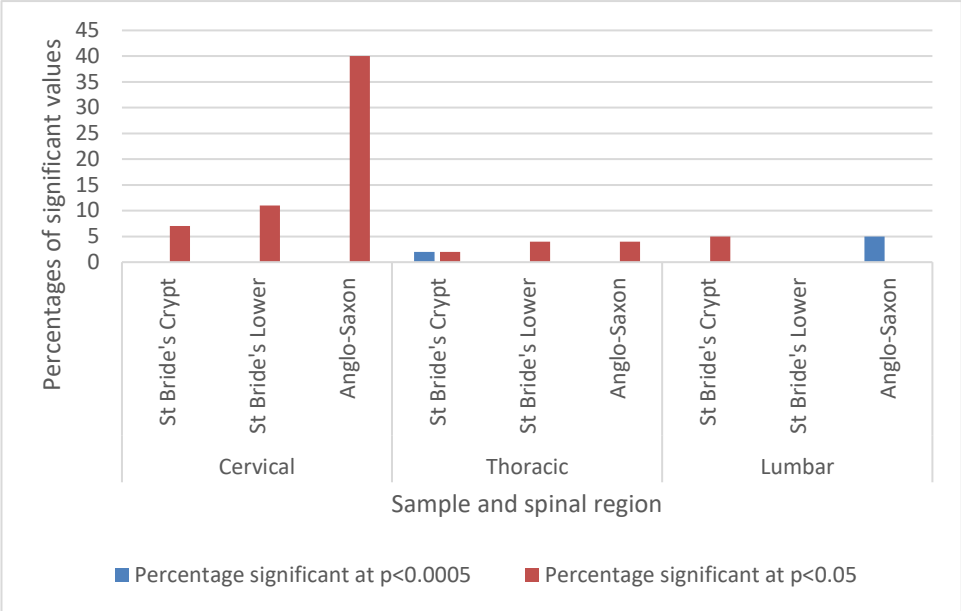


Figure 6-17 Percentage frequency of significant differences in facet angle with sex by sample and spinal region

6.4.4 Stepwise discriminant function analysis for facet angle

The derivation of stepwise discriminant function in this study depends on clear classification into male or female categories. Facet angle does not show statistical significance in angle differences, however the SDI showed greater variation for the Anglo-Saxon sample. Therefore, stepwise discriminant function analysis was performed as described in 5.8.2.1. (The rationale for using this process is explained in section 6.3.4). The results of this analysis can be seen in Table 6-43. The equations relate to each vertebral level and are derived from the values of all four facets angles for that vertebral level. This creates more equations than would be achieved if each facet was considered individually. The p value result is from the Wilk's Lambda test for goodness of fit for the model and tests for significant differences between the male and female groups. In this analysis, the p value was set at 0.0006 (with Bonferroni correction). Results for each sample are included in the table. This analysis generated discriminant functions to identify the sex of an individual based on the angle of the facets at each vertebral level. In the event of little of no difference in facet angle between the sexes, no variables qualified for inclusion in the equation.

The total percentage accuracy of correct assignment listed in this table will be used to compare accuracy against the use of extrinsic variables in deriving discriminant function equations in Section 6.4.

Table 6-43 Stepwise discriminant function analysis of facet angle

Vertebral Level	Sample	p	F(n)	Zm	Zf	Nm	Nf	Z0	% Accuracy		
									M	F	Total
C1	SBC	0.017	F=(-5.84)+(0.17)C1RI	0.39	-0.29	7	29	0.05	30	70	66
	SBL		No qualifying variables								
	AS	0.038	F=(-3.47)+(0.01)C1LtI	0.36	-0.63	13	5	-0.13	93	56	78
C2	SBC		No qualifying variables								
	SBL	0.024	F=(-5.53)+(0.1)C2RI	-0.29	0.403	26	10	0.06	90	50	74
	AS	0.013	F=(-4.59)+(0.07)C2LtI	0.51	-0.76	9	6	-0.13	75	67	71
C3	SBC		No qualifying variables								
	SBL	0.005	F=(-9.56)+(0.12)C3LtI	-0.37	0.5	21	11	0.07	78	52	67
	AS	0.001	F=(-8.29)+(0.09)C3LtI	0.65	-1.01	12	7	-0.18	86	78	83
C4	SBC		No qualifying variables								
	SBL		No qualifying variables								
	AS		No qualifying variables								
C5	SBC		No qualifying variables								
	SBL		No qualifying variables								
	AS	0.037	F=(-7.64)+(0.08)C5RS	-0.456	0.557	9	6	0.051	82	67	75
C6	SBC		No qualifying variables								
	SBL	0.052	F=(-20.44)+(0.23)C6LtI	-0.25	0.31	23	11	0.03	74	48	63
	AS		No qualifying variables								
C7	SBC		No qualifying variables								
	SBL		No qualifying variables								
	AS		No qualifying variables								

Key to Table 6-43: SBC = St Bride's Crypt, SBL = St Bride's Lower, AS = Anglo-Saxon, C = cervical, T = thoracic, L = lumbar, 1,2,3 etc. refers to the vertebral level L = left, R = right, S = superior, I = inferior Zm = male group centroid, Zf = female group centroid, Nm = number of males identified, Nf= number of females identified, Z_0= demarcation point.

Table 6—43 Stepwise discriminant function analysis of facet angle continued

Vertebral Level	Sample	p	F(n)	Zm	Zf	Nm	Nf	Z0	% Accuracy		
									M	F	Total
T1	SBC		No qualifying variables								
	SBL		No qualifying variables								
	AS		No qualifying variables								
T2	SBC	0.001	F=(-22.54)+(0.22)T2RS	0.52	-0.36	14	31	0.08	54	82	70
	SBL		No qualifying variables								
	AS		No qualifying variables								
T3	SBC		No qualifying variables								
	SBL		No qualifying variables								
	AS		No qualifying variables								
T4	SBC		No qualifying variables								
	SBL		No qualifying variables								
	AS	0.025	F=(-22.95)+(0.21)T4RS	0.4	-0.55	12	6	-0.07	80	50	67
T5	SBC		No qualifying variables								
	SBL		No qualifying variables								
	AS		No qualifying variables								
T6	SBC		No qualifying variables								
	SBL		No qualifying variables								
	AS		No qualifying variables								

Table 6-43 Stepwise discriminant function analysis of facet angle continued

Vertebral Level	Sample	p	F(n)	Zm	Zf	Nm	Nf	Z0	% Accuracy		
									M	F	Total
T7	SBC		No qualifying variables								
	SBL		No qualifying variables								
	AS		No qualifying variables								
T8	SBC		No qualifying variables								
	SBL	0.016	F=(-20.85)+(0.22)T8LtI	0.27	0.47	27	6	0.37	85	33	66
	AS		No qualifying variables								
T9	SBC		No qualifying variables								
	SBL		No qualifying variables								
	AS	0.053	F=(-22.29)+(0.21)T9RS	0.4	-0.48	10	9	-0.04	77	82	79
T10	SBC		No qualifying variables								
	SBL		No qualifying variables								
	AS		No qualifying variables								
T11	SBC	0.015	F=(-2.37)+(0.04)T11RI	-0.39	0.25	12	29	-0.07	48	74	64
	SBL		No qualifying variables								
	AS		No qualifying variables								
T12	SBC	0.015	F=(-2.24)+(0.03)T12RS	-0.4	0.26	15	26	-0.07	63	72	68
	SBL		No qualifying variables								
	AS		No qualifying variables								

Table 6-43 Stepwise discriminant function analysis of facet angle continued

Vertebral Level	Sample	p	F(n)	Zm	Zf	Nm	Nf	Z0	% Accuracy		
									M	F	Total
L1	SBC	0.002	F=(0.51)+(-0.16)L1LtI+(0.12)L1RS	-0.56	0.4	12	30	-0.08	48	83	69
	SBL		No qualifying variables								
	AS		No qualifying variables								
L2	SBC		No qualifying variables								
	SBL		No qualifying variables								
	AS		No qualifying variables								
L3	SBC		No qualifying variables								
	SBL		No qualifying variables								
	AS	0.034	F=(-3.32)+(0.11)L3RS	-0.41	0.48	13	9	0.03	81	64	73
L4	SBC		No qualifying variables								
	SBL		No qualifying variables								
	AS	0.002	F=(-4.29)+(0.91)Lt4RI	-0.56	0.84	12	8	0.14	80	80	80
L5	SBC		No qualifying variables								
	SBL		No qualifying variables								
	AS		No qualifying variables								

6.4.5 Relationship between age and facet angle.

This section presents the results of analysis of the relationship between facet angle and age. Samples were divided into age groups are described in Section 5.7.3. Kruskal Wallace one-way between–groups analysis of variance with Bonferroni correction ($p<0.0005$) was used to identify any significant differences in facet angle across the three age groups. Males and females were analysed separately to reduce the effect of sexual dimorphism. The full results can be seen in Appendix C-3.

Table 6-44 summarises the results of the Kruskal Wallace analysis of differences in facet angle with age. With the p value set at 0.0005 (with Bonferroni correction), there was no statistically significant difference in facet angle between age groups for either males or females for all three samples. When the results from $p<0.05$ are considered, in the St Bride's Crypt population, 4% of male cervical, 5% of male lumbar, 7% of female cervical and 5% of female lumbar vertebrae

showed change in facet size with age; for St Bride's lower, 2% of male thoracic, 4% of female cervical and thoracic vertebrae, 20% of lumbar and in the Anglo-Saxon population, 5% of male lumbar and 4% for female cervical vertebrae showed change in size with age.

Table 6-44 Percentage frequency of statistically significant results for facet angle with age group

Spinal Region	Population	Significant at p<0.0005		Significant at p<0.05	
		Male	Female	Male	Female
Cervical	SBC	0	0	4	7
	SBL	0	0	0	4
	AS	0	0	0	4
Thoracic	SBC	0	0	0	0
	SBL	0	0	2	4
	AS	0	0	0	0
Lumbar	SBC	0	0	5	5
	SBL	0	0	0	20
	AS	0	0	5	0

The results show that age at death is not a significant variable in relation to facet angle. The null hypothesis tested in this section was that there would be no difference in facet angle with age group. This null hypothesis cannot be rejected. The results presented suggest that increasing age does not cause a change in sagittal orientation of the facet joints of the spine.

6.4.6 Age groups v actual age

Section 6.3.6 describes the opportunity to test the outcomes of analysing facet size with age group and actual age at death when a sample is from a documented population. This process was repeated for facet angle.

In Section 6.4.5, the relationship between facet angle and age at death using age groups for the St Bride's Crypt population was explored using a Kruskal-Wallis one way between groups analysis of variance with Bonferroni adjustment (p=0.0005). The results showed that there were no statistically significant relationship between facet angle and age group for both males and females. (See Table 6-44).

Spearman's Rho correlational analysis with Bonferroni correction (p<0.0005) was used to test the interrelationship between facet angle and age at death of males and females (disaggregated data) from St Bride's Crypt. The results can be seen in Appendix C-4.

The results are presented in Table 6-45. Both males and females demonstrated facets with negative correlation for angle with age (68% for males and 51% for females). This implies that for certain vertebral levels, lower facets angle are associated with older age at death. Table 6-46 summarises the correlation results by spinal region. No strong correlations were observed and there were no statistically significant relationships between facet angle and age.

Table 6-45 Percentage frequency of correlation classification between facet angle and actual age at death, St Bride's Crypt

Sex	No Correlation	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)	Negative Correlation	P<0.0005
Male	28	53	19	0	68	0
Female	41	51	8	0	51	0

Table 6-46 Percentage frequency of correlation classification between facet angle and actual age at death by spinal region

Spinal Region	Sex	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)
Cervical	Male	14	72	14	0
	Female	29	54	18	0
Thoracic	Male	38	43	19	0
	Female	40	54	6	0
Lumbar	Male	25	50	25	0
	Female	60	40	0	0

The results of comparison between aggregated and disaggregated data for facet angle and age at death does not reveal any strong correlation results that would have been missed by using aggregated age groups.

For facet angle the null hypothesis that there is no loss of resolution of the archaeological record when broad age ranges are used to define age at death in a sample cannot be rejected.

6.4.7 Relationship between facet angle and sample and temporal patterning

As for facet size inter-sample comparison (see section 6.3.7), Kruskal-Wallace ($p<0.0005$ with Bonferroni adjustment) with Mann-Whitney U post hoc analysis was used to test the null hypothesis that there was no difference in facet angle means between samples.

Table 6-47 summarises the results for the Kruskal Wallis test. It highlights the number of facets showing significant difference in facet angle between the groups. The full table of results can be found in Appendix C-5. There are a 21 male and 12 female facets showing significant inter-sample differences after Bonferroni adjustment. When $p<0.05$, 57 male and 35 female facets show significant differences.

Table 6-47 Percentage frequency of significant results from Kruskal Wallis Test for inter-sample differences in facet angle

Spinal Region	Male		Female	
	p<0.0005	p<0.05	p<0.0005	p<0.05
Cervical	14	71	4	36
Thoracic	35	63	23	46
Lumbar	0	30	0	15

As with facet size, a post hoc Mann-Whitney U test was performed to differentiate between samples and the results are summarised in Table 6-48. The full table of results can be seen in Appendix C-6.

Significant inter-sample differences in facet angle were observed between all samples in all spinal regions (except lumbar region for St Bride's Crypt and Anglo-Saxon) for males and females when $p<0.0005$. The null hypothesis that there is no difference in inter-sample facet angle can be rejected.

Table 6-48 Percentage frequency of statistically significant differences in facet angle between sample groups by spinal region

Spinal Region	Inter-sample Comparison	P<0.0005		p<0.05	
		Number of facets		Number of facets	
		Male	Female	Male	Female
Cervical	St Bride's Crypt/St Bride's Lower	4	0	50	21
	St Bride's Crypt /Anglo-Saxon	4	4	43	21
	St Bride's Lower/Anglo-Saxon	21	4	39	25
Thoracic	St Bride's Crypt/St Bride's Lower	15	4	38	24
	St Bride's Crypt /Anglo-Saxon	13	13	46	35
	St Bride's Lower/Anglo-Saxon	35	23	56	48
Lumbar	St Bride's Crypt/St Bride's Lower	0	5	5	0
	St Bride's Crypt /Anglo-Saxon	0	0	35	10
	St Bride's Lower/Anglo-Saxon	5	0	50	10

6.4.8 Relationship between facet angle and predictor variables

This section presents the results of analyses of predictor variables identified in Section 5.7.7. Each variable was analysed separately. Strong correlations for each predictor variable are summarised in table and graph form in this section, whilst the complete tables of results can be found in the attached appendices.

6.4.8.1 Correlation between femoral robusticity and facet angle

The methods used to calculate femoral robusticity, the number of femora available for inclusion in the correlation analysis and the method of statistical analysis can be seen in 6.3.9.1. The percentage frequency of individual facets with each correlation classification are summarised in Table 6-49. The full table of results can be seen in Appendix C-7.

Table 6-49 presents the results of the correlation analysis with the numbers representing the percentage frequency of each facet with the same correlation attribute. Both males and females showed negative correlation. Negative correlation was distributed throughout the spinal regions and indicates that, as femoral robusticity increases facet angle decreases. The number of

vertebral levels with negative correlation is similar between males and females for all samples with little inter-sample variation

Table 6-49 Percentage frequency of correlation classifications between femoral robusticity and facet angle

Sex	Cemetery	No Correlation (r_s<0.01)		Weak Correlation (r_s=0.1-0.29)		Medium Correlation (r_s=0.3-0.49)		Strong Correlation (r_s=0.5-1.0)		Negative Correlation		P<0.0005	
		L	R	L	R	L	R	L	R	L	R	L	R
Male	SBC	39	27	47	48	24	19	10	6	41	44	0	0
	SBL	41	56	59	53	3	3	3	3	51	42	0	0
	AS	23	21	43	52	22	21	11	7	43	46	0	0
Female	SBC	18	26	54	49	21	22	6	2	55	55	0	0
	SBL	18	20	48	43	18	29	22	1	49	35	0	0
	AS	22	24	38	52	27	33	15	13	55	47	0	0

Table 6-50 Percentage frequency of correlation classifications between femoral robusticity and facet angle by spinal region

Spinal Region	Sex	Cemetery	No Correlation (r_s<0.01)		Weak Correlation (r_s=0.1-0.29)		Medium Correlation (r_s=0.3-0.49)		Strong Correlation (r_s=0.5-1.0)	
			L	R	L	R	L	R	L	R
Cervical	Male	SBC	18	21	43	27	25	28	14	4
		SBL	43	39	54	57	0	0	4	4
		AS	18	14	61	57	11	21	11	7
	Female	SBC	25	21	57	39	11	36	7	4
		SBL	29	29	36	39	18	29	18	4
		AS	14	11	29	39	21	25	36	25
Thoracic	Male	SBC	10	31	46	50	23	13	10	6
		SBL	42	48	60	29	6	2	4	4
		AS	25	23	42	52	23	21	10	6
	Female	SBC	19	27	52	52	27	19	2	2
		SBL	17	15	69	46	10	25	15	0
		AS	21	33	42	44	33	19	6	6
Lumbar	Male	SBC	15	25	55	45	25	20	1	10
		SBL	35	45	65	45	0	10	0	0
		AS	30	25	20	45	35	20	15	10
	Female	SBC	5	30	55	55	25	15	15	0
		SBL	5	20	15	40	35	40	45	0
		AS	35	20	40	40	20	30	5	10

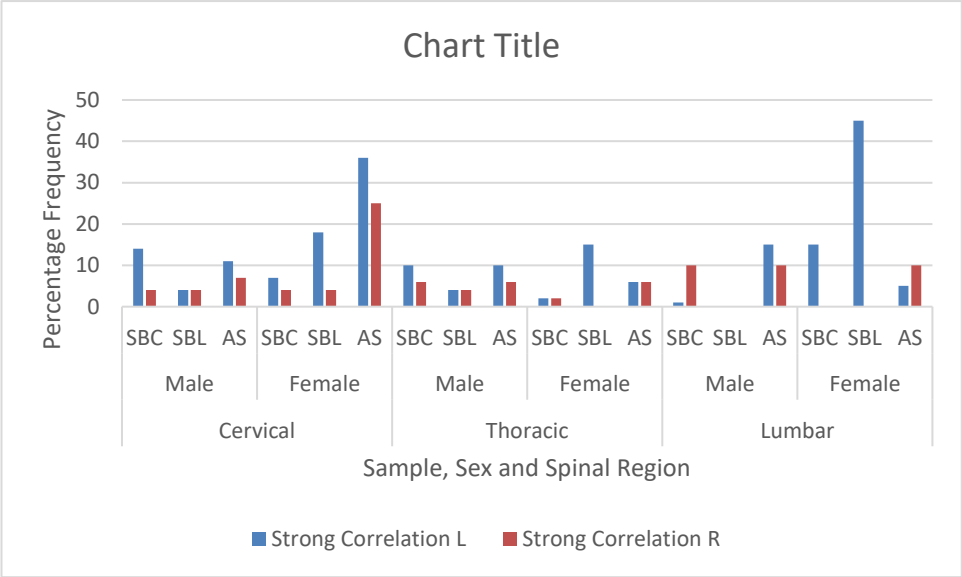


Figure 6-18 Percentage frequency of strong correlations between femoral robusticity and facet angle by spinal region

Table 6-50 summarises the results of the percentage frequency of individual facets with each correlation classification between femoral robusticity and facet angle by spinal region. In the St Bride's Crypt sample, a strong correlation was seen between facet angle and left femoral robusticity in the male right superior facet of C1, the left inferior facet of C4, the right superior and left inferior facet of C6, the left and right superior and right inferior facets of T7, the right inferior facet of T10, the right superior facet of T11 and the right inferior facet of L3 and between facet angle and right femoral robusticity in the left inferior facet of C7, the left superior facets of T9 and T10, the right inferior facet of T12, the right superior facet of L2 and the left inferior facet of L3. For females, a strong correlation between facet angle and left femoral robusticity was seen at the left and right superior facets of C4, the right superior facet of T12, the left and right inferior facets of L4 and the left superior facets of L5 and between facet angle and right femoral robusticity at the right superior facet of C4 and the right superior facet of T12.

For the St Bride's Lower sample, a strong correlation between facet angle and left femoral robusticity was seen in males at the right inferior facet of C3, T9 and T10, the left superior facet of T11, and between facet angle and right femoral robusticity at the right inferior facet of C3, T9 and T10. In the female spine, a strong correlation between facet angle and femoral robusticity was seen at the left and right superior and right inferior facets of C4, the right superior facet of C5, the right superior facet of C6, the left inferior facet of T1, the left and right inferior facets of T12, the left and right superior and right inferior facets of L1, the right superior and left and right inferior facets of L2, the right superior and right inferior facets of L3, the left superior facet of L5 and between facet angle and right femoral robusticity at the left superior facet of C5, the left and right inferior facets of T1, the right superior and left inferior facets of T2, T3 and T4, the right superior

facet of T5, the left superior facet of T7, the left superior facet of T9 and the left superior facet of T11.

For the Anglo-Saxon sample, a strong correlation between facet angle and left femoral robusticity in males was seen at the left superior and inferior facets of C2, the right inferior facet of C7, the left and right superior facets of T2, the left and right inferior facets of T6, the right inferior facet of T7, the right superior facet of L1, the left inferior facets of L4 and L5 and between facet angle and right femoral robusticity, the left superior and inferior facets of C2, the left and right superior facets of T2, the right inferior facet of T7, the left superior facet of L1 and the left inferior facet of L4. Anglo-Saxon females showed a higher number of strong correlations between facet angle and femoral robusticity than males. A strong correlation between facet angle and left femoral robusticity was seen at the right superior and inferior facets of C1, the left and right superior and left inferior facets of C2, the left and right inferior facets of C4, the left inferior facet of C5, the left inferior facets of C6 and C7, the right superior and inferior facets of T6, the right inferior facet of T12 and between facet angle and right femoral robusticity at the left and right inferior facets of C2, the left inferior facet of C3, the left and right inferior facets of C4, the left inferior facets of C5 and C7, the right inferior facet of T5, the left superior and right inferior facets of T12 and the right superior facets of L1 and L2.

As with the results for correlation between facet size and femoral robusticity, the loss of resolution when amalgamated data is used was also tested for facet angle. The results can be seen in Table 6-51. Again, there are superior and inferior facets from the same vertebra that do not have the same classification for strength of correlation and reporting them as pairs leads to loss of resolution of results. Therefore, it is appropriate to record the count of individual facets rather than amalgamated superior and inferior facets with strong correlation classification for this analysis.

Table 6-51 Percentage Frequency of superior and inferior facets with the same classification of correlation

Spinal Region	Sex	Cemetery	No Match		No Correlation (r_s<0.01)		Weak Correlation (r_s=0.1-0.29)		Medium Correlation (r_s=0.3-0.49)		Strong Correlation (r_s=0.5-1.0)	
			Lt	R	Lt	R	Lt	R	Lt	R	Lt	R
Cervical	Male	SBC	32	29	0	0	11	18	7	4	0	0
		SBL	36	36	7	4	7	11	0	0	0	0
		AS	25	25	0	0	21	21	0	0	4	4
	Female	SBC	29	32	0	0	21	11	0	7	0	0
		SBL	43	29	4	0	0	11	0	11	4	0
		AS	32	39	0	0	7	11	0	0	11	0
Thoracic	Male	SBC	33	31	4	8	8	6	2	4	2	0
		SBL	25	29	13	13	13	8	2	4	2	0
		AS	35	38	6	2	8	8	0	2	0	0
	Female	SBC	33	28	2	6	15	13	0	4	0	0
		SBL	28	38	2	4	17	4	2	2	2	2
		AS	35	40	0	2	6	4	8	4	0	0
Lumbar	Male	SBC	20	25	5	10	25	40	0	0	0	0
		SBL	40	5	0	5	10	20	0	0	0	0
		AS	30	25	0	5	15	20	5	0	0	0
	Female	SBC	30	25	0	0	20	20	0	5	0	5
		SBL	30	30	0	0	20	0	0	0	0	5
		AS	35	35	0	0	10	15	5	0	0	0

Table 6-52 reports the results for the percentage frequency of matching correlations between left facet and left leg relative with left facet and right leg and right facet and right leg with right facet and left leg as a measure of asymmetry. The numbers represent the percentage frequency of facets that have the same correlation classification for each comparison. The highest number of matching correlation strengths (45%) can be seen in St Bride's Lower males for right facet and right leg in agreement with right facet and left leg with the next highest (40%) also being for St Bride's Lower males for left facet and left leg in agreement with left facet and right leg.

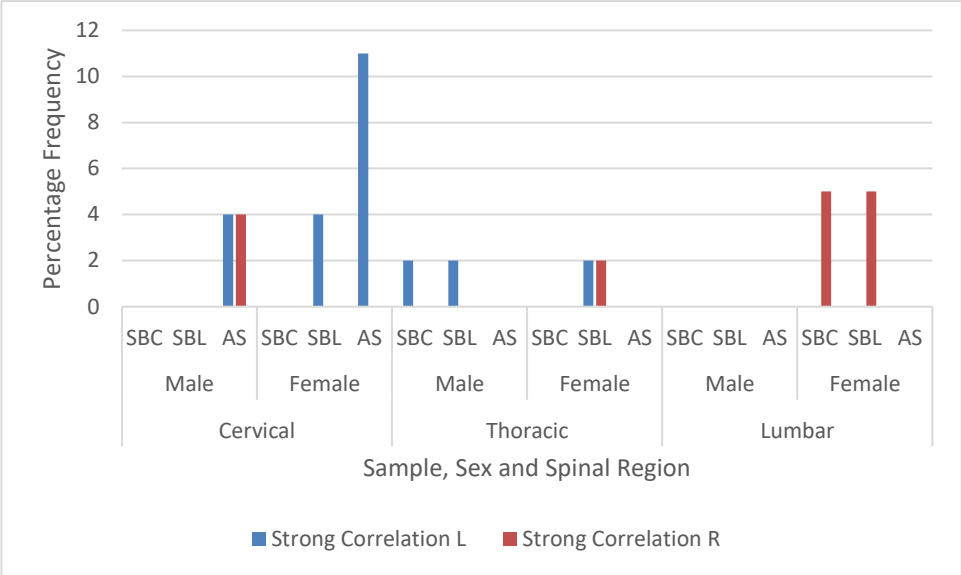


Figure 6-19 Percentage frequency of matching correlations between femoral robusticity and facet angle.

Table 6-52 Percentage frequency of ipsilateral and contralateral matching correlations femoral robusticity and facet angle

Spinal Region	St Bride's Crypt				St Bride's Lower				Anglo-Saxon			
	Male		Female		Male		Female		Male		Female	
	L	R	L	R	L	R	L	R	L	R	L	R
Cervical	21	19	18	17	37	32	21	11	18	18	32	36
Thoracic	19	21	23	25	38	40	10	15	27	31	21	29
Lumbar	5	10	20	20	25	45	10	5	15	20	25	25

6.4.8.2 Correlation between humeral and facet angle asymmetry

As in the previous section data analysis was hampered by poor preservation of humeri. The numbers of humeri by cemetery available for inclusion in this correlation study can be seen in Table 6-28. The directional asymmetry between right and left upper limb and right and left superior and inferior facet angle was calculated using the method described in section 5.7.7.2. The correlation between the two directional asymmetries was then analysed using a 2 x 2 table. Yates' continuity correction was used to compensate for over-estimation of the chi-squared value. The phi coefficient was used to measure the degree of association between the two directional asymmetries and classified according to Cohen's (1998) criteria as outlined in the introduction to this chapter ($p<0.001$ with Bonferroni adjustment). The full results are presented in Appendix C--8 and summarised in Table 6-53 and Table 6-54.

Table 6-53 Percentage frequency of correlation classification between humeral and facet angle directional asymmetry

Sex	Cemetery	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)	Negative Correlation	P<0.001
Male	SBC	9	23	10	5	15	0
	SBL	21	19	8	1	21	0
	AS	5	10	16	18	21	0
Female	SBC	17	30	3	0	21	0
	SBL	13	22	13	3	20	0
	AS	2	5	13	12	15	0

Table 6-53 presents the results of the correlation analysis. The numbers represent the percentage frequency of facets with each correlation classification (left and right facets were paired together to measure the degree of directional asymmetry). No correlations showed statistical significance but strong correlations between humeral and facet angle asymmetry were noted at the inferior angles C7 and T2, the superior angles of T9, T12 and L3 in males and no strong correlations noted in females from St Bride's Crypt; the superior angles of C2, T9 and L2 in females from St Bride's Lower and the superior angles of C1, C4, C5, C6, T5, T6, T11, T12, L2, L4 and L5 and the inferior angles of C2, C7, T8 and T11 in males and superior angles of T3, T4, T5, T6, T9, T12, L2 and L4 and the inferior angles of T2, T6, and L3 in females from the Anglo-Saxon sample.

Table 6-54 summarises the results of correlation analysis by spinal region. It can be seen that the association between humeral and facet angle directional asymmetry is non- existent or weak in the majority of vertebral levels for St Bride's Crypt, with most medium strength associations occurring in the thoracic spine with females having 7 thoracic facet levels (including superior and inferior levels) and males 5 thoracic levels at medium strength correlation. A strong correlation was seen on 5 vertebral levels for males and none in females. St Bride's Lower population showed less strong correlations (2 males and 3 female) and most medium strength associations occurred in the thoracic spine (overall 8 male and 12 female levels). The Anglo-Saxon sample showed much higher numbers of strong correlations between humeral and facet angle directional asymmetry; 11 male and 12 female, although correlations were not performed for the female cervical spine due to lack of measurable data. Figure 6-20 is a graphical representation of the data in Table 6-54. The graph clearly identifies that increased count of strong correlations seen in the Anglo-Saxon sample when compared the St Bride's Samples.

Table 6-54 Percentage frequency between humeral and facet angle directional asymmetry by spinal region

Spinal Region	Sex	Sample	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)
Cervical	Male	SBC	11	25	11	3
		SBL	18	25	11	3
		AS	0	7	18	25
	Female	SBC	14	32	3	0
		SBL	18	25	3	3
		AS	No data	No data	No data	No data
Thoracic	Male	SBC	10	19	10	6
		SBL	23	15	10	0
		AS	10	10	15	13
	Female	SBC	17	31	2	0
		SBL	10	10	19	2
		AS	4	6	17	17
Lumbar	Male	SBC	5	30	10	5
		SBL	20	30	0	0
		AS	0	15	15	20
	Female	SBC	20	25	5	0
		SBL	10	20	15	5
		AS	0	10	20	15

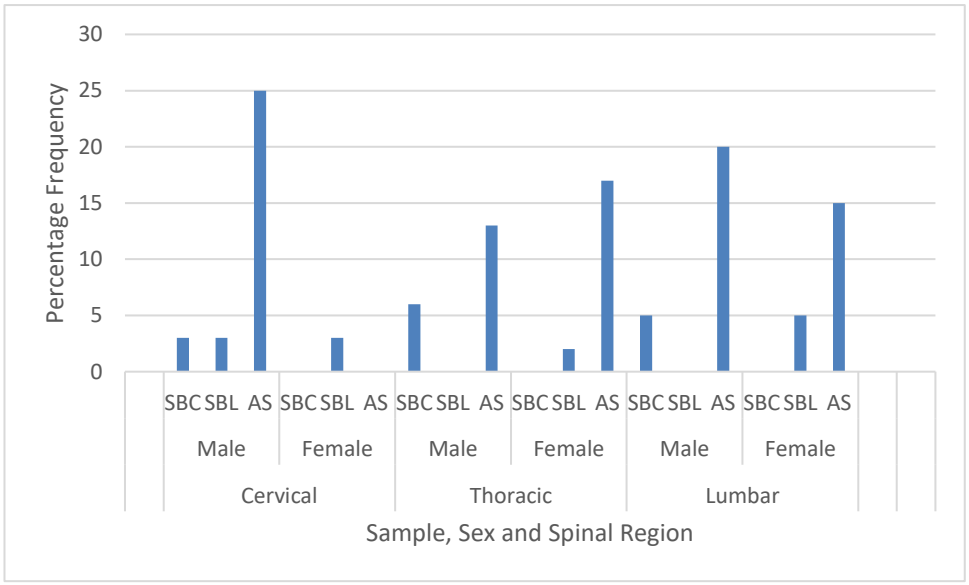


Figure 6-20 Percentage frequency of strong correlations between humeral and facet angle asymmetry

These results indicate that humeral directional and facet angle asymmetry show more strong correlations in the Anglo-Saxon sample (particularly in the cervical and thoracic region in males and thoracic and lumbar regions in females) than the St Bride's Samples and indicates the potential for humeral directional asymmetry to be a predictor variable in relation to Anglo-Saxon facet angle asymmetry.

6.4.8.3 Correlation between eburnation score and facet angle

The same method of scoring eburnation and statistical method were used as for eburnation and facet size (See Section 6.3.9.4). The full results are presented in Appendix C-9 and summarised below in Table 6-55 and Table 6-56.

Table 6-55 Percentage frequency of correlation classification between ebtot (total eburnation score)and facet angle

Sex	Sample	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)	Negative Correlation	P<0.001
Male	SBC	18	31	18	3	29	0
	SBL	25	33	7	0	24	0
	AS	21	40	15	14	42	0
Female	SBC	24	38	10	0	34	0
	SBL	19	21	13	1	28	0
	AS	13	30	12	15	48	0

Negative correlations were noted between facet angle and ebtot in 28 (29%) of male and 33 (34%) of female facets from St Bride's Crypt, 23 (24%) of males and 27 (28%) of female facets from St Bride's Lower and 40 (42%) of male and 46 (48%) of female facets from the Anglo-Saxon population. This indicates that in these facets increased ebtot was correlated with smaller facet angle. Although no correlations showed statistical significance, strong correlation was noted in the male cervical and lumbar spine from St Bride's Crypt, the female cervical spine from St Bride's Lower, and the male and female cervical and lumbar from the Anglo-Saxon sample. Table 6-56 summarises the results of the correlation analysis by spinal region. The count of facets without eburnation is identified in the "No Eburnation" column and is represented by blank cells in Appendix C-9. Figure 6-21 illustrates the results listed in Table 6-56. The results indicate that whilst the highest count of strong correlations can be seen in the cervical region for Anglo-Saxon males and females, the low levels and in some cases lack of correlation mean that there is a sample specific relationship between ebtot and facet angle.

Table 6-56 Percentage frequency of correlation classification between ebtot (total eburnation score) and facet angle by spinal region

Spinal Region	Sex	Sample	No Eburnation	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)
Cervical	Male	SBC	21	18	29	25	7
		SBL	3	25	46	25	0
		AS	0	14	39	29	18
	Female	SBC	21	14	57	7	0
		SBL	18	29	18	36	3
		AS	18	3	36	11	36
Thoracic	Male	SBC	44	21	27	10	0
		SBL	40	25	27	0	0
		AS	0	17	46	0	6
	Female	SBC	8	38	38	17	0
		SBL	35	19	21	0	0
		AS	0	17	46	0	6
Lumbar	Male	SBC	20	5	45	25	5
		SBL	45	25	30	0	0
		AS	0	25	40	30	5
	Female	SBC	75	10	15	0	0
		SBL	60	5	25	10	0
		AS	0	20	30	40	10

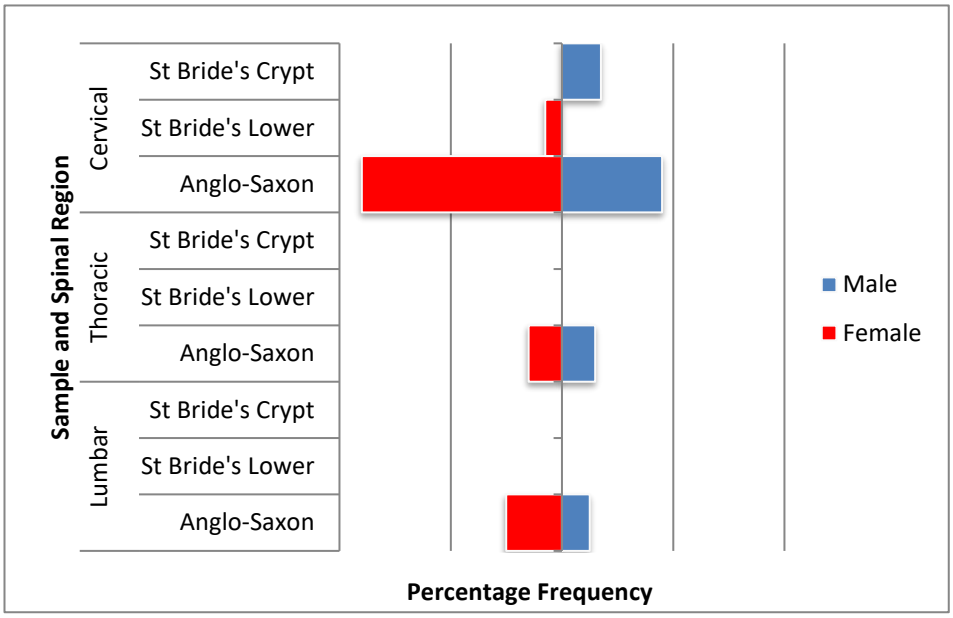


Figure 6-21 Percentage frequency of strong correlations between ebtot (total eburnation score) and facet angle

6.4.8.4 Correlation between pitting score and facet angle

The method and statistical analysis for correlation between pitting score and facet angle are the same as used for eburnation (see section 6.3.9.4), generating the new variable pitot. The full results are presented in Appendix C-10 and summarised below in Table 6-57 and Table 6-58.

Table 6-57 Percentage frequency of correlation classification between pitot (total pitting score) and facet angle

Sex	Sample	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)	Negative Correlation	P<0.001
Male	SBC	38	34	25	3	46	0
	SBL	26	49	11	3	36	0
	AS	29	39	14	9	45	0
Female	SBC	35	52	11	1	53	0
	SBL	16	40	17	6	45	0
	AS	19	31	17	22	55	0

Negative correlations were noted between facet angle and extent of pitting in 44 (46%) of male and 51 (53%) of female facets from St Bride's Crypt, 35 (36%) of males and 43 (45%) of female facets from St Bride's Lower and 43 (45%) of male and 53 (55%) of female facets from the Anglo-Saxon sample. This indicates that in these facets increasing pitot was correlated with smaller facet

angle. Although no correlations showed a statistical significance, strong correlations were noted in the male cervical and thoracic and female thoracic spine from St Bride's Crypt, the male thoracic spine and all regions in the female spine from St Bride's Lower, and all regions in the male and female spine from the Anglo-Saxon sample.

Table 6-58 summarises the results of the correlation analysis by spinal region. The number of facets without pitting is identified in the "No Pitting" column and represented by blank cells in Appendix C-10. Figure 6-22 illustrates the results presented in Table 6-58.

Table 6-58 Percentage frequency of correlation classifications between pitot (total pitting score) and facet angle by spinal region

Spinal Region	Sex	Sample	No Pitting	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)
Cervical	Male	SBC	0	32	29	29	11
		SBL	0	14	61	25	0
		AS	0	39	39	21	3
	Female	SBC	0	32	57	11	0
		SBL	3	7	54	29	7
		AS	0	0	14	36	46
Thoracic	Male	SBC	0	57	71	39	3
		SBL	0	23	52	0	4
		AS	0	29	40	0	13
	Female	SBC	0	35	56	6	2
		SBL	15	21	35	0	2
		AS	2	21	44	0	6
Lumbar	Male	SBC	0	55	15	25	0
		SBL	5	50	25	20	0
		AS	0	30	25	30	15
	Female	SBC	0	40	35	35	0
		SBL	5	5	35	40	15
		AS	0	0	40	35	15

For St Bride's Crypt, all males and female facets have an overall measure of pitting in all regions. It can be seen that the association between pitot and facet angle is non-existent or weak in the majority of the facets with medium strength associations occurring in all spinal regions for males and females. Strong correlation between pitot and facet angle was seen in the right superior facet of C4, the left inferior facet of C5, the left inferior facet of C7 and the right superior facet of T11 in males and the left inferior facet of T9 in females.

For St Bride's Lower, females have a slightly higher number of facets without pitting in the cervical region (males 0, females 1), with a similar pattern seen in the thoracic region (males 0, females 7). In the lumbar region, males and females both have 1 facet without pitting. It can be seen that the association between pitot and facet angle is non-existent or weak in the majority of the facets with most medium strength associations occurring in the cervical and lumbar spine in males and females. Strong correlation between pitot and facet angle were seen at the right inferior facet of T4 and the left superior facet of T8 in males and the left inferior facet of C2 and C5, the right inferior facet of T1, the left superior facet of L3, the left inferior facet of L4 and L5 in females.

For the Anglo-Saxon sample, most regions have facets with pitting, the exception being in the thoracic region of the female spine (n=1). It can be seen that the association between pitot and facet angle is non-existent or weak in the majority of the facets with some medium strength associations occurring in the cervical and lumbar regions for males and females. Strong correlation between pitot and facet angle were seen at the left inferior facet of C7 the right superior facet of T1, the left inferior facet of T5 and T6, the right inferior facet of T9 and T11, the right superior facet of T12 and the left superior and right inferior facet of L5 in males and the left superior facet of C2, the left and right inferior facets of C2, the left and right superior and left inferior facets of C3, the right superior facet of C4, the left and right superior and right inferior facets of C5, the left superior and left and right inferior facets of C7, the right superior and left and right inferior facets of T5, the right superior facet of T6, the right superior facet of T12, the right superior and right inferior facet of L1 and the right inferior facet of L3 in females.

The results indicate that the highest score for strong correlation classification between pitot and facet angle can be seen in the female Anglo-Saxon sample in the cervical region. The low level of correlation overall and lack of statistical significance implies that there is a poor relationship between pitot and facet angle.

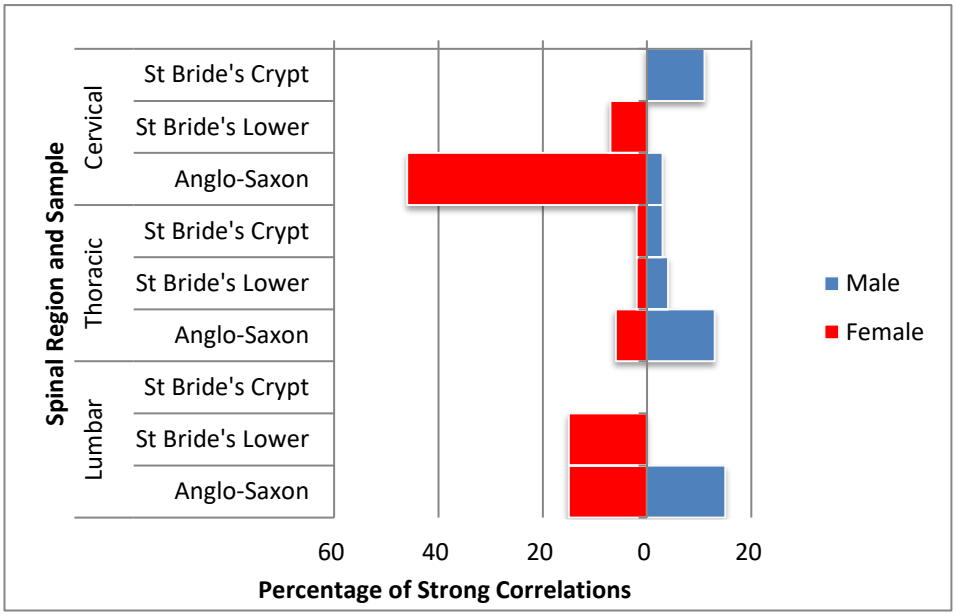


Figure 6-22 Percentage frequency of strong correlations between pitot (total pitting score)and facet angle

6.4.8.5 Correlation between osteophyte score and facet angle

See Section 6.3.9.4 for details of data handling and statistical analysis. The new variable ostot was created. The full results are presented in Appendix C-11 and summarised below in Table 6-59 and Table 6-60.

Table 6-59 Count of correlation classifications between ostot (total osteophyte score) and facet angle

Sex	Sample	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)	Negative Correlation	P<0.001
Male	SBC	27	44	14	6	52	0
	SBL	25	48	11	1	34	0
	AS	21	29	10	5	26	0
Female	SBC	34	48	13	2	34	0
	SBL	27	36	8	4	40	0
	AS	15	34	6	23	48	0

Negative correlations between facet angle and extent of osteophytes were noted in 50 (52%) of male and 33 (34%) of female facets from St Bride's Crypt, 33 (34%) of males and 38 (40%) of female facets from St Bride's Lower and 25 (26%) of male and 46 (48%) of female facets from the Anglo-Saxon sample. This indicates that in these facets increased ostot was correlated with smaller facet angle. Although no correlations showed a statistical significance, a strong correlation was noted in all regions of the male spine and in the cervical and thoracic regions of female spines

from St Bride's Crypt, the male thoracic spine and all regions in the female spine from St Bride's Lower, and all regions in the male and female spine from the Anglo-Saxon sample.

Table 6-60 summarises the results of the correlation analysis by spinal region. The number of facets without osteophytes is identified in the "No Osteophyte" column and are represented by blank cells in Appendix C-11.Figure 6-23 illustrates the results presented in Table 6-60.

Table 6-60 Percentage frequency of correlation between ostot (total osteophyte score) and facet angle by spinal region

Spinal Region	Sex	Sample	No osteophytes	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)
Cervical	Male	SBC	14	25	46	11	3
		SBL	7	25	46	25	0
		AS	36	14	21	18	11
	Female	SBC	11	32	46	7	3
		SBL	21	29	29	18	3
		AS	36	3	11	7	43
Thoracic	Male	SBC	13	33	35	13	6
		SBL	17	27	44	0	2
		AS	33	21	29	0	4
	Female	SBC	0	38	52	8	2
		SBL	8	27	35	0	2
		AS	2	23	40	0	15
Lumbar	Male	SBC	0	15	60	15	10
		SBL	0	20	60	20	0
		AS	5	30	40	25	0
	Female	SBC	0	30	40	30	0
		SBL	0	25	50	15	10
		AS	0	10	55	20	15

For St Bride's Crypt, all males and female facets have an overall measure of osteophytes in the lumbar region but not in the cervical and thoracic regions. It can be seen that the association between ostot and facet angle is non-existent or weak in the majority of the facets with medium strength associations occurring in all spinal regions for males and females. Strong correlation between ostot and facet angle was seen in the right superior facet of C4, the right inferior facet of

T4, the right inferior facet of T10, the right superior facet of T12, the right superior facet of L1, and the left superior facet of L2 in males and the left inferior facet of C3 and right superior facet of T5 in females.

For St Bride's Lower, females have more facets without osteophytes in the cervical region (males 2, females 6) and in the thoracic region (males 8, females 4). In the lumbar region all facets demonstrated osteophytes. It can be seen that the association ostot and facet angle is non-existent or weak in the majority of the facets with most medium strength associations occurring

in the cervical and lumbar spine in males and females. Strong correlation between ostot and facet angle were seen at the left inferior facet of T10 in males and right inferior facet of C4, T10, L2 and L5 in females.

For the Anglo-Saxon sample, 10 facets did not have osteophytes in the cervical region for both males and females. In the thoracic region, males had a much higher number of facets without osteophytes compared to females (males 16, females 1). In the lumbar region there was only 1 male facet without osteophytes. It can be seen that the association between ostot and facet angle is non-existent or weak in the majority of the facets with some medium strength associations occurring in the cervical and lumbar for males and females. Strong correlation between ostot and facet size were seen at the right inferior facet of C4, the left superior facet of C6, the right inferior facet of C7 and T5 and the left superior facet of C6 in males and the left and right superior facets of C3, the right superior and left and right inferior facets of C4, the left and right superior and right inferior facets of C5, the left superior facet of C6, the left and right superior and left and right inferior facets of C7, the tight superior facet of T2, the right inferior facet of T6, the left inferior facet of T9, the left superior and right inferior facets of T10, the right superior facet of T11, the right inferior facet of T12 and L2, the right superior facets of L4 and L5 in females.

The highest number of strong correlations can be seen in the cervical and thoracic regions of Anglo-Saxon females. The overall count of strong correlations is low indicating a poor relationship between ostot and facet angle.

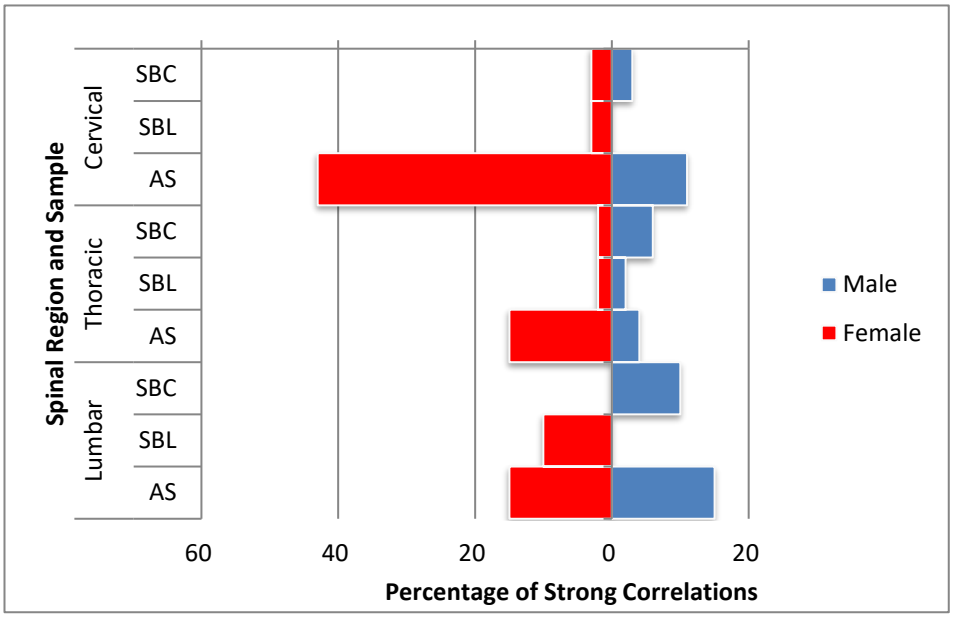


Figure 6-23 Percentage frequency of strong correlations between ostot (total osteophyte score) and facet angle

6.4.8.6 Correlation between vertebral osteophytosis score and facet angle

See Section 6.3.9.7 for details of data management and statistical analysis. The full results are presented in Appendix C-12 and summarised below in Table 6-61 and Table 6-62.

Table 6-61 Percentage frequency of correlation classification between cvostot (total vertebral body osteophytosis score) and facet angle

Sex	Sample	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)	Negative Correlation	P<0.001
Male	SBC	47	35	11	2	44	0
	SBL	44	35	13	4	45	0
	AS	24	19	28	17	40	0
Female	SBC	60	33	2	0	38	0
	SBL	33	33	13	3	43	0
	AS	19	22	15	11	24	0

Negative correlations between facet angle and vertebral osteophytosis were noted in 42 (44%) of male and 36 (38%) of female facets from St Bride's Crypt, 42 (45%) of males and 41 (43%) of female facets from St Bride's Lower and 38 (40%) of male and 23 (24%) of female facets from the Anglo-Saxon sample. This indicates that in these facets increased cvostot was correlated with

smaller facet angle. Although no correlations showed a statistical significance, strong correlations were noted in all regions of the male spine and in the cervical and thoracic regions of female spines from St Bride's Crypt, the male thoracic and lumbar spine and lumbar region in the female spine from St Bride's Lower, and all regions in the male and female spine from the Anglo-Saxon sample, apart from the female cervical where no analysis could be performed due to missing vertebral bodies.

Table 6-62 summarises the results of the correlation analysis by spinal region. Figure 6-24 illustrates the results reported in Table 6-62. The full results can be seen in Appendix C-12. See section 6.3.9.7 for details of recording of missing data within this table.

Table 6-62 Percentage frequency of correlations between cvostot (total score vertebral osteophytosis) and facet angle by spinal region

Spinal Region	Sex	Sample	No vertebral bodies	No Correlation (r_s<0.01)	Weak Correlation (r_s=0.1-0.29)	Medium Correlation (r_s=0.3-0.49)	Strong Correlation (r_s=0.5-1.0)
Cervical	Male	SBC	0	32	43	7	6
		SBL	0	54	25	11	0
		AS	2	0	21	21	11
	Female	SBC	0	57	29	3	0
		SBL	0	36	43	11	0
		AS	6				
Thoracic	Male	SBC	0	58	35	6	0
		SBL	0	50	42	6	2
		AS	0	33	17	38	15
	Female	SBC	0	63	35	2	0
		SBL	0	40	56	6	6
		AS	1	19	35	23	15
Lumbar	Male	SBC	0	40	25	30	0
		SBL	0	15	35	30	15
		AS	0	35	20	15	30
	Female	SBC	0	60	35	0	0
		SBL	5	5	15	30	15
		AS	0	45	20	15	20

For St Bride's Crypt, all males and female spinal regions have a sufficient number of intact vertebral bodies for analyses to be performed for all areas. It can be seen that the association between cvostot and facet angle is non-existent or weak in the majority of the facets with

medium strength associations occurring in all spinal regions for males and females. Strong correlation between cvostot and facet angle was seen in the right inferior facet of C5 and right superior facet of C6 in males and no facets in females.

For St Bride's Lower, all males and female spinal regions with the exception of Female L4 have a sufficient number of intact vertebral bodies for analyses to be performed for all areas. It can be seen that the association between cvostot and facet angle is non-existent or weak in the majority of the facets with most medium strength associations occurring in the cervical and lumbar spine in males and females. Strong correlation between cvostot and facet angle were seen at the left inferior facet of T10, the right superior and right inferior facets of L3 and the left inferior facet of L4 in males and the left inferior facet of L2, the right superior and right inferior facets of L3 in females.

For the Anglo-Saxon sample, vertebral bodies were absent at C2 and C4 in males and C2, C3, C4, C5, C6, C7 and T1 in females. It can be seen that the association between cvostot and facet angle is non-existent or weak in the majority of the facets with some medium strength associations occurring in all spinal regions for males and females. However, in this population, much higher numbers of strong correlations were observed despite the amount of missing data. Strong correlation between cvostot and facet angle was seen at the right and left inferior facets of C5, the left superior facet of C7, the left superior facet of T1, the left and right inferior facets of T2, the right superior facet of T4, the left inferior facets of T6 and T9, the lefty and right inferior facets of L1, the left and right superior facets of L5 in males and the left and right inferior facets of T2, the right inferior facet of T5, the left superior and right inferior facets of T8, the left inferior facet of T9, the left superior facet of T12, the left inferior facet of L1 and the left superior facet of L3 and the left superior and right inferior facets of L4 in females.

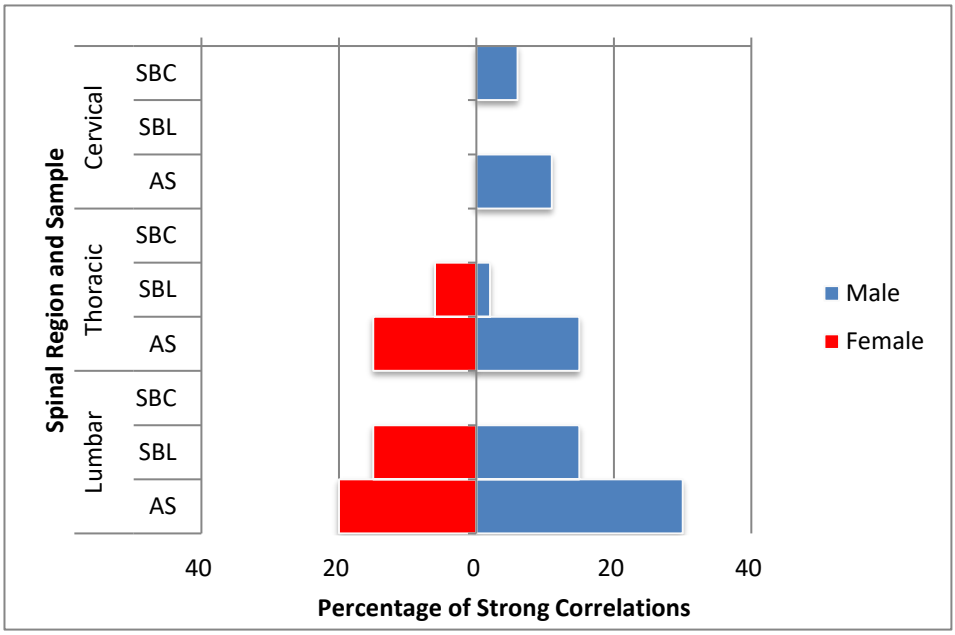


Figure 6-24 Percentage frequency of strong correlations between cvostot (total vertebral body osteophytosis score and facet angle)

The highest count of strong correlations can be seen in the Anglo-Saxon sample (thoracic and lumbar regions). The lack intact vertebral bodies in the female Anglo-Saxon sample meant that no conclusions could be drawn from analysis of the cervical region.

6.5 Stepwise discriminant function with extrinsic variables

Stepwise discriminant function equations were calculated for each vertebral level using extrinsic variables, facet size and angle. The functions are presented at the end of this section. Finally, the percentage accuracy of correct classification of sex using functions derived from facet size and facet angle alone was compared with those for functions including predictor variables to measure the effectiveness of considering lifestyle markers in predicting sex.

6.5.1 Derivation of discriminant function equations for all parameters

Facet size, angle and all extrinsic variables (femoral robusticity, humeral directional asymmetry, eburnation, pitting, osteophytes and osteophytosis) were subjected to multivariate discriminant function analysis to create equations using stepwise selection to identify the combination of variables that best discriminate between males and females. The method is described in Section 5.2.9.2 and the results can be seen in Table 6-63.

The p value from the Wilk's Lambda test for goodness of fit for the model tests for significant differences between male and female groups. In this analysis p was set at $p<0.0006$ with Bonferroni adjustment (significant results are written in bold). Results for all vertebral levels for each sample are included in the table. This analysis generated discriminant functions for each vertebra that identify the sex of an individual based on the size and angle of all four facets for each vertebral level and extrinsic variables relevant to the facets. In the event of little or no difference between sexes, no variables qualified for inclusion in the equation.

The total percentage of correct classification listed in this table was used to compare accuracy in using extrinsic variables rather than facet size or angle alone and the results presented in this section.

Key for Table 6-63:

C = cervical,

T = thoracic,

L = lumbar

Numbers represent the vertebral level

Lt = left,

R = right,

S =superior,

I = inferior

E.g. C1LtSA = facet size for C1, left superior facet and C1LS = facet angle for C1 left superior facet.

ebtot = eburnation severity and extent added together

pitot = pitting severity and extent added together

ostot = osteophyte severity and extent added together

FemrobustL = femoral robusticity of left femur

FemrobustR = femoral robusticity of right femur

Hasym = humeral asymmetry

Table 6-63 Stepwise discriminant function analysis with extrinsic variables

Vertebral Level	Sample	Wilks Lambda p	Discriminant Function Equation F(n)	Zm	Zf	Nm	Nf	Z0	% Correct Classification		
									M	F	Total
C1	SBC	0.001	F=(-0.384)+(0.029)C1LtIArea+(1.488)C1LtIpitot-(2.11)C1LtS	1.926	-1.051	10	29	0.44	44	91	71
	SBL	0.004	F=(-7.717)-(0.28)C1LtIArea+(1.731)C1tLIebtot+(0.508)C1LtS	-0.83	1.661	21	9	0.42	81	45	65
	AS	0.012	F=(-67.953)-(13.356)C1LtIpitot+(4.416)C1LS+(2.031)C1RIpitot	-14.97	59.879	8	4	22.45	53	50	52
C2	SBC	**<0.001**	F=(7.009) –(0.36)C2LtSArea+(0.692)C2LtSebtot+(0.032)Hasym	-1.833	1.166	10	20	-0.33	63	71	68
	SBL	0.002	F=(0.029)+(0.02)C2LtSArea-(0.084)C2RI	0.589	-1.474	26	11	-0.44	90	55	76
	AS	0.16	F=(-33.155)+(0.471)C2RI	2.907	-5.814	11	5	-1.45	85	56	73
C3	SBC	0.025	F=(-3.836)+(0.037)C3RSArea	0.809	-0.486	7	26	0.16	35	81	64
	SBL	0.001	F=(-13.74)+(0.228)C3LtI+(1.01)C3LtIpitot-(0.044)C3LSArea-(0.71)C3LtSostot	-0.971	1.943	20	14	0.49	74	67	71
	AS	0.298	F=(-5.103)+(0.061)C3LtI	1.138	-2.275	8	1	-0.57	100	11	68
C4	SBC	0.055	F=(-0.839)+(0.186)FemrobustLt	-0.593	0.461	11	7	-0.07	85	30	50
	SBL	0.001	F=(4.55)-(0.054)C4LtIArea-(0.77)C4LtSostot-(1.17)C4RIostot)+(1.19)C4RSostot	-0.861	1.844	24	11	0.49	83	52	70
	AS	0.181	F=(-22.062)+(0.283)C4LtS	-2.404	4.808	5	7	1.20	36	78	52

Table 6-63 Stepwise discriminant function analysis with extrinsic variables continued

Vertebral Level	Sample	Wilks Lambda p	Discriminant Function Equation F(n)	Zm	Zf	Nm	Nf	Z0	% Correct Classification		
									M	F	Total
C5	SBC	0.007	F=(-4.557)+(0.043)C5LtSArea	0.801	-0.712	12	23	0.04	52	68	61
	SBL	0.029	F=(-0.419)+(1.316)C5RIostot	-0.419	0.605	24	6	0.09	83	25	57
	AS	0.095	F=(-47.412)+(0.453)C5RS+(0.537)FemrobustR	-4.293	12.878	8	2	4.29	100	29	67
C6	SBC		No variables qualify for this equation								
	SBL		No variables qualify for this equation								
	AS	0.006	F=(136.938)-(4.07)C6LtI+(1.32)C6LtIArea+(0.612)C6RI	24.16	-96.651	9	5	-36.25	75	63	70
C7	SBC	0.016	F=(-4.999)+(0.041)C7LtIArea	1.006	-0.559	10	35	0.22	40	90	70
	SBL	0.008	F=(-1.689)-(0.034)C7LtSArea+(0.572)C7RIpitot+(0.046)C7RSArea	0.579	-1.094	22	13	-0.26	73	54	65
	AS		No variables qualify for this equation								
T1	SBC		No variables qualify for this equation								
	SBL	0.028	F=(-0.455)+(1.138)T1RIpitot	-0.321	0.683	30	8	0.18	86	35	66
	AS	0.197	F=(-55.154)+(0.471)T1	-123	4.243	13	2	-59.38	93	18	60
T2	SBC	0.003	F=(-6.597)+(0.065)T2RIArea	1.141	-0.685	14	31	0.23	54	82	70
	SBL	0.006	F=(2.785)-(0.3)T2LIArea+(1.149)T2RSostot	-0.575	1.078	30	4	0.25	88	18	61
	AS	0.013	F=(-55.973)+(0.55)Hasym+(28.136)T2LtIebtot	55.256	-55.256	4	3	0.00	36	100	50

Table 6-63 Stepwise discriminant function analysis with predictor variables continued

Vertebral Level	Sample	Wilks Lambda p	Discriminant Function Equation F(n)	Zm	Zf	Nm	Nf	Z0	% Correct Classification		
									M	F	Total
T3	SBC	**<0.001**	F=(-56.2)+(-0.19)Hasym-(0.42)T3LI+(0.19)T3LIArea+(3.08)T3LtIebtot +T3LtSebtot+(0.75)T3RI+(13.2)T3RSebtot-(3.424)T3RSpitot	8.137	-4.882	11	22	1.63	69	73	72
	SBL		No variables qualify for this equation								
	AS	0.051	F=(-752.247)+(7.211)T3LtI-(4.443)T3RSpitot	13.7	-13.73	10	4	-0.02	100	44	74
T4	SBC	0.001	F=(-15.188)+(1.954)T4LIebtot-(0.027)T4LtSarea+(0.144)T4RIarea	2.398	-2.877	16	19	-0.24	70	76	73
	SBL	**<0.001**	F=(-13.3)+(1.28)T4LtI+(8.33)T4LtIpitot-(1.29)T4LtS)-(0.23)T4LtSArea+(25.52)T4tLSostot+(1.64)T4RI-(1.537)T4RSArea	-15.032	40.085	26	8	12.53	93	44	74
	AS	0.074	F=(-82.779)-(0.875)T4RSArea	19.991	-9.995	14	11	5.00	61	69	64
T5	SBC	0.002	F=(-4.403)+(0.048)T5RSArea-(0.757)T5RSebtot	1.335	-0.935	13	31	0.20	52	84	71
	SBL	0.024	F=(-0.427)+(1.708)T5LStostot	-0.427	0.939	22	5	0.26	79	25	56
	AS	0.018	F=(-117.66)+(10.34)T5LtSostot+(0.876)T5RSArea+(5.549)T5RSostot	26.741	-17.827	8	10	4.46	36	71	50
T6	SBC	**<0.001**	F=(-113.77)+(1.23)T6LS-(0.119)T6LtSArea-(0.07)T6RIArea+T6RSebtot	-4.755	3.17	16	10	-0.79	62	77	71
	SBL		No variables qualify for this equation								
	AS	0.024	F=(-192.359)+(1.753)T6LtSArea+(15.984)T6LtSostot	51.69	-17.23	3	12	17.23	18	100	52
T7	SBC	0.001	F=(12.37)+(0.056)T7LtSArea-(0.159)T7RI	1.461	-0.93	19	25	0.27	76	66	70
	SBL	0.001	F=(11.481)+(-0.421)T7RI+(0.194)T7LtS+(0.114)T7RI	0.908	-1.686	26	11	-0.39	93	55	77
	AS	0.1	F=(-42.38)+(-0.782)T7LtSArea+(3.216)T7LtSpitot+(4.991)T7RSArea	27.262	-41.194	5	9	-6.97	45	75	61

Table 6-63 Stepwise discriminant function analysis with predictor variables continued

Vertebral Level	Sample	Wilks Lambda p	Discriminant Function Equation F(n)	Zm	Zf	Nm	Nf	Z0	% Correct Classification		
									M	F	Total
T8	SBC	0.003	F=(-15.549)+(0.158)FemrobustLt-(0.105)T8tLIArea+(0.221)T8LtS	-1.744	1.047	11	15	-0.35	92	79	83
	SBL	0.009	F=(-5.203)+(0.064)T8LtSArea	0.356	-1.009	32	9	-0.33	97	45	77
	AS		No variables qualify for this equation								
T9	SBC	0.001	F=(-22.055)+(0.051)Hasym+(0.275T9LtS)-(0.069)T9RSArea	-0.001	1.072	10	25	0.54	56	83	73
	SBL	0.004	F=(-4.687)+(0.057)T9LtSArea	0.461	-0.923	26	11	-0.23	84	55	73
	AS	<0.001	F=(-107.503)-(1.876)T9LtSArea+(10.075)T9LtSebtot+(2.456)T9RSArea	-32.685	32.685	16	4	0.00	89	25	59
T10	SBC	0.002	F=(-11.733)+(0.067)T10tLI+(0.047)T10LtIArea+(0.7)T10LtSostot	1.634	-1.144	18	31	0.25	72	80	77
	SBL	0.011	F=(-4.052)+(0.044)T10RIArea	0.403	-0.806	27	9	-0.20	90	45	72
	AS	0.039	F=(-1.501)+(0.584)T10pitot	1.223	-0.918	9	7	0.15	45	78	55
T11	SBC	0.01	F=(0.038)+(0.041)T11RSArea	0.785	-0.571	8	36	0.11	31	92	68
	SBL	0.015	F=(-4.093)+(0.038)T11tLSArea	0.381	-0.762	25	8	-0.19	89	40	69
	AS	0.001	F=(-226.699)+(19.956)T11LtSostot+(1.546)T11RSArea	18.329	-27.494	10	10	-4.58	63	83	71
T12	SBC	0.008	F=(-2.371)+(-0.177)FemrobustLt+(0.028)T12LtIArea	1.004	-0.73	8	17	0.14	62	90	78
	SBL		No variables qualify for this equation								
	AS	0.007	F=(-75.904)+((0.327)T12LtIArea+(13.189)T12LtIebtot+(1.947)T12RSebtot	51.734	-34.489	3	8	8.62	21	80	45

Table 6-63 Stepwise discriminant function analysis with predictor variables continued

Vertebral Level	Sample	Wilks Lambda p	Discriminant Function Equation F(n)	Zm	Zf	Nm	Nf	Z0	% Correct Classification		
									M	F	Total
L1	SBC	0.004	F=(-3.527)+(0.135)FemrobustLt+(0.112)L1RS-(0.653)L1RSpitot	-1.28	0.931	10	18	-0.17	83	90	88
	SBL	0.011	F=(-3.667)+(0.093)t+(0.392)L1RSostot	-0.497	0.994	23	5	0.25	82	25	58
	AS	0.015	F=(-212.902)+(3.251)L1LtS+(0.749)L1RIArea+(23.164)L1VOS	20.255	-30.383	7	5	-5.06	70	63	67
L2	SBC	0.003	F=(-4.152)-(0.177)FemrobusttL+(0.03)L2RIArea	1.141	-0.913	9	17	0.11	69	85	79
	SBL	0.062	F=(-2.594)+(0.015)L2LtSArea	0.3	-0.563	26	6	-0.13	90	31	65
	AS	0.001	F=(-14.976)+(0.429)L2LtI+(1.229)L2RIosot	-3.074	3.074	11	8	0.00	69	80	73
L3	SBC	0.008	F=(-5.937)-(0.048)Hasym+(0.035)L3RIArea	1.271	-0.953	6	25	0.16	33	89	67
	SBL		No variables qualify for this equation								
	AS	0.006	F=(-303.28)-(0.17)L3LtIArea-(6.5)L3LtIpitot+(23.37)L3LtIpitot+(0.92)L3LtSArea	29.716	-29.716	3	14	0.00	18	88	52
L4	SBC	0.001	F=(-4.619)-(0.147)FemrobustLt+(0.031)L4LtIArea	1.342	-1.073	10	18	0.13	77	86	82
	SBL	0.002	F=(-56.042)+(1.1)Hasym-(1.366)L4LS+(0.777)L4LtSArea-(16.392)L4LtSostot	35.826	-71.652	16	7	-17.91	89	54	74
	AS		No variables qualify for this equation								
L5	SBC	0.024	F=(-1.1877)-(0.195)FemrobustLt+(0.012)L5LtIArea	0.913	-0.913	9	12	0.00	75	67	70
	SBL	0.053	F=(-6.459)+(0.123)L5LtI	-0.285	0.713	23	4	0.21	82	21	57
	AS		No variables qualify for this equation								

6.5.2 Comparison of percentage correct classification using stepwise discriminant function analysis (DFA) with and without predictor variables

The percentage of correct classification results for stepwise discriminant function analysis using facet size, facet angle alone and predictor variables were compared to see if the use of predictor variables increased the degree of precision in sex identification. The results are shown in Table 6-64. In some circumstances there were no suitable variables for calculation of a discriminant function equation and therefore the percentage accuracy could not be calculated (marked as a blank cell). Discriminant function equations could not be created in 21/72 (29%) of analyses for facet size only, 55/72 (76%) of analyses for facet angle only and 11/72 (15%) of analyses using all predictor variables. The highest percentage correct classification for each sample and vertebral level is highlighted for clarity.

Table 6-64 Comparison of percentage of correct classification of sex identification using stepwise DFA

Vertebral Level	Sample	% Accuracy Facet Size	% Accuracy Facet Angle	% Accuracy All Predictor Variables
C1	SBC	71	66	71
	SBL	80		65
	AS		78	52
C2	SBC	67		68
	SBL	84	74	76
	AS		71	73
C3	SBC	71		64
	SBL	65	67	71
	AS	65	83	68
C4	SBC	66		50
	SBL	65		70
	AS			52
C5	SBC			61
	SBL			57
	AS		75	67
C6	SBC	72		
	SBL		63	
	AS			70
C7	SBC	67		70
	SBL	71		65
	AS			

Table 6-64 Comparison of percentage of correct classification of sex identification using stepwise DFA continued

T1	SBC	69		
	SBL			66
	AS			60
T2	SBC	72	70	70
	SBL	64		61
	AS			50
T3	SBC	67		72
	SBL	78		
	AS	79		74
T4	SBC	76		73
	SBL	80		74
	AS	72	67	64
T5	SBC	76		71
	SBL			56
	AS	71		50
T6	SBC	77		71
	SBL	74		
	AS	68		52
T7	SBC	70		70
	SBL	82		77
	AS			61
T8	SBC	67		83
	SBL	77	66	77
	AS	59		
T9	SBC	78		73
	SBL	75		73
	AS	67	79	59

Table 6-64 Comparison of percentage of correct classification of sex identification using stepwise DFA continued

Vertebral Level	Sample	% Accuracy Facet Size	% Accuracy Facet Angle	% Accuracy All Predictor Variables
T10	SBC	74		77
	SBL	72		72
	AS			55
T11	SBC	67	64	68
	SBL	73		69
	AS	61		71
T12	SBC	64	68	78
	SBL	71		
	AS			45
L1	SBC	63	69	88
	SBL	69		58
	AS			67
L2	SBC	71		79
	SBL	71		65
	AS			73
L3	SBC	66		67
	SBL	77		
	AS		73	52
L4	SBC	69		82
	SBL	78		74
	AS		80	
L5	SBC	73		70
	SBL	71		57
	AS			

Table 6-65 presents a summary of the highest percentages of correct classification highlighted in the previous table. Where there are equally high percentages of correct classification in two

results, they were counted twice (e.g. vertebral level C1 for St Bride's Crypt where both % accuracy for facet size and all predictors has the same value of 71%). Facet angle alone is generally a poor predictor for sex difference for St Brides Crypt and St Bride's Lower, however this is less evident in the Anglo-Saxon sample The stepwise discriminant function analysis using all predictor variables gave the highest total levels of correct classification for St Brides Crypt (14/72) and Anglo-Saxon (11/70, taking missing data into account) whereas facet size gave the highest total levels of correct classification for St Bride's Lower (18/72). Facet size is an important factor in sexual dimorphism particularly in the thoracic region of all three samples.

Table 6-65 Summary of highest percentages for correct classification

Sample	Spinal Region	% Size	% Angle	% All	Missing data
SBC	Cervical	4		4	
	Thoracic	7		6	
	Lumbar	1		4	
	Total	12	0	14	
SBL	Cervical	3	1	3	
	Thoracic	10		4	
	Lumbar	5		1	
	Total	18	1	8	
AS	Cervical		3	3	1
	Thoracic	5	1	6	
	Lumbar		2	2	1
	Total	5	6	11	2

Chapter 7 Discussion

This study is divided into two parts. The first section used statistical methods to estimate sex in three British samples. Discriminant functions derived from measurements of facet size and angle for the whole spine were used in this process. The second part explored the relationship between extrinsic factors and facet morphology using a comparative approach; the relationship between facet morphology and gendered division of labour was explored in the three samples in response to Armelagos et al. (1982: 318-9) comment:

> "*Although a methodology for interpreting the functional significance of sexual dimorphism [in postcranial dimensions] could have been developed, it was not. Physical anthropologists instead created statistical techniques for determining sex without concern for the functional factors that lead to these differences"*

7.1 Summary of Results – Sexual Dimorphism

The analysis of samples from rural and urban settings described in Chapter 5 has identified a number of interesting findings in relation to the use of facet size and to a lesser degree facet angle in the determination of sex. The main findings for each skeletal sample will be outlined in this section followed by a discussion of the over-arching trends relating to statistical analysis for determination of sex using the facet joints of the spine.

Sexual Dimorphism

Sexual dimorphism can be defined as "systematic difference in form between individuals of different sex in the same species" (Plavcan and van Schaik, 1994). The metric differences between the sexes can be quantified using a ratio. The SDI method used for this study provides results that indicate a feature is similar in males and females when SDI value is close to 100, a value > 110 indicates that male measurements are higher than females conversely, a value < 90 indicates that the female measurement is higher.

Sexual dimorphism has been much studied in humans and nonhuman primates, with males being on average larger than females in general body size and other skeletal parts (Stini 1974; Ross and Ward 1982; Clutton-Brock 1985; Frayer and Wolpoff, 1985; Leutenegger and Cheveraud, 1985; Ruff 1987, 2000; Plavcan and van Schaik 1994; Spradley and Jantz, 2011).

The male larger than female pattern has also been observed in human vertebral measurements (Taylor and Twomey, 1984; MacLaughlin and Oldale, 1992; Marino 1995; Grave et al., 1999; Wescott 2000; Bonivitch et al., 2006; Rühli et al., 2006; Yu et al 2008; Marlow and Pastor 2011; Zheng et al 2012; Hou et al., 2012; Amores et al 2013; Bethard and Seet, 2013; Bastir et al., 2014).

Evaluation of Sexual Dimorphism

This study has demonstrated a difference in the degree of sexual dimorphism of facet size between samples, with St Bride's Crypt being the most sexually dimorphic and the Anglo-Saxon the least for facet size. Facet angle does not show the same degree of variation. Milne (1991) obtained similar results for facet angle in the cervical spine, being unable to identify any significant differences between male and female facet angle. Differences in adult vertebral dimensions reflect differences in bone growth that evolves during early skeletal development, and so changes in bone size during childhood have important biomechanical implications in respect to loading capacity of the skeleton in adulthood (Bonjour et al., 1991; Einhorn 1992). The gendered division of labour can also affect sexual dimorphism because bones respond to external force and remodel according to the loading on them (Ruff, 1987; Steyn and Işcan, 1999).

Historically, there have been a number of studies of sexual dimorphism in vertebrae with varying degrees of accuracy for estimation of sex (from 60-91%) when using multivariable discriminant function equations (Schaffler et al., 1992; MacLauglin and Oldale, 1992; Marino, 1993; Haughen, 1994; Wescott, 2000; Marlow and Pastor, 2011; Swenson, 2013; Bethard and Seet, 2013; Amores et al., 2014; Bastir, 2014). Many of these studies have limitations as a result of data being collected from single vertebral levels or from a spinal region, using unilateral measurements, employing different methodologies to derive discriminant function equations, using only single samples and/or changes due to age not being taken into consideration. None of the studies reviewed had collected data from the whole spine. Most of the studies justified their choice of vertebra by selecting those with easily recognisable morphology (Marino, 1995; Wescott, 2000; Yu et al., 2008; Amores et al., 2014). Other studies were replications of existing studies with no further justification for use of a particular vertebra (Marlow and Pastor, 2011; Bethard and Seet, 2013). Finally, some studies gave no rationale for the choice of vertebra (Hou et al., 2012; Zheng et al., 2012). The majority of published facet angle studies are clinical in nature, rather than archaeological, and used male spines for data

collection (Pal and Routal, 2001; Masharawi et al., 2007). A few studies, however, did identify differences in sagittal angle between sexes when looking at spinal regions rather than individual vertebrae (Tulse and Hermanis, 1993; Boyle et al., 1996; Masharawi et al., 2004; Whitcombe et al., 2007), but Milne (1991) found no sex differences in his analysis of upper cervical spine facet angles. None of these studies considered using sagittal angle as a method to estimate the sex of an individual. Discriminant function equations were not calculated from the data collected in any of these studies.

The current study examined the zygapophyseal joints of the whole spine in order to assess whether all vertebrae were equally dimorphic and to give a more complete picture of the effects of lifestyle on the spine. The zygapophyseal (facet) joints of the spine were selected for measurement in the present study because, although there is existing evidence for sexual dimorphism in vertebrae based on multiple measurements (Marino, 1995; Wescott, 2000; Yu et al., 2008; Marlow and Pastor, 2011; Bethard and Seet, 2013 Hou et al., 2012; Zheng et al., 2012; Amores et al., 2014), the facet joint has not been a point of focus. The facet joints are considered susceptible to degenerative changes caused by activity due to the direct influence of load bearing (Moore and Petty, 2005). This could make them a suitable candidate for investigating the effect of extrinsic influences. It was not possible to make direct comparison between actual facet joint dimensions from this study with other published research due to the variation in methods used to collect data. This results in a wide range of reported osteometric values. Furthermore size sexual dimorphism is also known to depend on the genetic make up and environment of individuals and thus is therefore population specific (Cheveraud, 1988).

St Bride's Crypt

Metric analysis of St Bride's Crypt facet joint size found that the degree of difference between the sexes appeared to be high, with many facets (85%) showing a sexual dimorphism index (SDI) of >110. All spinal regions exhibited a high percentage of facets with SDI > 110 (cervical 79%, thoracic 85%, lumbar, 95%). Only 6/28 cervical, 7/48 thoracic and 1/20 lumbar facets were not classifiable for sex due to a lack of size difference between males and females. Male mean facet size was greater than that of females for most facets.

A clear pattern of facet size sexual dimorphism was confirmed in this sample after statistical analysis using Mann-Whitney U test. The thoracic region demonstrated the highest overall

number of facets showing significant difference in facet size between males and females, followed by the lumbar then cervical region.

Facet angle analysis produced a different pattern than that seen for facet size in this sample. There was much lower sexual dimorphism seen, with only one cervical facet having SDI > 110. However, index values of < 90 were seen in 5 thoracic and 8 lumbar facets. Regionally, 27 cervical, 43 thoracic and 12 lumbar facets could not be classified from their index values indicating a lack of sexual dimorphism for facet angle. The diminished degree of sexual dimorphism in facet angle was confirmed by statistical analysis with only one thoracic facet showing significant difference in facet angle between males and females. There is thus little sexual dimorphism in facet angle indicating that this parameter would be a poor indicator of sex in this sample.

St Bride's Lower

The two St Bride's samples show similarity in the degree of sexual size difference in facet joint size, with both having 85% of facets with an SDI > 110. The distribution of facets with an SDI > 110 (cervical 68%, thoracic, 92%, lumbar, 95% for St Bride's Lower) differed from the St Bride's Crypt sample.

Fewer facet size sex differences showed statistical significance than in the St Bride's Crypt sample, again, the highest number of significant differences was seen in the thoracic region, followed by the cervical and lumbar regions. There are fewer significant facet size differences than seen in the Crypt sample indicating that the degree of sexual dimorphism for facet size is lower in the St Bride's Lower sample. This may be an indication that these individuals had a less gendered division of labour or division of labour but equal degrees of physical activity throughout their lives than the St Bride's Crypt group thereby resulting in reduced sexual dimorphism in facet size.

Facet angle analysis revealed that there was no statistically significant difference in facet angle between the sexes. This lack of sexual dimorphism was confirmed using SDI values. No SDI values were >110 and only one facet from each spinal region demonstrated a mean value of <90. Ninety-five percent of facets (27 cervical, 47 thoracic, and 19 lumbar) did not demonstrate sexual dimorphism, hence making this a poor indicator of sex.

Anglo-Saxon

The previous samples are of urban origin from the same time period but of contrasting socio-economic status. The Anglo- Saxon sample was included in this study to provide a contrasting rural sample from a different time period. The difference in lifestyle of this group is expected to display a difference in facet size and angle due to the differing degrees of activity and gendered division of labour undertaken by this group.

Calculation of SDI for this sample showed a lower degree of sexual dimorphism for facet size when compared to the two St Bride's samples, with only 47% of facets having an SDI>110 and 1% of facets <90. This meant that over half (52%) of the facets did not show size difference between the sexes. Statistical analysis indicated significant difference in facet size for just two facets in the thoracic region. Differences in facet size between males and females are a poor indicator of sex for this sample.

Facet angle showed a greater degree of sexual dimorphism than the other two samples when SDI was calculated. SDI>110 was observed in 13% of facets (10% of this value being observed in the cervical region) and < 90 in 13% of facets (13% of this value being observed in the lumbar region), however, only one lumbar value showed statistical significance indicating that facet angle is a poor indicator of sex for this sample. The facet angle results from the lumbar region may be due to the deepening of the lumbar lordosis in females during pregnancy. This acts as a counterbalance to the growing weight of the foetus (Whitcombe et al., 2007). Whitcombe et al. (2007) found that the females present with a longer series of dorsally wedged lumbar vertebrae and lumbar facets that are more frontally orientated than males and consider this to be a physiological adaptation increasing resistance to forward displacement of the vertebrae. Masharawi et al. (2004) were unable to confirm this finding, suggesting that female adaptation to pregnancy stems from combination of a smaller kyphotic vertebral body wedging into the thoracic and upper lumbar vertebrae, the relatively greater interspinous spacing and the larger interfacet width in the lumbar spine. This contradiction in results may be the result of using different methods (calliper v digitiser) and/or because the data was collected from different samples. Hay et al. (2015) urge caution with interpretation of Whitcombe et al. (2007) and Marashawi et al. (2004) studies as it is not clear whether the bone modifications described in them equal real differences in lordosis between the sexes.

This study has identified variation in degree of vertebral facet orientation in the lumbar region in males and females with the St Bride's Lower and the Anglo-Saxon sample matching the

Whitcombe et al. (2007) results and the St Bride's Crypt sample matching the Masharawi et al. (2004) result. These conflicting outcomes represent an area for further research. For the majority of facet comparisons, particularly in the upper and mid-thoracics, there was no clear differential between males' and females' mean facet angle and thus facet angle is a poor indicator of sex.

Discriminant Functions

The use of discriminant functions for classification of sex is a much-used practice in bioarchaeology (Schwartz, 2006). The accuracy of any discriminant function (DF) relies on similarity between the individual/group being tested and the sample from which the function is derived. The strength of sexual dimorphism displayed at population level is thus of great importance. Some populations display a greater degree of dimorphism than others. The existing vertebral discriminant functions are population specific and, when used in other eco-geographic or time contexts, may provide misleading results, with accuracies lower than that reported in the reference sample (Kotěrová et al., 2017; Hora and Sládek, 2018). Kotěrová et al. (2017) tested the effect of ignoring population specificity when using DF equations for tibial measurements from Portuguese, European and North American populations on measurements from a Czech sample and found that correct sex assessment was significantly decreased. Earlier studies have reported population differences in vertebral dimensions (Pastor, 2005; Yu et al., 2008; Marlow and Pastor, 2011).

To control for this factor, stepwise discriminant functions were calculated individually for each sample as it is not clear to what degree temporal or socioeconomic factors affect the degree of accuracy. Garvin et al. (2014) recommend that stepwise discriminant function should be utilised when estimating sex if the weighting of the factors under study is unknown. Methods of sex assessment using stepwise discriminant function equations are generally considered useful if the degree of accuracy is at least 80% (Rogers, 1999). In this study, the degree of accuracy achieved for facet size ranged from 64% -77% for St Bride's Crypt, 64-84% for St Bride's Lower and 59-79% for the Anglo-Saxon sample. Similarly, the degree of accuracy for facet angle ranged from 64-70% for St Bride's Crypt, 63-74% for St Bride's Lower and 67-83% for the Anglo-Saxon sample. Missing data or lack of sexual dimorphism in measurements from the samples meant that some equations could not be calculated (e.g. facet size: 1/24 for St Bride's Crypt; 6/24 for St Bride's Lower and 15/24 for Anglo-Saxon; facet angle: 19/24 for St Bride's Crypt, 20/24 for St Bride's Lower and 16/24 for Anglo-Saxon). These results meet

Rogers (1999) level of useful degree of accuracy greater than 80% (e.g. facet size of C1, C2, T4, T7 from St Bride's Lower; facet angle of C3 and L4 from Anglo-Saxon), whilst many of lower degrees of accuracy obtained are comparable to those achieved for vertebral levels using different parameters in other studies.

Marino (1995) achieved a 75-81% accuracy rate for C1 size: this compares favourably with the 71% for St Bride's Crypt and 80% for St Bride's Lower (even though different vertebral size parameters were used. Wescott (2000) achieved a range of accuracy of 81.7% to 83.4% for C2. Marlow and Pastor (2011) achieved degrees of accuracy of 70.91% to 75.89% when replicating Wescott's method applied to an English (Spitalfields) rather than American (Hamann-Todd and Terry) sample. Furthermore, they increased the degree of accuracy to 83.3% by using measurements from the Spitalfields collection supporting the hypothesis that discriminant function equations are population specific. Bethard and Seet (2013) further replicated Wescott (2000) using the William M. Bass and Hamilton County Forensic Centre samples and achieved a degree of accuracy between 82.3 and 86.7%. The current study achieved an accuracy of 67% for St Bride's Crypt and 84% for St Bride's Lower, but again, different vertebral size parameters were used in the studies. The St Bride's Lower results agree favourably with the results from studies listed above.

Amores et al. (2014) and MacLaughlin and Oldale (1992) achieved degrees of accuracy of 80% and 90% respectively for C7 using a combination of vertebral size measurements. These are higher than the results for St Bride's Crypt (67%) and St Bride's Lower (71%). The degree of accuracy for T12 in comparative studies varies from 80.2% (Amores, 2014), 83.3% (Yu et al., 2008) to 87% (MacLaughlin and Oldale, 1992). This study achieved degrees of accuracy of 64% for St Bride's Crypt and 71% for St Bride's Lower. The other studies used multiple parameters rather than just facet size for their equation derivation and this may explain the lower degree of accuracy achieved by this study. Discriminant function equations could not be calculated for C7 in the Anglo-Saxon sample due to a lack of qualifying variables and therefore no comparison for C7 could be drawn for this sample.

In the lumbar region, this study achieved accuracy of between 66% at L3 (St Bride's Crypt) and 78% at L4 (St Bride's Lower). This contrasts with Ostrofsky and Churchill (2015) who achieved 76% at L5 and 85.9% at L3. Once again, St Bride's Lower results compare favourably.

The Anglo-Saxon sample showed a lower degree of statistically significant sex differences in facet size when compared with the other two samples. This is reflected in the lack of

discriminant function equations that could be derived, and hence no results could be generated for the lumbar region for this sample. There are no published equations for discriminant function for facet angle.

Facet size has a significant ability to classify males and females, with a level of accuracy that can be compared relatively favourably with other single bone methods e.g. forearms: 76-86% (Barrier and Abbe, 2008) and humerus: 76-86% (Frutos, 2005). There is, however, the caveat that there must be a sufficient degree of sexual size dimorphism between the sexes in the sample under study. Facet angle is less suitable for separation of males and females due to lack of sexual dimorphism. However, for the vertebral levels where a discriminant equation could be calculated, there was again a significant ability to classify males and females with a reasonably high degree of accuracy. The greatest degree of precision was seen at C3 and L4 in the Anglo-Saxon sample, with percentage accuracy of 83% and 80% respectively.

The value of vertebral discriminant functions in bioarchaeology is limited due to the unknown degree of population specificity. Dimensions of social identity such as age, race or class may actually account for more of the variation in a specific human population than does biological sex (Agarwal, 2012). Furthermore, there has been little inter-population research related to vertebral dimensions and none that considers the remodelling effects of extrinsic factors and their relationship to facet size and angle.

In summary, a reasonable degree of facet size sexual dimorphism can be seen in the St Bride's Crypt and St Bride's Lower samples with less seen in the Anglo-Saxon sample. No vertebra stands out as being more dimorphic than the others, and the cervical region has the least number of statistically significant sex differences in size. There is little sexual dimorphism in facet angle, with the degree of orientation being similar for males and females.

This section has discussed the results relating to sexual dimorphism and the validity of using discriminant functions in the estimation of sex for the samples under investigation. It was noted that there were differing degrees of sexual dimorphism in facet size between the samples. The statistical method of estimating sex criticised by Armelagos et al. (1983:318-9) is not able to offer any valid reason for the differences seen between the samples. The next section summarises the results from exploration of the relationship between extrinsic factors with facet size and angle. Inter-sample differences in these factors may indicate differing levels of physical activity and the gendered division of labour, leading to a greater understanding of populational differences in sexual dimorphism.

7.2 Summary of Results Extrinsic Factors

Whilst sex differences have been studied in a number of post-cranial elements, there has been little attempt to provide a functional interpretation of these differences. This part of the discussion begins with a summary of the results for each extrinsic factor analysed in this study and concludes with a discussion of the overall trends.

7.2.1 Age related changes.

It could be argued that aging is a biological process and not an extrinsic factor, however the process of aging has been shown to alter dimorphic morphology and affect sex determination methods (Walker, 1995) with older individuals tending to become less discriminable between sexes and therefore it is appropriate to include it in this section. The effect of age-related morphological change on facet size and angle was tested in this study. The results show that there is no statistically significant relationship between facet size and angle with age. The lack of significant change with age may be explained by the variation inherent in facet size and angle in a group of individuals of the same age and sex (large standard deviations were recorded for most measurements), thereby masking small changes with increasing age. A further explanation for the lack of change is that longitudinal data was not used to assess true change,

Previous research has identified small but significant changes in spinal dimensions when analysed with respect to age (Erikson, 1976; Jankauskas, 1994; Humphries et al., 1998; Mosekilde and Mosekilde, 1990; Tatarek, 2001). These studies focussed on vertebral body and spinal canal dimensions. Whitmarsh et al. (2012) also found increase in vertebral body width in relation to aging with concurrent decrease in height of the lumbar vertebrae and intervertebral discs. The decrease in height leads to overloading of the facet joints, which increases facet hypertrophy and risk of osteophyte development at the margins of the facets. Facet hypertrophy was not identified in the samples used in this study. Wang and Yang (2009) reported significant differences in sagittal orientation of the lumbar facet joints by age in a clinical sample from a Chinese sample. Their data was collected from CT images rather than from dry bones. The differences between their outcome and the results of the current study may be explained by the different samples and methods used.

The accuracy of age at death estimations, particularly when ageing the skeletons of older individuals, is a key concern in age studies. Jackes (2000) argued that the study of degenerative

or age-related conditions could be limited by the current challenges of accurately estimating the age of death over 50. Age at death estimations assess the physiological age, not the chronological age, of an individual, thereby normally leading to the use of broad age ranges (Campanacho et al., 2012). A conservative approach was used in this study to manage the inaccuracies of precise age estimates. Individuals were assigned to the broad age groups of Young Adult (21-35 years), Middle Adult (36-45 years) and Old Adult (46+ years). To allow for direct comparison between samples, this division of individuals into age groups was also applied to the St Bride's Crypt sample even though the actual age at death for each individual was known.

The St Bride's Crypt data provided a perfect opportunity to test the outcome of using aggregated and disaggregated data to identify any loss of resolution when assessing age related changes in facet size and angle (Section 6.3.6). The results indicate that ascribing an individual to an age group can "dilute" the relationship between facet size and age, with the risk that a small number of strong correlational relationships could be overlooked. The "dilution effect" was not apparent for facet angle. One of the principal effects of using ageing techniques to estimate the age of an individual is to drag the estimated ages of old individuals downwards: this has the effect of reducing age-estimation accuracy in the uppermost age range (Milner and Boldsen, 2012). This can lead to an apparent shortage of individuals aged 46+ and may be a contributory factor to the loss of resolution identified above.

Facet measurements were taken as described in Section 5.2.3. Osteophytes could be seen on facets from some older individuals but were not included in the size measurements (articular surface only), which may account for the differences in size with age seen in other studies.

In summary, no significant changes in facet size and angle with age were identified in the samples used in this study. The large range of variation that occurs within each sample means that the differences in facet size and angle are not statistically significantly different between age groups and therefore it is valid to pool the age groups for comparative purposes.

7.2.2 Sample and Temporal Patterning

There is no single factor that determines the variation in sexual dimorphism between populations, but rather the patterning results from an interaction of many factors (Frayer and Wolpoff, 1985). There is variation in the expression of sexual dimorphism between and within populations (Isçan et al., 1998; Rios-Frutos, 2005 Charisi et al. 2011). Traits that are sexually

dimorphic in one sample may be less so in another, with spatial variation within and between populations (Mall et al., 2001). Variation in average male and female morphology depends on the population; this means that it is necessary to re-evaluate the accuracy of sex estimation from a specific trait each time a new population is studied (Garvin et al., 2014). Low levels of dimorphism can be seen in populations that have experienced environmental stress (e.g. nutritional stress, lower socio-economic status) and high levels in populations that are not subject to high stress levels (Rickland and Tobias, 1986).

Previous research has identified the existence of population specific differences in vertebral morphometrics (Marlow and Pastor, 2011; Yu et al., 2008; Pastor, 2005; Bethard and Seet. 2012). The concept of population/sample specific variation in facet size and angle was explored in this study. All three samples investigated in this study are from South–East England, however they are from different time-periods, socioeconomic groups and environments (urban v rural). The aim was to identify inter-sample variation by comparison of mean measurement values for each facet. Meindl et al. (1985) consider that discriminant function techniques that use multiple linear measurements are population specific and environmentally labile. This theory was tested by comparison of the degree of accuracy with which sex could be estimated using the St Bride's Crypt control group data and substituting the discriminant function equations derived from the St Bride's Lower and Anglo-Saxon samples.

The results from this study showed that there are no statistically significant inter-sample differences for facet size after Bonferroni adjustment was applied. The application of the Bonferroni adjustment reduces the risk of Type I errors but can increase the risk of Type 2 errors where truly important differences can be deemed non-significant (Armstrong, 2014). Pergener (1998) advocates discussing the possible interpretations of each result from multiple testing to reach a reasonable conclusion without the help of Bonferroni adjustments. Applying Perneger's ideas to the results shows that there is little difference in facet size for males and females between St Brides' Crypt and St Bride's Lower for all age groups. This is not an unrealistic result as both samples are from the same area of London and same time period but derive from different socioeconomic groups. Greater inter-sample difference in facet size can be seen between the St Bride's Crypt and Lower groups when compared with the Anglo-Saxon sample, with the Anglo-Saxon facets being predominantly larger (particularly in females). Differences in facet angle were less obvious, however the Anglo-Saxon sample had predominantly greater means than the other two samples. Temporal trends in vertebral size may be a measure of bone remodelling as a result of adaptive mechanisms due to differences

in living conditions and physical activity levels (the Anglo-Saxon sample were from a rural setting with increased physical activity related to working on the land). It is not possible to fully understand the factors that lie behind the decrease in facet size and to a degree facet angle from Anglo-Saxon to Georgian times. Almost certainly, the Anglo-Saxon sample would have undertaken greater physical activity in childhood than the higher ranked Georgian sample (Stoodley, 2011), as the children would have likely helped on the land. There is evidence that there was not a rigid gendered division of labour and, although females had domestic duties to fulfil, they also joined the males in the fields to help with seasonal agricultural activities and the equally strenuous lifestyles of males and females would have begun early in life (Hagen, 2010). The concept that the Anglo-Saxon sample undertook greater activity is not entirely supported by the results achieved in this study when femoral robusticity is compared between the three samples (See next section). Higher levels of physical activity that occur in early life could affect facet size and angle due to phenotypic plasticity. Facet size and angle has evidently decreased from Anglo Saxon times, but it is not possible to give a simple or single explanation for this phenomenon. Low levels of physical activity are thought to be a contributory factor in reduced vertebral size (Junno et al., 2009). Differences in activity levels between rural Anglo-Saxon individuals and Urban Georgian individuals may play a role. Rühli and Henneberg (2003) identified that, from a clinical perspective, there is a lack of research into secular trends in vertebral dimensions. This is an area for further research, answers from which may help to explain the differences seen in this study.

To date, there has been little comparative research exploring differences in facet morphometrics between populations and the significance any such variation may have in terms of accuracy of discriminant function. To address this, the discriminant function equations for sex estimation using facet size from St Bride's Lower and the Anglo-Saxon sample were substituted into the St Bride's Crypt functions and the accuracy of classification achieved was tested for statistically significant difference. The results indicated that the DF were not interchangeable between the samples used in this study. Gapert et al. (2009) expressed concerns over the accuracy of discriminant functions when applied to groups from dissimilar temporal contexts and the results of this study support that concern. The results support the argument for generation of sample specific discriminant functions.

7.2.3 Femoral robusticity

Bone adapts to and is shaped by its mechanical environment (Trinkaus et al., 1994; Ruff, 2008). Mechanical loading, as it relates to lifestyle and habitual activity, plays a leading role in explaining robusticity (Stock, 2006; Martin, 2007), thus inter-sample variation in femoral robusticity may provide evidence of differing lifestyle between the samples in this study.

Previous studies of the relationship between extrinsic factors and post-cranial element size have tended to focus on measures of overall size (Oura, 2016). Ruff (1987) is critical of this approach and argues that size alone is a relatively general and imprecise indicator of biological adaptation. He argues that changes in bone geometry or shape may be more informative as to specific environmental adaptations, in particular, adaptation to mechanical forces that are indicative of functional use and thus behavioural differences (Ruff et al., 1984).

The femur and lumbar vertebrae have a similar function in relation to carrying upper body mass (Junno et al., 2009). Ruff (2008) describes the femoral midshaft section as being phenotypically flexible in response to physical activity, with the cross-sectional dimensions having high correlation with the individual's physical activity level. Similarly, Junno et al., (2009) identified that vertebral body dimensions (height and width) are connected to the individual's overall skeletal robusticity and level of physical activity. In the current study, no clear pattern of correlation between facet size, angle and femoral robusticity was observed for individual facets, however there were a higher number of strong correlations seen in Anglo-Saxons (particularly in females) than in the other two samples. This may support the suggestion that this sample had a more physically active lifestyle than the other groups. However, inter-sample comparison of femoral robusticity did not demonstrate any significant difference between left or right femoral robusticity across all three samples for males and females, which suggests that there was no difference in activity level. This is a somewhat unexpected result, which might be due to the lack of complete femora in the Anglo-Saxon population, thereby skewing the data. This is an area for further research using a larger sample size.

7.2.4 Humeral asymmetry

Humeral asymmetry has the potential to be extrinsic factor relating to facet size and angle. Differential mechanical loading, such as hand preference, is thought to result in bilateral asymmetry of paired elements (Jaskulska, 2009). It could be argued that this trait is the result

of the sexual division of labour as differences in mechanical load experienced as a result of activity by an individual may result in differences in observed bone proportions. There is much behavioural, lifestyle and occupational evidence to demonstrate variable use of the upper limbs both within and between populations (Bridges, 1991).

In this study, the relationship between intra-individual humeral and facet directional asymmetry was explored to understand how physical activity can influence facet size and angle. This analysis was hampered by the lack of intact humeri and cervical vertebra morphometric data, particularly in the female Anglo-Saxon sample, and this should be taken into account when considering the results. The greatest number of strong correlations between humeral and facet asymmetry were observed in the Anglo-Saxon sample, particularly in the thoracic and lumbar regions (no results could be calculated for the Anglo-Saxon female cervical region). The lack of statistical significance after Bonferroni adjustment means that these outcomes should be viewed with caution. No inter-sample difference in humeral directional asymmetry was identified for males and females. This is not an entirely unexpected result given that the humerus and upper arm perform a wide variety of activities and experience a wide variation in mechanical loading (Stirland, 1993; Weiss, 2003). Strong muscle groups insert into the humerus (biceps, latissimus dorsi, teres major, pectoralis major (Moore and Dalley, 2006) and differences in engagement of these muscles may impact on humeral robusticity. Lack of complete elements may have affected the outcome of this analysis.

7.2.5 Osteoarthritis

Intensive physical demands and mechanical strains are implicated in the development of osteoarthritis (OA) (Rogers and Waldron, 1995; Goodman and Martin, 2002; Weiss and Jurmain, 2007). OA is associated with activity leading to its use as an indicator of social stratification and inequality (Woo and Sciulli, 2011; Merbs, 1983). The skeletal distribution and severity of osteoarthritis has been used to reconstruct past societal changes such as gendered division of labour and occupational or habitual activity patterns (Lai and Lovell, 1992; Sofaer Deverenski, 2000; Molnar et al., 2011).

This study is particularly interested in bone plasticity and remodelling and the effect this may have on the degree of sexual dimorphism seen in the facets. Changes in the contour of bones (widening and flattening) are a well-reported effect of osteoarthritis (Waldron, 2009), making this a potentially important extrinsic factor when considering sex differences in facet size and

angle. Factors considered to be important precipitants for osteoarthritis (OA) include age (Prieto-Alhambra et al., 2014), genetic predisposition (Johnson and Hunter, 2014), sex (Cross et al., 2010), race (Chopra, 2013), obesity (De Angelis and Chen, 2013), trauma (Jurmain et al., 2012), vascular (Conaghan et al., 2005) and neurologic factors (Tait and Bird, 1994) and, potentially most important, movement (Jurmain et al., 2012). OA is a disease of articular cartilage and the morphological changes that occur secondarily to breakdown of the cartilage (Larsen, 1997). Movement is thus the essential prerequisite for the development of OA: joints that do not move do not develop OA (Waldron, 2012). If the samples under investigation had dissimilar levels of movement (physical activity or lifestyle), this should manifest as differing degrees of OA in the spine (and other joints). Given that a number of factors affect the frequency and type of OA, it is not possible to directly equate it with type of physical activity or lifestyle, but Larsen (1997) generalised by commenting that populations that had demanding physical lifestyles had more OA than populations living under less demanding circumstances.

The major diagnostic characteristics of OA are considered to be the development of osteophytes and pitting together or eburnation alone (Bourke, 1967; Rogers et al., 1987; Jurmain and Kilgore, 1995; Weiss and Jurmain, 2007). Correlation studies in this thesis revealed that Anglo-Saxon females had the highest levels of strong correlation with facet size for eburnation (cervical region), pitting (cervical region) and osteophyte formation (cervical and thoracic regions), whilst Anglo-Saxon males had the highest levels of strong correlation with facet size for eburnation in the thoracic and lumbar regions. Given the variation in numbers of strong correlations between diagnostic factors with facet size, angle and inter-sample variation in facet size and angle, differences in prevalence rates for the diagnostic factors and also OA were estimated.

Crude prevalence rate is the prevalence of a disease presented as the percentage of individuals displaying pathological changes associated with the disease within the sample group studied (Klaus, 2014). Crude prevalence rates for the OA diagnostic factors were calculated for the three samples in this study to provide an overall picture of OA prevalence. The crude rates indicated inter-sample differences in rates for eburnation and pitting, but no inter-sample differences for osteophyte formation. This method does not always take into account the preservation and observability of the specific skeletal elements than manifest the pathological changes (Dutour, 2008:133). Roberts and Cox (2003:41) argue that crude prevalence can misrepresent the true prevalence because this method assumes that all bones of all skeletons are equally preserved. This is not the case for the samples used in this study; the Anglo-Saxon

sample had a poorer level of bone preservation than the St Bride's samples, therefore, true prevalence rates of OA were also calculated to facilitate inter-sample comparison. True prevalence rates represent a percentage value of the number of facets observed and the number affected by pathological change due to OA (Waldron, 2007: 62). Crude prevalence rates should be presented alongside true prevalence rates for facet joint OA. The number of facets displaying OA in skeletons within a sample is not a direct indicator of the number of individuals who may have been affected by OA. This is because individuals may display varying degrees of vertebral involvement, from one facet to the entire spine. Differences between true and crude prevalence rates between samples may be the result of the involvement of a greater distribution of OA across the spine in some individuals (i.e. OA may have been found on multiple facets in some individuals, increasing the true prevalence). The two methods of calculating prevalence can perform different roles in the analysis of OA of individuals within a sample. While crude prevalence can help aid in understanding the potential extent that facet OA affected the population, true prevalence can provide a more accurate understanding of the distribution of facet OA throughout the spine of individuals.

The different methods used to diagnose OA make inter-assemblage comparison of crude and true prevalence rates difficult. It is not always clear which factors have been used to diagnose OA nor which denominators have been used in the calculation of prevalence (Waldron, 2012). For this reason, only inter-sample prevalence comparison is discussed in this study.

Statistical analysis of the true prevalence rates of the diagnostic features of OA identified differences between the male and female Anglo-Saxon sample and the St Bride's samples for pitting, but not eburnation nor osteophytes. The true prevalence rates for OA are significantly higher for Anglo-Saxon males and females than in the St Bride's sample. No significant difference in prevalence of OA was observed between the St Bride's Crypt and St Bride's Lower males and females. It is well established that the gendered division of labour could result in differences in the prevalence of OA seen between males and females (Bridges, 1992; Larsen et al., 2008). Bridges (1992) identified that males show higher prevalence of OA than females as they are generally involved in more and heavier labour tasks. The data from St Bride's Crypt support this hypothesis, however the lack of significant difference in prevalence of OA between males and females from St Bride's Lower and Anglo-Saxon samples does not.

The differences in true prevalence of OA between the samples cannot directly be linked to specific physical activities however, the differences do indicate differing degrees of physical

activity undertaken between the samples. The only significant inter-sex differences for OA were seen in the St Bride's Crypt sample, indicating that these males and females had differing levels of physical activity whereas the males and females from the other samples may have undertaken the same degree of physical activity. These latter two groups are of lower socioeconomic status and so the distribution of overall activity between the sexes and age groups was probably different from the high socio-economic status St Bride's Crypt group.

Brocher and Willert (1980) report degenerative changes in the cervical region are generally seen in the most flexible part of the cervical spine, in the region of C5-C6. Aufderheide and Rodriguez-Martin (1998) expand this to identify the most commonly affected areas as C6-T1, T2-T5 and L2-L4. Waldron (1991) agrees but uses a broader description of the cervical and upper thoracic regions and also the lower lumbar spine. The cervical spine of males and females from all three samples show the presence of OA, with more found in females than males. Sindermann and Flohr (2007) attribute this to anatomical causes rather than physical workload, describing the female neck as being proportionally longer and less muscular than its male equivalent and therefore more prone to early onset degeneration. Srikanth et al. (2005) undertook a meta-analysis of 40 papers to resolve uncertainty regarding sex differences in prevalence and severity of OA. Eleven of the papers analysed were related to spinal OA. They failed to identify any association between sex, age at onset and prevalence of cervical OA. This supports the finding that physical work rather than anatomy is the precursor to cervical OA.

For the thoracic region, the female mean values of true prevalence between T7 and L5 vary between 1.7 (St Bride's Lower), 4.1 (St Bride's Crypt) to 14.8 (Anglo-Saxon) and male mean true prevalence values between 2.9 (St Bride's Lower), 5.0 (St Bride's Crypt) to 10.8 (Anglo-Saxon). Clearly, there is a lifestyle difference between the St Bride's and Anglo-Saxon samples. Waldron (2012) states that joints that do not move do not develop OA. From this it can be conjectured that St Bride's individuals have a factor that restricts movement of their spines, which in turn inhibits the development of OA. Gibson (2015) examined a number of female skeletons including 18 from St Bride's Lower and identified skeletal markers (flattened spinous processes) consistent with long-term pressure. She was able to calculate waist sizes (derived from coronal rib measurements) and found them to be considerably smaller in the St Bride's Lower group than in modern women. These factors were seen in older individuals and are thought to be a measure of the effect of long-term tight-laced corseting. Corseting was very popular from the 1600's (Bendall, 2014). In the early 19th Century, corseting became very popular and women were expected to wear them, regardless of their socioeconomic status

(Bendall, 2014; Steele, 2010). Male corsets were also worn in the 18th and early 19th century (Cole, 2010; Schwartz, 1979). There are few bioanthropological studies measuring the physical changes caused by corseting, however, Moore and Buckberry (2016) reported on a vertebral compression changes associated with the wearing of a corset identified in a 19th century adult male with Pott's disease of the vertebral column. It is thought that the corset was worn as a corrective treatment for the spinal deformity caused by the Pott's disease. It cannot be precisely determined if the corset was for sartorial rather than medical reasons. Moore and Buckberry (2016) note that the types of thoracic deformation seen in this individual have been described in a small number of female skeletons without TB. The effect of wearing corsets may be a factor in differences in true prevalence of OA from the St Bride's samples when compared to the Anglo-Saxon sample. However, this may be an oversimplification and the differences seen may be due to generally lower levels of physical activity.

The results of this section indicate that the facet joints of Anglo-Saxon individuals were significantly more physically stressed than the St Bride's individuals, which supports the assertion that both sexes were subject to broadly similar forms and levels of stress over the life course. This may be associated with the reduction in degree of sexual dimorphism identified for this group.

7.2.6 Vertebral body osteophytosis

Vertebral osteophytes (osteophytosis) are thought to develop as an adaptive response to joint instability as a result of intervertebral disc degeneration and/or the physiological effects of continual loading through the vertebral column (Nathan et al., 1994). Osteophytosis has been widely studied and shown to be associated with sex and age (Nathan et al., 1994; Sofaer Deverenski, 2000; Snodgrass, 2004). However, the frequency of osteophytosis distribution varies between groups of individuals and increases with age to the extent that Watanabe and Terazawa (2006) consider that osteophytosis formation is very specific to each individual. Lindblom (1951) ascribed differences in osteophytosis distribution to differences in lifestyle from the comparison of spines from Swedish prehistoric skeletons with those of modern living individuals (identifying osteophytosis distribution from radiographs). Studies have identified a higher frequency of osteophytes in males compared to females (Van de Merwe et al., 2006; Kacar et al. 2017). These studies reported that males had a significantly higher frequency of osteophytes than females in the lower segments of the thoracic region and lumbar region. Kacar et al., (2017) suggested that this distribution could be explained by the fact that males

generally have a higher body mass, are more robust, and participate in more strenuous activity than females, thereby leading to greater pressure on the spine and thus the development of more osteophytes. Males or females engaged in heavy manual work are more likely to develop osteophytosis than sedentary workers (Nathan, 1962; O'Neill, 1999). Occupational and lifestyle factors play an important role in the development of osteophytosis, with sex differences in osteophytosis development being more pronounced in the gendered division of labour where heavy physical labour is structured by sex (Kennedy, 1989). The males and females from the Anglo-Saxon sample had a similar pattern of osteophytosis development supporting the hypothesis that there was much less gendered division of labour in terms of overall activity but not in terms of specific activities than in the St Bride's samples. This sample also demonstrated a higher true prevalence of osteophytosis indicating a more physical lifestyle.

Some clinical research has indicated that OA follows and may even result from osteophytosis (Prescher, 1988; Fujiwara et al., 2001; Benoist, 2003). In this study, not all vertebrae with osteophytosis of the vertebral body also have facet joint OA, particularly in the St Bride's samples. This may be because the individuals died before they had time to develop OA.

There are no published studies that look at the relationship between vertebral osteophytosis and facet size and angle. The strongest correlations between vertebral osteophytosis and facet size were seen in Anglo-Saxon males and females, particularly in the cervical (male), thoracic (female) and lumbar (male and female) spines. A similar pattern was seen for facet angle with the strongest correlations being seen in the cervical (male), thoracic and lumbar (male and female) Anglo-Saxon. Increased scores of vertebral osteophytosis are negatively correlated with facet size and angle in many individuals from all three samples. Smaller facets and angles would lead to greater dissipation of load through the vertebral bodies leading to the development of vertebral osteophytosis. This would act as a compensation mechanism to increase the body area.

7.2.7 DFA using Extrinsic Factor Variables

Whilst many studies have successfully used vertebral measurements to estimate sex (MacLaughlin and Oldale, 1992; Liguoro, 1994; Marino, 1995; Wescott, 2000; Marlow and Pastor, 2011; Hou et al., 2012), there has been no attempt to explain differences in degree of sexual dimorphism between samples. The present study demonstrated sexual dimorphism in St Bride's sample facet size. Some facets from the St Bride's Crypt and St Bride Lower samples

have mean metric measurements that are larger in males than females (in agreement with the studies of Wescott, 2000; Yu et al., 2008; Hou et al., 2012 Zheng et al., 2012). The converse is true for the Anglo-Saxon sample, but also associated with little difference facet size sexual dimorphism. The lack of dimorphism seen in the Anglo-Saxon sample meant that it was not possible to generate discriminant function equations to estimate sex for many vertebral levels.

The vertebral measurements used in this study reveal the biological differences between males and females. The effect of biomechanical differences leading to functional adaptation of the facets was assessed by evaluating the relationship between extrinsic factors that are indicative of activity and facet size and angle. Multiple discriminant functions generated from the seven variables (facet size, facet angle, femoral robusticity, humeral and facet asymmetry, eburnation pitting and osteophyte and osteophytosis score) for all vertebrae from the three samples were used to estimate sex. The percentage accuracy of correct classification when using functions that included extrinsic factors was compared to the outcome of using functions derived from facet size or angle alone. Varying degrees of accuracy were obtained when extrinsic factors were included in functions, with T8 and L1 (St Bride's Crypt) and L4 (St Bride's Lower) achieving posterior probability scores of 80% or over. Rogers (1999) reports that this is the generally accepted standard for determining the utility of a sex assessment method with the caveat that it corresponds between methods where true sex is not known. In comparison, functions generated from facet size alone failed to generate posterior probability scores of 80% or over in the St Bride's Crypt sample, but reached that score for C1, C2, T4 and T7 (St Bride's Lower). Functions derived from facet angle achieved a posterior probability of 83% for C3 (Anglo-Saxon) only. The lack of dimorphism in facet angle meant that few functions could be calculated.

The overall results demonstrate that a higher number of discriminant functions can be generated to estimate sex when extrinsic factors are included, particularly in samples that do not demonstrate high degrees of dimorphism.

7.2.8 General discussion

The use of discriminant functions to estimate sex is well established in the field of bioarchaeology (Moore, 2013). Many equations have been created for different skeletal elements with varying degrees of accuracy of classification (Schwartz, 2006). This study clearly demonstrates that vertebral discriminant functions (DF) from a suitably dimorphic sample can

be used for sex classification. However, there are two major limitations to the use of discriminant functions for sex estimation that should be taken into consideration; there must be demonstrable sexual dimorphism in the bones being measured, and the equations are population specific and hence should be developed for each population or region separately (Hora and Sládek, 2018). The lack of sexual dimorphism in facet size between males and females from the Anglo-Saxon sample limited the number of vertebral levels for which functions could be generated. A similar issue arose for facet angle for all three samples. Generation of such discriminant functions was also hampered by poor preservation and missing elements, particularly in the Anglo-Saxon female sample.

The population specificity of discriminant functions is a much-discussed topic (Bidmus and Dayal, 2004; Dabbs, and Moore-Jansen, 2004; Hora and Sládek, 2018), however, few studies attempt to explain the rationale behind this in relation to lifestyle and activity factors. Lower sex classification accuracy is seen in discriminant functions derived from geographically distant samples (Hou et al., 2011). The samples in this study are geographically close but the degree of accuracy achieved when data from St Bride's Lower and Anglo-Saxon samples were substituted into the discriminant functions for St Bride's Crypt were significantly lower for some vertebral levels. There was some reduction in accuracy for St Bride's Lower and a much lower degree of accuracy for the Anglo-Saxon sample, indicating that the derived functions are sample specific. Clearly geographical distance is not the only factor to be considered. Associated environmental factors relating to each population in terms of historical period and socioeconomic status also should be considered.

Previous studies have shown that variation in sexual dimorphism can be used as a sensitive indicator of the quality of life as it has been demonstrated that dimorphism responds to environmental stress (Stini, 1982; Stinson, 1985; Charisi et al., 2011). Major differences in the degree of sexual dimorphism were observed between the St Bride's and the Anglo-Saxon samples. Could this be attributable to socio-economic or lifestyle factors? Sex differences in physical activity would have been a key component affecting dimorphism in the samples under study. Biomechanical force (in the form of physical activity) directly affects bone remodelling (Ruff et al., 2006). Both males and females from the rural Anglo-Saxon samples would have been engaged in hard labour associated with a farming lifestyle (Welch, 2000; Hines, 2003). Documentary evidence exists that there was not a rigid sexual division of labour (Fisher, 1995). Females would have worked in the fields with the males as dictated by the seasons (e.g. harvest) but would also have been associated with spinning and weaving as well as dairy work

and domestic chores such as bread making (Fell, 1984). The lifestyles of males and females would have been equally strenuous and started early in life (Welch, 2000).

St Bride's Lower was known to be a resting place for the poor of the parish, prostitutes, lodgers, the incarcerated from Fleet Street prison or workhouse inmates (Miles and Conheeney, 2010). Miles and Conheeney (2010) identify that those that were working were employed as merchants, craftsmen and artisans, however many individuals were extremely poor and relied on charity and workhouses for survival. The remains of affluent families were buried in St Bride's Crypt, in contrast those of an impoverished society from a different social class and lifestyle were interred in St Bride's Lower.

The pattern and degree of sexual dimorphism seen in the Anglo-Saxon samples differ from that seen in the St Bride's samples. Nutrition, reproduction and physical activity would have played an important role as non-genetic factors influencing vertebral morphology. Nutrition and reproduction are difficult parameters to measure in archaeological samples and therefore, in this study, focus was placed on markers of physical activity. Both sexes from the Anglo-Saxon sample demonstrated similar patterns of eburnation, pitting and osteophytes as a result of degenerative changes (OA). This result is similar to that seen during analysis of a sample from Wharram Percy by Sofaer-Deverenski (2000). The pattern of changes supports the assertion that both sexes were subject to broadly similar forms and levels of physical stress in their lifetime.

Bioarchaeological analysis of rural and urban samples enables comparison between the type and intensity of physical activity. The samples used in this study did not demonstrate inter-sample differences in femoral robusticity (as measured by cross-sectional geometry of the femur) for males or females from rural and urban settings. This does not support the assertion that there are differing levels of physical activity between the sexes in a rural setting. This is a somewhat surprising result. Increasing bone robusticity has long been considered a result of repeated heavy physical activity patterns associated with growing crops (Bridges et al., 2000). However, the relationship between lifestyle and robusticity is not fully understood (Stock and Pfeiffer, 2001; Ruff, 2005). Bone robusticity represents bone strength according to the physical properties of that bone (Stock and Shaw, 2007). The use of external bone measurements to estimate robusticity, whilst still considered an appropriate method to assess mechanical loading (Stock and Shaw. 2007) is being superseded by the use of cross-sectional bone geometry (Stock and Pfeiffer, 2001; Stock and Shaw, 2007; Ruff, 2005). The use of external

measurements has been criticised by Ruff (1987) as these are only a partial reflection of the cross-sectional geometric distribution of bone and cannot measure variation in internal contours, thereby reducing the accuracy with which they can provide information about mechanical loading an individual has undergone. Pearson and Lieberman (2004: 76) suggest that mechanical loads during adulthood have little effect on the external dimensions of long bone diaphyses but result in greater cross-sectional areas from smaller medullary cavities. Ruff and Haynes (1983) documented an increase in femoral robusticity with age but the Campanacho et al. (2012) reported the converse. The age effects on femoral robusticity were not controlled for in the present study, and this may have affected the degree of inter-sample difference observed.

Similarly, there were no significant differences in mean humeral directional asymmetry between the samples or between sexes. This indicates that work undertaken by the individuals in this study was generally similar in magnitude of strength (Mays, 2007), but comparison of mean humeral robusticity failing to identify a single individual who had significant difference in humeral robusticity due to a repetitive one-handed task. A further complication of this analysis was the poor state of preservation of female Anglo-Saxon humeri, thus limiting the conclusions that can be drawn.

This is one of the first studies to examine facet joints for all vertebrae and to test their application for sex estimation in three samples from a similar region of England from different time periods and of varied socioeconomic status. This study examined sexual dimorphism in Georgian and Anglo-Saxon samples and generated nine multivariate discriminant functions for sex estimation with overall accuracy rates of 80% or above (4 for the St Bride's Lower sample based on facet size, 2 for the Anglo-Saxon sample based on facet angle and 3 for the St Bride's Crypt sample based on inclusion of extrinsic factors). The results of this study have implications for the use of discriminant functions for determining sex from vertebral measurements. Generation of discriminant functions for less sexually dimorphic samples using extrinsic factors not only increases the number of functions that can be generated improving the opportunity to estimate sex but also provides evidence for the effects of physical activity on the facets as a factor in the degree of dimorphism seen.

Variations in the accuracy of such techniques have been attributed to population specificity alone. The results of the present study suggest that specific mechanical factors may explain some of the lack of dimorphism seen in the results. Thus, variations in the accuracy of sex

discrimination between different samples may reflect at least partly, the degree of sexual dimorphism in activity patterns in those populations. Environmental factors that may influence dimorphism in a particular historic or socioeconomic setting should be considered and used to test population homogeneity when comparing samples from a similar period. Any future attempts to employ these methods in sex determination should take into account these population differences in behaviour.

Chapter 8 Conclusion

The current study identified two main questions in relation to zygapophyseal joints:

1) Do vertebral facet size and sagittal angle demonstrate sexual dimorphism?

2) Does the inclusion of extrinsic factors (relating to physical activity) in discriminant functions increase the degree of accuracy for sex estimation when there are low levels of sexual dimorphism?

The results of the current study have demonstrated that there is sexual dimorphism in the facet joints, particularly in terms of facet size, however, the degree of dimorphism varies for different samples. This indicates a complexity that has not been previously commented on by other researchers in this field, but partly explains the population specificity of discriminant functions used to estimate sex. The inclusion of extrinsic factors (related to physical activity) allows for generation of discriminant functions for vertebral levels where the degree of sexual dimorphism is too small for derivation from facet size only, thereby increasing the opportunity to estimate the sex of an unknown individual from the same population.

Analysis of facet size sexual dimorphism showed clear difference between males and females from the St Bride's samples but this was less apparent in the Anglo-Saxon sample. Calculation of a sexual dimorphic index for facet size demonstrated a pattern of male dominated indices throughout the spine for St Bride's samples and less so in the Anglo-Saxon sample. A much higher number of facets remained unclassified for sex from their index values in the Anglo-Saxon sample. A different picture was seen when sexual dimorphism indices were calculated for facet angle with many facets being unclassified. In the St Bride's Crypt and Anglo-Saxon sample, a high proportion of lumbar facets were classified as "female". The lumbar facet angles may be due to the deepening of the lumbar lordosis in females during pregnancy, which acts to counterbalance the growing foetal weight (Whitcombe et al., 2007). Overall, there were fewer vertebral levels across all three samples with facet angles showing sexual dimorphism leading to difficulty in generation of discriminant functions. Facet angle is a poor determinant of sex.

Inter-sample comparison of facet size and angle showed a significant difference in facet size and angle particularly between the St Bride's sample and the Anglo-Saxon females. How could these differences be explained? An interesting picture emerged in this study when the

relationship between extrinsic factors and facet size and angle were explored. The use of Bonferroni adjustment to reduce the risk of Type I error (where a true null hypothesis is rejected i.e. creation of a false positive) increased the risk of Type II error (where truly important results are deemed insignificant i.e. creation of a false negative) masking the true number of strong relationships. However, the highest number of strong correlations for each relationship was always seen in the Anglo-Saxon sample in the females for both facet size and angle. These results differentiate this group of females from the others. Given that the strong correlations were between facet morphology and extrinsic factors relating to activity, the implication is that this group undertook a different degree of activity to the other female samples. The results do not indicate a specific activity, only that this group were more physically active. This is a clear indication that facet morphology is moderated by physical activity.

Sexually dimorphic features of the skeleton are of fundamental importance when constructing a biological profile from unidentified human remains. It is not uncommon to encounter broken or poorly preserved skeletons and therefore there is a need to be able to use as many elements as possible for sex determination. Most metric studies of skeletal sexual dimorphism focus on bones that manifest gross size differences whilst avoiding those that do not (Wescott, 2000). However, bioarchaeologists sometimes need to reliably estimate sex from unknown individuals represented by only a few bones. This research aimed to look at the effectiveness with which vertebral facet joints could be used as a predictor of sex and was able to demonstrate that, for a sexually dimorphic sample, a good degree of accuracy of correct classification could be achieved at some vertebral levels. This study also responded to the call from a number of researchers for renewed emphasis on function and shape-related rather than simply size-related characteristics when analysing sex differences in skeletal structure (Van Gerven, 1972; Armelagos et al., 1982; DiBennardo and Taylor, 1982, Ruff, 1987). The present study illustrates one way in which a biomechanical approach, combining behavioural reconstruction with metric analysis, can be used to contribute new insights into this area of research. This study also shows that facet morphology may contain important information regarding past mechanical loading history and thus behavioural patterns.

The study began with a detailed comparison of sexual dimorphism in facet size and angle in three archaeological samples, two from Georgian London of contrasting socioeconomic status and a third from Anglo-Saxon southeast England. Sex differences in facet size were noted in the St Bride's samples with male facet size generally than female. This sex difference was much

lower in the Anglo-Saxon sample with females and males having more comparable facet size. Results were then interpreted in light of functional adaptation as a result of physical activity, leading to the following conclusions:

1) Sexual dimorphism in facet size and of varying degree is characteristic of the samples under study. These results can be compared to many human populations from England to the US, Europe to China (Wescott, 2008; Amores et al., 2014; Yu et al., 2008).
2) There is consistent systematic variation between populations in the degree of sexual dimorphism seen in vertebral facets. This may be related to the gendered division of labour. In this study, the urban samples showed the greatest sexual dimorphism and rural agricultural samples the least. This corresponds to an increase in in the sexual division of labour from rural to urban lifestyle.
3) Techniques for the assessment of sex from vertebral measurements should consider systematic population differences. Inclusion of extrinsic factors related to physical activity, in addition to size measures, may aid in the discrimination between the sexes, whilst providing an understanding of the lifestyle of the sample under study. It is recommended that this process be added to studies of sexual dimorphism to provide evidence of different degrees of physical activity and functional adaptation of the element under study.

In conclusion, in order to gain the most comprehensive understanding of the complexities of sex estimation using the facet joints, it is recommended that the most inclusive method possible should be used. This increases understanding of sample variation and the effects that the gendered division of labour can have on the sexual dimorphism of a joint.

8.1 Future directions

The results from the present study have identified a number of potential avenues through for future research. It would be useful to incorporate geometric 3D data from the samples studied. The method used in this study measures the gross area of the facets without taking facet depth or curvature into account. Information about the depth of curvature of the facet would add another useful dimension for analysis. Furthermore, measurement of femoral cross-sectional geometry would elicit a greater degree of accuracy for robusticity measurements than those derived from metric dimensions. This could be particularly true

when assessing humeral directional asymmetry as it has been suggested that metric dimensions are less asymmetric than geometric ones (Auerbach and Ruff, 2006).

In terms of metric analysis, there is scope for adding more vertebral measurements (e.g. vertebral body height and diameter) to subsequent analyses, which may benefit from the incorporation of more dimensions in line with previously published studies of sex determination from vertebrae. This would identify the optimum data needed to maximise the accuracy of sex classification. The studies previously discussed in Chapter 3 focus on one or two vertebral levels without rationale for choice of level. Application of a multidimensional approach to all vertebrae would help in identifying if certain levels offer a greater degree of classification accuracy.

The lifestyle, occupation and body size of individuals were unknown factors in this study. Each of these factors can have an influence on facet morphology. Whilst lifestyle in terms of physical activity can be assessed by examination of degenerative changes seen on the facets, actual occupation remains unknown. Body size correlates with vertebral body dimensions, with males being larger than females (Gilsantz, 1997). The relationship between body and facet size is not clear from the existing literature and is an area for further investigation. Body size (stature) calculated using Raxter et al.'s (2006) revised Fully method, body weight calculated from femoral head breadth (Auerbach and Ruff, 2004) or other regression equations for incomplete remains (Ruff et al., 2012) could be included as further extrinsic factors and the correlation between them and facet size and angle measured.

Statistically, the number of analyses performed meant that Bonferroni adjustment was applied to reduce the risk of Type 1 errors; this however increased the risk of Type II errors. A true picture of the relationship between facet size/angle and extrinsic factors may not have been seen. This could be addressed by using Bayesian statistical analysis.

The inclusion of extrinsic factors in discriminant functions for the less sexually dimorphic Anglo-Saxon sample allows the generation of discriminant functions for a greater number of vertebral levels than if these factors were ignored. However, when the extrinsic factor functions were used, the percentage degree of accuracy of classification ranged between 47-70% for this sample. Hora and Sládek (2018) demonstrated that increasing the posterior probability in discriminant function analysis increased the percentage accuracy of correct of classification to over 90% for the samples in their study. Application of this method to the Anglo-Saxon sample in this study may increase the degree of certainty of correct classification.

This would lead to greater confidence in estimating sex of individuals whose results fell above the increased prior probability. However, the number of individuals that could not be classified would be increased.

The current study identified many interesting findings in relation to the incorporation of functional adaptation and shape in the analysis of sex differences between samples. Further investigation using a wider range of samples will allow for better understanding of the complexities of sex estimation from vertebrae.

Abbreviations used in appendices

C – cervical

T – thoracic

L-lumbar

Lt- left

R- right

S- superior

I-inferior

H – height

W – width

A-angle

Appendix A. Measure of Intra-Observer Agreement

Appendix A-1 One-way repeated-measures ANOVA for facet width and height

Facet	Wilks' Lambda	P
C1SLW	0.759	0.288
C1SRW	0.989	0.953
C1SLH	0.943	0.769
C1SRH	0.706	0.209
C1ILW	0.976	0.909
C1IRW	0.809	0.384
C1ILH	0.479	0.053
C1IRH	0.887	0.582
C2SLW	0.897	0.552
C2SRW	0.871	0.501
C2SLH	0.954	0.774
C2SRH	0.892	0.563
C2ILW	0.616	0.07
C2IRW	0.802	0.298
C2ILH	0.882	0.502
C2IRH	0.681	0.12
C3SLW	0.967	0.831
C3SRW	0.87	0.466
C3SLH	0.948	0.747
C3SRH	0.788	0.27
C3ILW	0.9	0.561
C3IRW	0.771	0.239
C3ILH	0.666	0.107
C3IRH	0.987	0.93

Appendix A—1 One-way repeated-measures ANOVA for facet width and height continued

Facet	Wilks' Lambda	P
C4SLW	0.852	0.448
C4SRW	0.537	**0.045**
C4SLH	0.925	0.676
C4SRH	0.979	0.9
C4ILW	0.998	0.992
C4IRW	0.85	0.444
C4ILH	0.809	0.386
C4IRH	0.819	0.367
C5SLW	0.78	0.225
C5LRW	0.959	0.779
C5SLH	0.859	0.403
C5SRH	0.897	0.521
C5ILW	0.82	0.305
C5IRW	0.802	0.266
C5ILH	0.922	0.613
C5IRH	0.928	0.639
C6SLW	0.544	**0.035**
C6SRW	0.744	0.196
C6SLH	0.852	0.414
C6SRH	0.872	0.472
C6ILW	0.966	0.825
C6IRW	0.895	0.543
C6ILH	0.995	0.973
C6IRH	0.642	0.087

Appendix A—1 One-way repeated-measures ANOVA for facet width and height continued

Facet	Wilks' Lambda	P
C7SRW	0.961	0.82
C7SLH	0.956	0.782
C7SRH	0.959	0.812
C7ILW	0.803	0.299
C7IRW	0.779	0.253
C7ISH	0.725	0.17
C7IRH	0.893	0.537
T1SLW	0.993	0.963
T1SRW	0.761	0.194
T1SLH	0.933	0.683
T1SRH	0.997	0.985
T1ILW	0.983	0.905
T1IRW	0.56	**0.031**
T1ILH	0.853	0.386
T1IRH	0.789	0.24
T2SLW	0.99	0.93
T2SRW	0.83	0.272
T2SLH	0.849	0.319
T2SRH	0.821	0.252
T2ILW	0.982	0.88
T2IRW	0.899	0.473
T2ILH	0.701	0.083
T2IRH	0.852	0.327

Appendix A—1 One-way repeated-measures ANOVA for facet width and height continued

Facet	Wilks' Lambda	P
T3SLW	0.937	0.613
T3SRW	0.805	0.196
T3SLH	0.824	0.234
T3SRH	0.951	0.684
T3ILW	0.884	0.398
T3IRW	0.887	0.406
T3ILH	0.895	0.433
T3IRH	0.831	0.25
T3SLW	0.976	0.822
T3SRW	0.92	0.512
T4SLH	0.973	0.802
T4SRH	0.811	0.187
T4ILW	0.915	0.515
T4IRW	0.983	0.879
T4ILH	0.951	0.687
T4IRH	0.9	0.455
T5SLW	0.973	0.814
T5SRW	0.975	0.826
T5SLH	0.941	0.634
T5SRH	0.941	0.632
T5ILW	0.88	0.409
T5IRW	0.793	0.197
T5ISH	0.893	0.453
T5IRH	0.94	0.649

Appendix A—1 One-way repeated-measures ANOVA for facet width and height continued

Facet	Wilks' Lambda	P
T6SLW	0.631	**0.032**
T6SRW	0.994	0.956
T6SLH	0.912	0.502
T6SRH	0.949	0.673
T6ISW	0.992	0.946
T6IRW	0.962	0.764
T6ILH	0.612	**0.032**
T6IRH	0.796	0.202
T7SLW	0.966	0.759
T7SRW	0.921	0.52
T7SLH	0.799	0.166
T7SRH	0.929	0.556
T7ILW	0.995	0.96
T7IRW	0.807	0.2
T7ILH	0.811	0.187
T7IRH	0.824	0.235
T8SLW	0.962	0.736
T8SRW	0.78	0.136
T8SLH	0.808	0.182
T8SRH	0.99	0.925
T8ILW	0.885	0.377
T8ILH	0.834	0.233
T8IRH	0.97	0.782
T8IRH	0.9	0.429

Appendix A—1 One-way repeated-measures ANOVA for facet width and height continued

Facet	Wilks' Lambda	P
T9SLW	0.927	0.527
T9SRW	0.895	0.369
T9SLH	0.84	0.209
T9SRH	0.776	0.102
T9ILW	0.869	0.284
T9IRW	0.847	0.223
T9ILH	0.891	0.353
T9IRH	0.875	0.3
T10SLW	0.77	0.095
T10SRW	0.892	0.356
T10SLH	0.704	**0.042**
T10SRH	0.82	0.168
T10ILW	0.772	0.098
T10IRW	0.968	0.749
T10ILH	0.915	0.451
T10IRH	0.994	0.949
T11SLW	0.918	0.505
T11SRW	0.864	0.29
T11SLH	0.683	**0.048**
T11ILW	0.907	0.436
T11IRW	0.967	0.749
T11ILH	0.915	0.47
T11IRH	0.955	0.69

Appendix A—1 One-way repeated-measures ANOVA for facet width and height continued

Facet	Wilks' Lambda	P
T12SLW	0.105	**0.045**
T12SRW	0.074	0.05
T12SLH	0.806	0.177
T12SRH	0.815	0.176
T12ILW	0.608	**0.019**
T12IRW	0.982	0.859
T12ILH	0.962	0.733
T12IRH	0.615	**0.016**
L1SLW	0.469	**0.002**
L1SRW	0.874	0.341
L1SLH	0.878	0.352
L1SRH	0.961	0.727
L1ILW	0.871	0.308
L1ILH	0.959	0.703
L1IRH	0.86	0.278
L2SLW	0.728	0.079
L2SRW	0.959	0.718
L2SLH	0.76	0.112
L2SRH	0.819	0.202
L2ILW	0.878	0.402
L2IRW	0.971	0.804
L2ILH	0.904	0.492
L2IRH	0.931	0.587

Appendix A—1 One-way repeated-measures ANOVA for facet width and height continued

Facet	Wilks' Lambda	P
L3SLW	0.956	0.681
L3SRW	0.998	0.985
L3SLH	0.842	0.232
L3SRH	0.891	0.373
L3ILW	0.976	0.81
L3IRW	0.905	0.43
L3ILH	0.945	0.62
L3IRH	0.884	0.35
L$SLW	0.986	0.884
L4SRW	0.657	**0.028**
L4SLH	0.9	0.408
L4SRH	0.928	0.53
L4ILW	0.924	0.511
L4IRW	0.895	0.388
L4ILH	0.916	0.494
L4IRH	0.963	0.739
L5SLW	0.883	0.393
L5SRW	0.931	0.586
L5SLH	0.869	0.348
L5SRH	0.65	**0.039**
L5ILW	0.965	0.763
L5IRW	0.649	**0.039**
L5ILH	0.772	0.144
L5IRH	0.841	0.272

Appendix A-1 One-way repeated measures ANOVA facet angle

Facet	Wilks' Lambda	P
C1SLA	0.483	0.5
C1SRA	0.566	0.103
C1ILA	0.952	0.843
C1IRA	0.839	0.496
C2SLA	0.725	0.235
C2SRA	0.626	0.122
C2ILA	0.719	0.226
C2IRA	0.986	0.937
C3SLA	0.76	0.291
C3SRA	0.641	0.108
C3ILA	0.98	0.914
C3IRA	0.724	0.863
C4SLA	0.714	0.22
C4SRA	0.936	0.743
C4ILA	0.956	0.834
C4IRA	0.902	0.629
C5SLA	0.963	0.813
C5SRA	0.954	0.773
C5ILA	0.906	0.61
C5IRA	0.527	**0.041**

Appendix A—2 One-way repeated measures ANOVA facet angle continued

Facet	Wilks' Lambda	P
C6SLA	0.879	0.524
C6SRA	0.658	0.123
C6ILA	0.607	0.106
C6IRA	0.929	0.744
C7SLA	0.616	0.113
C7SRA	0.828	0.427
C7ISA	0.606	0.105
C7IRA	0.909	0.65
T1SLA	0.881	0.529
T1SRA	0.71	0.18
T1ILA	0.672	0.137
T1IRA	0.846	0.434
T2SLA	0.883	0.473
T2SRA	0.824	0.313
T2ILA	0.826	0.318
T2IRA	0.956	0.763
T3SLA	0.938	0.66
T3SRA	0.669	0.073
T3ILA	0.789	0.214
T3IRA	0.723	0.122
T4SLA	0.87	0.378
T4SRA	0.951	0.702
T4ILA	0.638	0.054
T4IRA	0.644	0.058

Appendix A—2 One-way repeated measures ANOVA facet angle continued

Facet	Wilks' Lambda	P
T5SLA	0.791	0.218
T5SRA	0.677	0.079
T5ILA	0.612	0.052
T5IRA	0.779	0.223
T6SLA	0.89	0.468
T6SRA	0.549	**0.02**
T6ILA	0.666	0.087
T6IRA	0.717	0.136
T7SLA	0.949	0.695
T7SRA	0.941	0.654
T7ILA	0.578	**0.028**
T7IRA	0.831	0.3
T8SLA	0.913	0.53
T8SRA	0.547	**0.015**
T8ILA	0.807	0.223
T8IRA	0.833	0.279
T9SLA	0.949	0.659
T9SRA	0.745	0.095
T9ILA	0.545	**0.008**
T9IRA	0.752	0.102
T10SLA	0.821	0.206
T10SRA	0.786	0.146
T10ILA	0.734	0.084
T10IRA	0.685	**0.049**

Appendix A—2 One-way repeated measures ANOVA facet angle continued

Facet	Wilks' Lambda	P
T11SLA	0.672	0.051
T11SRA	0.571	**0.015**
T11ILA	0.918	0.527
T11IRA	0.985	0.896
T12SLA	0.83	0.246
T12SRA	0.914	0.509
T12ILA	0.86	0.324
T12IRA	0.994	0.957
L1SLA	0.959	0.748
L1SRA	0.803	0.216
L1ILA	0.69	0.062
L1IRA	0.825	0.237
L2SLA	0.481	**0.006**
L2SRA	0.832	0.275
L2ILA	0.466	**0.015**
L2IRA	0.738	0.162
L3SLA	0.854	0.307
L3SRA	0.631	**0.032**
L3ILA	0.898	0.446
L3IRA	0.897	0.442
L4SLA	0.987	0.907
L4SRA	0.852	0.302
L4ILA	1	1
L4IRA	0.803	0.214

Appendix A—2 One-way repeated measures ANOVA facet angle continued

Facet	Wilks' Lambda	P
L5SLA	0.834	0.307
L5SRA	0.996	0.974
L5ILA	0.932	0.632
L5IRA	0.523	**0.015**

Appendix A-3 Fleiss' Kappa Measure of Agreement for Eburnation

Vertebral Level	N	Measure of Agreement (κ value)	Level of Agreement (Landis and Koch, 1977).
C1LSscore	11	1	Perfect
C1RSscore	11	1	Perfect
C1LSextent	11	1	Perfect
C1RSextent	11	1	Perfect
C1LIscore	10	1	Perfect
C1RIscore	11	1	Perfect
C1LIextent	10	1	Perfect
C1RIextent	10	1	Perfect
C2LSscore	13	1	Perfect
C2RSscore	13	1	Perfect
C2LSextent	13	0.833	Almost Perfect
C2RSextent	13	1	Perfect
C2LIscore	13	0.833	Almost Perfect
C2RIscore	13	1	Perfect
C2LIextent	13	1	Perfect
C2RIextent	13	1	Perfect
C3LSscore	13	1	Perfect
C3RSscore	13	0.966	Almost Perfect
C3LSextent	13	1	Perfect
C3RSextent	13	0.947	Almost Perfect
C3LIscore	13	0.978	Almost Perfect
C3RIscore	13	1	Perfect
C3LIextent	13	1	Perfect
C3RIextent	13	1	Perfect

Appendix A-2 Fleiss' kappa measure of agreement for eburnation continued

Vertebral Level	N	Measure of Agreement (κ value)	Level of Agreement (Landis and Koch, 1977).
C4LSscore	12	1	Perfect
C4Rsscore	12	1	Perfect
C4Lsextent	12	1	Perfect
C4Rsextent	12	1	Perfect
C4Liscore	12	0.902	Almost Perfect
C4Riscore	12	0.947	Almost Perfect
C4Liextent	12	0.928	Almost Perfect
C4Riextent	11	0.949	Almost Perfect
C5Lsscore	14	0.954	Almost Perfect
C5Rsscore	14	1	Perfect
C5Lsextent	14	0.948	Almost Perfect
C5Rsextent	14	1	Perfect
C5Liscore	14	1	Perfect
C5Riscore	14	1	Perfect
C5Liextent	14	1	Perfect
C5Riextent	14	1	Perfect
C6Lsscore	13	1	Perfect
C6Rsscore	13	1	Perfect
C6Lsextent	13	1	Perfect
C6Rsextent	13	0.813	Almost Perfect
C6Liscore	13	0.928	Almost Perfect
C6Riscore	13	1	Perfect
C6Liextent	13	1	Perfect
C6Riextent	13	0.838	Almost Perfect

Appendix A-3 Fleiss' kappa measure of agreement for eburnation continued

Vertebral Level	N	Measure of Agreement (κ value)	Level of Agreement (Landis and Koch, 1977).
C7Lsscore	12	1	Perfect
C7Rsscore	11	1	Perfect
C7Lsextent	12	1	Perfect
C7Rsextent	11	1	Perfect
C7Liscore	13	0.894	Almost Perfect
C7Riscore	12	0.959	Almost Perfect
C7Liextent	12	1	Perfect
C7Riextent	13	1	Perfect
T1Lsscore	14	0.96	Almost Perfect
T1Rsscore	14	0.958	Almost Perfect
T1LSExtent	14	0.588	Moderate
T1RSExtent	14	1	Perfect
T1Liscore	14	1	Perfect
T1Riscore	14	1	Perfect
T1LIExtent	14	0.889	Almost Perfect
T1RIExtent	14	1	Perfect
T2Lsscore	16	1	Perfect
T2Rsscore	16	0.963	Almost Perfect
T2LSExtent	16	1	Perfect
T2RSExtent	16	0.952	Almost Perfect
T2Liscore	16	1	Perfect
T2Riscore	16	0.971	Almost Perfect
T2LISExtent	16	1	Perfect
T2RIExtent	16	1	Perfect

Appendix A-3 Fleiss' kappa measure of agreement for eburnation continued

Vertebral Level	N	Measure of Agreement (κ value)	Level of Agreement (Landis and Koch, 1977).
T3LSscore	17	1	Perfect
T3RSscore	17	1	Perfect
T3LSExtent	17	1	Perfect
T3RSExtent	17	1	Perfect
T3LIscore	17	0.912	Almost Perfect
T3RIscore	17	0.885	Almost Perfect
T3LIExtent	17	0.912	Almost Perfect
T3RIExtent	17	1	Perfect
T4LSscore	18	0.962	Almost Perfect
T4RSscore	18	1	Perfect
T4LSExtent	18	0.634	Substantial
T4RSExtent	18	0.968	Almost Perfect
T4LIscore	18	1	Perfect
T4RIscore	18	0.976	Almost Perfect
T4LIExtent	18	1	Perfect
T4RIExtent	18	0.961	Almost Perfect
T5LSscore	17	0.73	Substantial
T5RSscore	17	0.95	Almost Perfect
T5LSExtent	17	0.927	Almost Perfect
T5RSExtent	17	0.954	Almost Perfect
T5LIscore	17	1	Perfect
T5RIscore	13	1	Perfect
T5LIExtent	16	1	Perfect

Appendix A-3 Fleiss' kappa measure of agreement for eburnation continued

Vertebral Level	N	Measure of Agreement (κ value)	Level of Agreement (Landis and Koch, 1977).
T6LSscore	16	1	Perfect
T6RSscore	17	0.952	Almost Perfect
T6LSExtent	17	1	Perfect
T6RSExtent	17	0.844	Almost Perfect
T6LIscore	16	1	Perfect
T6RIscore	16	0.882	Almost Perfect
T6LIExtent	16	1	Perfect
T6RIExtent	16	1	Perfect
T7LSscore	18	1	Perfect
T7RSscore	18	1	Perfect
T7LSExtent	18	1	Perfect
T7RSExtent	18	0.943	Almost Perfect
T7LIscore	17	0.742	Substantial
T7RIscore	18	0.955	Almost Perfect
T7LIExtent	17	1	Perfect
T7RIExtent	18	1	Perfect
T8LSscore	18	0.971	Almost Perfect
T8RSscore	17	0.661	Substantial
T8LSExtent	18	1	Perfect
T8RSExtent	18	1	Perfect
T8LIscore	18	1	Perfect
T8RIscore	18	0.966	Almost Perfect
T8LIExtent	18	0.926	Almost Perfect
T8RIExtent	18	0.861	Almost Perfect

Appendix A-3 Fleiss' kappa measure of agreement for eburnation continued

Vertebral Level	N	Measure of Agreement (κ value)	Level of Agreement (Landis and Koch, 1977).
T9LSscore	20	0.949	Almost Perfect
T9RSscore	20	0.954	Almost Perfect
T9LSExtent	20	0.844	Almost Perfect
T9RSExtent	20	1	Perfect
T9LIscore	20	0.846	Almost Perfect
T9RIscore	20	0.913	Almost Perfect
T9LIExtent	19	0.907	Almost Perfect
T9RIExtent	19	1	Perfect
T10LSscore	20	0.966	Almost Perfect
T10RSscore	20	0.928	Almost Perfect
T10LSExtent	20	0.936	Almost Perfect
T10RSExtent	20	0.939	Almost Perfect
T10LIscore	20	0.964	Almost Perfect
T10RIscore	20	1	Perfect
T10LIExtent	20	0.942	Almost Perfect
T10RIExtent	20	0.979	Almost Perfect
T11LSscore	19	0.982	Almost Perfect
T11RSscore	19	0.952	Almost Perfect
T11LSExtent	19	1	Perfect
T11RSExtent	19	1	Perfect
T11LIscore	18	0.98	Almost Perfect
T11RIscore	19	1	Perfect
T11LIExtent	19	0.918	Almost Perfect
T11RIExtent	19	1	Perfect

Appendix A-3 Fleiss' kappa measure of agreement for eburnation continued

Vertebral Level	N	Measure of Agreement (κ value)	Level of Agreement (Landis and Koch, 1977).
T12LSscore	19	0.977	Almost Perfect
T12RSscore	19	0.953	Almost Perfect
T12LSExtent	19	0.954	Almost Perfect
T12RSExtent	19	0.975	Almost Perfect
T12LIscore	18	1	Perfect
T12RIscore	18	0.833	Almost Perfect
T12LIExtent	18	0.934	Almost Perfect
T12RIExtent	19	1	Perfect
L1LSscore	18	0.927	Almost Perfect
L1RSscore	18	0.914	Almost Perfect
L1LSextent	18	0.949	Almost Perfect
L1RSextent	18	0.969	Almost Perfect
L1LIscore	19	0.975	Almost Perfect
L1RIscore	19	0.933	Almost Perfect
L1LIextent	19	0.937	Almost Perfect
L1RIextent	19	1	Perfect
L2LSscore	18	0.955	Almost Perfect
L2RSscore	18	0.98	Almost Perfect
L2LSextent	18	0.961	Almost Perfect
L2RSextent	18	0.981	Almost Perfect
L2LIscore	16	1	Perfect
L2RIscore	16	1	Perfect
L2LIextent	16	1	Perfect
L2RIextent	16	0.966	Almost Perfect

Appendix A-3 Fleiss' kappa measure of agreement for eburnation continued

Vertebral Level	N	Measure of Agreement (κ value)	Level of Agreement (Landis and Koch, 1977).
L3LSscore	19	0.95	Almost Perfect
L3RSscore	19	0.927	Almost Perfect
L3LSextent	19	0.94	Almost Perfect
L3RSextent	19	0.984	Almost Perfect
L3LIscore	19	0.925	Almost Perfect
L3RIscore	19	1	Perfect
L3LIextent	19	0.964	Almost Perfect
L3RIextent	19	0.91	Almost Perfect
L4LSscore	19	0.883	Almost Perfect
L4RSscore	19	0.97	Almost Perfect
L4LSextent	19	0.935	Almost Perfect
L4RSextent	19	0.959	Almost Perfect
L4LIscore	19	1	Perfect
L4RIscore	19	1	Perfect
L4LIextent	19	0.928	Almost Perfect
L4RIextent	18	0.96	Almost Perfect
L5LSscore	17	0.944	Almost Perfect
L5RSscore	17	0.907	Almost Perfect
L5LSextent	17	0.984	Almost Perfect
L5RSextent	17	0.985	Almost Perfect
L5LIscore	17	0.986	Almost Perfect
L5RIscore	7	0.983	Almost Perfect
L5LIextent	17	0.908	Almost Perfect
L5RIextent	17	0.984	Almost Perfect

Appendix A-3 Fleiss' kappa measure of agreement for pitting

Vertebral Level	N	Measure of Agreement (κ value)	Level of Agreement (Landis and Koch, 1977).
C1LSscore	12	0.933	Almost Perfect
C1RSscore	12	0.936	Almost Perfect
C1LSextent	12	1	Perfect
C1RSextent	12	0.894	Almost Perfect
C1LIscore	11	0.93	Almost Perfect
C1RIscore	12	0.966	Almost Perfect
C1LIextent	11	0.529	Moderate
C1RIextent	12	0.953	Almost Perfect
C2LSscore	13	0.952	Almost Perfect
C2RSscore	13	0.968	Almost Perfect
C2LSextent	13	0.935	Almost Perfect
C2RSextent	13	1	Perfect
C2LIscore	13	0.967	Almost Perfect
C2RIscore	13	0.888	Almost Perfect
C2LIextent	13	1	Perfect
C2RIextent	13	0.943	Almost Perfect
C3LSscore	13	0.967	Almost Perfect
C3RSscore	13	0.919	Almost Perfect
C3LSextent	13	0.932	Almost Perfect
C3RSextent	13	0.98	Almost Perfect
C3LIscore	13	0.942	Almost Perfect
C3RIscore	13	0.822	Almost Perfect
C3LIextent	13	0.877	Almost Perfect
C3RIextent	13	0.973	Almost Perfect
C4LSscore	12	0.607	Substantial
C4RSscore	12	0.955	Almost Perfect
C4LSextent	12	0.975	Almost Perfect
C4RSextent	12	0.968	Almost Perfect
C4LIscore	12	0.875	Almost Perfect
C4RIscore	12	1	Perfect
C4LIextent	12	0.909	Almost Perfect
C4RIextent	12	0.955	Almost Perfect
C5LSscore	14	0.941	Almost Perfect
C5RSscore	13	0.957	Almost Perfect
C5LSextent	14	0.9	Almost Perfect
C5RSextent	14	0.944	Almost Perfect
C5LIscore	14	0.925	Almost Perfect
C5RIscore	14	0.974	Almost Perfect
C5LIextent	14	0.933	Almost Perfect
C5RIextent	14	0.931	Almost Perfect

Appendix A-4 Fleiss' kappa measure of agreement for pitting continued

Vertebral Level	N	Measure of Agreement (κ value)	Level of Agreement (Landis and Koch, 1977).
C6LSscore	13	1	Perfect
C6RSscore	13	0.935	Almost Perfect
C6LSextent	13	0.982	Almost Perfect
C6RSextent	13	1	Perfect
C6LIscore	13	0.91	Almost Perfect
C6RIscore	13	0.858	Almost Perfect
C6LIextent	13	0.748	Substantial
C6RIextent	13	0.981	Almost Perfect
C7LSscore	13	0.942	Almost Perfect
C7RSscore	11	0.946	Almost Perfect
C7LSextent	12	0.913	Almost Perfect
C7RSextent	11	0.888	Almost Perfect
C7LIscore	12	0.953	Almost Perfect
C7RIscore	12	0.944	Almost Perfect
C7LIextent	12	0.981	Almost Perfect
C7RIextent	12	0.981	Almost Perfect
T1LSscore	15	1	Perfect
T1RSscore	15	0.964	Almost Perfect
T1LSExtent	15	0.985	Almost Perfect
T1RSExtent	15	0.982	Almost Perfect
T1LIscore	14	1	Perfect
T1RIscore	14	0.923	Almost Perfect
T1LIExtent	14	0.925	Almost Perfect
T1RIExtent	14	0.97	Almost Perfect
T2LSscore	16	1	Perfect
T2RSscore	16	1	Perfect
T2LSExtent	16	0.985	Almost Perfect
T2RSExtent	16	1	Perfect
T2LIscore	16	1	Perfect
T2RIscore	15	0.982	Almost Perfect
T2LISExtent	16	1	Perfect
T2RIExtent	16	0.986	Almost Perfect
T3LSscore	17	1	Perfect
T3RSscore	17	0.973	Almost Perfect
T3LSExtent	17	0.97	Almost Perfect
T3RSExtent	17	0.972	Almost Perfect
T3LIscore	16	0.992	Almost Perfect
T3RIscore	17	0.989	Almost Perfect
T3LIExtent	17	0.991	Almost Perfect
T3RIExtent	17	0.987	Almost Perfect

Appendix A-4 Fleiss' kappa measure of agreement for pitting continued

Vertebral Level	N	Measure of Agreement (κ value)	Level of Agreement (Landis and Koch, 1977).
T4LSscore	18	0.99	Almost Perfect
T4RSscore	18	0.884	Almost Perfect
T4LSExtent	18	0.964	Almost Perfect
T4RSExtent	18	0.934	Almost Perfect
T4LIscore	18	0.955	Almost Perfect
T4RIscore	18	0.984	Almost Perfect
T4LIExtent	18	0.948	Almost Perfect
T4RIExtent	18	0.876	Almost Perfect
T5LSscore	18	1	Perfect
T5RSscore	18	0.93	Almost Perfect
T5LSExtent	18	0.973	Almost Perfect
T5RSExtent	18	0.966	Almost Perfect
T5LIscore	16	0.989	Almost Perfect
T5RIscore	17	0.99	Almost Perfect
T5LIExtent	17	1	Perfect
T5RIExtent	17	1	Perfect
T6LSscore	17	0.987	Almost Perfect
T6RSscore	17	0.968	Almost Perfect
T6LSExtent	17	0.91	Almost Perfect
T6RSExtent	17	0.931	Almost Perfect
T6LIscore	16	0.984	Almost Perfect
T6RIscore	16	0.953	Almost Perfect
T6LIExtent	16	0.974	Almost Perfect
T6RIExtent	16	0.54	Moderate
T7LSscore	18	0.973	Almost Perfect
T7RSscore	18	0.981	Almost Perfect
T7LSExtent	18	0.959	Almost Perfect
T7RSExtent	18	1	Perfect
T7LIscore	17	0.987	Almost Perfect
T7RIscore	18	0.992	Almost Perfect
T7LIExtent	17	0.859	Almost Perfect
T7RIExtent	18	0.979	Almost Perfect
T8LSscore	19	0.983	Almost Perfect
T8RSscore	19	0.991	Almost Perfect
T8LSExtent	19	0.981	Almost Perfect
T8RSExtent	19	1	Perfect
T8LIscore	19	0.914	Almost Perfect
T8RIscore	19	0.992	Almost Perfect
T8LIExtent	19	0.978	Almost Perfect
T8RIExtent	19	0.989	Almost Perfect

Appendix A-4 Fleiss' kappa measure of agreement for pitting continued

Vertebral Level	N	Measure of Agreement (κ value)	Level of Agreement (Landis and Koch, 1977).
T9LSscore	20	0.967	Almost Perfect
T9RSscore	20	0.948	Almost Perfect
T9LSExtent	20	0.975	Almost Perfect
T9RSExtent	20	0.938	Almost Perfect
T9LIscore	20	0.896	Almost Perfect
T9RIscore	20	0.945	Almost Perfect
T9LIExtent	19	0.989	Almost Perfect
T9RIExtent	20	0.979	Almost Perfect
T10LSscore	19	0.993	Almost Perfect
T10RSscore	20	1	Perfect
T10LSExtent	20	0.951	Almost Perfect
T10RSExtent	20	0.953	Almost Perfect
T10LIscore	20	0.92	Almost Perfect
T10RIscore	20	0.943	Almost Perfect
T10LIExtent	19	0.969	Almost Perfect
T10RIExtent	20	0.945	Almost Perfect
T11LSscore	19	0.923	Almost Perfect
T11RSscore	19	0.989	Almost Perfect
T11LSExtent	19	0.989	Almost Perfect
T11RSExtent	19	0.979	Almost Perfect
T11LIscore	19	0.923	Almost Perfect
T11RIscore	19	0.989	Almost Perfect
T11LIExtent	19	0.831	Almost Perfect
T11RIExtent	19	0.908	Almost Perfect
T12LSscore	19	0.93	Almost Perfect
T12RSscore	19	0.919	Almost Perfect
T12LSExtent	19	0.959	Almost Perfect
T12RSExtent	19	0.971	Almost Perfect
T12LIscore	18	0.992	Almost Perfect
T12RIscore	19	0.967	Almost Perfect
T12LIExtent	18	0.939	Almost Perfect
T12RIExtent	19	0.847	Almost Perfect
L1LSscore	18	0.984	Almost Perfect
L1RSscore	18	1	Perfect
L1LSextent	18	0.962	Almost Perfect
L1RSextent	18	0.976	Almost Perfect
L1LIscore	19	0.992	Almost Perfect
L1RIscore	19	0.939	Almost Perfect
L1LIextent	19	0.921	Almost Perfect
L1RIextent	19	0.949	Almost Perfect

Appendix A-4 Fleiss' kappa measure of agreement for pitting continued

Vertebral Level	N	Measure of Agreement (κ value)	Level of Agreement (Landis and Koch, 1977).
L2LSscore	18	0.991	Almost Perfect
L2RSscore	18	1	Perfect
L2LSextent	17	1	Perfect
L2RSextent	17	0.988	Almost Perfect
L2LIscore	16	0.991	Almost Perfect
L2RIscore	16	0.934	Almost Perfect
L2LIextent	16	0.943	Almost Perfect
L2RIextent	16	1	Perfect
L3LSscore	19	0.985	Almost Perfect
L3RSscore	19	0.991	Almost Perfect
L3LSextent	19	0.956	Almost Perfect
L3RSextent	19	0.988	Almost Perfect
L3LIscore	19	0.888	Almost Perfect
L3RIscore	19	0.919	Almost Perfect
L3LIextent	19	0.987	Almost Perfect
L3RIextent	19	0.919	Almost Perfect
L4LSscore	19	0.987	Almost Perfect
L4RSscore	19	0.948	Almost Perfect
L4LSextent	19	0.993	Almost Perfect
L4RSextent	19	0.965	Almost Perfect
L4LIscore	19	0.989	Almost Perfect
L4RIscore	19	0.984	Almost Perfect
L4LIextent	19	0.98	Almost Perfect
L4RIextent	18	0.993	Almost Perfect
L5LSscore	19	0.967	Almost Perfect
L5RSscore	18	0.987	Almost Perfect
L5LSextent	17	0.925	Almost Perfect
L5RSextent	17	1	Perfect
L5LIscore	17	0.988	Almost Perfect
L5RIscore	17	0.986	Almost Perfect
L5LIextent	17	0.974	Almost Perfect
L5RIextent	17	0.953	Almost Perfect

Appendix A-4 Fleiss' kappa measure of agreement for osteophytes

Vertebral Level	N	Measure of Agreement (κ value)	Level of Agreement (Landis and Koch, 1977).
C1LSscore	11	1	Perfect
C1RSscore	11	1	Perfect
C1LSextent	11	1	Perfect
C1RSextent	11	1	Perfect
C1LIscore	10	1	Perfect
C1RIscore	11	1	Perfect
C1LIextent	10	1	Perfect
C1RIextent	10	1	Perfect
C2LSscore	13	1	Perfect
C2RSscore	13	1	Perfect
C2LSextent	13	0.833	Almost Perfect
C2RSextent	13	1	Perfect
C2LIscore	13	0.833	Almost Perfect
C2RIscore	13	1	Perfect
C2LIextent	13	1	Perfect
C2RIextent	13	1	Perfect
C3LSscore	13	1	Perfect
C3RSscore	13	0.966	Almost Perfect
C3LSextent	13	1	Perfect
C3RSextent	13	0.947	Almost Perfect
C3LIscore	13	0.978	Almost Perfect
C3RIscore	13	1	Perfect
C3LIextent	13	1	Perfect
C3RIextent	13	1	Perfect
C4LSscore	12	1	Perfect
C4RSscore	12	1	Perfect
C4LSextent	12	1	Perfect
C4RSextent	12	1	Perfect
C4LIscore	12	0.902	Almost Perfect
C4RIscore	12	0.947	Almost Perfect
C4LIextent	12	0.928	Almost Perfect
C4RIextent	11	0.949	Almost Perfect
C5LSscore	14	0.954	Almost Perfect
C5RSscore	14	1	Perfect
C5LSextent	14	0.948	Almost Perfect
C5RSextent	14	1	Perfect
C5LIscore	14	1	Perfect
C5RIscore	14	1	Perfect
C5LIextent	14	1	Perfect
C5RIextent	14	1	Perfect

Appendix A-5 Fleiss' kappa measure of agreement for osteophytes continued

Vertebral Level	N	Measure of Agreement (κ value)	Level of Agreement (Landis and Koch, 1977).
C6LSscore	13	1	Perfect
C6RSscore	13	1	Perfect
C6LSextent	13	1	Perfect
C6RSextent	13	0.813	Almost Perfect
C6LIscore	13	0.928	Almost Perfect
C6RIscore	13	1	Perfect
C6LIextent	13	1	Perfect
C6RIextent	13	0.838	Almost Perfect
C7LSscore	12	1	Perfect
C7RSscore	11	1	Perfect
C7LSextent	12	1	Perfect
C7RSextent	11	1	Perfect
C7LIscore	13	0.894	Almost Perfect
C7RIscore	12	0.959	Almost Perfect
C7LIextent	12	1	Perfect
C7RIextent	13	1	Perfect
T1LSscore	14	0.96	Almost Perfect
T1RSscore	14	0.958	Almost Perfect
T1LSExtent	14	0.588	Moderate
T1RSExtent	14	1	Perfect
T1LIscore	14	1	Perfect
T1RIscore	14	1	Perfect
T1LIExtent	14	0.889	Almost Perfect
T1RIExtent	14	1	Perfect
T2LSscore	16	1	Perfect
T2RSscore	16	0.963	Almost Perfect
T2LSExtent	16	1	Perfect
T2RSExtent	16	0.952	Almost Perfect
T2LIscore	16	1	Perfect
T2RIscore	16	0.971	Almost Perfect
T2LISExtent	16	1	Perfect
T2RIExtent	16	1	Perfect
T3LSscore	17	1	Perfect
T3RSscore	17	1	Perfect
T3LSExtent	17	1	Perfect
T3RSExtent	17	1	Perfect
T3LIscore	17	0.912	Almost Perfect
T3RIscore	17	0.885	Almost Perfect
T3LIExtent	17	0.912	Almost Perfect
T3RIExtent	17	1	Perfect

Appendix A-5 Fleiss' kappa measure of agreement for osteophytes continued

Vertebral Level	N	Measure of Agreement (κ value)	Level of Agreement (Landis and Koch, 1977).
T4LSscore	18	0.962	Almost Perfect
T4RSscore	18	1	Perfect
T4LSExtent	18	0.634	Substantial
T4RSExtent	18	0.968	Almost Perfect
T4LIscore	18	1	Perfect
T4RIscore	18	0.976	Almost Perfect
T4LIExtent	18	1	Perfect
T4RIExtent	18	0.961	Almost Perfect
T5LSscore	17	0.73	Substantial
T5RSscore	17	0.95	Almost Perfect
T5LSExtent	17	0.927	Almost Perfect
T5RSExtent	17	0.954	Almost Perfect
T5LIscore	17	1	Perfect
T5RIscore	13	1	Perfect
T5LIExtent	16	1	Perfect
T5RIExtent	16	1	Perfect
T6LSscore	16	1	Perfect
T6RSscore	17	0.952	Almost Perfect
T6LSExtent	17	1	Perfect
T6RSExtent	17	0.844	Almost Perfect
T6LIscore	16	1	Perfect
T6RIscore	16	0.882	Almost Perfect
T6LIExtent	16	1	Perfect
T6RIExtent	16	1	Perfect
T7LSscore	18	1	Perfect
T7RSscore	18	1	Perfect
T7LSExtent	18	1	Perfect
T7RSExtent	18	0.943	Almost Perfect
T7LIscore	17	0.742	Substantial
T7RIscore	18	0.955	Almost Perfect
T7LIExtent	17	1	Perfect
T7RIExtent	18	1	Perfect
T8LSscore	18	0.971	Almost Perfect
T8RSscore	17	0.661	Substantial
T8LSExtent	18	1	Perfect
T8RSExtent	18	1	Perfect
T8LIscore	18	1	Perfect
T8RIscore	18	0.966	Almost Perfect
T8LIExtent	18	0.926	Almost Perfect
T8RIExtent	18	0.861	Almost Perfect

Appendix A-5 Fleiss' kappa measure of agreement for osteophytes continued

Vertebral Level	N	Measure of Agreement (κ value)	Level of Agreement (Landis and Koch, 1977).
T9LSscore	20	0.949	Almost Perfect
T9RSscore	20	0.954	Almost Perfect
T9LSExtent	20	0.844	Almost Perfect
T9RSExtent	20	1	Perfect
T9LIscore	20	0.846	Almost Perfect
T9RIscore	20	0.913	Almost Perfect
T9LIExtent	19	0.907	Almost Perfect
T9RIExtent	19	1	Perfect
T10LSscore	20	0.966	Almost Perfect
T10RSscore	20	0.928	Almost Perfect
T10LSExtent	20	0.936	Almost Perfect
T10RSExtent	20	0.939	Almost Perfect
T10LIscore	20	0.964	Almost Perfect
T10RIscore	20	1	Perfect
T10LIExtent	20	0.942	Almost Perfect
T10RIExtent	20	0.979	Almost Perfect
T11LSscore	19	0.982	Almost Perfect
T11RSscore	19	0.952	Almost Perfect
T11LSExtent	19	1	Perfect
T11RSExtent	19	1	Perfect
T11LIscore	18	0.98	Almost Perfect
T11RIscore	19	1	Perfect
T11LIExtent	19	0.918	Almost Perfect
T11RIExtent	19	1	Perfect
T12LSscore	19	0.977	Almost Perfect
T12RSscore	19	0.953	Almost Perfect
T12LSExtent	19	0.954	Almost Perfect
T12RSExtent	19	0.975	Almost Perfect
T12LIscore	18	1	Perfect
T12RIscore	18	0.833	Almost Perfect
T12LIExtent	18	0.934	Almost Perfect
T12RIExtent	19	1	Perfect
L1LSscore	18	0.927	Almost Perfect
L1RSscore	18	0.914	Almost Perfect
L1LSextent	18	0.949	Almost Perfect
L1RSextent	18	0.969	Almost Perfect
L1LIscore	19	0.975	Almost Perfect
L1RIscore	19	0.933	Almost Perfect
L1LIextent	19	0.937	Almost Perfect
L1RIextent	19	1	Perfect

Appendix A-5 Fleiss' kappa measure of agreement for osteophytes continued

Vertebral Level	N	Measure of Agreement (κ value)	Level of Agreement (Landis and Koch, 1977).
L2LSscore	18	0.955	Almost Perfect
L2RSscore	18	0.98	Almost Perfect
L2LSextent	18	0.961	Almost Perfect
L2RSextent	18	0.981	Almost Perfect
L2LIscore	16	1	Perfect
L2RIscore	16	1	Perfect
L2LIextent	16	1	Perfect
L2RIextent	16	0.966	Almost Perfect
L3LSscore	19	0.95	Almost Perfect
L3RSscore	19	0.927	Almost Perfect
L3LSextent	19	0.94	Almost Perfect
L3RSextent	19	0.984	Almost Perfect
L3LIscore	19	0.925	Almost Perfect
L3RIscore	19	1	Perfect
L3LIextent	19	0.964	Almost Perfect
L3RIextent	19	0.91	Almost Perfect
L4LSscore	19	0.883	Almost Perfect
L4RSscore	19	0.97	Almost Perfect
L4LSextent	19	0.935	Almost Perfect
L4RSextent	19	0.959	Almost Perfect
L4LIscore	19	1	Perfect
L4RIscore	19	1	Perfect
L4LIextent	19	0.928	Almost Perfect
L4RIextent	18	0.96	Almost Perfect
L5LSscore	17	0.944	Almost Perfect
L5RSscore	17	0.907	Almost Perfect
L5LSextent	17	0.984	Almost Perfect
L5RSextent	17	0.985	Almost Perfect
L5LIscore	17	0.986	Almost Perfect
L5RIscore	7	0.983	Almost Perfect
L5LIextent	17	0.908	Almost Perfect
L5RIextent	17	0.984	Almost Perfect

Appendix B. Results for Facet Size Analyses

Appendix B-1 Descriptive statistics and SDI for facet size

Facet Level	Sample	Male			Female			SDI
		N	Mean	Std dev.	N	Mean	Std dev.	
C1LS	SBC	23	202.09	44.30	32	180.18	38.22	112.16
	SBL	26	206.79	31.34	20	178.35	36.15	115.95
	AS	17	214.66	46.08	10	206.16	35.58	104.12
C1RS	SBC	23	197.85	40.44	32	173.93	39.95	113.75
	SBL	27	207.96	30.28	20	171.05	23.18	121.58
	AS	19	208.42	33.00	10	205.80	36.33	101.27
C1LI	SBC	23	225.49	34.94	32	192.86	27.21	116.92
	SBL	26	222.74	31.19	20	178.90	27.07	124.51
	AS	15	229.23	28.26	9	199.03	51.18	115.17
C1RI	SBC	23	219.30	40.25	32	193.23	34.41	113.49
	SBL	27	222.37	25.87	20	189.45	27.93	117.38
	AS	17	224.00	33.31	10	219.27	19.16	102.16
C2LS	SBC	23	239.24	45.27	35	199.86	33.28	119.7
	SBL	29	234.41	39.40	20	183.83	20.70	127.52
	AS	14	235.17	20.69	14	199.04	45.25	118.15
C2RSA	SBC	23	220.12	46.59	35	187.70	37.14	117.27
	SBL	29	213.22	31.05	20	176.52	29.59	120.79
	AS	17	239.13	48.82	13	198.59	43.20	120.42
C2LI	SBC	22	140.74	74.59	35	97.33	33.51	114.6
	SBL	29	110.48	31.70	20	91.00	22.31	121.41
	AS	13	112.40	31.04	12	125.95	20.34	89.24
C2RI	SBC	22	119.31	30.56	35	98.55	18.71	121.06
	SBL	29	98.33	22.69	20	90.99	26.44	108.06
	AS	14	114.95	25.19	12	112.95	25.71	101.77
C3LS	SBC	19	128.45	71.27	32	98.34	41.27	130.61
	SBL	28	109.85	36.91	21	90.12	25.75	121.89
	AS	17	111.68	28.33	13	101.77	18.71	109.74

Appendix B-1 Descriptive statistics and SDI for facet size continued

Facet Level	Sample	Male			Female			SDI
		N	Mean	Std dev.	N	Mean	Std dev.	
C3RS	SBC	20	115.44	37.32	32	97.73	23.73	118.13
	SBL	28	103.48	22.43	20	94.88	32.23	109.06
	AS	18	114.77	32.57	13	106.10	19.45	108.17
C3LI	SBC	20	130.39	46.97	31	107.03	24.16	121.83
	SBL	27	108.74	32.26	21	101.03	23.68	107.63
	AS	17	129.04	19.73	13	133.85	65.72	96.41
C3RI	SBC	20	115.40	39.22	31	110.57	36.57	104.37
	SBL	28	104.47	24.90	20	103.12	32.39	101.31
	AS	15	131.48	23.81	13	112.71	19.59	116.65
C4LS	SBC	19	119.26	42.87	28	95.87	16.12	124.4
	SBL	29	110.48	37.30	22	92.42	19.89	119.54
	AS	15	117.87	20.49	12	105.33	17.04	111.91
C4RS	SBC	19	124.96	67.67	28	102.94	24.10	121.38
	SBL	29	105.56	28.79	22	98.69	30.70	106.96
	AS	17	115.11	25.61	13	119.67	16.71	96.19
C4LIA	SBC	20	114.13	27.61	29	111.14	35.81	102.69
	SBL	29	108.75	30.86	23	99.54	23.68	109.26
	AS	15	124.37	27.98	12	124.11	28.62	100.21
C4RI	SBC	20	117.72	52.02	29	107.11	32.80	109.91
	SBL	29	106.90	27.71	22	97.27	17.31	109.89
	AS	16	122.37	31.67	12	117.97	14.57	103.72
C5LS	SBC	23	113.58	31.41	34	99.36	33.11	114.31
	SBL	30	103.55	28.23	24	97.04	25.03	106.70
	AS	12	109.75	20.42	14	109.62	21.84	100.12
C5RS	SBC	24	121.68	62.85	34	104.63	31.15	116.29
	SBL	30	104.95	22.07	24	94.30	20.35	111.29
	AS	12	112.44	29.29	14	103.57	19.32	108.56
C55LI	SBC	24	102.58	42.68	34	91.47	19.48	112.14
	SBL	29	105.47	29.95	24	92.12	25.88	114.49
	AS	12	131.18	19.89	13	118.16	26.22	111.02

Appendix B-1 Descriptive statistics and SDI for facet size continued

Facet Level	Sample	Male			Female			SDI
		N	Mean	Std dev.	N	Mean	Std dev.	
C5RI	SBC	24	108.90	56.73	34	96.02	18.99	113.41
	SBL	29	104.29	30.55	24	97.31	25.40	107.17
	AS	12	134.44	37.57	14	112.08	23.81	119.94
C6LS	SBC	20	104.96	40.24	37	91.44	18.33	114.79
	SBL	30	98.89	21.61	23	87.31	18.06	113.27
	AS	14	110.39	23.93	10	109.00	18.26	101.28
C6RS	SBC	20	107.16	50.81	37	89.81	21.39	119.32
	SBL	29	101.48	18.70	24	91.91	16.73	110.41
	AS	15	125.51	34.06	11	111.67	23.72	112.39
C6LIA	SBC	20	109.11	26.92	37	92.39	20.36	118.1
	SBL	31	98.40	22.07	23	86.47	25.26	113.80
	AS	14	157.35	61.12	11	130.38	19.50	120.68
C6RI	SBC	20	73.99	24.29	37	71.38	18.71	103.62
	SBL	30	75.04	17.26	23	66.69	21.81	112.52
	AS	14	114.58	36.17	11	94.48	17.09	121.27
C7LS	SBC	23	92.10	23.49	39	92.40	25.44	99.67
	SBL	32	104.39	30.04	24	86.03	23.97	121.34
	AS	13	138.10	71.29	7	110.21	32.41	125.31
C7RSA	SBC	24	99.46	21.77	38	95.46	22.89	99.67
	SBL	32	106.99	26.64	24	87.77	22.08	121.90
	AS	15	130.39	37.06	8	117.71	27.09	110.77
C7LIA	SBC	25	129.75	32.80	39	114.19	26.51	104.18
	SBL	32	125.86	44.15	24	103.75	35.12	121.32
	AS	15	144.45	34.82	7	135.06	17.03	106.95
C7RI	SBC	25	138.09	37.06	39	114.30	30.43	113.62
	SBL	32	125.11	32.25	24	112.03	27.94	111.68
	AS	16	147.01	40.29	8	147.70	27.89	99.53
T1LS	SBC	23	120.36	41.19	39	118.66	31.75	120.82
	SBL	34	127.79	34.83	22	117.40	42.57	108.85
	AS	15	134.18	44.03	12	129.03	34.29	103.99

Appendix B-1 Descriptive statistics and SDI for facet size continued

Facet Level	Sample	Male			Female			SDI
		N	Mean	Std dev.	N	Mean	Std dev.	
T1RS	SBC	24	133.02	38.17	40	128.18	38.65	101.43
	SBL	34	132.73	34.30	23	117.95	29.82	112.53
	AS	17	134.02	33.87	13	128.52	25.08	104.28
T1LI	SBC	24	110.50	27.31	40	100.96	22.75	103.77
	SBL	35	123.53	33.18	23	98.64	28.61	125.23
	AS	19	133.52	50.36	13	124.50	20.63	107.24
T1RI	SBC	24	112.41	31.28	40	104.02	21.75	109.44
	SBL	35	121.49	31.41	23	98.81	24.42	122.95
	AS	17	136.47	49.44	13	122.13	29.46	111.74
T2LS	SBC	26	112.37	21.40	38	101.78	20.06	108.06
	SBL	34	116.43	27.85	22	92.12	22.43	126.38
	AS	20	126.37	53.20	17	106.13	23.21	119.07
T2RS	SBC	26	115.39	29.44	38	103.75	19.65	110.4
	SBL	35	115.00	25.13	22	94.21	25.10	122.06
	AS	22	126.57	55.86	17	120.04	23.21	105.44
T2LI	SBC	26	109.93	16.43	38	100.88	28.61	111.22
	SBL	34	118.29	30.25	22	92.91	24.66	127.32
	AS	23	115.09	40.86	15	96.04	18.94	119.83
T2RI	SBC	26	111.94	24.83	38	94.20	18.04	108.96
	SBL	34	113.10	28.23	22	99.44	21.51	113.74
	AS	22	112.18	21.28	15	110.33	36.27	101.68
T3LS	SBC	25	99.05	15.53	39	92.47	26.00	118.83
	SBL	29	108.09	30.26	21	82.87	29.13	130.44
	AS	20	110.19	27.09	16	94.31	17.32	116.83
T3RS	SBC	25	104.76	22.58	39	90.66	18.61	107.12
	SBL	30	107.56	30.11	21	92.10	23.35	116.79
	AS	23	109.61	21.32	17	108.16	32.26	101.3
T3LI	SBC	25	103.97	20.96	39	84.27	17.14	115.54
	SBL	30	110.46	27.45	21	88.56	29.16	124.72
	AS	22	105.40	18.43	14	83.84	16.35	125.71

Appendix B-1 Descriptive statistics and SDI for facet size continued

Facet Level	Sample	Male			Female			SDI
		N	Mean	Std dev.	N	Mean	Std dev.	
T3RI	SBC	25	111.93	38.76	39	94.82	29.61	123.37
	SBL	30	117.76	37.42	21	102.85	39.56	114.50
	AS	22	111.08	28.86	16	111.91	27.64	99.25
T4LS	SBC	26	98.85	24.70	37	78.19	17.56	118.04
	SBL	30	105.74	26.90	19	79.26	20.49	133.42
	AS	23	107.92	21.87	18	90.10	19.61	119.78
T4RS	SBC	26	113.11	44.46	36	93.02	28.46	126.42
	SBL	29	104.67	24.43	19	88.18	29.14	118.69
	AS	23	108.18	20.82	18	100.34	22.99	107.82
T4LI	SBC	26	105.87	34.14	36	79.78	16.87	121.59
	SBL	29	101.18	24.83	18	84.06	24.58	120.36
	AS	22	109.96	18.74	16	90.99	18.72	120.86
T4RI	SBC	23	92.34	16.81	25	81.03	17.76	132.7
	SBL	20	97.43	17.18	12	92.17	17.67	105.70
	AS	16	95.24	14.11	12	99.11	13.61	96.10
T5LS	SBC	25	103.35	35.32	37	73.85	17.05	113.96
	SBL	28	89.89	20.09	20	81.75	23.70	109.95
	AS	21	104.77	20.81	17	94.15	20.59	111.28
T5RS	SBC	25	109.19	23.22	37	88.56	24.92	139.95
	SBL	28	109.76	28.91	20	101.88	42.95	107.74
	AS	22	111.73	29.00	17	106.50	25.55	104.91
T5LI	SBC	25	90.35	16.73	36	76.03	22.20	123.29
	SBL	26	99.54	25.86	20	87.08	25.24	114.32
	AS	19	101.72	26.57	15	88.75	21.41	114.62
T5RI	SBC	25	97.27	27.93	36	79.70	24.29	118.84
	SBL	28	101.70	29.55	20	85.28	23.20	119.25
	AS	20	124.62	36.53	15	100.48	26.65	124.02
T6LS	SBC	26	88.53	20.97	36	74.69	21.21	122.04
	SBL	31	96.11	22.65	21	80.49	23.77	119.41
	AS	18	95.78	26.33	14	83.90	12.41	114.15

Appendix B-1 Descriptive statistics and SDI for facet size continued

Facet Level	Sample	Male			Female			SDI
		N	Mean	Std dev.	N	Mean	Std dev.	
T6RS	SBC	26	88.79	22.90	36	80.37	19.59	118.53
	SBL	31	101.04	28.11	21	84.77	26.15	119.19
	AS	18	115.16	30.08	14	90.29	19.00	127.54
T6LI	SBC	26	95.87	19.11	38	73.31	17.82	110.47
	SBL	29	94.17	19.50	21	74.64	18.90	126.16
	AS	17	105.38	30.78	14	89.19	25.87	118.16
T6RI	SBC	26	88.34	14.98	38	73.55	21.57	130.77
	SBL	28	85.59	14.58	21	68.51	16.80	124.94
	AS	17	97.36	20.75	14	85.92	16.79	113.32
T7LS	SBC	26	93.50	18.05	38	74.41	17.56	120.11
	SBL	31	89.02	18.77	20	69.39	14.28	128.29
	AS	16	98.69	19.13	17	85.90	15.59	114.89
T7RS	SBC	26	92.57	22.98	38	74.12	15.57	125.66
	SBL	32	87.08	19.39	19	68.09	13.16	127.89
	AS	16	98.69	19.13	17	85.90	15.59	114.89
T7LI	SBC	25	90.68	15.13	38	74.30	16.77	124.89
	SBL	30	92.53	18.76	20	75.34	14.25	122.81
	AS	14	94.86	24.11	17	95.71	20.55	99.11
T7RI	SBC	25	81.29	12.65	38	70.91	16.55	122.04
	SBL	31	85.12	13.35	20	64.71	13.72	131.55
	AS	14	94.62	21.05	15	97.30	16.64	97.25
T8LS	SBC	25	89.17	21.24	36	76.55	14.58	114.64
	SBL	33	87.37	15.30	20	66.88	12.71	130.64
	AS	17	102.80	21.35	17	93.52	18.13	109.92
T8RS	SBC	25	168.50	34.07	36	145.94	30.25	116.49
	SBL	33	171.15	33.86	20	130.95	24.43	130.70
	AS	18	98.54	24.31	18	101.09	23.15	97.48
T8LI	SBC	26	101.10	26.36	36	81.98	27.26	115.46
	SBL	33	100.90	21.00	18	77.80	16.85	129.69
	AS	18	110.11	26.41	16	101.65	16.07	108.32

Appendix B-1 Descriptive statistics and SDI for facet size continued

Facet Level	Sample	Male			Female			SDI
		N	Mean	Std dev.	N	Mean	Std dev.	
T8RI	SBC	26	95.65	28.70	36	77.87	23.76	123.32
	SBL	33	87.19	16.94	19	72.99	14.00	119.45
	AS	18	110.11	26.41	16	101.65	16.07	108.32
T9LS	SBC	26	96.97	28.76	39	84.26	22.10	122.84
	SBL	31	91.89	22.06	20	70.29	16.54	130.74
	AS	18	107.93	26.28	18	100.30	18.86	107.61
T9RS	SBC	26	101.52	32.13	39	81.16	21.71	115.08
	SBL	31	88.82	19.39	20	72.09	14.28	123.21
	AS	18	98.54	24.31	18	101.09	23.15	97.48
T9LI	SBC	25	114.89	30.84	39	95.32	25.87	120.53
	SBL	31	110.61	31.45	20	84.37	20.10	131.11
	AS	17	114.21	21.67	16	101.90	23.66	112.08
T9RI	SBC	25	107.37	29.24	38	83.91	16.06	127.95
	SBL	29	97.58	27.22	20	76.24	15.06	127.98
	AS	16	122.83	32.48	16	96.33	21.95	127.51
T10LS	SBC	25	100.16	17.50	39	87.92	22.81	113.93
	SBL	30	98.30	19.87	20	82.24	16.63	119.54
	AS	19	109.22	19.32	14	108.06	21.97	101.07
T10RS	SBC	25	102.09	21.71	39	83.99	21.23	121.56
	SBL	31	92.54	21.14	20	76.18	18.25	121.47
	AS	18	115.59	18.77	14	106.65	23.93	108.38
T10LI	SBC	26	133.17	38.92	39	96.97	31.50	137.33
	SBL	30	128.37	43.06	20	94.21	20.79	136.26
	AS	19	125.63	24.94	14	109.26	13.50	114.99
T10RI	SBC	26	114.58	26.40	39	89.16	29.91	128.51
	SBL	30	111.57	36.34	20	76.97	20.03	144.95
	AS	19	123.34	20.31	14	127.06	40.96	97.07
T11LS	SBC	26	128.99	31.72	39	106.80	34.30	120.77
	SBL	28	126.91	38.58	20	92.51	22.21	137.19
	AS	15	130.87	31.58	14	112.81	18.00	116.01

Appendix B-1 Descriptive statistics and SDI for facet size continued

Facet Level	Sample	Male			Female			SDI
		N	Mean	Std dev.	N	Mean	Std dev.	
T11RS	SBC	26	105.40	30.50	39	84.55	17.06	124.66
	SBL	29	105.06	24.38	21	81.78	20.13	128.45
	AS	19	126.90	26.35	15	127.90	49.44	99.22
T11LI	SBC	25	108.36	29.19	39	88.63	22.42	122.27
	SBL	28	107.76	32.17	21	84.99	28.52	126.79
	AS	18	134.07	43.90	15	108.05	19.53	124.08
T11RI	SBC	25	113.55	32.81	39	84.04	31.72	135.11
	SBL	29	104.13	30.09	21	89.62	36.16	116.19
	AS	16	137.05	39.40	12	110.24	20.19	124.31
T12LS	SBC	24	117.83	40.44	37	92.22	25.89	127.76
	SBL	28	105.33	42.62	21	75.81	21.49	138.93
	AS	14	121.71	42.54	15	114.98	25.63	105.85
T12RS	SBC	24	117.64	42.12	37	92.79	33.47	126.79
	SBL	29	106.18	32.52	21	86.66	32.01	122.53
	AS	14	122.37	35.69	15	102.75	33.80	119.09
T12LI	SBC	25	111.30	30.54	37	94.31	25.80	118.01
	SBL	29	113.00	29.86	21	90.82	21.99	124.42
	AS	14	128.58	42.48	12	115.37	23.11	111.44
T12RI	SBC	25	108.05	23.54	37	98.30	30.75	109.92
	SBL	29	108.94	35.19	21	92.76	18.95	117.44
	AS	13	118.37	32.10	14	109.70	32.89	107.90
L1LS	SBC	25	151.06	40.49	36	130.01	43.59	116.19
	SBL	28	144.23	42.79	20	118.25	33.27	121.96
	AS	16	150.38	54.87	17	152.48	30.03	98.62
L1RS	SBC	25	162.70	38.68	35	129.40	51.59	125.73
	SBL	28	146.83	39.26	20	134.75	55.59	108.97
	AS	15	162.83	61.81	15	161.05	41.82	101.11
L1LI	SBC	25	144.31	32.60	36	121.38	32.29	118.89
	SBL	29	149.42	42.85	20	119.30	27.88	125.25
	AS	15	149.24	39.90	17	138.30	25.71	107.91

Appendix B-1 Descriptive statistics and SDI for facet size continued

Facet Level	Sample	Male			Female			SDI
		N	Mean	Std dev.	N	Mean	Std dev.	
L1RI	SBC	25	139.91	33.86	35	125.78	39.38	111.23
	SBL	28	154.48	41.60	20	122.03	26.07	126.59
	AS	16	156.80	40.72	16	145.01	42.54	108.13
L2LS	SBC	26	187.56	46.80	36	150.65	46.48	124.5
	SBL	29	194.95	64.68	20	139.18	26.12	140.07
	AS	18	199.63	40.34	14	184.48	29.27	108.21
L2RS	SBC	26	192.53	43.52	36	160.01	48.60	120.33
	SBL	28	199.07	60.52	18	156.48	38.45	127.22
	AS	18	209.62	52.28	14	188.30	39.64	111.32
L2LI	SBC	26	172.98	37.88	36	136.62	29.67	126.61
	SBL	30	169.38	42.85	19	137.72	25.23	122.99
	AS	17	179.75	40.64	14	162.01	45.09	110.95
L2RI	SBC	26	173.07	32.68	36	142.47	30.94	121.48
	SBL	30	171.70	47.76	19	142.83	32.35	120.21
	AS	17	164.97	44.65	15	169.26	33.14	97.47
L3LS	SBC	26	208.48	53.73	37	175.28	45.71	118.94
	SBL	26	206.86	58.91	20	169.58	42.95	121.98
	AS	17	214.49	63.05	19	202.88	47.66	105.72
L3RS	SBC	26	209.99	49.50	35	175.77	42.51	119.46
	SBL	25	225.62	70.20	18	167.62	43.18	134.60
	AS	15	222.04	77.23	14	221.91	46.93	100.06
L3LI	SBC	26	175.96	45.36	37	147.78	34.05	119.07
	SBL	27	179.27	30.29	21	144.52	33.88	124.05
	AS	18	187.31	43.08	18	155.90	35.02	120.15
L3RI	SBC	26	165.86	41.00	37	150.59	33.79	110.14
	SBL	26	183.41	39.79	21	157.24	37.63	116.64
	AS	16	196.92	44.35	17	161.59	29.66	121.87
L4LS	SBC	26	221.07	43.82	38	189.91	49.95	116.41
	SBL	25	223.99	44.75	15	178.61	38.64	125.41
	AS	19	250.43	55.28	17	228.04	66.60	109.82

Appendix B-1 Descriptive statistics and SDI for facet size continued

Facet Level	Sample	Male			Female			SDI
		N	Mean	Std dev.	N	Mean	Std dev.	
L4RS	SBC	26	230.80	54.88	38	202.90	56.61	113.75
	SBL	26	229.59	54.27	15	197.21	69.40	116.42
	AS	20	243.20	47.13	17	223.09	51.63	109.01
L4LI	SBC	26	194.60	45.90	38	160.06	42.95	121.58
	SBL	25	200.33	50.49	16	159.54	64.56	125.57
	AS	19	201.84	30.04	15	200.17	49.06	100.83
L4RI	SBC	26	186.89	48.95	38	169.98	49.49	109.95
	SBL	26	191.36	51.88	16	162.69	55.93	117.62
	AS	18	196.90	37.27	15	196.72	44.58	100.09
L5LS	SBC	25	240.03	60.15	34	194.06	44.87	123.69
	SBL	29	254.41	56.03	19	192.10	41.35	132.43
	AS	17	263.92	48.34	15	250.05	54.81	105.55
L5RS	SBC	25	240.15	48.60	34	204.17	42.21	117.62
	SBL	27	243.36	60.64	19	208.01	79.35	117.00
	AS	16	272.32	48.95	15	242.60	62.01	112.25
L5LI	SBC	25	224.41	58.71	34	186.29	55.61	120.46
	SBL	29	213.87	46.94	19	183.93	59.11	116.28
	AS	16	238.04	55.61	14	207.60	34.62	114.66
L5RI	SBC	25	222.28	50.01	34	188.39	47.43	117.99
	SBL	28	221.22	45.48	19	194.85	56.90	113.53
	AS	17	243.72	53.99	15	221.38	48.27	110.09

Key: C=Cervical, T=Thoracic, L=Lumbar, Number = Vertebral level, R=Right, L=Left, S=Superior, I = Inferior, Std Dev = Standard Deviation, SDI = Sexual dimorphism Index

Appendix B-2 Mann-Whitney U test for sex differences in facet size

Facet Level	SBC		SBL		AS	
	Mann-Whitney U	p	Mann-Whitney U	p	Mann-Whitney U	p
C1LS	285.50	0.16	128.00	**<0.001**	81.00	0.84
C1RS	247.00	0.04	79.00	**<0.001**	85.50	0.66
C1LI	163.00	**<0.001**	72.00	**<0.001**	39.00	0.09
C1RI	249.00	0.04	111.00	**<0.001**	72.00	0.51
C2LS	194.50	**<0.001**	70.00	**<0.001**	40.00	0.01
C2RS	215.00	**<0.001**	117.00	**<0.001**	58.00	0.03
C2LI	171.00	**<0.001**	173.00	0.02	50.00	0.13
C2RI	231.00	0.01	206.00	0.09	77.00	0.72
C3LS	162.00	0.01	194.00	0.04	94.00	0.49
C3RS	224.50	0.07	210.00	0.14	100.00	0.50
C3LI	210.00	0.05	233.00	0.29	81.00	0.22
C3RI	289.00	0.69	250.00	0.53	50.00	0.03
C4LS	168.00	0.03	198.00	0.02	53.00	0.07
C4RS	208.00	0.21	240.00	0.13	96.00	0.54
C4LI	240.00	0.31	248.00	0.12	88.00	0.92
C4RI	254.00	0.46	236.00	0.11	86.00	0.64
C5LS	263.00	0.04	308.50	0.37	83.00	0.96
C5RS	320.00	0.16	261.00	0.08	73.00	0.57
C55LI	371.00	0.56	258.00	0.11	45.00	0.07
C5RI	391.00	0.79	303.00	0.42	48.00	0.06
C6LS	300.00	0.24	211.00	0.02	67.00	0.86
C6RS	295.00	0.21	240.00	0.05	62.50	0.30
C6LI	223.50	0.01	236.00	0.04	60.00	0.35
C6RI	358.00	0.84	251.00	0.09	49.00	0.13
C7LS	427.00	0.75	227.00	0.01	35.00	0.41
C7RS	394.00	0.37	219.00	0.01	51.00	0.56
C7LI	332.00	0.03	221.00	0.01	43.50	0.53
C7RI	269.00	**<0.001**	297.00	0.15	62.00	0.90

Appendix B-2 Mann-Whitney U test for sex differences in facet size continued

Facet Level	SBC		SBL		AS	
	Mann-Whitney U	p	Mann-Whitney U	p	Mann-Whitney U	p
T1LS	437.00	0.87	268.00	0.08	85.00	0.81
T1RS	454.00	0.72	304.00	0.16	104.00	0.79
T1LI	367.00	0.12	201.00	**<0.001**	123.00	0.98
T1RI	359.00	0.09	240.00	0.01	92.00	0.44
T2LS	336.00	0.03	167.00	**<0.001**	139.00	0.34
T2RS	375.00	0.10	200.00	**<0.001**	180.00	0.84
T2LI	303.00	0.01	145.00	**<0.001**	106.50	0.05
T2RI	260.00	**<0.001**	267.00	0.07	162.00	0.93
T3LS	318.00	0.02	122.00	0.00	97.00	0.04
T3RS	297.00	0.01	215.50	0.06	174.50	0.57
T3LI	240.50	**<0.001**	158.00	**<0.001**	55.00	**<0.001**
T3RI	322.00	0.02	228.00	0.10	171.00	0.88
T4LS	226.00	**<0.001**	95.00	**<0.001**	117.00	0.02
T4RS	288.00	0.01	172.00	0.03	145.00	0.10
T4LI	199.00	**<0.001**	144.00	0.01	68.00	**<0.001**
T4RI	173.00	0.02	106.00	0.59	80.00	0.46
T5LS	136.00	**<0.001**	196.00	0.08	120.00	0.09
T5RS	241.00	**<0.001**	200.00	0.09	174.00	0.71
T5LI	229.00	**<0.001**	178.00	0.07	101.00	0.15
T5RI	246.00	**<0.001**	182.00	0.04	80.00	0.02
T6LS	261.00	**<0.001**	190.50	0.01	89.00	0.16
T6RS	346.00	0.08	191.50	0.01	71.00	0.04
T6LI	168.00	**<0.001**	138.00	**<0.001**	81.00	0.13
T6RI	221.50	**<0.001**	123.00	**<0.001**	78.00	0.10
T7LS	201.00	**<0.001**	113.00	**<0.001**	93.00	0.19
T7RS	218.00	**<0.001**	116.00	**<0.001**	82.00	0.05
T7LI	219.00	**<0.001**	147.00	**<0.001**	109.00	0.69
T7RI	246.50	**<0.001**	87.00	**<0.001**	97.50	0.74

Appendix B-2 Mann-Whitney U test for sex differences in facet size continued

Facet Level	SBC		SBL		AS	
	Mann-Whitney U	p	Mann-Whitney U	p	Mann-Whitney U	p
T8LS	289.00	0.02	92.00	**<0.001**	106.00	0.18
T8RS	283.00	0.01	109.00	**<0.001**	88.00	0.05
T8LI	223.00	**<0.001**	123.00	**<0.001**	118.00	0.25
T8RI	220.00	**<0.001**	171.00	0.01	114.00	0.30
T9LS	351.00	0.04	129.00	**<0.001**	132.00	0.34
T9RS	293.00	**<0.001**	155.00	**<0.001**	153.00	0.78
T9LI	293.00	0.01	126.00	**<0.001**	92.00	0.11
T9RI	237.00	**<0.001**	129.00	**<0.001**	68.00	0.02
T10LS	299.00	0.01	162.00	0.01	117.00	0.56
T10RS	260.00	**<0.001**	169.00	0.01	90.00	0.17
T10LI	208.00	**<0.001**	152.00	**<0.001**	71.00	0.02
T10RI	234.00	**<0.001**	118.00	**<0.001**	112.00	0.44
T11LS	292.00	**<0.001**	111.00	**<0.001**	61.00	0.05
T11RS	288.00	**<0.001**	148.00	**<0.001**	120.00	0.44
T11LI	274.00	**<0.001**	173.00	0.01	85.00	0.07
T11RI	211.00	**<0.001**	222.00	0.10	51.00	0.04
T12LS	250.00	**<0.001**	166.00	0.01	96.00	0.69
T12RS	294.00	0.03	198.50	0.04	75.00	0.19
T12LI	331.00	0.06	148.00	**<0.001**	75.00	0.64
T12RI	340.00	0.08	222.00	0.10	75.00	0.44
L1LS	335.00	0.09	164.00	0.02	123.00	0.64
L1RS	244.00	**<0.001**	206.00	0.12	110.00	0.92
L1LI	281.00	0.01	160.00	0.01	112.00	0.56
L1RI	326.00	0.09	146.00	0.01	99.00	0.27
L2LS	260.00	**<0.001**	113.00	**<0.001**	94.00	0.22
L2RS	264.00	**<0.001**	131.00	0.01	91.00	0.18
L2LI	211.00	**<0.001**	156.00	0.01	89.00	0.23
L2RI	254.00	**<0.001**	181.00	0.03	108.00	0.46

Appendix B-2 Mann-Whitney U test for sex differences in facet size continued

Facet Level	SBC		SBL		AS	
	Mann-Whitney U	p	Mann-Whitney U	p	Mann-Whitney U	p
L3LS	306.00	0.01	154.00	0.02	145.00	0.60
L3RS	266.00	0.01	108.00	**<0.001**	98.00	0.76
L3LI	308.00	0.02	95.00	**<0.001**	89.00	0.02
L3RI	340.00	0.05	154.00	0.01	70.00	0.02
L4LS	293.50	0.01	66.00	**<0.001**	127.00	0.27
L4RS	344.00	0.04	118.00	0.04	131.00	0.23
L4LI	249.00	**<0.001**	102.00	0.01	136.00	0.82
L4RI	383.00	0.13	123.00	0.03	131.00	0.89
L5LS	224.00	**<0.001**	99.00	**<0.001**	101.00	0.32
L5RS	239.00	**<0.001**	139.00	0.01	96.00	0.34
L5LI	252.00	0.01	158.00	0.01	80.00	0.18
L5RI	244.00	0.01	165.00	0.03	92.00	0.18

Key: C=Cervical, T=Thoracic, L=Lumbar, Number = Vertebral level, R=Right, L=Left, S=Superior,

I = Inferior,

Appendix B-3 Kruskal-Wallace test for differences in facet size with age group

Facet	Sample	Male Size		Female Size	
		Chi-Square	P Value	Chi-Square	P Value
C1LS	SBC	0.32	0.85	0.27	0.88
	SBL	0.31	0.86	0.57	0.75
	AS	1.12	0.57	1.32	0.25
C1RS	SBC	2.67	0.26	0.21	0.90
	SBL	1.75	0.42	0.15	0.93
	AS	2.48	0.29	0.88	0.35
C1LI	SBC	1.25	0.54	13.33	<0.01
	SBL	0.02	0.99	6.20	0.05
	AS	3.75	0.15	0.06	0.81
C1RI	SBC	0.72	0.70	5.96	0.05
	SBL	0.48	0.79	5.42	0.07
	AS	0.79	0.67	1.32	0.25
C2LS	SBC	1.15	0.56	6.03	0.05
	SBL	0.02	0.99	2.43	0.30
	AS	0.39	0.82	4.51	0.11
C2RS	SBC	1.62	0.44	6.03	0.05
	SBL	1.16	0.56	4.12	0.13
	AS	1.05	0.59	2.19	0.33
C2LI	SBC	6.29	0.04	1.03	0.60
	SBL	4.76	0.09	1.67	0.43
	AS	2.60	0.27	2.55	0.28
C2RI	SBC	0.02	0.99	2.61	0.27
	SBL	1.66	0.44	4.94	0.08
	AS	2.79	0.25	8.11	0.02
C3LS	SBC	0.73	0.70	0.45	0.80
	SBL	2.53	0.28	2.69	0.26
	AS	2.68	0.26	3.00	0.22

Appendix B-3 Kruskal-Wallace test for differences in facet size with age group continued

Facet	Sample	Male Size		Female Size	
		Chi-Square	P Value	Chi-Square	P Value
C3RS	SBC	1.10	0.58	1.63	0.44
	SBL	0.01	0.99	2.69	0.26
	AS	2.87	0.24	5.40	0.07
C3LI	SBC	6.53	0.04	0.58	0.75
	SBL	1.99	0.37	7.63	0.02
	AS	0.34	0.85	1.39	0.50
C3RI	SBC	1.15	0.56	0.88	0.64
	SBL	4.96	0.08	2.14	0.34
	AS	2.88	0.24	4.17	0.12
C4LS	SBC	1.29	0.52	1.52	0.47
	SBL	0.94	0.63	8.02	0.02
	AS	2.94	0.23	3.72	0.16
C4RS	SBC	0.11	0.95	1.88	0.39
	SBL	1.29	0.53	2.81	0.24
	AS	1.07	0.59	1.16	0.56
C4LI	SBC	2.73	0.26	0.48	0.79
	SBL	0.21	0.90	7.67	0.02
	AS	0.24	0.89	3.90	0.14
C4RI	SBC	0.90	0.64	1.45	0.48
	SBL	0.90	0.64	8.14	0.02
	AS	3.72	0.16	2.05	0.36
C5LS	SBC	1.76	0.41	3.02	0.22
	SBL	0.16	0.92	10.82	<0.01
	AS	1.04	0.59	0.22	0.90
C5RS	SBC	0.40	0.82	2.43	0.30
	SBL	1.70	0.43	7.38	0.02
	AS	5.56	0.06	1.71	0.43
C55LI	SBC	2.86	0.24	0.15	0.93
	SBL	1.41	0.49	3.87	0.14
	AS	3.81	0.15	7.81	0.02

Appendix B-3 Kruskal-Wallace test for differences in facet size with age group continued

Facet	Sample	Male Size		Female Size	
		Chi-Square	P Value	Chi-Square	P Value
C5RI	SBC	0.16	0.92	0.59	0.74
	SBL	5.13	0.08	8.70	0.01
	AS	2.57	0.28	5.61	0.06
C6LS	SBC	2.03	0.36	0.04	0.98
	SBL	2.44	0.30	3.60	0.17
	AS	1.99	0.37	0.27	0.87
C6RS	SBC	0.35	0.84	1.25	0.54
	SBL	2.57	0.28	3.89	0.14
	AS	3.44	0.18	1.75	0.42
C6LI	SBC	0.74	0.69	3.64	0.16
	SBL	0.87	0.65	3.55	0.17
	AS	0.43	0.81	2.58	0.28
C6RI	SBC	0.57	0.75	1.11	0.57
	SBL	0.89	0.64	1.60	0.45
	AS	1.07	0.58	2.73	0.26
C7LS	SBC	0.43	0.80	0.14	0.93
	SBL	2.20	0.33	1.57	0.46
	AS	3.12	0.21	0.60	0.44
C7RS	SBC	0.11	0.95	3.15	0.21
	SBL	2.92	0.23	2.27	0.32
	AS	1.95	0.38	1.00	0.32
C7LI	SBC	2.03	0.36	0.82	0.66
	SBL	1.48	0.48	0.84	0.66
	AS	0.44	0.80	0.60	0.44
C7RI	SBC	1.93	0.38	1.14	0.57
	SBL	0.82	0.66	1.53	0.46
	AS	0.12	0.94	1.00	0.32
T1LS	SBC	1.96	0.38	1.37	0.50
	SBL	5.01	0.08	0.29	0.87
	AS	0.08	0.96	2.38	0.30

Appendix B-3 Kruskal-Wallace test for differences in facet size with age group continued

Facet	Sample	Male Size		Female Size	
		Chi-Square	P Value	Chi-Square	P Value
T1RS	SBC	5.17	0.08	1.75	0.42
	SBL	0.54	0.76	4.34	0.11
	AS	2.27	0.32	0.66	0.72
T1LI	SBC	1.81	0.41	0.28	0.87
	SBL	0.84	0.66	0.44	0.8
	AS	0.22	0.90	1.98	0.37
T1RI	SBC	5.36	0.07	2.95	0.23
	SBL	2.85	0.24	0.20	0.91
	AS	4.54	0.10	0.22	0.89
T2LS	SBC	0.54	0.76	1.06	0.59
	SBL	0.24	0.89	1.23	0.54
	AS	0.37	0.83	0.73	0.69
T2RS	SBC	2.34	0.31	3.75	0.15
	SBL	1.39	0.50	0.06	0.97
	AS	3.18	0.20	0.61	0.74
T2LI	SBC	0.10	0.95	3.91	0.14
	SBL	0.59	0.74	0.15	0.93
	AS	0.66	0.72	0.58	0.75
T2RI	SBC	1.77	0.41	11.55	<0.01
	SBL	7.48	0.02	1.53	0.47
	AS	4.54	0.10	0.22	0.89
T3LS	SBC	0.12	0.94	5.56	0.06
	SBL	0.43	0.81	0.45	0.80
	AS	0.61	0.74	2.41	0.30
T3RS	SBC	1.32	0.52	8.07	0.02
	SBL	1.59	0.45	0.76	0.68
	AS	0.40	0.82	0.20	0.91
T3LI	SBC	4.39	0.11	6.38	0.04
	SBL	0.04	0.98	0.06	0.97
	AS	4.85	0.09	1.65	0.44

Appendix B-3 Kruskal-Wallace test for differences in facet size with age group continued

Facet	Sample	Male Size		Female Size	
		Chi-Square	P Value	Chi-Square	P Value
T3RI	SBC	0.16	0.92	7.06	0.03
	SBL	1.89	0.39	2.52	0.28
	AS	2.92	0.23	0.27	0.87
T4LS	SBC	0.30	0.86	13.31	<0.01
	SBL	0.40	0.82	3.17	0.20
	AS	0.90	0.64	1.28	0.53
T4RS	SBC	5.07	0.08	14.98	<0.01
	SBL	0.90	0.64	0.87	0.65
	AS	0.73	0.69	2.25	0.32
T4LI	SBC	0.92	0.63	1.09	0.58
	SBL	1.89	0.39	1.28	0.53
	AS	1.41	0.49	1.52	0.47
T4RI	SBC	0.11	0.94	6.80	0.03
	SBL	1.03	0.60	6.04	0.05
	AS	2.70	0.26	1.34	0.51
T5LS	SBC	0.67	0.71	4.12	0.13
	SBL	0.04	0.98	0.26	0.88
	AS	3.36	0.19	1.20	0.55
T5RS	SBC	6.00	0.05	8.49	0.01
	SBL	0.36	0.84	0.75	0.69
	AS	0.30	0.86	2.06	0.36
T5LI	SBC	1.08	0.58	0.91	0.63
	SBL	1.11	0.58	0.12	0.94
	AS	5.73	0.06	0.22	0.90
T5RI	SBC	2.48	0.29	3.25	0.20
	SBL	0.84	0.66	0.12	0.94
	AS	2.91	0.23	1.22	0.54
T6LS	SBC	1.35	0.51	0.38	0.83
	SBL	0.16	0.92	0.91	0.64
	AS	1.55	0.46	0.18	0.67

Appendix B-3 Kruskal-Wallace test for differences in facet size with age group continued

Facet	Sample	Male Size		Female Size	
		Chi-Square	P Value	Chi-Square	P Value
T6RS	SBC	7.51	0.02	5.50	0.06
	SBL	1.02	0.60	0.11	0.95
	AS	1.67	0.43	0.02	0.89
T6LI	SBC	4.44	0.11	2.05	0.36
	SBL	1.09	0.58	2.96	0.23
	AS	2.69	0.26	0.18	0.67
T6RI	SBC	0.62	0.73	7.78	0.02
	SBL	0.53	0.77	0.27	0.88
	AS	3.34	0.19	0.98	0.32
T7LS	SBC	4.10	0.13	2.00	0.37
	SBL	0.28	0.87	0.84	0.66
	AS	2.70	0.26	0.10	0.75
T7RS	SBC	1.43	0.49	11.55	<0.01
	SBL	0.60	0.74	0.65	0.72
	AS	5.63	0.06	0.71	0.40
T7LI	SBC	0.16	0.92	2.09	0.35
	SBL	1.97	0.37	0.68	0.71
	AS	6.85	0.03	0.40	0.53
T7RI	SBC	1.01	0.60	5.75	0.06
	SBL	0.02	0.99	0.34	0.84
	AS	3.15	0.21	0.02	0.90
T8LS	SBC	0.08	0.96	0.56	0.76
	SBL	0.60	0.74	3.51	0.17
	AS	1.07	0.59	1.07	0.59
T8RS	SBC	3.54	0.17	0.59	0.75
	SBL	2.04	0.36	2.82	0.24
	AS	0.17	0.92	2.74	0.25
T8LI	SBC	2.92	0.23	0.12	0.94
	SBL	0.67	0.72	1.37	0.50
	AS	1.86	0.39	0.25	0.88

Appendix B-3 Kruskal-Wallace test for differences in facet size with age group continued

Facet	Sample	Male Size		Female Size	
		Chi-Square	P Value	Chi-Square	P Value
T8RI	SBC	1.86	0.40	0.72	0.70
	SBL	0.23	0.89	0.38	0.83
	AS	2.77	0.25	0.14	0.93
T9LS	SBC	3.94	0.14	2.44	0.30
	SBL	1.09	0.58	0.78	0.68
	AS	2.11	0.35	1.04	0.60
T9RS	SBC	4.63	0.10	4.46	0.11
	SBL	0.71	0.70	0.41	0.82
	AS	2.15	0.34	2.72	0.26
T9LI	SBC	0.01	1.00	0.68	0.71
	SBL	0.76	0.68	0.14	0.93
	AS	3.71	0.16	0.63	0.43
T9RI	SBC	0.08	0.96	2.55	0.28
	SBL	0.34	0.84	2.61	0.27
	AS	0.81	0.67	0.54	0.46
T10LS	SBC	0.59	0.74	2.34	0.31
	SBL	1.60	0.45	0.70	0.71
	AS	3.77	0.15	0.32	0.57
T10RS	SBC	3.77	0.15	2.00	0.37
	SBL	0.90	0.64	1.67	0.43
	AS	0.24	0.89	0.18	0.67
T10LI	SBC	0.47	0.79	2.07	0.36
	SBL	0.35	0.84	2.82	0.24
	AS	0.98	0.61	0.02	0.89
T10RI	SBC	0.60	0.74	3.52	0.17
	SBL	0.14	0.93	2.91	0.23
	AS	2.14	0.34	0.02	0.89
T11LS	SBC	1.34	0.51	0.36	0.83
	SBL	0.16	0.92	0.90	0.64
	AS	0.05	0.82	0.32	0.57

Appendix B-3 Kruskal-Wallace test for differences in facet size with age group continued

Facet	Sample	Male Size		Female Size	
		Chi-Square	P Value	Chi-Square	P Value
T11RS	SBC	0.18	0.92	0.18	0.91
	SBL	1.55	0.46	2.84	0.24
	AS	0.01	0.93	0.02	0.90
T11LI	SBC	1.62	0.44	0.37	0.83
	SBL	2.87	0.24	4.27	0.12
	AS	0.02	0.89	0.38	0.54
T11RI	SBC	1.34	0.51	0.08	0.96
	SBL	1.66	0.44	6.89	0.03
	AS	1.18	0.28	2.34	0.13
T12LS	SBC	0.28	0.87	0.52	0.77
	SBL	3.16	0.21	2.05	0.36
	AS	0.60	0.44	3.13	0.08
T12RS	SBC	1.73	0.42	0.43	0.81
	SBL	0.39	0.82	3.32	0.19
	AS	1.67	0.20	0.50	0.48
T12LI	SBC	3.07	0.22	1.79	0.41
	SBL	0.62	0.73	0.15	0.93
	AS	1.67	0.20	5.67	0.02
T12RI	SBC	1.95	0.38	0.03	0.99
	SBL	0.71	0.70	4.85	0.09
	AS	0.73	0.39	0.04	0.84
L1LS	SBC	3.58	0.17	6.07	0.05
	SBL	2.64	0.27	3.50	0.17
	AS	1.24	0.27	0.17	0.92
L1RS	SBC	0.30	0.86	0.99	0.61
	SBL	1.52	0.47	5.10	0.08
	AS	0.13	0.72	0.66	0.72
L1LI	SBC	1.25	0.54	5.60	0.06
	SBL	1.14	0.57	2.61	0.27
	AS	0.89	0.35	0.72	0.70

Appendix B-3 Kruskal-Wallace test for differences in facet size with age group continued

Facet	Sample	Male Size		Female Size	
		Chi-Square	P Value	Chi-Square	P Value
L1RI	SBC	0.66	0.72	6.11	0.05
	SBL	1.72	0.42	4.18	0.12
	AS	0.00	0.96	0.16	0.92
L2LS	SBC	2.61	0.27	1.47	0.48
	SBL	1.63	0.44	2.26	0.32
	AS	1.51	0.47	2.55	0.28
L2RS	SBC	2.80	0.25	2.06	0.36
	SBL	0.86	0.65	1.14	0.57
	AS	0.29	0.87	1.10	0.58
L2LI	SBC	0.36	0.83	1.57	0.46
	SBL	1.41	0.49	4.01	0.13
	AS	0.82	0.37	0.42	0.81
L2RI	SBC	1.11	0.57	3.73	0.15
	SBL	0.32	0.85	3.50	0.17
	AS	0.49	0.48	2.66	0.26
L3LS	SBC	2.40	0.30	2.70	0.26
	SBL	3.98	0.14	6.33	0.04
	AS	1.61	0.20	0.55	0.76
L3RS	SBC	1.97	0.37	0.81	0.67
	SBL	2.06	0.36	2.59	0.27
	AS	0.00	1.00	0.54	0.76
L3LI	SBC	2.16	0.34	2.08	0.35
	SBL	0.18	0.91	1.63	0.44
	AS	0.90	0.34	0.46	0.79
L3RI	SBC	3.63	0.16	2.40	0.30
	SBL	0.19	0.91	11.24	<0.01
	AS	0.34	0.56	2.70	0.26
L4LS	SBC	1.13	0.57	0.37	0.83
	SBL	0.48	0.79	0.50	0.78
	AS	1.81	0.41	0.01	0.92

Appendix B-3 Kruskal-Wallace test for differences in facet size with age group continued

Facet	Sample	Male Size		Female Size	
		Chi-Square	P Value	Chi-Square	P Value
L4RS	SBC	0.78	0.68	0.31	0.86
	SBL	1.12	0.57	8.72	0.01
	AS	0.07	0.97	2.28	0.13
L4LI	SBC	5.66	0.06	3.61	0.16
	SBL	0.36	0.83	8.48	0.01
	AS	2.77	0.25	1.50	0.22
L4RI	SBC	0.45	0.80	3.89	0.14
	SBL	1.03	0.60	2.01	0.37
	AS	0.22	0.64	0.00	1.00
L5LS	SBC	0.24	0.89	0.83	0.66
	SBL	1.51	0.47	2.60	0.27
	AS	0.09	0.76	0.02	0.90
L5RS	SBC	1.56	0.46	1.72	0.42
	SBL	2.25	0.32	2.48	0.29
	AS	0.19	0.66	0.24	0.62
L5LI	SBC	0.90	0.64	5.42	0.07
	SBL	0.56	0.76	5.00	0.08
	AS	0.08	0.78	0.04	0.84
L5RI	SBC	0.21	0.90	13.69	<0.01
	SBL	1.23	0.54	1.44	0.49
	AS	1.71	0.19	1.82	0.18

Key: C=Cervical, T=Thoracic, L=Lumbar, Number = Vertebral level, R=Right, L=Left, S=Superior, I = Inferior

Appendix B-4 Spearman's Rho correlation between facet size and actual age

Facet	Males				Females			
	Correlation Coefficient	p	N	Strength of Relationship	Correlation Coefficient	p	N	Strength of Relationship
C1LS	-0.015	0.946	23	None	-0.065	0.722	32	Weak
C1RS	-0.23	0.29	23	Weak	-0.2	0.272	32	Weak
C1LI	0.242	0.267	23	Weak	0.427	0.015	32	Medium
C1RI	0.392	0.392	23	Medium	0.3	0.096	32	Medium
C2LS	0.202	0.355	23	Weak	0.208	0.23	35	Weak
C2RS	0.399	0.059	23	Medium	0.18	0.302	35	Weak
C2LI	**0.637**	**<0.0001**	**22**	**Strong**	-0.227	0.191	35	Weak
C2RI	0.12	0.594	22	Weak	-0.195	0.262	35	Weak
C3LS	0.377	0.111	19	Medium	-0.166	0.363	32	Weak
C3RS	0.178	0.454	20	Weak	-0.141	0.442	32	Weak
C3LI	0.366	0.113	20	Medium	-0.041	0.826	31	None
C3RI	-0.097	0.684	20	None	0.1	0.593	31	Weak
C4LS	0.258	0.286	19	Weak	0.186	0.345	28	Weak
C4RS	-0.029	0.906	19	None	0.027	0.891	28	None
C4LI	0.379	0.099	20	Medium	0.013	0.947	29	None
C4RI	0.423	0.063	20	Medium	-0.021	0.913	29	None
C5LS	0.35	0.101	23	Medium	0.122	0.492	34	Weak
C5RS	0.12	0.576	24	Weak	0.051	0.775	34	None
C5LI	0.36	0.084	24	Medium	-0.05	0.779	34	None
C5RI	0.054	0.801	24	None	-0.093	0.599	34	None
C6LS	0.072	0.762	20	None	0.032	0.851	37	None
C6RS	0.004	0.987	20	None	0.179	0.289	37	Weak
C6LI	0.226	0.337	20	Weak	-0.31	0.062	37	Medium
C6RI	-0.002	0.995	20	None	-0.144	0.395	37	Weak
C7LS	0.158	0.472	23	Weak	-0.09	0.585	39	None
C7RS	0.007	0.973	24	None	0.224	0.176	38	Weak
C7LI	-0.105	0.619	24	Weak	-0.027	0.87	39	None
C7RI	0.169	0.421	25	Weak	0.068	0.68	39	None
T1LS	0.185	0.399	23	Weak	0.114	0.488	39	Weak
T1RS	0.286	0.175	24	Weak	0.038	0.816	40	None
T1LI	0.156	0.487	24	Weak	0.02	0.904	40	None
T1RI	0.272	0.199	24	Weak	0.058	0.723	40	None
T2LS	0.215	0.291	26	Weak	-0.073	0.661	38	None
T2RS	0.137	0.504	26	Weak	0.031	0.854	38	None
T2LI	0.065	0.751	26	None	0.105	0.529	38	Weak
T2RI	0.152	0.46	26	Weak	0.378	0.019	38	Medium
T3LS	0.005	0.98	25	None	0.038	0.82	39	None
T3RS	0.166	0.427	25	Weak	0.064	0.697	39	None
T3LI	-0.371	0.068	25	Medium	0.291	0.072	39	Weak
T3RI	0.165	0.43	25	Weak	0.291	0.084	39	Weak

Appendix B-4 Spearman's Rho correlation between facet size and actual age continued

Facet	Males				Females			
	Correlation Coefficient	p	N	Strength of Relationship	Correlation Coefficient	p	N	Strength of Relationship
T4LS	0.026	0.901	26	None	-0.022	0.896	37	None
T4RS	0.46	0.018	26	Medium	0.339	0.043	36	Medium
T4LI	0.022	0.917	26	None	0.015	0.929	36	None
T4RI	0.119	0.588	23	Weak	**0.505**	**<0.0001**	**25**	**Strong**
T5LS	0.209	0.316	25	Weak	-0.082	0.631	37	None
T5RS	0.424	0.035	25	Medium	0.386	0.018	37	Medium
T5LI	-0.099	0.637	25	None	-0.086	0.619	36	None
T5RI	0.267	0.196	25	Weak	0.026	0.878	36	None
T6LS	0.215	0.291	26	Weak	-0.022	0.899	36	None
T6RS	0.379	0.056	26	Medium	0.27	0.112	36	Weak
T6LI	0.261	0.198	26	Weak	-0.081	0.63	38	None
T6RI	0.014	0.946	26	None	0.08	0.635	38	None
T7LS	0.304	0.131	26	Medium	-0.182	0.274	38	Weak
T7RS	0.351	0.079	26	Medium	-0.063	0.706	38	None
T7LI	0.033	0.874	25	None	-0.259	0.116	38	Weak
T7RI	-0.099	0.637	25	None	-0.243	0.141	38	Weak
T8LS	0.061	0.773	25	None	-0.051	0.766	36	None
T8RS	0.179	0.392	25	Weak	0.011	0.948	36	None
T8LI	0.363	0.068	26	Medium	0.028	0.871	36	None
T8RI	0.257	0.205	26	Weak	-0.115	0.504	36	Weak
T9LS	0.364	0.068	26	Medium	0.218	0.182	39	Weak
T9RS	0.329	0.101	26	Medium	0.196	0.231	39	Weak
T9LI	0.194	0.353	25	Weak	-0.202	0.218	39	Weak
T9RI	0.129	0.54	25	Weak	-0.145	0.386	38	Weak
T10LS	0.093	0.657	25	None	0.192	0.241	39	Weak
T10RS	0.294	0.154	25	Weak	0.025	0.879	39	None
T10LI	0.134	0.514	26	Weak	0.085	0.606	39	None
T10RI	0.182	0.373	26	Weak	0.005	0.977	39	None
T11LS	0.14	0.494	26	Weak	-0.042	0.798	39	None
T11RS	-0.06	0.771	26	None	0.072	0.663	39	None
T11LI	0.197	0.344	25	Weak	-0.147	0.373	39	Weak
T11RI	-0.007	0.974	25	None	-0.097	0.559	39	None
T12LS	0.084	0.698	24	None	-0.179	0.289	37	Weak
T12RS	-0.07	0.744	24	None	-0.055	0.748	37	None
T12LI	0.312	0.128	25	Medium	0.035	0.835	37	None
T12RI	0.108	0.608	25	Weak	-0.073	0.67	37	None

Appendix B-4 Spearman's Rho correlation between facet size and actual age continued

Facet	Males				Females			
	Correlation Coefficient	p	N	Strength of Relationship	Correlation Coefficient	p	N	Strength of Relationship
L1LS	0.185	0.375	25	Weak	-0.093	0.591	36	None
L1RS	0.204	0.329	25	Weak	-0.026	0.882	35	None
L1LI	0.165	0.43	25	Weak	-0.024	0.89	36	None
L1RI	0.081	0.7	25	None	0.019	0.915	35	None
L2LS	0.183	0.37	26	Weak	0.036	0.834	36	None
L2RS	0.196	0.338	26	Weak	0.012	0.944	36	None
L2LI	0.064	0.755	26	None	0.116	0.501	36	Weak
L2RI	0.168	0.411	26	Weak	0.01	0.952	36	None
L3LS	0.126	0.539	26	Weak	0.079	0.64	37	None
L3RS	0.223	0.274	26	Weak	-0.1	0.567	35	Weak
L3LI	0.058	0.779	26	None	0.108	0.524	37	Weak
L3RI	0.258	0.203	26	Weak	0.224	0.183	37	Weak
L4LS	0.115	0.577	26	Weak	0.071	0.674	38	None
L4RS	0.241	0.235	26	Weak	-0.094	0.576	38	None
L4LI	**0.61**	**<0.0001**	**26**	**Strong**	0.098	0.557	38	None
L4RI	0.353	0.077	26	Weak	0.191	0.25	38	Weak
L5LS	0.17	0.415	25	Weak	-0.104	0.559	34	Weak
L5RS	-0.036	0.864	25	None	0.203	0.25	34	Weak
L5LI	0.355	0.081	35	Medium	0.323	0.062	34	Medium
L5RI	0.067	0.749	25	None	0.4	0.021	33	Medium

Appendix B-5 Kruskal-Wallace test for inter-sample variation in facet size

Facet	Male		Female	
	Chi-Square	p	Chi-Square	p
C1LS	0.764	0.683	4.962	0.084
C1RS	1.188	0.552	6.779	**0.034**
C1LI	0.086	0.958	6.681	**0.035**
C1RI	0.52	0.771	8.115	**0.017**
C2LS	0.1	0.951	5.097	0.078
C2RS	3.982	0.137	5.477	0.065
C2LI	4.399	0.111	15.167	**0.001**
C2RI	7.766	**0.021**	6.428	**0.04**
C3LS	0.719	0.698	2.501	0.286
C3RS	1.823	0.402	3.295	0.193
C3LI	9.008	**0.011**	2.585	0.275
C3RI	9.315	**0.009**	3.552	0.169
C4LS	1.68	0.432	3.982	0.137
C4RS	1.605	0.448	9.682	**0.008**
C4LI	2.616	0.27	6.61	**0.037**
C4RI	2.317	0.314	8.417	**0.015**
C5LS	2.192	0.334	3.914	0.141
C5RS	0.627	0.731	1.813	0.404
C55LI	11.209	**0.004**	9.426	**0.009**
C5RI	7.435	**0.024**	5.962	0.051
C6LS	1.438	0.487	8.198	**0.017**
C6RS	6.002	0.05	8.631	**0.013**
C6LI	13.554	**0.001**	18.612	**<0.001**
C6RI	16.653	**<0.001**	13.838	**0.001**
C7LS	8.474	**0.014**	3.899	0.142
C7RS	8.567	**0.014**	8.664	**0.013**
C7LI	3.801	0.15	15.173	**0.001**
C7RI	3.294	0.193	9.559	**0.008**
T1LS	2.279	0.32	2.102	0.35
T1RS	0.084	0.959	1.05	0.592
T1LI	2.215	0.33	11.491	**0.003**
T1RI	2.303	0.316	6.007	**0.05**
T2LS	0.78	0.677	4.716	0.095
T2RS	0.214	0.898	10.158	**0.006**
T2LI	1.241	0.538	1.83	0.4
T2RI	0.109	0.947	3.543	0.17

Appendix B-5 Kruskal-Wallace test for inter-sample variation in facet size continued

Facet	Male		Female	
	Chi-Square	p	Chi-Square	p
T3LS	2.928	0.231	5.672	0.059
T3RS	1.218	0.544	2.676	0.262
T3LI	0.746	0.689	0.108	0.947
T3RI	1.128	0.569	3.996	0.136
T4LS	3.584	0.167	6.642	**0.036**
T4RS	0.532	0.766	2.499	0.287
T4LI	3.056	0.217	4.035	0.133
T4RI	0.52	0.771	9.909	**0.007**
T5LS	6.419	**0.04**	11.796	**0.003**
T5RS	0.024	0.988	5.388	0.068
T5LI	1.897	0.387	7.181	**0.028**
T5RI	1.703	**0.005**	9.11	**0.011**
T6LS	0.919	0.632	5.228	0.073
T6RS	9.382	**0.009**	3.539	0.17
T6LI	1.206	0.547	4.227	0.121
T6RI	3.86	0.145	8.383	**0.015**
T7LS	1.208	0.546	9.46	**0.009**
T7RS	5.084	0.079	14.527	**0.001**
T7LI	0.228	0.892	13.813	**0.001**
T7RI	5.274	0.072	24.114	**<0.001**
T8LS	5.793	0.055	19.573	**<0.001**
T8RS	14.216	**0.001**	17.831	**<0.001**
T8LI	2.603	0.272	11.646	**0.003**
T8RI	9.492	**0.009**	19.336	**<0.001**
T9LS	5.096	0.078	21.522	**<0.001**
T9RS	2.469	0.291	17.091	**<0.001**
T9LI	1.144	0.564	7.752	**0.021**
T9RI	6.478	**0.039**	11.346	**0.003**
T10LS	3.855	0.145	11.842	**0.003**
T10RS	13.508	**0.001**	13.746	**0.001**
T10LI	0.213	0.899	6.603	**0.037**
T10RI	3.466	0.177	16.66	**<0.001**
T11LS	0.93	0.628	6.991	**0.03**
T11RS	7.925	**0.019**	13.84	**0.001**
T11LI	5.063	**0.08**	9.623	**0.008**
T11RI	8.289	**0.016**	10.024	**0.007**
T12LS	2.09	0.352	15.909	**<0.001**
T12RS	1.78	0.411	3.235	0.198
T12LI	1.746	0.418	8.803	**0.012**
T12RI	0.908	0.635	2.395	0.302

Appendix B-5 Kruskal-Wallace test for inter-sample variation in facet size continued

Facet	Male		Female	
	Chi-Square	p	Chi-Square	p
L1LS	1.22	0.543	7.148	**0.028**
L1RS	2.003	0.367	5.545	0.063
L1LI	0.004	0.998	6.702	**0.035**
L1RI	2.585	0.275	5.212	0.074
L2LS	1.151	0.562	10.325	**0.006**
L2RS	1.153	0.562	6.59	**0.037**
L2LI	0.79	0.674	5.657	0.059
L2RI	1.146	0.564	6.085	**0.048**
L3LS	0.278	0.87	5.262	0.072
L3RS	0.572	0.751	12.88	**0.002**
L3LI	2.572	0.276	2.724	0.256
L3RI	5.45	0.066	1.915	0.384
L4LS	4.273	0.118	9.272	**0.01**
L4RS	1.604	0.448	4.133	0.127
L4LI	0.566	0.754	9.7	**0.008**
L4RI	1.114	0.573	6.724	**0.035**
L5LS	1.63	0.443	13.818	**0.001**
L5RS	2.548	0.28	5.445	0.066
L5LI	2.626	0.269	5.093	0.078
L5RI	1.86	0.395	5.047	0.08

Appendix B-6 Mann-Whitney U inter-sample comparison of facet size

Facet	Male						Female					
	SBC/SBL		SBC/AS		SBL/AS		SBC/SBL		SBC/AS		SBL/AS	
	Z	p	Z	p	Z	p	Z	p	Z	p	Z	p
C1LS	-0.501	0.616	-0.917	0.359	-1.772	0.076	-0.997	0.319	-1.772	0.076	-2.024	**0.043**
C1RS	-0.74	0.459	-1.049	0.294	-2.274	**0.023**	-0.433	0.665	-2.274	**0.023**	-2.508	**0.012**
C1LI	-0.04	0.968	-0.194	0.846	-1.26	0.208	-1.919	0.055	-1.26	0.208	-2.263	**0.024**
C1RI	-0.516	0.606	-0.616	0.538	-2.303	**0.021**	-0.922	0.357	-2.303	**0.021**	-2.772	**0.006**
C2LS	-0.212	0.832	-0.376	0.707	-0.731	0.465	-1.61	0.107	-0.731	0.465	-2.321	**0.02**
C2RS	-0.599	0.549	-1.3	0.194	-1.391	0.164	-1.522	0.128	-1.391	0.164	-2.141	**0.032**
C2LI	-1.978	**0.048**	-1.502	0.133	-3.644	**<0.001**	-0.367	0.713	-3.644	**<0.001**	-3.468	**0.001**
C2RI	-2.453	**0.014**	-0.195	0.846	-1.584	0.113	-1.75	0.08	-1.584	0.113	-2.147	**0.032**
C3LS	-0.824	0.41	-0.333	0.739	-1.239	0.216	-0.473	0.636	-1.239	0.216	-1.572	0.116
C3RS	-1.192	0.233	-0.146	0.884	-1.291	0.197	-0.677	0.498	-1.291	0.197	-1.868	0.062
C3LI	-1.743	0.081	-0.731	0.465	-1.029	0.304	-1.054	0.292	-1.029	0.304	-1.385	0.166
C3RI	-0.836	0.403	-2	**0.046**	-0.812	0.417	-1.196	0.232	-0.812	0.417	-1.946	0.052
C4LS	-0.432	0.666	-0.642	0.521	-1.741	0.082	-0.528	0.598	-1.741	0.082	-1.802	0.072
C4RS	-1.022	0.307	-0.048	0.962	-2.521	**0.012**	-1.153	0.249	-2.521	**0.012**	-2.834	**0.005**
C4LI	-0.651	0.515	-0.867	0.386	-1.633	0.102	-1.225	0.22	-1.633	0.102	-2.572	**0.01**
C4RI	-0.468	0.64	-0.987	0.324	-2.063	**0.039**	-0.742	0.458	-2.063	**0.039**	-3.099	**0.002**
C5LS	-1.418	0.156	-0.07	0.945	-1.903	0.057	-0.047	0.962	-1.903	0.057	-1.686	0.092
C5RS	-0.749	0.454	-0.101	0.92	-0.499	0.617	-0.789	0.43	-0.499	0.617	-1.495	0.135
C55LI	-1.179	0.238	-2.953	**0.003**	-2.977	**0.003**	-0.111	0.912	-2.977	**0.003**	-2.618	**0.009**
C5RI	-0.75	0.453	-2.55	**0.011**	-2.354	**0.019**	-0.205	0.837	-2.354	**0.019**	-2.068	**0.039**
C6LS	-0.238	0.812	-1.19	0.234	-2.469	**0.014**	-0.449	0.654	-2.469	**0.014**	-2.86	**0.004**
C6RS	-0.57	0.569	-2.167	**0.03**	-2.784	**0.005**	-0.768	0.443	-2.784	**0.005**	-2.452	**0.014**
C6LI	-1.023	0.307	-2.589	**0.01**	-3.962	**<0.001**	-1.254	0.21	-3.962	**<0.001**	-3.736	**<0.001**
C6RI	-0.673	0.501	-3.534	**<0.001**	-3.299	**0.001**	-1.072	0.284	-3.299	**0.001**	-3.368	**0.001**
C7LS	-1.57	0.116	-2.948	**0.003**	-1.422	0.155	-0.934	0.35	-1.422	0.155	-1.984	**0.047**
C7RS	-1.176	0.24	-2.916	**0.004**	-2.376	**0.017**	-1.387	0.165	-2.376	**0.017**	-2.655	**0.008**
C7LI	-0.917	0.359	-1.355	0.175	-2.829	**0.005**	-2.42	**0.016**	-2.829	**0.005**	-3.26	**0.001**
C7RI	-1.287	0.198	-0.695	0.487	-3.085	**0.002**	0	1	-3.085	**0.002**	-2.655	**0.008**
T1LS	-1.301	0.193	-1.299	0.194	-1.132	0.257	-0.511	0.61	-1.132	0.257	-1.441	0.149
T1RS	-0.237	0.813	-0.212	0.832	-0.455	0.649	-0.685	0.493	-0.455	0.649	-1.037	0.3
T1LI	-1.018	0.308	-1.37	0.171	-3.06	**0.002**	-0.857	0.392	-3.06	**0.002**	-3.014	**0.003**
T1RI	-0.679	0.497	-1.429	0.153	-2.191	**0.028**	-0.657	0.511	-2.191	**0.028**	-2.19	**0.029**
T2LS	-0.776	0.438	-0.753	0.451	-0.909	0.363	-1.718	0.086	-0.909	0.363	-1.892	**0.058**
T2RS	-0.204	0.838	-0.393	0.694	-2.122	**0.034**	-1.902	0.057	-2.122	**0.034**	-2.868	**0.004**
T2LI	-0.686	0.493	-0.601	0.548	-0.206	0.837	-1.243	0.214	-0.206	0.837	-1.071	0.284
T2RI	-0.313	0.754	-0.021	0.983	-1.733	0.083	-1.15	0.25	-1.733	0.083	-0.844	0.399

Appendix B-6 Mann-Whitney U inter-sample comparison of facet size continued

Facet	Male						Female					
	SBC/SBL		SBC/AS		SBL/AS		SBC/SBL		SBC/AS		SBL/AS	
	Z	p	Z	p	Z	p	Z	p	Z	p	Z	p
T3LS	-1.258	0.208	-1.599	0.11	-0.975	0.329	-1.837	0.066	-0.975	0.329	-2.166	**0.03**
T3RS	-0.541	0.589	-1.104	0.27	-1.612	0.107	-0.101	0.92	-1.612	0.107	-1.257	0.209
T3LI	-0.794	0.427	-0.384	0.701	-0.053	0.958	-0.271	0.786	-0.053	0.958	-0.337	0.736
T3RI	-1.099	0.272	-0.235	0.815	-2.037	**0.042**	-0.411	0.681	-2.037	**0.042**	-1.332	0.183
T4LS	-1.281	0.2	-1.923	0.054	-2.468	**0.014**	-0.19	0.849	-2.468	**0.014**	-2.044	**0.041**
T4RS	0	1	-0.841	0.4	-1.315	0.189	-0.602	0.547	-1.315	0.189	-1.378	0.168
T4LI	-0.135	0.893	-1.614	0.107	-2.026	**0.043**	-0.459	0.646	-2.026	**0.043**	-1.302	0.193
T4RI	-0.755	0.45	-0.314	0.753	-2.952	**0.003**	-1.882	0.06	-2.952	**0.003**	-1.097	0.273
T5LS	-1.318	0.187	-1.422	0.155	-3.399	**0.001**	-1.07	0.285	-3.399	**0.001**	-2.194	**0.028**
T5RS	-0.16	0.873	-0.064	0.949	-2.319	**0.02**	-0.92	0.358	-2.319	**0.02**	-1.25	0.211
T5LI	-1.112	0.266	-1.22	0.222	-2.439	**0.015**	-1.761	0.078	-2.439	**0.015**	-0.933	0.351
T5RI	-0.499	0.618	-3.106	**0.002**	-2.977	**0.003**	-0.992	0.321	-2.977	**0.003**	-1.967	**0.04**9
T6LS	-0.897	0.37	-0.692	0.489	-2.161	**0.031**	-1.257	0.209	-2.161	**0.031**	-1.145	0.252
T6RS	-1.682	0.093	-2.96	**0.003**	-1.837	0.066	-0.645	0.519	-1.837	0.066	-1.28	0.201
T6LI	-0.354	0.723	-0.77	0.441	-2.063	**0.039**	-0.285	0.776	-2.063	**0.039**	-1.515	0.13
T6RI	-0.26	0.795	-1.515	0.13	-2.434	**0.015**	-0.728	0.466	-2.434	**0.015**	-2.761	**0.006**
T7LS	-0.881	0.378	-0.271	0.787	-2.368	**0.018**	-1.194	0.232	-2.368	**0.018**	-2.929	**0.003**
T7RS	-0.907	0.364	-1.399	0.162	-3.031	**0.002**	-1.49	0.136	-3.031	**0.002**	-3.51	**<0.001**
T7LI	-0.186	0.852	-0.439	0.661	-3.467	**0.001**	-0.327	0.744	-3.467	**0.001**	-3.168	**0.002**
T7RI	-1.294	0.196	-2.079	**0.038**	-4.291	**<0.001**	-1.276	0.202	-4.291	**<0.001**	-4.444	**<0.001**
T8LS	-0.086	0.931	-2.012	**0.044**	-3.192	**0.001**	-2.308	**0.021**	-3.192	**0.001**	-4.011	**<0.001**
T8RS	-0.432	0.666	-3.472	**0.001**	-3.113	**0.002**	-1.847	0.065	-3.113	**0.002**	-4.011	**<0.001**
T8LI	-0.58	0.562	-1.48	0.139	-3.133	**0.002**	-0.073	0.941	-3.133	**0.002**	-2.967	**0.003**
T8RI	-1.008	0.314	-2.077	**0.038**	-3.886	**<0.001**	-0.159	0.873	-3.886	**<0.001**	-4.11	**<0.001**
T9LS	-0.272	0.785	-1.719	0.086	-3.163	**0.002**	-2.482	**0.013**	-3.163	**0.002**	-4.358	**<0.001**
T9RS	-1.442	0.149	-0.215	0.83	-3.306	**0.001**	-1.329	0.184	-3.306	**0.001**	-3.931	**<0.001**
T9LI	-0.915	0.36	-0.218	0.828	-1.651	0.099	-1.841	0.066	-1.651	0.099	-2.533	**0.011**
T9RI	-1.379	0.168	-1.443	0.149	-2.35	**0.019**	-1.799	0.072	-2.35	**0.019**	-3.133	**0.002**
T10LS	-0.186	0.852	-1.789	0.074	-2.906	**0.004**	-0.849	0.396	-2.906	**0.004**	-3.316	**0.001**
T10RS	-1.59	0.112	-2.462	**0.014**	-2.821	**0.005**	-1.761	0.078	-2.821	**0.005**	-3.426	**0.001**
T10LI	-0.476	0.634	-0.161	0.872	-2.462	**0.014**	-0.048	0.962	-2.462	**0.014**	-2.174	**0.03**
T10RI	-0.624	0.532	-1.402	0.161	-3.138	**0.002**	-1.505	0.132	-3.138	**0.002**	-4.053	**<0.001**
T11LS	-0.658	0.511	-0.244	0.808	-1.448	0.148	-1.601	0.109	-1.448	0.148	-2.69	**0.007**
T11RS	-0.067	0.946	-2.436	**0.015**	-3.47	**0.001**	-0.457	0.648	-3.47	**0.001**	-3.232	**0.001**
T11LI	-0.232	0.817	-2.142	**0.032**	-2.824	**0.005**	-0.736	0.462	-2.824	**0.005**	-2.694	**0.007**
T11RI	-0.997	0.319	-2.111	**0.035**	-3.153	**0.002**	-0.721	0.471	-3.153	**0.002**	-2.32	**0.02**
T12LS	-1.248	0.212	-0.151	0.88	-2.681	**0.007**	-2.435	**0.015**	-2.681	**0.007**	-3.536	**<0.001**
T12RS	-0.822	0.411	-0.454	0.65	-1.435	0.151	-0.736	0.462	-1.435	0.151	-1.65	0.099
T12LI	-0.477	0.633	-1.171	0.242	-2.514	**0.012**	-0.752	0.452	-2.514	**0.012**	-2.877	**0.004**
T12RI	-0.286	0.775	-0.785	0.433	-1.272	0.203	-0.493	0.622	-1.272	0.203	-1.471	0.141

Appendix B-6 Mann-Whitney U inter-sample comparison of facet size continued

Facet	Male						Female					
	SBC/SBL		SBC/AS		SBL/AS		SBC/SBL		SBC/AS		SBL/AS	
	Z	p	Z	p	Z	p	Z	p	Z	p	Z	p
L1LS	-1.265	0.206	-0.267	0.789	-1.646	0.1	-0.992	0.321	-1.646	0.1	-2.993	**0.003**
L1RS	-1.39	0.165	-0.265	0.791	-2.102	**0.036**	-0.385	0.7	-2.102	**0.036**	-2.17	**0.03**
L1LI	-0.026	0.979	-0.07	0.944	-2.26	**0.024**	-0.222	0.824	-2.26	**0.024**	-2.42	**0.016**
L1RI	-1.354	0.176	-1.39	0.165	-2.001	**0.045**	-0.105	0.916	-2.001	**0.045**	-2.167	**0.03**
L2LS	-0.152	0.879	-1.003	0.316	-2.4	**0.016**	-0.855	0.393	-2.4	**0.016**	-3.426	**0.001**
L2RS	-0.26	0.795	-1.05	0.294	-2.31	**0.021**	-0.239	0.811	-2.31	**0.021**	-2.362	**0.018**
L2LI	-0.394	0.693	-0.522	0.602	-2.242	**0.025**	-0.018	0.986	-2.242	**0.025**	-2.053	**0.04**
L2RI	-0.476	0.634	-1.118	0.264	-2.312	**0.021**	-0.177	0.86	-2.312	**0.021**	-2.113	**0.035**
L3LS	-0.439	0.66	-0.099	0.921	-2.027	**0.043**	-0.334	0.738	-2.027	**0.043**	-2.046	**0.041**
L3RS	-0.773	0.44	-0.406	0.685	-3.19	**0.001**	-0.601	0.548	-3.19	**0.001**	-3.283	**0.001**
L3LI	-1.139	0.255	-1.408	0.159	-1.145	0.252	-0.591	0.555	-1.145	0.252	-1.717	0.086
L3RI	-1.72	0.085	-2.02	**0.043**	-1.298	0.194	-0.607	0.544	-1.298	0.194	-0.92	0.358
L4LS	-0.038	0.97	-1.838	0.066	-2.538	**0.011**	-0.889	0.374	-2.538	**0.011**	-2.807	**0.005**
L4RS	-0.366	0.714	-1.263	0.207	-1.402	0.161	-1.066	0.286	-1.402	0.161	-1.937	0.053
L4LI	-0.283	0.777	-0.712	0.476	-2.95	**0.003**	-0.72	0.472	-2.95	**0.003**	-2.453	**0.014**
L4RI	-0.641	0.522	-0.955	0.34	-2.187	**0.029**	-0.89	0.373	-2.187	**0.029**	-2.328	**0.02**
L5LS	-0.616	0.538	-1.268	0.205	-3.493	**<0.001**	-0.074	0.941	-3.493	**<0.001**	-3.169	**0.002**
L5RS	-0.284	0.777	-1.71	0.087	-2.064	**0.039**	-0.427	0.67	-2.064	**0.039**	-2.113	**0.035**
L5LI	-0.703	0.482	-1.016	0.31	-1.831	0.067	-0.519	0.604	-1.831	0.067	-2.245	**0.025**
L5RI	-0.303	0.762	-1.089	0.276	-2.07	**0.038**	-0.352	0.725	-2.07	**0.038**	-1.931	0.054

Appendix B-7 Spearman's rho correlation between facet size and femoral robusticity

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
C1LS	SBC	0.00	0.99	11	None	-0.25	0.49	10	Weak	-0.15	0.57	17	Weak	-0.37	0.18	15	Medium
	SBL	0.13	0.61	18	Weak	-0.07	0.79	19	None	-0.12	0.74	11	Weak	-0.43	0.22	10	Medium
	AS	-0.23	0.44	13	Weak	-0.16	0.59	14	Weak	0.16	0.74	7	Weak	0.39	0.29	9	Medium
C1RS	SBC	0.03	0.93	11	None	0.07	0.85	10	None	-0.11	0.67	17	Weak	-0.25	0.36	15	Weak
	SBL	-0.15	0.54	19	Weak	-0.04	0.86	20	None	-0.05	0.89	11	None	-0.22	0.54	10	Weak
	AS	-0.39	0.17	14	Medium	-0.19	0.48	16	Weak	0.25	0.59	7	Weak	0.46	0.22	9	Medium
C1LI	SBC	-0.30	0.37	11	Medium	-0.08	0.82	10	None	-0.09	0.73	17	None	-0.36	0.19	15	Medium
	SBL	0.22	0.39	18	Weak	0.08	0.76	19	None	0.14	0.68	11	Weak	-0.15	0.68	10	Weak
	AS	0.08	0.82	11	None	0.01	0.97	12	None	-0.11	0.84	6	Weak	-0.30	0.47	8	Medium
C1RI	SBC	-0.24	0.48	11	Weak	-0.09	0.81	10	None	0.04	0.87	17	None	-0.39	0.15	15	Medium
	SBL	0.16	0.51	19	Weak	-0.05	0.83	20	None	0.36	0.28	11	Medium	-0.32	0.36	10	Medium
	AS	-0.29	0.36	12	Weak	-0.29	0.31	14	Weak	0.42	0.35	7	Medium	0.43	0.25	9	Medium

Appendix B-7 Spearman's rho correlation between facet size and femoral robusticity continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
C2LS	SBC	-0.35	0.27	12	Medium	-0.39	0.23	11	Medium	0.07	0.79	19	None	-0.02	0.93	17	None
	SBL	0.12	0.63	20	Weak	0.03	0.90	22	None	0.12	0.72	11	Weak	-0.10	0.77	10	Weak
	AS	0.01	0.98	10	None	0.10	0.78	11	None	0.13	0.72	10	Weak	0.16	0.63	12	Weak
C2RS	SBC	0.02	0.94	12	None	-0.01	0.98	11	None	0.21	0.40	19	Weak	-0.05	0.84	17	None
	SBL	0.35	0.13	20	Medium	0.18	0.42	22	Weak	0.28	0.40	11	Weak	-0.44	0.20	10	Medium
	AS	-0.18	0.57	12	Weak	-0.19	0.51	14	Weak	-0.09	0.82	9	None	0.00	0.99	11	None
C2LI	SBC	-0.29	0.35	12	Weak	-0.13	0.69	11	Weak	0.19	0.45	19	Weak	0.25	0.34	17	Weak
	SBL	-0.16	0.49	20	Weak	-0.12	0.60	22	Weak	-0.18	0.60	11	Weak	0.39	0.27	10	Medium
	AS	-0.03	0.93	9	None	-0.03	0.94	10	None	0.00	0.99	9	None	-0.05	0.90	10	None
C2RI	SBC	-0.06	0.86	11	None	-0.15	0.65	11	Weak	0.20	0.42	19	Weak	0.25	0.34	17	Weak
	SBL	0.13	0.59	20	Weak	0.03	0.89	22	None	0.01	0.97	11	None	-0.29	0.42	10	Weak
	AS	0.43	0.22	10	Medium	0.39	0.21	12	Medium	0.77	0.01	9	**Strong**	0.79	0.01	10	**Strong**
C3LS	SBC	-0.24	0.48	11	Weak	-0.13	0.72	10	Weak	-0.06	0.82	17	None	0.11	0.68	16	Weak
	SBL	-0.18	0.45	20	Weak	-0.16	0.46	22	Weak	0.07	0.84	12	None	0.06	0.86	12	None
	AS	0.06	0.85	11	None	0.21	0.49	13	Weak	0.47	0.17	10	Medium	0.51	0.11	11	**Strong**

Appendix B-7 Spearman's rho correlation between facet size and femoral robusticity continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
C3RS	SBC	0.12	0.71	12	Weak	-0.14	0.67	11	Weak	-0.01	0.97	17	None	0.42	0.11	16	Medium
	SBL	0.04	0.86	20	None	-0.10	0.66	22	Weak	0.14	0.69	11	Weak	-0.10	0.76	11	Weak
	AS	0.02	0.94	12	None	0.10	0.73	14	Weak	0.69	0.03	10	**Strong**	0.70	0.02	11	**Strong**
C3LI	SBC	-0.25	0.43	12	Weak	-0.42	0.20	11	Medium	-0.06	0.81	17	None	-0.10	0.71	16	Weak
	SBL	0.38	0.11	19	Medium	0.26	0.25	21	Weak	0.02	0.94	12	None	-0.19	0.56	12	Weak
	AS	0.03	0.92	11	None	0.08	0.79	13	None	0.16	0.65	10	Weak	0.23	0.49	11	Weak
C3RI	SBC	-0.13	0.69	12	Weak	-0.09	0.79	11	None	-0.01	0.97	17	None	0.07	0.81	16	None
	SBL	0.41	0.07	20	Medium	0.17	0.46	22	Weak	-0.08	0.82	11	None	-0.19	0.57	11	Weak
	AS	0.46	0.16	11	Medium	0.40	0.20	12	Medium	0.31	0.38	10	Medium	0.32	0.33	11	Medium
C4LS	SBC	-0.28	0.37	12	Weak	-0.29	0.39	11	Weak	-0.14	0.62	15	Weak	-0.24	0.38	15	Weak
	SBL	0.10	0.67	21	None	-0.02	0.94	23	None	-0.13	0.66	14	Weak	0.03	0.93	11	None
	AS	-0.35	0.32	10	Medium	-0.30	0.34	12	Medium	0.51	0.20	8	**Strong**	0.55	0.13	9	**Strong**
C4RS	SBC	-0.10	0.75	12	None	-0.07	0.83	11	None	0.01	0.96	15	None	-0.03	0.91	15	None
	SBL	0.17	0.47	21	Weak	-0.04	0.87	23	None	-0.06	0.83	14	None	-0.15	0.67	11	Weak
	AS	0.38	0.23	12	Medium	0.32	0.27	14	Medium	0.21	0.59	9	Weak	0.11	0.77	10	Weak

Appendix B-7 Spearman's rho correlation between facet size and femoral robusticity continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
C4LI	SBC	-0.33	0.30	12	Medium	-0.28	0.40	11	Weak	-0.18	0.52	15	Weak	0.13	0.63	15	Weak
	SBL	-0.05	0.84	21	None	-0.03	0.88	23	None	0.50	0.06	15	**Strong**	0.00	0.99	12	None
	AS	0.34	0.34	10	Medium	0.34	0.27	12	Medium	0.16	0.71	8	Weak	0.24	0.54	9	Weak
C4RI	SBC	-0.23	0.46	12	None	-0.03	0.92	11	None	0.71	0.00	15	**Strong**	0.43	0.11	15	Medium
	SBL	0.11	0.62	21	Weak	-0.01	0.98	23	None	0.37	0.20	14	Medium	0.02	0.94	11	None
	AS	0.61	0.05	11	**Strong**	0.59	0.03	13	**Strong**	0.60	0.11	8	**Strong**	0.26	0.51	9	Weak
C5LS	SBC	0.18	0.56	13	Weak	-0.40	0.20	12	Medium	-0.01	0.98	17	None	-0.07	0.83	14	None
	SBL	-0.05	0.83	21	None	-0.09	0.69	22	None	0.27	0.34	15	Weak	-0.17	0.57	13	Weak
	AS	-0.03	0.94	9	None	-0.15	0.68	10	Weak	-0.32	0.36	10	Medium	-0.10	0.76	12	Weak
C5RS	SBC	-0.17	0.59	13	Weak	-0.13	0.69	12	Weak	-0.02	0.95	17	None	0.42	0.13	14	Medium
	SBL	0.38	0.09	21	Medium	0.16	0.49	22	Weak	0.27	0.33	15	Weak	-0.30	0.33	13	Medium
	AS	-0.28	0.47	9	Weak	-0.34	0.34	10	Medium	0.25	0.49	10	Weak	0.10	0.75	12	Weak
C5LI	SBC	-0.04	0.89	13	None	-0.09	0.77	12	None	-0.09	0.74	17	None	0.32	0.26	14	Medium
	SBL	0.15	0.52	20	Weak	0.02	0.94	21	None	0.27	0.34	15	Weak	-0.12	0.71	13	Weak
	AS	-0.37	0.33	9	Medium	-0.38	0.28	10	Medium	0.77	0.02	9	**Strong**	0.80	0.00	11	**Strong**

Appendix B-7 Spearman's rho correlation between facet size and femoral robusticity continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
C5RI	SBC		1.00	13	None	-0.14	0.67	12	Weak	0.17	0.51	17	Weak	0.66	0.01	14	**Strong**
	SBL		0.29	20	Weak	0.08	0.73	21	None	0.27	0.33	15	Weak	-0.33	0.27	13	Medium
	AS		0.52	9	Weak	-0.18	0.62	10	Weak	0.65	0.04	10	**Strong**	0.54	0.07	12	**Strong**
C6LS	SBC		0.65	9	Weak	-0.08	0.82	10	None	-0.26	0.24	22	Weak	-0.14	0.58	19	Weak
	SBL		0.64	23	Weak	0.03	0.91	24	None	0.45	0.11	14	Medium	-0.01	0.96	13	None
	AS		0.31	10	Medium	-0.32	0.31	12	Medium	0.52	0.19	8	**Strong**	0.49	0.22	8	Medium
C6RS	SBC		0.70	9	Weak	-0.17	0.64	10	Weak	-0.26	0.23	22	Weak	-0.14	0.57	19	Weak
	SBL		0.25	22	Weak	0.13	0.54	23	Weak	0.07	0.80	15	None	-0.28	0.36		Weak
	AS		0.78	11	None	-0.04	0.89	13	None	0.62	0.10	8	**Strong**	0.22	0.57	9	Weak
C6LI	SBC		0.71	9	Weak	0.03	0.94	10	None	0.48	0.02	22	Medium	0.38	0.10	19	Medium
	SBL		0.59	24	Weak	0.03	0.90	25	None	0.10	0.74	14	None	-0.03	0.92	13	None
	AS		0.44	10	Weak	0.01	0.99	12	None	0.35	0.39	8	Medium	0.28	0.47	9	Weak
C6RI	SBC		0.88	9	None	0.12	0.73	10	Weak	0.43	0.05	22	Medium	0.32	0.18	19	Medium
	SBL		0.85	23	None	-0.01	0.96	24	None	-0.20	0.50	14	Weak	-0.04	0.88	13	None
	AS	-0.18	0.63	10	Weak	-0.09	0.78	12	None	0.39	0.34	8	Medium	0.52	0.15	9	**Strong**

Appendix B-7 Spearman's rho correlation between facet size and femoral robusticity continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
C7LS	SBC	-0.08	0.81	11	None	-0.08	0.81	11	None	0.11	0.64	21	Weak	0.37	0.13	18	Medium
	SBL	0.23	0.26	25	Weak	0.13	0.54	25	Weak	0.00	0.99	15	None	-0.29	0.34	13	Weak
	AS	-0.36	0.39	8	Medium	-0.26	0.46	10	Weak	0.58	0.23	6	**Strong**	0.59	0.22	6	**Strong**
C7RS	SBC	-0.41	0.21	11	Medium	-0.08	0.82	11	None	-0.01	0.97	20	None	0.28	0.28	17	Weak
	SBL	0.24	0.26	24	Weak	0.28	0.18	25	Weak	-0.11	0.70	15	Weak	-0.22	0.48	13	Weak
	AS	-0.04	0.90	11	None	0.21	0.50	13	Weak	0.50	0.25	7	**Strong**	0.51	0.24	7	**Strong**
C7LI	SBC	-0.44	0.15	12	Medium	0.08	0.81	11	None	0.31	0.17	21	Medium	0.25	0.31	18	Weak
	SBL	0.21	0.33	24	Weak	-0.07	0.74	26	None	0.14	0.63	15	Weak	-0.05	0.87	13	None
	AS	-0.05	0.90	10	None	-0.09	0.79	12	None	0.50	0.32	6	**Strong**	0.51	0.30	6	**Strong**
C7RI	SBC	-0.27	0.40	12	Weak	0.00	0.99	11	None	0.34	0.14	21	Medium	-0.12	0.65	18	Weak
	SBL	0.06	0.79	24	None	0.06	0.75	26	None	0.06	0.85	15	None	-0.24	0.42	13	Weak
	AS	0.21	0.53	11	Weak	0.07	0.83	13	None	0.32	0.48	7	Medium	0.33	0.48	7	Medium
T1LS	SBC	0.01	0.97	11	None	-0.05	0.90	10	None	-0.14	0.54	22	Weak	0.16	0.52	18	Weak
	SBL	-0.12	0.55	25	Weak	-0.07	0.72	26	None	-0.20	0.52	13	Weak	-0.02	0.94	12	None
	AS	-0.12	0.74	11	Weak	-0.16	0.65	11	Weak	0.46	0.30	7	Medium	0.38	0.27	10	Medium

Appendix B-7 Spearman's rho correlation between facet size and femoral robusticity continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
T1RS	SBC	0.20	0.52	12	Weak	-0.33	0.33	11	Medium	-0.05	0.83	22	None	0.24	0.33	18	Weak
	SBL	0.02	0.92	25	None	0.09	0.65	26	None	-0.21	0.48	14	Weak	-0.08	0.81	12	None
	AS	-0.04	0.90	12	None	0.08	0.79	13	None	-0.05	0.91	8	None	-0.06	0.85	11	None
T1LI	SBC	0.00	0.99	12	None	0.08	0.82	11	None	0.05	0.83	22	None	0.02	0.94	18	None
	SBL	0.43	0.03	26	Medium	0.07	0.73	26	None	0.21	0.46	14	Weak	-0.03	0.93	12	None
	AS	-0.10	0.75	14	Weak	-0.12	0.66	15	Weak	0.21	0.61	8	Weak	0.04	0.91	11	None
T1RI	SBC	0.11	0.72	12	Weak	-0.37	0.27	11	Medium	0.27	0.22	22	Weak	0.36	0.15	18	Medium
	SBL	0.36	0.07	26	Medium	0.03	0.90	26	None	0.04	0.90	14	None	-0.13	0.69	12	Weak
	AS	-0.37	0.23	12	Medium	-0.39	0.18	13	Medium	-0.08	0.85	8	None	0.00	0.99	11	None
T2LS	SBC	-0.28	0.35	13	Weak	-0.05	0.88	12	None	0.26	0.25	21	Weak	0.49	0.05	17	Medium
	SBL	0.14	0.52	25	Weak	-0.15	0.47	25	Weak	0.20	0.52	13	Weak	-0.13	0.69	12	Weak
	AS	-0.35	0.24	13	Medium	-0.37	0.19	14	Medium	-0.16	0.63	11	Weak	-0.18	0.54	14	Weak
T2RS	SBC	-0.30	0.32	13	Medium	-0.20	0.52	12	Weak	0.30	0.19	21	Medium	0.52	0.03	17	**Strong**
	SBL	0.14	0.50	26	Weak	-0.08	0.71	26	None	0.30	0.33	13	Medium	-0.30	0.34	12	Medium
	AS	-0.37	0.19	14	Medium	-0.36	0.17	16	Medium	0.09	0.79	11	None	0.07	0.81	14	None

Appendix B-7 Spearman's rho correlation between facet size and femoral robusticity continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
T2LI	SBC	0.06	0.84	13	None	-0.33	0.29	12	Medium	0.19	0.40	21	Weak	0.11	0.67	17	Weak
	SBL	0.23	0.28	25	Weak	-0.05	0.82	25	None	0.42	0.16	13	Medium	-0.32	0.31	12	Medium
	AS	-0.29	0.29	15	Weak	-0.16	0.54	17	Weak	0.02	0.96	10	None	-0.17	0.57	13	Weak
T2RI	SBC	-0.12	0.69	13	Weak	-0.02	0.94	12	None	-0.16	0.48	21	Weak	0.16	0.53	17	Weak
	SBL	0.14	0.50	25	Weak	0.05	0.82	25	None	0.66	0.01	13	**Strong**	-0.17	0.60	12	Weak
	AS	-0.50	0.06	15	**Strong**	-0.22	0.41	16	Weak	0.04	0.91	10	None	-0.05	0.87	13	None
T3LS	SBC	-0.09	0.77	13	None	-0.08	0.80	12	None	0.03	0.88	21	None	0.04	0.88	17	None
	SBL	0.04	0.85	21	None	-0.14	0.55	21	Weak	0.53	0.07	12	**Strong**	-0.21	0.52	12	Weak
	AS	-0.20	0.47	15	Weak	-0.20	0.48	15	Weak	-0.01	0.97	12	None	0.15	0.60	14	Weak
T3RS	SBC	-0.18	0.56	13	Weak	-0.29	0.35	12	Weak	0.01	0.98	21	None	0.43	0.09	17	Medium
	SBL	0.03	0.89	22	None	-0.10	0.65	22	Weak	0.61	0.03	12	**Strong**	-0.24	0.45	12	Weak
	AS	-0.21	0.44	16	Weak	0.03	0.92	18	None	0.18	0.57	12	Weak	0.14	0.62	15	Weak
T3LI	SBC	0.30	0.32	13	Medium	-0.18	0.57	12	Weak	-0.05	0.84	21	None	-0.05	0.86	17	None
	SBL	0.10	0.64	22	Weak	-0.19	0.40	22	Weak	0.48	0.12	12	Medium	-0.30	0.35	12	Medium
	AS	0.13	0.64	15	Weak	0.18	0.49	17	Weak	0.02	0.95	11	None	0.17	0.57	13	Weak

Appendix B-7 Spearman's rho correlation between facet size and femoral robusticity continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
T3RI	SBC	-0.14	0.64	13	Weak	-0.22	0.50	12	Weak	-0.11	0.65	21	Weak	-0.15	0.56	17	Weak
	SBL	0.05	0.83	22	None	-0.10	0.65	22	Weak	0.71	0.01	12	**Strong**	-0.21	0.51	12	Weak
	AS	-0.40	0.14	15	Medium	-0.49	0.05	17	Medium	0.09	0.78	12	None	0.16	0.58	15	Weak
T4LS	SBC	0.14	0.64	13	Weak	-0.16	0.62	12	Weak	0.37	0.11	20	Medium	0.39	0.13	16	Medium
	SBL	0.11	0.63	23	Weak	-0.13	0.57	22	Weak	0.26	0.46	10	Weak	0.21	0.56	10	Weak
	AS	-0.12	0.66	15	Weak	-0.05	0.85	18	None	-0.27	0.35	14	Weak	-0.39	0.13	16	Medium
T4RS	SBC	-0.39	0.19	13	Medium	-0.21	0.51	12	Weak	0.01	0.97	19	None	-0.05	0.87	15	None
	SBL	-0.05	0.82	22	None	-0.12	0.59	21	Weak	0.70	0.02	10	**Strong**	-0.23	0.52	10	Weak
	AS	-0.23	0.40	15	Weak	-0.20	0.44	18	Weak	-0.14	0.63	14	None	-0.26	0.32	16	Weak
T4LI	SBC	-0.08	0.79	13	None	0.05	0.87	12	None	0.02	0.94	19	None	0.33	0.21	16	Medium
	SBL	0.18	0.41	22	Weak	-0.01	0.96	21	None	0.48	0.19	9	Medium	-0.14	0.72	9	Weak
	AS	0.07	0.82	14	None	0.13	0.61	17	Weak	-0.14	0.64	13	None	0.10	0.72	15	Weak
T4RI	SBC	0.23	0.50	11	Weak	0.06	0.87	10	None	-0.48	0.09	13	Medium	-0.83	0.01	9	**Strong**
	SBL	0.14	0.61	15	Weak	-0.09	0.77	14	None	0.07	0.90	6	None	-0.53	0.28	6	**Strong**
	AS	-0.32	0.33	11	Medium	-0.44	0.14	13	Medium	-0.71	0.05	8	**Strong**	-0.62	0.06	10	**Strong**

Appendix B-7 Spearman's rho correlation between facet size and femoral robusticity continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
T5LS	SBC	-0.08	0.80	12	None	-0.07	0.82	12	None	0.17	0.46	20	Weak	0.45	0.07	17	Medium
	SBL	-0.09	0.69	21	None	-0.26	0.26	20	Weak	0.62	0.04	11	**Strong**	-0.18	0.61	10	Weak
	AS	-0.31	0.30	13	Medium	-0.16	0.55	16	Weak	0.19	0.55	12	Weak	0.07	0.82	14	None
T5RS	SBC	0.01	0.98	12	None	-0.51	0.09	12	**Strong**	-0.18	0.45	20	Weak	-0.43	0.08	17	Medium
	SBL	0.14	0.54	21	Weak	-0.11	0.65	20	Weak	0.29	0.39	11	Weak	-0.23	0.52	10	Weak
	AS	-0.27	0.35	14	Weak	-0.30	0.25	17	Medium	0.03	0.91	12	None	0.02	0.95	14	None
T5LI	SBC	0.01	0.98	12	None	0.08	0.80	12	None	0.18	0.45	20	Weak	0.06	0.81	17	None
	SBL	0.47	0.04	20	Medium	0.15	0.57	18	Weak	0.23	0.48	12	Weak	-0.03	0.93	10	None
	AS	-0.47	0.13	12	Medium	-0.15	0.62	14	Weak	0.32	0.33	11	Medium	0.30	0.32	13	Medium
T5RI	SBC	-0.17	0.60	12	Weak	-0.14	0.67	12	Weak	0.11	0.65	20	Weak	-0.27	0.29	17	Weak
	SBL	0.21	0.37	21	Weak	-0.06	0.81	20	None	0.04	0.89	12	None	-0.22	0.53	10	Weak
	AS	-0.65	0.02	13	**Strong**	-0.48	0.07	15	Medium	0.07	0.85	11	None	-0.11	0.72	13	Weak
T6LS	SBC	0.39	0.19	13	Medium	-0.03	0.93	12	None	-0.07	0.76	20	None	0.05	0.84	17	None
	SBL	0.21	0.33	24	Weak	-0.08	0.72	23	None	0.32	0.31	12	Medium	-0.36	0.28	11	Medium
	AS	-0.42	0.20	11	Medium	0.16	0.59	14	Weak	0.17	0.62	11	Weak	-0.09	0.76	13	None

Appendix B-7 Spearman's rho correlation between facet size and femoral robusticity continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
T6RS	SBC	-0.07	0.81	13	None	-0.46	0.13	12	Medium	-0.25	0.30	20	Weak	-0.26	0.31	17	Weak
	SBL	0.28	0.19	24	Weak	0.00	0.99	23	None	-0.05	0.89	12	None	-0.20	0.56	11	Weak
	AS	-0.64	0.03	11	**Strong**	-0.29	0.31	14	Weak	0.14	0.68	11	Weak	0.05	0.87	13	None
T6LI	SBC	-0.23	0.45	13	Weak	-0.46	0.13	12	Medium	0.33	0.15	21	Medium	-0.05	0.86	17	None
	SBL	0.06	0.77	23	None	-0.18	0.42	22	Weak	0.06	0.86	12	None	-0.19	0.57	11	Weak
	AS	0.22	0.57	9	Weak	0.26	0.41	12	Weak	0.14	0.68	11	Weak	-0.19	0.53	13	Weak
T6RI	SBC	-0.14	0.65	13	Weak	-0.31	0.33	12	Medium	0.16	0.49	21	Weak	0.24	0.35	17	Weak
	SBL	-0.03	0.88	22	None	-0.33	0.15	21	Medium	-0.10	0.75	12	Weak	-0.23	0.50	11	Weak
	AS	0.09	0.80	10	None	0.01	0.98	12	None	0.22	0.51	11	Weak	-0.28	0.35	13	Weak
T7LS	SBC	-0.29	0.33	13	Weak	-0.57	0.05	12	**Strong**	0.29	0.20	21	Weak	0.42	0.10	17	Medium
	SBL	0.20	0.36	23	Weak	-0.07	0.76	23	None	0.10	0.75	12	Weak	-0.23	0.50	11	Weak
	AS	-0.11	0.78	9	Weak	-0.24	0.47	11	Weak	0.06	0.85	14	None	0.00	1.00	16	None
T7RS	SBC	-0.06	0.85	13	None	-0.33	0.29	12	Medium	0.41	0.06	21	Medium	0.46	0.06	17	Medium
	SBL	0.06	0.80	24	None	-0.18	0.40	24	Weak	-0.18	0.57	12	Weak	-0.19	0.59	10	Weak
	AS	0.00	0.99	10	None	0.03	0.93	12	None	0.10	0.72	14	Weak	-0.05	0.87	16	None

Appendix B-7 Spearman's rho correlation between facet size and femoral robusticity continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
T7LI	SBC	0.27	0.39	12	Weak	-0.45	0.16	11	Medium	0.67	0.00	21	**Strong**	0.32	0.21	17	Medium
	SBL	0.21	0.34	23	Weak	-0.08	0.73	22	None	-0.17	0.59	12	Weak	-0.22	0.51	11	Weak
	AS	-0.27	0.49	9	Weak	-0.41	0.21	11	Medium	0.30	0.29	14	Medium	0.18	0.50	16	Weak
T7RI	SBC	0.08	0.81	12	None	0.10	0.78	11	None	0.61	0.00	21	**Strong**	0.43	0.08	17	Medium
	SBL	-0.05	0.83	23	None	-0.40	0.06	23	Medium	-0.08	0.82	12	None	-0.20	0.55	11	Weak
	AS	-0.21	0.60	9	Weak	-0.22	0.52	11	Weak	0.18	0.57	12	Weak	0.02	0.94	14	None
T8LS	SBC	0.02	0.94	12	None	-0.38	0.25	11	Medium	0.26	0.29	19	Weak	-0.05	0.85	16	None
	SBL	0.33	0.10	25	Medium	0.15	0.49	24	Weak	-0.32	0.31	12	Medium	-0.29	0.37	12	Weak
	AS	0.45	0.19	10	Medium	0.31	0.33	12	Medium	-0.13	0.68	12	Weak	-0.18	0.53	14	Weak
T8RS	SBC	-0.22	0.49	12	Weak	-0.55	0.08	11	**Strong**	0.20	0.41	19	Weak	-0.08	0.78	16	None
	SBL	0.00	0.98	25	None	-0.20	0.35	24	Weak	-0.12	0.72	12	Weak	-0.32	0.32	12	Medium
	AS	0.32	0.34	11	Medium	0.23	0.45	13	Weak	-0.01	0.97	12	None	-0.16	0.58	14	Weak
T8LI	SBC	-0.20	0.50	13	Weak	-0.34	0.28	12	Medium	-0.09	0.71	19	None	-0.15	0.57	16	Weak
	SBL	0.03	0.90	25	None	-0.19	0.36	24	Weak	-0.42	0.23	10	Medium	-0.10	0.79	10	Weak
	AS	0.18	0.59	11	Weak	0.04	0.90	13	None	0.26	0.41	12	Weak	0.08	0.78	14	None

Appendix B-7 Spearman's rho correlation between facet size and femoral robusticity continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
T8RI	SBC	-0.34	0.26	13	Medium	-0.09	0.79	12	None	0.32	0.19	19	Medium	-0.10	0.71	16	Weak
	SBL	0.00	0.98	25	None	-0.20	0.35	24	Weak	-0.12	0.72	12	Weak	-0.32	0.32	12	Medium
	AS	0.20	0.55	11	Weak	0.15	0.64	13	Weak	0.11	0.74	12	Weak	-0.06	0.85	14	None
T9LS	SBC	-0.18	0.56	13	Weak	-0.46	0.13	12	Medium	-0.27	0.23	21	Weak	-0.39	0.11	18	Medium
	SBL	0.15	0.48	25	Weak	-0.12	0.57	24	Weak	-0.07	0.83	11	None	-0.26	0.43	11	Weak
	AS	0.33	0.27	13	Medium	0.31	0.24	16	Medium	-0.10	0.73	14	Weak	-0.27	0.33	15	Weak
T9RS	SBC	-0.06	0.84	13	None	-0.51	0.09	12	**Strong**	0.06	0.81	21	None	-0.32	0.20	18	Medium
	SBL	0.16	0.45	24	Weak	-0.04	0.85	24	None	-0.03	0.94	12	None	-0.12	0.71	12	Weak
	AS	0.21	0.50	13	Weak	0.20	0.45	16	Weak	-0.03	0.93	14	None	-0.21	0.44	15	Weak
T9LI	SBC	0.20	0.53	12	Weak	-0.18	0.59	11	Weak	0.18	0.44	21	Weak	-0.10	0.70	18	Weak
	SBL	0.15	0.47	24	Weak	-0.12	0.57	24	Weak	-0.14	0.68	12	Weak	-0.12	0.72	12	Weak
	AS	-0.01	0.97	12	None	0.01	0.96	15	None	0.12	0.69	14	Weak	0.04	0.87	15	None
T9RI	SBC	0.40	0.20	12	Medium	-0.36	0.28	11	Medium	0.26	0.25	21	Weak	0.18	0.47	18	Weak
	SBL	0.22	0.31	22	Weak	-0.12	0.61	22	Weak	0.05	0.89	12	None	-0.42	0.18	12	Medium
	AS	0.27	0.43	11	Weak	0.20	0.49	14	Weak	0.09	0.75	14	None	-0.02	0.94	15	None

Appendix B-7 Spearman's rho correlation between facet size and femoral robusticity continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
T10LS	SBC	-0.08	0.81	12	None	-0.41	0.21	11	Medium	-0.07	0.75	21	None	-0.29	0.25	18	Weak
	SBL	0.00	0.98	23	None	-0.21	0.35	22	Weak	-0.01	0.97	12	None	0.09	0.78	12	None
	AS	-0.11	0.74	12	Weak	-0.06	0.82	16	None	0.30	0.32	13	Medium	0.14	0.62	14	Weak
T10RS	SBC	-0.46	0.13	12	Medium	-0.17	0.61	11	Weak	-0.09	0.71	21	None	-0.08	0.74	18	None
	SBL	0.13	0.55	23	Weak	0.06	0.79	23	None	0.08	0.80	12	None	-0.21	0.51	12	Weak
	AS	0.04	0.90	12	None	0.09	0.75	15	None	0.22	0.48	13	Weak	-0.07	0.80	14	None
T10LI	SBC	-0.04	0.89	13	None	-0.38	0.23	12	Medium	-0.03	0.89	21	None	-0.10	0.69	18	None
	SBL	-0.04	0.85	23	None	-0.18	0.40	23	Weak	0.10	0.75	12	Weak	-0.20	0.54	12	Weak
	AS	-0.12	0.71	12	Weak	-0.04	0.88	16	None	0.37	0.21	13	Medium	0.01	0.98	14	None
T10RI	SBC	0.08	0.79	13	None	-0.29	0.36	12	Weak	0.16	0.50	21	Weak	0.03	0.90	18	None
	SBL	-0.04	0.86	23	None	-0.17	0.45	23	Weak	0.28	0.37	12	Weak	-0.23	0.47	12	Weak
	AS	0.28	0.38	12	Weak	0.32	0.22	16	Medium	0.22	0.47	13	Weak	-0.03	0.91	14	None
T11LS	SBC	0.20	0.50	13	Weak	-0.45	0.14	12	Medium	0.16	0.50	21	Weak	0.00	0.99	18	None
	SBL	-0.07	0.76	23	None	-0.20	0.36	22	Weak	0.00	1.00	12	None	-0.21	0.51	12	Weak
	AS	0.19	0.57	11	Weak	0.20	0.51	13	Weak	0.09	0.77	13	None	-0.15	0.62	14	Weak

Appendix B-7 Spearman's rho correlation between facet size and femoral robusticity continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
T11RS	SBC	0.19	0.53	13	Weak	-0.36	0.25	12	Medium	-0.07	0.76	21	None	-0.19	0.45	18	Weak
	SBL	0.23	0.29	23	Weak	0.10	0.66	22	None	0.29	0.34	13	Weak	-0.53	0.08	12	**Strong**
	AS	-0.15	0.63	12	Weak	-0.10	0.73	15	Weak	0.20	0.52	13	Weak	-0.06	0.84	14	None
T11LI	SBC	-0.16	0.60	13	Weak	-0.32	0.30	12	Medium	0.05	0.83	21	None	0.02	0.95	18	None
	SBL	0.26	0.24	23	Weak	0.20	0.39	21	Weak	0.22	0.47	13	Weak	-0.38	0.22	12	Medium
	AS	0.06	0.86	12	None	0.04	0.90	15	None	0.13	0.68	13	Weak	-0.30	0.30	14	Medium
T11RI	SBC	0.03	0.93	13	None	-0.25	0.43	12	Weak	0.04	0.86	21	None	-0.09	0.71	18	None
	SBL	-0.07	0.74	23	None	-0.17	0.44	22	Weak	-0.01	0.98	13	None	-0.30	0.34	12	Medium
	AS	-0.40	0.25	10	Medium	-0.38	0.20	13	Medium	-0.35	0.30	11	Medium	-0.44	0.15	12	Medium
T12LS	SBC	-0.05	0.88	13	None	-0.18	0.58	12	Weak	0.28	0.25	19	Weak	0.28	0.28	17	Weak
	SBL	0.30	0.18	21	Medium	0.46	0.04	20	Medium	0.55	0.05	13	**Strong**	-0.32	0.31	12	Medium
	AS	0.01	0.97	10	None	-0.02	0.94	12	None	-0.21	0.48	13	Weak	-0.31	0.28	14	Medium
T12RS	SBC	-0.17	0.58	13	Weak	-0.26	0.42	12	Weak	0.32	0.18	19	Medium	0.22	0.40	17	Weak
	SBL	0.01	0.97	22	None	0.00	0.99	21	None	-0.07	0.82	13	None	-0.32	0.31	12	Medium
	AS	-0.21	0.57	10	Weak	-0.29	0.37	12	Weak	-0.16	0.60	13	Weak	-0.22	0.45	14	Weak

Appendix B-7 Spearman's rho correlation between facet size and femoral robusticity continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
T12LI	SBC	-0.10	0.74	13	Weak	-0.45	0.14	12	Medium	0.31	0.19	19	Medium	0.23	0.37	17	Weak
	SBL	0.18	0.43	22	Weak	0.00	1.00	21	None	-0.21	0.48	13	Weak	-0.26	0.41	12	Weak
	AS	-0.24	0.51	10	Weak	-0.27	0.39	12	Weak	-0.63	0.04	11	**Strong**	-0.62	0.03	12	**Strong**
T12RI	SBC	-0.24	0.43	13	Weak	-0.56	0.06	12	**Strong**	0.35	0.14	19	Medium	0.20	0.45	17	Weak
	SBL	0.16	0.49	22	Weak	-0.05	0.82	21	None	0.13	0.66	13	Weak	-0.28	0.38	12	Weak
	AS	-0.31	0.39	10	Medium	-0.32	0.34	11	Medium	0.21	0.50	13	Weak	0.10	0.73	14	Weak
L1LS	SBC	-0.31	0.33	12	Medium	-0.32	0.31	12	Medium	0.19	0.41	20	Weak	0.12	0.65	17	Weak
	SBL	0.11	0.64	22	Weak	0.02	0.94	22	None	-0.42	0.17	12	Weak	-0.43	0.17	12	Medium
	AS	-0.46	0.18	10	Medium	-0.54	0.05	13	**Strong**	0.25	0.44	12	Weak	0.39	0.16	14	Medium
L1RS	SBC	-0.26	0.42	12	Weak	0.02	0.95	12	None	0.00	0.99	19	None	0.13	0.63	17	Weak
	SBL	0.06	0.80	22	None	-0.09	0.68	22	None	-0.20	0.53	12	Weak	-0.22	0.50	12	Weak
	AS	-0.42	0.26	9	Medium	-0.31	0.33	12	Medium	-0.06	0.84	12	None	0.10	0.74	13	Weak
L1LI	SBC	-0.18	0.57	12	Weak	-0.23	0.48	12	Weak	0.38	0.10	20	Medium	0.46	0.06	17	Medium
	SBL	0.19	0.38	23	Weak	0.15	0.48	23	Weak	-0.22	0.50	12	Weak	-0.28	0.38	12	Weak
	AS	-0.51	0.16	9	**Strong**	-0.44	0.15	12	Medium	0.01	0.97	13	None	-0.04	0.89	15	None

Appendix B-7 Spearman's rho correlation between facet size and femoral robusticity continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
L1RI	SBC	-0.17	0.59	12	Weak	-0.27	0.40	12	Weak	0.33	0.16	19	Medium	0.25	0.32	17	Weak
	SBL	0.01	0.96	22	None	-0.01	0.98	22	None	0.11	0.74	12	Weak	-0.20	0.54	12	Weak
	AS	-0.17	0.64	10	Weak	-0.11	0.72	13	Weak	0.16	0.63	12	Weak	0.09	0.77	14	None
L2LS	SBC	-0.33	0.28	13	Medium	0.04	0.91	12	None	-0.08	0.75	20	None	0.12	0.63	18	Weak
	SBL	0.02	0.93	22	None	0.04	0.88	22	None	0.09	0.79	12	None	0.00	0.99	12	None
	AS	-0.54	0.07	12	**Strong**	-0.49	0.07	15	Medium	-0.32	0.34	11	Medium	-0.35	0.26	12	Medium
L2RS	SBC	-0.11	0.72	13	Weak	-0.45	0.14	12	Medium	0.12	0.60	20	Weak	0.17	0.51	18	Weak
	SBL	0.04	0.87	21	None	0.02	0.94	21	None	0.36	0.25	12	Medium	0.04	0.91	11	None
	AS	-0.20	0.53	12	Weak	-0.23	0.40	15	Weak	0.07	0.83	11	None	0.07	0.84	12	None
L2LI	SBC	0.21	0.48	13	Weak	-0.46	0.13	12	Medium	-0.12	0.60	20	Weak	-0.18	0.49	18	Weak
	SBL	0.15	0.51	23	Weak	0.13	0.55	23	Weak	-0.04	0.91	11	None	-0.36	0.27	11	Medium
	AS	-0.26	0.46	10	Weak	-0.34	0.25	13	Medium	0.10	0.78	11	None	0.00	1.00	12	None
L2RI	SBC	-0.15	0.63	13	Weak	-0.48	0.12	12	Medium	0.02	0.92	20	None	0.07	0.79	18	None
	SBL	0.11	0.61	23	Weak	0.10	0.65	23	None	-0.04	0.89	12	None	0.00	1.00	12	None
	AS	-0.32	0.37	10	Medium	-0.37	0.22	13	Medium	-0.13	0.70	12	Weak	-0.25	0.40	13	Weak

Appendix B-7 Spearman's rho correlation between facet size and femoral robusticity continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
L3LS	SBC	-0.10	0.74	13	Weak	-0.60	0.04	12	**Strong**	0.35	0.12	21	Medium	0.11	0.67	18	Weak
	SBL	0.03	0.90	20	None	0.09	0.70	20	None	-0.02	0.94	13	None	-0.11	0.75	11	Weak
	AS	-0.49	0.11	12	Medium	-0.55	0.04	14	**Strong**	0.20	0.50	14	Weak	-0.05	0.86	15	None
L3RS	SBC	-0.13	0.66	13	Weak	-0.47	0.12	12	Medium	0.28	0.25	19	Weak	0.29	0.27	17	Weak
	SBL	0.03	0.91	20	None	0.11	0.66	19	Weak	0.16	0.61	12	Weak	0.02	0.95	11	None
	AS	-0.27	0.48	9	Weak	-0.33	0.29	12	Medium	-0.03	0.94	11	None	-0.06	0.86	12	None
L3LI	SBC	0.19	0.54	13	Weak	-0.35	0.27	12	Medium	-0.13	0.59	21	Weak	-0.05	0.85	18	None
	SBL	-0.01	0.96	21	None	-0.03	0.89	21	None	-0.07	0.82	13	None	-0.18	0.58	12	Weak
	AS	-0.09	0.78	12	None	0.04	0.88	15	None	0.02	0.95	14	None	0.09	0.74	15	None
L3RI	SBC	-0.09	0.76	13	None	-0.35	0.26	12	Medium	-0.07	0.76	21	None	-0.28	0.25	18	Weak
	SBL	0.06	0.82	20	None	-0.08	0.74	21	None	0.07	0.82	13	None	-0.12	0.70	12	Weak
	AS	-0.29	0.37	12	Weak	-0.08	0.78	13	None	-0.20	0.50	13	Weak	-0.26	0.36	14	Weak
L4LS	SBC	0.37	0.22	13	Medium	-0.31	0.32	12	Medium	-0.30	0.19	21	Medium	-0.26	0.30	18	Weak
	SBL	-0.13	0.58	19	Weak	-0.10	0.71	18	None	0.77	0.01	10	**Strong**	-0.01	0.97	11	None
	AS	-0.29	0.36	12	Weak	-0.17	0.53	15	Weak	-0.07	0.81	14	None	0.01	0.97	15	None

Appendix B-7 Spearman's rho correlation between facet size and femoral robusticity continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
L4RS	SBC	0.14	0.65	13	Weak	-0.13	0.70	12	Weak	0.23	0.31	21	Weak	0.04	0.88	18	None
	SBL	0.01	0.95	20	None	-0.02	0.94	19	None	0.65	0.04	10	**Strong**	-0.14	0.69	10	Weak
	AS	-0.31	0.30	13	Medium	-0.13	0.64	16	Weak	-0.36	0.20	14	Medium	-0.35	0.20	15	Medium
L4LI	SBC	-0.35	0.24	13	Medium	-0.37	0.23	12	Medium	0.26	0.26	21	Weak	0.08	0.76	18	None
	SBL	-0.06	0.82	19	None	0.04	0.88	18	None	0.64	0.05	10	**Strong**	-0.23	0.50	11	Weak
	AS	-0.24	0.45	12	Weak	-0.12	0.67	15	Weak	-0.30	0.34	12	Medium	-0.29	0.34	13	Weak
L4RI	SBC	-0.08	0.81	13	None	-0.22	0.49	12	Weak	0.40	0.07	21	Medium	0.00	0.99	18	None
	SBL	-0.12	0.60	20	Weak	-0.02	0.94	19	None	0.76	0.01	10	**Strong**	-0.15	0.65	11	Weak
	AS	0.23	0.46	12	Weak	0.32	0.27	14	Medium	0.13	0.70	12	Weak	0.08	0.80	13	None
L5LS	SBC	0.39	0.22	12	Medium	-0.06	0.85	11	None	0.18	0.47	18	Weak	-0.12	0.67	16	Weak
	SBL	0.14	0.55	22	Weak	0.10	0.65	22	Weak	0.31	0.33	12	Medium	0.15	0.66	11	Weak
	AS	0.10	0.78	10	None	0.14	0.64	13	Weak	-0.20	0.50	13	Weak	-0.25	0.38	14	Weak
L5RS	SBC	-0.16	0.62	12	Weak	-0.01	0.97	11	None	-0.09	0.72	18	None	-0.28	0.29	16	Weak
	SBL	0.02	0.93	20	None	0.11	0.64	20	Weak	-0.11	0.73	12	Weak	0.14	0.69	11	Weak
	AS	0.10	0.77	10	Weak	0.17	0.58	13	Weak	-0.31	0.30	13	Medium	-0.25	0.39	14	Weak

Appendix B-7 Spearman's rho correlation between facet size and femoral robusticity continued

Facet	Sample	Male								Female							
L5LI	SBC	-0.02	0.96	12	None	-0.12	0.72	11	Weak	0.15	0.56	18	Weak	-0.20	0.47	16	Weak
	SBL	0.12	0.61	22	Weak	-0.39	0.08	22	Medium	0.06	0.86	12	None	-0.05	0.88	11	None
	AS	-0.03	0.94	9	None	0.04	0.90	12	None	-0.12	0.72	12	Weak	-0.22	0.47	13	Weak
L5RI	SBC	0.11	0.73	12	Weak	0.03	0.94	11	None	0.15	0.54	18	Weak	-0.02	0.95	16	None
	SBL	0.05	0.83	21	None	-0.24	0.29	21	Weak	0.19	0.55	12	Weak	-0.05	0.88	11	None
	AS	0.20	0.59	10	Weak	0.28	0.36	13	Weak	-0.37	0.21	13	Medium	-0.37	0.19	14	Medium

Appendix B-8 Correlation between humeral and facet size directional asymmetry

Facet	Sample	Male				Female			
		Continuity Coefficient	P	Phi	Phi correlation Strength	Continuity Coefficient	P	Phi	Phi correlation Strength
C1S	SBC	0.00	1.00	0.13	Weak	0.23	0.63	0.17	Weak
	SBL	0.44	0.51	0.26	Weak	0.00	1.00	-0.12	Weak
	AS	0.32	0.57	0.47	Medium	No data			
C1I	SBC	0.00	1.00	-0.16	Weak	0.02	0.90	-0.10	Weak
	SBL	0.00	1.00	-0.09	None	0.00	1.00	-0.06	None
	AS	0.00	1.00	0.15	Weak				
C2S	SBC	0.56	0.46	-0.32	Medium	1.26	0.26	-0.28	Weak
	SBL	0.20	0.65	-0.23	Weak	1.13	0.29	0.38	Medium
	AS	0.10	0.74	-0.42	Medium	0.00	1.00	-0.10	Weak
C2I	SBC	0.00	1.00	-0.05	None	0.00	0.97	0.08	None
	SBL	0.00	1.00	0.07	None	0.00	0.98	0.13	Weak
	AS	0.00	1.00	0.00	None	0.00	1.00	0.10	Weak
C3S	SBC	0.29	0.59	0.29	Weak	0.00	1.00	0.04	None
	SBL	0.11	0.74	0.18	Weak	0.35	0.55	0.26	Weak
	AS	0.00	1.00	-0.15	Weak	0.00	1.00	0.10	Weak
C3I	SBC	0.35	0.55	0.32	Medium	1.67	0.20	-0.34	Medium
	SBL	0.00	0.98	-0.12	Weak	0.00	1.00	0.03	None
	AS	0.00	1.00	-0.15	Weak	0.00	1.00	0.10	Weak
C4S	SBC	0.00	1.00	-0.06	None	0.00	1.00	0.00	None
	SBL	0.00	0.98	-0.12	Weak	3.58	0.06	0.54	**Strong**
	AS	1.18	0.28	-0.73	**Strong**				
CC4I	SBC	0.00	1.00	0.07	None	0.02	0.88	-0.11	Weak
	SBL	0.47	0.49	-0.25	Weak	1.88	0.17	0.41	Medium
	AS	0.00	1.00	-0.09	None				
C5S	SBC	0.23	0.64	-0.22	Weak	0.02	0.89	-0.10	Weak
	SBL	0.04	0.83	-0.15	Weak	2.31	0.13	0.43	Medium
	AS	0.00	1.00	0.00	None	0.00	1.00	0.10	Weak

Appendix B-8 Correlation between humeral and facet size directional asymmetry continued

Facet	Sample	Male				Female			
		Continuity Coefficient	P	Phi	Phi correlation Strength	Continuity Coefficient	P	Phi	Phi correlation Strength
C5I	SBC	1.83	0.18	-0.43	Medium	0.00	1.00	0.05	None
	SBL	0.01	0.91	0.13	Weak	0.08	0.78	0.16	Weak
	AS	0.09	0.76	0.50	**Strong**				
C6S	SBC	0.00	1.00	-0.07	None	0.03	0.87	-0.11	Weak
	SBL	0.00	1.00	-0.07	None	0.00	1.00	0.01	None
	AS	0.11	0.74	-0.42	Medium				
C6I	SBC					0.05	0.82	0.24	weak
	SBL	0.02	0.88	-0.19	Weak	0.04	0.83	0.28	Weak
	AS								
C7S	SBC	0.00	1.00	0.00	None	0.00	1.00	0.03	None
	SBL	0.00	1.00	0.06	None	0.95	0.33	0.31	Medium
	AS	0.37	0.55	0.55	**Strong**				
C7!	SBC	0.47	0.49	-0.29	Weak	0.00	1.00	-0.01	None
	SBL	0.53	0.47	-0.25	Weak	0.00	1.00	0.01	None
	AS	0.00	1.00	-0.09	None				
T1S	SBC	0.00	1.00	0.00	None	0.12	0.73	-0.14	Weak
	SBL	0.00	1.00	0.06	None	0.00	1.00	-0.08	None
	AS	0.18	0.67	0.45	Medium				
T1I	SBC	0.00	1.00	-0.13	Weak	0.52	0.47	-0.13	Weak
	SBL	0.81	0.37	-0.27	Weak	0.01	0.93	0.12	Weak
	AS	0.00	1.00	0.16	Weak				
T2S	SBC	0.00	1.00	-0.08	None	5.17	0.23	0.48	Medium
	SBL	0.00	1.00	-0.04	None	0.67	0.41	-0.30	Weak
	AS	0.03	0.86	0.33	Medium				
T2I	SBC	0.00	1.00	0.00	None	1.76	0.19	0.31	Medium
	SBL	2.40	0.12	0.40	Medium	4.02	0.05	-0.57	**Strong**
	AS	0.00	1.00	-0.07	None				
T3S	SBC	0.38	0.54	-0.27	Weak	5.17	0.02	0.48	Medium
	SBL	0.71	0.40	0.29	Weak	0.03	0.87	0.16	Weak
	AS	0.00	1.00	-0.07	None				

Appendix B-8 Correlation between humeral and facet size directional asymmetry continued

Facet	Sample	Male				Female			
		Continuity Coefficient	P	Phi	Phi correlation Strength	Continuity Coefficient	P	Phi	Phi correlation Strength
T3I	SBC	1.42	0.23	0.41	Medium	3.03	0.08	0.39	Medium
	SBL	0.21	0.65	-0.21	Weak	0.00	0.96	0.13	Weak
	AS	2.34	0.63	0.41	Medium				
T4S	SBC	0.00	0.96	0.13	Weak	3.41	0.07	0.42	Medium
	SBL	0.00	1.00	-0.12	Weak	0.33	0.57	0.27	Weak
	AS	0.00	1.00	0.13	Weak	0.00	1.00	-0.17	Weak
T4I	SBC	0.00	1.00	-0.06	None	1.61	0.20	-0.32	Medium
	SBL	0.86	0.36	-0.30	Medium	0.00	1.00	-0.12	Weak
	AS	0.00	1.00	0.00	None	0.00	1.00	-0.41	Medium
T5S	SBC	0.00	1.00	-0.06	None	0.00	1.00	-0.07	None
	SBL	0.46	0.50	0.27	Weak	0.09	0.77	0.21	Weak
	AS	0.05	0.83	-0.25	Weak	0.00	1.00	-0.58	**Strong**
T5I	SBC	0.23	0.64	-0.22	Weak	0.02	0.89	0.11	Weak
	SBL	0.42	0.52	-0.25	Weak	0.04	0.84	-0.17	Weak
	AS	0.33	0.57	-0.39	Medium	0.00	1.00	-0.33	Medium
T6S	SBC	0.14	0.71	0.20	Weak	0.00	1.00	-0.05	None
	SBL	0.50	0.95	-0.13	Weak	0.00	1.00	-0.11	Weak
	AS	0.00	1.00	0.35	Medium	0.44	0.51	1.00	**Strong**
T6I	SBC	0.00	1.00	0.08	None	0.00	1.00	-0.07	None
	SBL	0.00	1.00	-0.12	Weak	1.43	0.23	0.40	Medium
	AS	0.00	1.00	-0.07	None	0.00	1.00	0.58	**Strong**
T7S	SBC	0.00	1.00	0.03	None	0.00	1.00	-0.07	None
	SBL	0.00	1.00	0.10	None	0.14	0.71	0.20	Weak
	AS	0.14	0.71	-0.35	Medium	0.00	1.00	0.41	Medium
T7I	SBC	0.50	0.48	0.31	Medium	3.76	0.05	0.43	Medium
	SBL	0.00	1.00	0.09	None	0.00	1.00	-0.19	Weak
	AS	0.00	1.00	0.10	Weak	0.31	0.58	-0.67	**Strong**
T8S	SBC								
	SBL								
	AS	0.05	0.83	-0.41	Medium				

Appendix B-8 Correlation between humeral and facet size directional asymmetry continued

Facet	Sample	Male				Female			
		Continuity Coefficient	P	Phi	Phi correlation Strength	Continuity Coefficient	P	Phi	Phi correlation Strength
T8I	SBC	0.68	0.41	0.33	Medium	0.00	1.00	0.01	None
	SBL	0.00	1.00	0.06	None	0.03	0.86	-0.18	Weak
	AS	0.42	0.52	0.41	Medium				
T9S	SBC	0.00	1.00	0.00	None	0.01	0.94	0.09	None
	SBL	0.15	0.70	0.18	Weak	0.59	0.44	0.31	Medium
	AS	0.00	1.00	0.16	Weak	0.00	1.00	-0.41	Medium
T9I	SBC	1.81	0.18	-0.45	Medium	0.00	1.00	0.59	**Strong**
	SBL	0.00	1.00	-0.08	None	0.00	1.00	-0.03	None
	AS	0.00	1.00	0.07	None	0.05	0.82	-0.61	**Strong**
T10S	SBC	0.11	0.74	0.20	Weak	0.01	0.94	-0.08	None
	SBL	0.93	0.34	0.30	Medium	0.81	0.37	0.33	Medium
	AS	0.97	0.32	-0.60	**Strong**	0.00	1.00	-0.41	Medium
T10I	SBC	0.00	1.00	-0.03	None	0.01	0.94	-0.09	None
	SBL	0.00	1.00	0.00	None	0.00	1.00	0.04	None
	AS	0.00	1.00	-0.26	Weak	0.00	1.00	-0.41	Medium
T11S	SBC	0.70	0.40	0.32	Medium	1.31	0.25	-0.29	Weak
	SBL	0.00	1.00	-0.01	None	0.00	1.00	0.11	Weak
	AS	0.97	0.32	0.60	**Strong**	0.00	1.00	-0.41	Medium
T11I	SBC	0.03	0.88	-0.17	Weak	0.00	1.00	0.00	None
	SBL	0.00	1.00	0.02	None	0.00	0.98	0.12	Weak
	AS	1.41	0.24	0.63	**Strong**	0.00	1.00	0.17	Weak
T12S	SBC	0.47	0.49	-0.29	Weak	0.00	1.00	-0.04	None
	SBL	0.00	1.00	0.12	Weak	1.82	0.18	0.44	Medium
	AS	0.89	0.35	0.60	**Strong**	0.31	0.58	0.67	**Strong**
T12I	SBC	0.23	0.64	-0.22	Weak	0.07	0.80	-0.12	Weak
	SBL	0.00	1.00	0.04	None	1.05	0.31	0.35	Medium
	AS	0.00	1.00	-0.26	Weak	0.00	1.00	0.17	Weak
L1S	SBC	0.00	1.00	0.03	None	0.00	1.00	-0.03	None
	SBL	0.21	0.65	-0.21	Weak	0.00	1.00	0.03	None
	AS	0.00	1.00	0.00	None	0.00	1.00	0.41	Medium

Appendix B-8 Correlation between humeral and facet size directional asymmetry continued

Facet	Sample	Male				Female			
		Continuity Coefficient	P	Phi	Phi correlation Strength	Continuity Coefficient	P	Phi	Phi correlation Strength
L1I	SBC	0.14	0.71	0.20	Weak	0.01	0.93	-0.09	None
	SBL	0.00	1.00	0.09	None	0.00	0.96	0.13	Weak
	AS	1.18	0.28	-0.73	**Strong**	0.00	1.00	0.17	Weak
L2S	SBC	3.85	0.05	0.58	**Strong**	1.61	0.20	0.32	Medium
	SBL	0.03	0.85	0.15	Weak	0.00	1.00	-0.03	None
	AS	1.60	0.21	0.75	**Strong**	1.70	0.19	-1.00	**Strong**
L2I	SBC	0.00	1.00	0.67	**Strong**	0.02	0.90	-0.10	Weak
	SBL	0.00	1.00	0.00	None	0.23	0.64	-0.22	Weak
	AS	0.08	0.79	0.49	Medium	0.00	1.00	-0.17	Weak
L3S	SBC	0.81	0.37	0.33	Medium	0.00	1.00	0.73	**Strong**
	SBL	0.54	0.46	0.29	Weak	0.00	0.96	-0.13	Weak
	AS	2.96	0.09	-1.00	**Strong**	0.31	0.58	0.67	**Strong**
L3I	SBC	0.35	0.55	0.26	Weak	0.22	0.64	-0.16	Weak
	SBL	0.31	0.58	0.24	Weak	0.09	0.76	-0.22	Weak
	AS	0.32	0.57	-0.47	Medium	1.70	0.19	1.00	**Strong**
L4S	SBC	0.00	1.00	0.06	None	1.95	0.16	-0.34	Medium
	SBL	0.00	1.00	-0.05	None	0.00	1.00	-0.15	Weak
	AS	0.00	1.00	0.15	Weak	0.31	0.58	-0.67	**Strong**
L4I	SBC	0.00	1.00	-0.06	None	0.21	0.64	-0.16	Weak
	SBL	0.13	0.71	0.22	Weak	0.11	0.74	0.24	Weak
	AS	0.89	0.35	0.60	**Strong**	0.31	0.58	0.67	**Strong**
L5S	SBC	0.00	1.00	0.07	None	0.00	1.00	0.01	None
	SBL	1.06	0.30	-0.34	Medium	0.04	0.84	0.17	Weak
	AS	0.00	1.00	0.26	Weak				
L5I	SBC	1.83	0.18	0.43	Medium	3.40	0.07	0.40	Medium
	SBL	0.22	0.64	0.19	Weak	0.00	1.00	0.04	None
	AS	0.43	0.84	-0.24	Weak	0.00	1.00	-0.17	Weak

Appendix B-9 Correlation between eburnation and facet size

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C1LS	SBC	0.04	0.86	19	None			21	
	SBL	-0.26	0.29	19	Weak			15	
	AS	-0.03	0.94	11	None			6	
C1RS	SBC	-0.01	0.99	18	None	-0.10	0.66	22	Weak
	SBL	-0.02	0.93	20	None			15	
	AS	0.01	0.97	14	None			6	
C1LI	SBC	-0.22	0.38	19	Weak	-0.36	0.11	21	Medium
	SBL	-0.31	0.20	19	Medium	0.00	1.00	15	None
	AS	0.23	0.52	10	Weak			5	
C1RI	SBC			19				22	
	SBL	-0.37	0.11	20	Medium	-0.31	0.26	15	Medium
	AS	-0.23	0.44	13	Weak			6	
C2LS	SBC	-0.35	0.13	20	Medium	0.16	0.46	23	Weak
	SBL	-0.29	0.21	21	Weak	0.03	0.91	14	None
	AS	-0.23	0.49	11	Weak	-0.39	0.26	10	Medium
C2RS	SBC	-0.30	0.19	21	Medium	-0.14	0.53	24	Weak
	SBL	-0.16	0.48	21	Weak	-0.45	0.11	14	Medium
	AS	-0.38	0.20	13	Medium	-0.18	0.63	10	Weak
C2LI	SBC	0.16	0.52	18	Weak	0.21	0.34	23	Weak
	SBL	-0.14	0.56	20	Weak	-0.08	0.80	13	None
	AS	0.16	0.68	9	Weak	0.58	0.13	8	**Strong**
C2RI	SBC			17		0.26	0.24	23	Weak
	SBL	0.19	0.42	21	Weak	-0.31	0.28	14	Medium
	AS	0.32	0.40	9	Medium	0.58	0.13	8	**Strong**
C3LS	SBC	0.36	0.23	13	Medium	0.20	0.37	23	Weak
	SBL	0.28	0.20	22	Weak	0.25	0.37	15	Weak
	AS	-0.25	0.37	15	Weak	0.60	0.09	9	**Strong**

Appendix B-9 Correlation between eburnation and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C3RS	SBC	-0.08	0.80	13	None	0.00	1.00	23	None
	SBL	-0.26	0.25	22	Weak	-0.56	0.04	14	**Strong**
	AS	-0.29	0.30	15	Weak	0.53	0.15	9	**Strong**
C3LI	SBC	-0.37	0.22	13	Medium	-0.33	0.14	21	Medium
	SBL	-0.18	0.44	21	Weak	0.25	0.37	15	Weak
	AS	-0.09	0.75	15	None	0.17	0.67	9	Weak
C3RI	SBC			13		0.29	0.19	22	Weak
	SBL	-0.22	0.32	22	Weak	-0.03	0.91	14	None
	AS	0.14	0.65	13	Weak	-0.55	0.13	9	**Strong**
C4LS	SBC	-0.29	0.31	14	Weak	-0.13	0.57	21	Weak
	SBL			24				17	
	AS	-0.42	0.18	12	Medium	0.00	1.00	6	None
C4RS	SBC	0.22	0.50	12	Weak	-0.34	0.15	20	Medium
	SBL	-0.16	0.45	25	Weak	-0.31	0.25	16	Medium
	AS	-0.18	0.57	13	Weak	0.62	0.19	6	**Strong**
C4LI	SBC	0.30	0.32	13	Medium	0.28	0.22	21	Weak
	SBL	-0.31	0.13	25	Medium	0.20	0.43	17	Weak
	AS	-0.09	0.78	12	None	0.21	0.69	6	Weak
C4RI	SBC	0.39	0.21	12	Medium	0.21	0.36	21	Weak
	SBL	-0.23	0.28	25	Weak	-0.31	0.25	16	Medium
	AS	0.08	0.82	12	None	0.39	0.44	6	Medium

Appendix B-9 Correlation between eburnation and facet size continued

Facet	Sample	Male					Female		
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C5LS	SBC	0.21	0.37	20	Weak	-0.04	0.85	26	None
	SBL	-0.16	0.45	24	Weak	0.07	0.76	20	None
	AS	-0.05	0.90	8	None	-0.08	0.85	8	None
C5RS	SBC	0.24	0.31	20	Weak	-0.28	0.17	26	Weak
	SBL	-0.44	0.03	25	Medium	-0.26	0.27	20	Weak
	AS	-0.19	0.65	8	Weak	0.52	0.19	8	**Strong**
C5LI	SBC			20		-0.07	0.75	26	None
	SBL	-0.19	0.38	24	Weak			20	
	AS	-0.06	0.90	8	None	0.74	0.04	8	**Strong**
C5RI	SBC	-0.47	0.04	20	Medium			26	
	SBL	0.21	0.32	24	Weak	-0.38	0.10	20	Medium
	AS	0.18	0.67	8	Weak	0.74	0.04	8	**Strong**
C6LS	SBC	-0.17	0.50	19	Weak	-0.14	0.51	24	Weak
	SBL	0.08	0.72	25	None	-0.16	0.53	18	Weak
	AS	-0.08	0.84	9	None	0.36	0.43	7	Medium
C6RS	SBC	-0.01	0.96	19	None	-0.33	0.11	25	Medium
	SBL	0.53	0.01	24	**Strong**	-0.30	0.22	18	Medium
	AS	0.01	0.98	11	None	0.11	0.80	8	Weak
C6LI	SBC	0.05	0.85	19	None			24	
	SBL	0.17	0.40	26	Weak	0.07	0.78	18	None
	AS	-0.08	0.85	9	None	-0.45	0.26	8	Medium
C6RI	SBC			19				25	
	SBL	-0.32	0.13	24	Medium			18	
	AS	0.03	0.94	10	None	0.25	0.56	8	Weak
C7LS	SBC	0.19	0.44	19	Weak	0.09	0.64	28	None
	SBL	0.01	0.95	26	None	-0.13	0.57	21	Weak
	AS	-0.03	0.93	10	None	0.03	0.95	6	None
C7RS	SBC	0.03	0.90	19	None			27	
	SBL	0.09	0.65	27	None	-0.51	0.02	21	**Strong**
	AS	-0.19	0.51	14	Weak	0.73	0.06	7	**Strong**

Appendix B-9 Correlation between eburnation and facet size continued

Facet	Sample	Male					Female		
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C7LI	SBC	0.13	0.60	19	Weak	0.05	0.82	28	None
	SBL	-0.23	0.25	28	Weak	-0.22	0.33	21	Weak
	AS	-0.40	0.17	13	Medium	0.66	0.16	6	**Strong**
C7RI	SBC			19		-0.38	0.05	28	Medium
	SBL	0.20	0.30	28	Weak			21	
	AS	-0.15	0.61	14	Weak	0.20	0.66	7	Weak
T1LS	SBC	0.52	0.03	18	**Strong**	-0.04	0.84	29	None
	SBL	-0.23	0.23	30	Weak	-0.44	0.06	19	Medium
	AS	-0.31	0.30	13	Medium	-0.11	0.78	9	Weak
T1RS	SBC	0.02	0.93	19	None	-0.07	0.71	30	None
	SBL	0.07	0.73	29	None	-0.33	0.14	21	Medium
	AS	-0.02	0.94	16	None	0.22	0.55	10	Weak
T1LI	SBC			20		-0.13	0.50	31	Weak
	SBL	0.08	0.66	31	None	-0.26	0.26	21	Weak
	AS	-0.12	0.64	17	Weak	-0.14	0.71	10	Weak
T1RI	SBC			20		-0.10	0.59	31	Weak
	SBL			31		-0.15	0.52	21	Weak
	AS	-0.16	0.57	15	Weak	0.28	0.44	10	Weak
T2LS	SBC			23		-0.04	0.83	28	None
	SBL	0.24	0.18	32	Weak			19	
	AS	-0.04	0.86	19	None	-0.20	0.50	14	Weak
T2RS	SBC	-0.21	0.33	23	Weak	-0.03	0.89	29	None
	SBL	-0.15	0.42	33	Weak			20	
	AS	-0.13	0.61	19	Weak	0.00	0.99	14	None
T2LI	SBC	-0.24	0.29	21	Weak	0.32	0.10	29	Medium
	SBL			33				19	
	AS	-0.50	0.03	20	**Strong**	0.16	0.58	14	Weak
T2RI	SBC	0.13	0.56	23	Weak	0.25	0.19	29	Weak
	SBL	0.03	0.86	31	None	0.34	0.15	20	Medium
	AS	-0.40	0.11	17	Medium	0.26	0.38	14	Weak

Appendix B-9 Correlation between eburnation and facet size continued

Facet	Sample	Male					Female		
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T3LS	SBC	-0.24	0.30	21	Weak	0.15	0.46	26	Weak
	SBL	0.12	0.59	22	Weak	0.05	0.83	21	None
	AS	0.07	0.78	19	None	-0.21	0.44	16	Weak
T3RS	SBC	-0.59	0.00	22	**Strong**	-0.08	0.68	27	None
	SBL	0.26	0.20	25	Weak	0.30	0.19	21	Medium
	AS	0.14	0.54	22	Weak	0.15	0.56	17	Weak
T3LI	SBC			22		0.21	0.29	27	Weak
	SBL			25		0.38	0.10	20	Medium
	AS	0.13	0.61	18	Weak	0.24	0.41	14	Weak
T3RI	SBC	-0.22	0.33	22	Weak	0.12	0.55	27	Weak
	SBL	-0.13	0.55	25	Weak	0.05	0.84	20	None
	AS	-0.08	0.76	18	None	-0.23	0.38	16	Weak
T4LS	SBC	-0.53	0.02	19	**Strong**	-0.04	0.87	25	None
	SBL	0.16	0.44	26	Weak	0.39	0.10	19	Medium
	AS	0.16	0.51	18	Weak	-0.32	0.22	17	Medium
T4RS	SBC	-0.43	0.07	19	Medium	-0.07	0.74	24	None
	SBL	-0.23	0.26	25	Weak	-0.20	0.41	19	Weak
	AS	-0.38	0.10	20	Medium	0.10	0.70	17	Weak
T4LI	SBC	0.39	0.10	19	Medium	0.10	0.63	24	Weak
	SBL			25				16	
	AS	-0.09	0.73	17	None	-0.12	0.68	15	Weak
T4RI	SBC			17		0.17	0.51	17	Weak
	SBL			17		0.48	0.11	12	Medium
	AS	-0.38	0.20	13	Medium	-0.18	0.58	12	Weak
T5LS	SBC	-0.17	0.48	19	Weak	-0.28	0.18	25	Weak
	SBL	0.05	0.82	22	None	0.30	0.21	19	Medium
	AS	-0.20	0.10	18	Weak	0.27	0.31	16	Weak

Appendix B-9 Correlation between eburnation and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T5RS	SBC	0.02	0.93	19	None	0.13	0.54	25	Weak
	SBL	0.08	0.72	21	None	-0.24	0.32	19	Weak
	AS	-0.45	0.05	20	Medium	0.30	0.26	16	Medium
T5LI	SBC	-0.05	0.85	17	None	-0.11	0.63	22	Weak
	SBL			20				19	
	AS	-0.41	0.12	16	Medium	-0.01	0.98	15	None
T5RI	SBC	-0.21	0.40	18	Weak	-0.17	0.44	22	Weak
	SBL			23		-0.30	0.22	18	Medium
	AS	-0.62	0.01	17	**Strong**	-0.25	0.37	15	Weak
T6LS	SBC	-0.36	0.16	17	Medium	-0.09	0.67	26	None
	SBL	-0.37	0.07	24	Medium	0.08	0.74	19	None
	AS	0.09	0.75	15	None	0.08	0.80	14	None
T6RS	SBC	0.02	0.95	17	None	-0.03	0.89	26	None
	SBL	0.07	0.73	24	None	-0.15	0.53	20	Weak
	AS	-0.20	0.45	16	Weak	-0.17	0.55	14	Weak
T6LI	SBC			19		0.08	0.67	28	None
	SBL			23				20	
	AS	0.26	0.39	13	Weak	-0.38	0.18	14	Medium
T6RI	SBC			19				28	
	SBL			22		0.06	0.80	20	None
	AS	-0.37	0.20	14	Medium	-0.56	0.04	14	**Strong**
T7LS	SBC			20		0.06	0.76	27	None
	SBL	-0.01	0.98	23	None	0.27	0.27	18	Weak
	AS	-0.15	0.62	14	Weak	-0.11	0.70	16	Weak
T7RS	SBC			20		-0.24	0.24	26	Weak
	SBL	-0.29	0.17	24	Weak	-0.05	0.85	17	None
	AS	-0.29	0.29	15	Weak	0.38	0.15	16	Medium
T7LI	SBC			19				26	
	SBL			19				18	
	AS	-0.65	0.02	12	**Strong**	0.46	0.08	16	Medium

Appendix B-9 Correlation between eburnation and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T7RI	SBC			19				26	
	SBL			22		0.12	0.64	18	Weak
	AS	-0.31	0.31	13	Medium	0.28	0.34	14	Weak
T8LS	SBC	0.06	0.80	21	None	0.28	0.18	24	Weak
	SBL			25		0.41	0.10	17	Medium
	AS	0.23	0.40	15	Weak	-0.15	0.57	16	Weak
T8RS	SBC			21		-0.34	0.11	24	Medium
	SBL	0.11	0.59	25	Weak	0.46	0.07	17	Medium
	AS	0.11	0.70	15	Weak	-0.30	0.26	16	Medium
T8LI	SBC	-0.04	0.87	21	None	-0.05	0.80	24	None
	SBL	-0.16	0.44	25	Weak			15	
	AS	0.05	0.85	16	None	-0.25	0.35	16	Weak
T8RI	SBC			22		-0.17	0.44	24	Weak
	SBL	0.02	0.94	25	None			16	
	AS	0.14	0.62	16	Weak	0.31	0.26	15	Medium
T9LS	SBC	0.00	1.00	21	None	-0.02	0.92	29	None
	SBL	-0.23	0.26	26	Weak	0.04	0.88	16	None
	AS	-0.23	0.36	18	Weak	0.01	0.96	17	None
T9RS	SBC	-0.38	0.09	21	Medium	0.35	0.06	29	Medium
	SBL	-0.14	0.49	26	Weak	0.31	0.25	16	Medium
	AS	-0.20	0.44	18	Weak	-0.01	0.98	17	None
T9LI	SBC			19		-0.16	0.40	29	Weak
	SBL	-0.14	0.50	25	Weak			16	
	AS	-0.18	0.50	17	Weak	-0.17	0.54	15	Weak
T9RI	SBC			19		-0.05	0.81	28	None
	SBL			23		-0.03	0.92	16	None
	AS	-0.40	0.12	16	Medium	0.23	0.40	15	Weak
T10LS	SBC	-0.14	0.55	20	Weak	-0.08	0.69	28	None
	SBL	-0.04	0.85	26	None			14	
	AS	-0.28	0.25	18	Weak	-0.52	0.07	13	**Strong**

Appendix B-9 Correlation between eburnation and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T10RS	SBC			20		-0.25	0.21	27	Weak
	SBL	0.03	0.90	27	None	0.14	0.64	14	Weak
	AS	-0.18	0.49	17	Weak	0.22	0.48	13	Weak
T10LI	SBC			20		0.06	0.76	28	None
	SBL			27		0.30	0.29	14	Medium
	AS	-0.17	0.50	18	Weak	0.32	0.30	13	Medium
T10RI	SBC			20		-0.03	0.90	27	None
	SBL			27		-0.20	0.47	16	Weak
	AS	-0.32	0.20	18	Medium	0.33	0.27	13	Medium
T11LS	SBC			20		0.08	0.70	28	None
	SBL	-0.09	0.69	24	None			14	
	AS	-0.28	0.33	14	Weak	0.52	0.07	13	**Strong**
T11RS	SBC	0.29	0.21	21	Weak	0.09	0.65	28	None
	SBL	0.24	0.27	24	Weak	-0.06	0.83	15	None
	AS	0.11	0.67	17	Weak	0.56	0.04	14	**Strong**
T11LI	SBC	-0.26	0.27	20	Weak	0.00	1.00	27	None
	SBL			23		0.03	0.91	14	None
	AS	-0.55	0.02	17	**Strong**	-0.08	0.80	14	None
T11RI	SBC			20		-0.08	0.71	27	None
	SBL			25				15	
	AS	-0.59	0.02	15	**Strong**	-0.46	0.16	11	Medium
T12LS	SBC	0.12	0.64	18	Weak	0.17	0.40	26	Weak
	SBL	0.29	0.18	23	Weak	-0.17	0.56	14	Weak
	AS	-0.42	0.14	14	Medium	-0.25	0.41	13	Weak
T12RS	SBC	0.02	0.93	18	None	-0.07	0.75	26	None
	SBL			23				14	
	AS	-0.40	0.16	14	Medium	0.16	0.61	13	Weak
T12LI	SBC	0.08	0.74	19	None	0.30	0.13	27	Medium
	SBL	0.23	0.30	23	Weak			14	
	AS	-0.83	0.00	12	**Strong**	-0.46	0.18	10	Medium

Appendix B-9 Correlation between eburnation and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T12RI	SBC	-0.12	0.64	18	Weak			27	
	SBL	0.19	0.38	23	Weak			14	
	AS	-0.57	0.04	13	**Strong**	0.18	0.59	12	Weak
L1LS	SBC	-0.24	0.32	19	Weak			25	
	SBL			23		-0.31	0.31	13	Medium
	AS	-0.35	0.22	14	Medium	0.19	0.51	14	Weak
L1RS	SBC	0.10	0.70	19	Weak			23	
	SBL	-0.32	0.13	24	Medium			12	
	AS	0.02	0.95	13	None	0.12	0.69	13	Weak
L1LI	SBC	0.00	1.00	19	None			24	
	SBL	-0.17	0.42	25	Weak			13	
	AS	-0.50	0.08	13	**Strong**	-0.22	0.41	16	Weak
L1RI	SBC	0.00	0.99	19	None			23	
	SBL	0.03	0.89	25	None			12	
	AS	-0.37	0.19	14	Medium	-0.34	0.21	15	Medium
L2LS	SBC	0.11	0.63	21	Weak	0.31	0.13	25	Medium
	SBL			22				13	
	AS	0.06	0.83	17	None	-0.76	0.00	12	**Strong**
L2RS	SBC			21				24	
	SBL			23				11	
	AS	-0.20	0.46	16	Weak	-0.32	0.31	12	Medium
L2LI	SBC			21				24	
	SBL			24				12	
	AS	-0.61	0.02	14	**Strong**	-0.17	0.59	13	Weak
L2RI	SBC			20				24	
	SBL	-0.11	0.62	24	Weak			12	
	AS	0.01	0.97	14	None	-0.48	0.10	13	Medium
L3LS	SBC	-0.20	0.40	20	Weak			28	
	SBL	-0.06	0.80	20	None			13	
	AS	-0.63	0.01	17	**Strong**	-0.27	0.27	18	Weak

Appendix B-9 Correlation between eburnation and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
L3RS	SBC	0.00	1.00	21	None			25	
	SBL	-0.07	0.78	18	None			13	
	AS	-0.45	0.10	15	Medium	0.18	0.55	13	Weak
L3LI	SBC	0.21	0.35	21	Weak	0.10	0.62	29	None
	SBL	-0.14	0.56	20	Weak			15	
	AS	-0.17	0.50	18	Weak	0.00	1.00	16	None
L3RI	SBC	-0.35	0.12	21	Medium			28	
	SBL			20		-0.06	0.83	15	None
	AS	-0.06	0.83	15	None	-0.10	0.72	15	Weak
L4LS	SBC			20				25	
	SBL			19				10	
	AS	-0.06	0.82	17	None	-0.06	0.81	16	None
L4RS	SBC	0.08	0.73	20	None	0.09	0.69	25	None
	SBL			20		0.00	1.00	9	None
	AS	-0.12	0.65	18	Weak	-0.35	0.18	16	Medium
L4LI	SBC	-0.30	0.20	20	Medium			25	
	SBL			18		0.06	0.87	10	None
	AS	0.14	0.61	16	Weak	-0.47	0.10	13	Medium
L4RI	SBC	0.30	0.20	20	Medium	-0.31	0.13	26	Medium
	SBL			20				10	
	AS	0.39	0.15	15	Medium	-0.01	0.99	13	None
L5LS	SBC	-0.13	0.59	19	Weak	0.10	0.68	20	Weak
	SBL	-0.15	0.47	24	Weak	-0.51	0.08	13	**Strong**
	AS	0.04	0.89	14	None	-0.45	0.12	13	Medium
L5RS	SBC	-0.17	0.48	19	Weak			20	
	SBL	0.36	0.10	22	Medium	-0.08	0.80	13	None
	AS	0.04	0.90	13	None	-0.20	0.51	13	Weak
L5LI	SBC	0.10	0.68	19	Weak			18	
	SBL	-0.35	0.10	24	Medium	-0.08	0.80	13	None
	AS	0.10	0.76	11	Weak	-0.23	0.88	13	Weak

Appendix B-9 Correlation between eburnation and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
L5RI	SBC	-0.09	0.73	19	None			19	
	SBL	0.23	0.30	23	Weak			13	
	AS	0.06	0.84	14	None	-0.15	0.64	13	Weak

Appendix B-10 Correlation between pitting score and facet size

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C1LS	SBC	-0.15	0.57	18	Weak	-0.46	0.03	23	Medium
	SBL	-0.03	0.92	19	None	0.31	0.28	14	Medium
	AS	0.15	0.65	12	Weak	0	1	7	None
C1RS	SBC	0.26	0.31	18	Weak	-0.44	0.04	23	Medium
	SBL	-0.17	0.47	20	Weak			14	
	AS	0.26	0.37	14	Weak	0.36	0.43	7	Medium
C1LI	SBC	-0.34	0.17	18	Medium	-0.28	0.2	23	Weak
	SBL	-0.23	0.35	19	Weak	0.03	0.91	14	None
	AS	0.01	0.97	10	None	-0.54	0.27	6	**Strong**
C1RI	SBC	-0.06	0.8	18	None	-0.13	0.57	23	Weak
	SBL	-0.18	0.45	20	Weak	-0.1	0.73	14	Weak
	AS	-0.25	0.42	13	Weak	0.61	0.14	7	**Strong**
C2LS	SBC	0.12	0.62	20	Weak	-0.01	0.97	25	None
	SBL	-0.28	0.24	20	Weak	0	1	13	None
	AS	0.01	0.99	11	None	0.66	0.03	11	**Strong**
C2RS	SBC	0.38	0.1	20	Medium	-0.21	0.3	25	Weak
	SBL	0.01	0.98	21	None	-0.04	0.89	13	None
	AS	-0.11	0.72	13	Weak	0.55	0.1	10	**Strong**
C2LI	SBC	-0.4	0.1	18	Medium	-0.01	0.96	25	None
	SBL	0.3	0.21	19	Medium	0.1	0.76	13	None
	AS	0.11	0.79	9	Weak	0.4	0.28	9	Medium
C2RI	SBC	-0.15	0.56	17	Weak	0.03	0.9	25	None
	SBL	0.26	0.26	21	Weak	-0.39	0.19	13	Medium
	AS	0.03	0.95	9	None	0.69	0.04	9	**Strong**
C3LS	SBC	0.11	0.72	13	Weak	-0.26	0.25	22	Weak
	SBL	-0.06	0.81	21	None	0.04	0.89	17	None
	AS	-0.07	0.82	15	None	0.09	0.84	8	None
C3RS	SBC	-0.37	0.22	13	Medium	0.18	0.42	22	Weak
	SBL	0	0.99	21	None	-0.27	0.32	16	Weak
	AS	-0.21	0.46	15	Weak	0.51	0.19	8	**Strong**
C3LI	SBC	-0.32	0.29	13	Medium	0.13	0.59	20	Weak
	SBL	0.09	0.69	20	None	-0.01	0.96	17	None
	AS	0.2	0.48	15	Weak	0.37	0.37	8	Medium
C3RI	SBC	-0.09	0.77	13	None	-0.12	0.61	20	Weak
	SBL	0.15	0.52	21	Weak	-0.12	0.67	16	Weak
	AS	0.39	0.19	13	Medium	-0.03	0.95	8	None

Appendix B-10 Correlation between pitting score and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C4LS	SBC	-0.08	0.79	13	None	0.22	0.36	20	Weak
	SBL	-0.04	0.85	23	None	0.02	0.94	16	None
	AS	-0.18	0.58	12	Weak	0.52	0.3	6	**Strong**
C4RS	SBC	-0.02	0.96	11	None	0.2	0.38	21	Weak
	SBL	-0.08	0.72	24	None	0.26	0.36	15	Weak
	AS	0.39	0.19	13	Medium	0.62	0.19	6	**Strong**
C4LI	SBC	-0.15	0.63	13	Weak	0.18	0.42	23	Weak
	SBL	-0.44	0.03	24	Medium	0.04	0.89	16	None
	AS	0.26	0.42	12	Weak	0.35	0.49	6	Medium
C4RI	SBC	-0.03	0.92	12	None	0.27	0.21	23	Weak
	SBL	-0.02	0.93	24	None	-0.31	0.26	15	Medium
	AS	0.52	0.08	12	**Strong**	0.1	0.85	6	Weak
C5LS	SBC	0.24	0.3	20	Weak	-0.26	0.18	27	Weak
	SBL	-0.26	0.22	24	Weak	-0.09	0.72	20	None
	AS	-0.24	0.56	8	Weak	0.26	0.53	8	Weak
C5RS	SBC	-0.22	0.35	20	Weak	-0.1	0.64	27	None
	SBL	0.11	0.59	25	Weak	0.03	0.91	17	None
	AS	-0.56	0.15	8	**Strong**	0.85	0.01	8	**Strong**
C5LI	SBC	-0.3	0.2	20	Medium	0.38	0.05	27	Medium
	SBL	-0.13	0.54	24	Weak	0.1	0.68	20	Weak
	AS	-0.29	0.48	8	Weak	0.58	0.13	8	**Strong**
C5RI	SBC	-0.2	0.4	20	Weak	0.09	0.66	27	None
	SBL	0.22	0.29	24	Weak	0.06	0.8	20	None
	AS	-0.41	0.31	8	Medium	0.58	0.13	8	**Strong**
C6LS	SBC	-0.13	0.6	18	Weak	-0.15	0.49	25	Weak
	SBL	0.12	0.58	23	Weak	0.11	0.66	19	Weak
	AS	-0.07	0.86	9	None	0.51	0.24	7	**Strong**
C6RS	SBC	0.05	0.84	18	None	0	1	26	None
	SBL	0.52	0.01	22	**Strong**	0.12	0.63	19	Weak
	AS	-0.38	0.24	11	Medium	0.29	0.49	8	Weak
C6LI	SBC	0.15	0.56	18	Weak	0.13	0.53	25	Weak
	SBL	-0.27	0.19	26	Weak	-0.25	0.31	19	Weak
	AS	-0.3	0.44	9	Weak	-0.22	0.61	8	Weak
C6RI	SBC	0.26	0.3	18	Weak	0.19	0.35	25	Weak
	SBL	-0.16	0.47	22	Weak	-0.28	0.24	19	Weak
	AS	-0.36	0.31	10	Medium	0	1	8	None
C7LS	SBC	0.14	0.59	18	Weak	-0.2	0.32	28	Weak
	SBL	-0.31	0.12	26	Medium	-0.21	0.37	20	Weak
	AS	-0.3	0.38	11	Weak	-0.06	0.91	6	None

Appendix B-10 Correlation between pitting score and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C7RS	SBC	-0.15	0.56	18	Weak	0.22	0.26	28	Weak
	SBL	0.45	0.03	25	Medium	-0.41	0.06	22	Medium
	AS	-0.07	0.83	12	None	0.22	0.63	7	Weak
C7LI	SBC	-0.28	0.26	18	Weak	-0.03	0.89	29	None
	SBL	-0.1	0.62	27	Weak	-0.35	0.12	22	Medium
	AS	0.02	0.95	12	None	0.21	0.69	6	Weak
C7RI	SBC	0.24	0.34	18	Weak	0.08	0.68	29	None
	SBL	-0.02	0.91	27	None	0.22	0.32	22	Weak
	AS	0.17	0.58	13	Weak	-0.05	0.92	7	None
T1LS	SBC	-0.09	0.76	16	None	-0.44	0.01	31	Medium
	SBL	0.15	0.45	29	Weak	-0.3	0.2	20	Weak
	AS	-0.27	0.4	12	Weak	0.36	0.31	10	Medium
T1RS	SBC	0.04	0.88	18	None	0.04	0.84	32	None
	SBL	0.05	0.79	29	None	-0.3	0.18	21	Medium
	AS	-0.25	0.38	14	Weak	0.31	0.32	12	Medium
T1LI	SBC	-0.31	0.2	19	Medium	0.31	0.08	32	Medium
	SBL	-0.06	0.75	30	None	0.02	0.92	22	None
	AS	0.15	0.28	14	Weak	0.02	0.94	12	None
T1RI	SBC	-0.29	0.22	19	Weak	0.07	0.71	32	None
	SBL	0.24	0.21	30	Weak	-0.1	0.66	21	Weak
	AS	-0.16	0.58	14	Weak	0.29	0.37	12	Weak
T2LS	SBC	0.04	0.83	29	None	-0.44	0.07	18	Medium
	SBL	0.04	0.83	29	None	-0.44	0.07	18	Medium
	AS	-0.28	0.27	17	Weak	0.05	0.85	16	None
T2RS	SBC	-0.1	0.58	34	None	0.41	0.08	19	Medium
	SBL	-0.1	0.58	34	None	0.41	0.08	19	Medium
	AS	-0.53	0.02	19	**Strong**	-0.05	0.85	16	None
T2LI	SBC	0.26	0.25	21	Weak	0.4	0.02	31	Medium
	SBL	-0.03	0.85	33	None	0.11	0.65	19	Weak
	AS	-0.23	0.32	20	Weak	-0.04	0.9	14	None
T2RI	SBC	-0.16	0.5	21	Weak	-0.15	0.44	30	Weak
	SBL	0.02	0.92	32	None	-0.15	0.52	20	Weak
	AS	-0.08	0.75	19	None	0.17	0.55	14	Weak
T3LS	SBC	-0.06	0.82	20	None	0.44	0.02	28	Medium
	SBL	0.07	0.73	24	None	0.06	0.8	20	None
	AS	0.03	0.92	18	None	-0.2	0.48	15	Weak

Appendix B-10 Correlation between pitting score and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T3RS	SBC	0.19	0.41	20	Weak	-0.06	0.77	29	None
	SBL	0.15	0.46	26	Weak	0.28	0.24	20	Weak
	AS	0.11	0.63	21	Weak	0.1	0.72	16	None
T3LI	SBC	0.59	0.01	20	**Strong**	0.35	0.06	29	Medium
	SBL	-0.14	0.5	24	Weak	0.1	0.67	21	Weak
	AS	-0.18	0.46	20	Weak	0.01	0.98	13	None
T3RI	SBC	-0.38	0.1	20	Medium	0.03	0.86	29	None
	SBL	-0.18	0.38	25	Weak	0.17	0.47	21	Weak
	AS	-0.13	0.59	20	Weak	-0.03	0.92	15	None
T4LS	SBC	-0.31	0.25	16	Medium	0.04	0.82	28	None
	SBL	-0.01	0.95	26	None	0.05	0.85	18	None
	AS	-0.39	0.1	19	Medium	-0.17	0.53	17	Weak
T4RS	SBC	0	1	16	None	-0.05	0.82	27	None
	SBL	0.1	0.65	24	None	0.13	0.61	18	Weak
	AS	0.02	0.93	18	None	0.04	0.89	17	None
T4LI	SBC	-0.2	0.45	16	Weak	0.13	0.51	27	Weak
	SBL	0.03	0.88	24	None	0.49	0.05	16	**Strong**
	AS	0.1	0.71	17	None	0.17	0.55	15	Weak
T4RI	SBC	-0.34	0.24	14	Medium	-0.46	0.05	19	Medium
	SBL	0.5	0.05	16	**Strong**	0.45	0.14	12	Medium
	AS	-0.32	0.24	15	Medium	-0.56	0.07	11	**Strong**
T5LS	SBC	-0.23	0.39	16	Weak	-0.11	0.58	28	Weak
	SBL	0.29	0.19	22	Weak	-0.05	0.83	19	None
	AS	-0.12	0.61	19	Weak	-0.07	0.81	16	None
T5RS	SBC	-0.35	0.18	16	Medium	-0.22	0.29	25	Weak
	SBL	0.4	0.07	21	Medium	-0.12	0.63	19	Weak
	AS	0.19	0.41	19	Weak	-0.13	0.63	17	Weak
T5LI	SBC	0.46	0.08	15	Medium	-0.23	0.26	24	Weak
	SBL	-0.04	0.86	20	None	0.3	0.19	20	Medium
	AS	0.21	0.46	15	Weak	0.52	0.07	13	**Strong**
T5RI	SBC	-0.25	0.35	16	Weak	-0.26	0.22	24	Weak
	SBL	0.01	0.98	23	None	-0.07	0.78	20	None
	AS	-0.47	0.07	16	Medium	-0.15	0.63	13	Weak
T6LS	SBC	-0.36	0.14	18	Medium	0.13	0.53	26	Weak
	SBL	-0.1	0.63	25	Weak	-0.18	0.47	19	Weak
	AS	-0.14	0.62	15	Weak	-0.2	0.54	12	Weak
T6RS	SBC	-0.32	0.2	18	Medium	-0.19	0.36	26	Weak
	SBL	0.09	0.67	25	None	-0.14	0.57	19	Weak
	AS	-0.06	0.83	16	None	-0.33	0.29	12	Medium

Appendix B-10 Correlation between pitting score and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T6LI	SBC	-0.11	0.66	19	Weak	-0.28	0.16	27	Weak
	SBL	0.05	0.84	22	None	0.18	0.44	20	Weak
	AS	0.37	0.18	15	Medium	-0.04	0.89	12	None
T6RI	SBC	-0.08	0.74	19	None	-0.34	0.08	28	Medium
	SBL	-0.11	0.61	23	Weak	-0.2	0.43	17	Weak
	AS	0	1	15	None	-0.76	0	12	**Strong**
T7LS	SBC	0.19	0.43	19	Weak	0.28	0.14	29	Weak
	SBL	0.04	0.85	25	None	0.25	0.33	18	Weak
	AS	-0.46	0.1	14	Medium	0.06	0.83	16	None
T7RS	SBC	0.36	0.13	19	Medium	0.04	0.84	27	None
	SBL	-0.12	0.59	24	Weak	-0.17	0.52	16	Weak
	AS	-0.32	0.25	15	Medium	-0.02	0.93	16	None
T7LI	SBC	0.22	0.38	18	Weak	0.06	0.78	28	None
	SBL	-0.04	0.87	22	None	-0.2	0.43	17	Weak
	AS	-0.54	0.07	12	**Strong**	0.5	0.05	16	**Strong**
T7RI	SBC	0.17	0.49	18	Weak	-0.13	0.53	28	Weak
	SBL	-0.11	0.61	23	Weak	-0.2	0.43	17	Weak
	AS	-0.48	0.1	13	Medium	0.49	0.07	14	Medium
T8LS	SBC	0.47	0.04	19	Medium	0.3	0.12	28	Medium
	SBL	0.04	0.85	25	None	0.25	0.33	18	Weak
	AS	-0.27	0.35	14	Weak	0.09	0.75	16	None
T8RS	SBC	0.41	0.08	19	Medium	-0.05	0.79	28	None
	SBL	-0.16	0.45	25	Weak	0.16	0.52	18	Weak
	AS	-0.29	0.3	15	Weak	-0.13	0.63	16	Weak
T8LI	SBC	0.28	0.25	19	Weak	-0.28	0.15	28	Weak
	SBL	-0.12	0.56	25	Weak			16	
	AS	-0.57	0.02	16	**Strong**	-0.05	0.85	16	None
T8RI	SBC	0.04	0.87	20	None	-0.02	0.92	28	None
	SBL	0.15	0.49	25	Weak	0.36	0.16	17	Medium
	AS	-0.3	0.26	16	Weak	-0.21	0.46	15	Weak
T9LS	SBC	-0.34	0.16	19	Medium	0	0.99	30	None
	SBL	0.29	0.16	26	Weak	-0.09	0.74	17	None
	AS	0.28	0.27	17	Weak	0.12	0.64	18	Weak
T9RS	SBC	-0.23	0.35	19	Weak	-0.2	0.28	30	Weak
	SBL	0.55	0	26	**Strong**			17	
	AS	0.06	0.82	16	None	0.13	0.62	18	Weak

Appendix B-10 Correlation between pitting score and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T9LI	SBC	-0.17	0.51	18	Weak	-0.23	0.24	29	Weak
	SBL	-0.08	0.72	25	None			17	
	AS	0.28	0.32	15	Weak	0.15	0.57	16	Weak
T9RI	SBC	-0.03	0.89	18	None	-0.17	0.4	28	Weak
	SBL	-0.22	0.32	22	Weak			17	
	AS	-0.08	0.79	14	None	0.28	0.29	16	Weak
T10LS	SBC	0.03	0.91	18	None	0.01	0.97	28	None
	SBL	0.1	0.65	25	None	0.36	0.17	16	Medium
	AS	-0.34	0.22	15	Medium	-0.05	0.88	14	None
T10RS	SBC	0.15	0.57	18	Weak	0.11	0.56	29	Weak
	SBL	0.26	0.21	26	Weak			16	
	AS	0.08	0.76	16	None	-0.32	0.27	14	Medium
T10LI	SBC	0.34	0.17	18	Medium	0.17	0.37	29	Weak
	SBL	0.07	0.74	26	None			16	
	AS	-0.12	0.68	14	Weak	-0.44	0.11	14	Medium
T10RI	SBC	-0.05	0.84	18	None	0.16	0.4	29	Weak
	SBL	-0.28	0.17	26	Weak			15	
	AS	-0.05	0.86	15	None	0	0.99	14	None
T11LS	SBC	0.1	0.69	19	None	0.01	0.96	28	None
	SBL	-0.04	0.85	23	None	0.15	0.13	16	Weak
	AS	-0.19	0.55	13	Weak	0.01	0.99	14	None
T11RS	SBC	-0.12	0.61	19	Weak	-0.06	0.78	29	None
	SBL	-0.01	0.96	24	None	-0.29	0.28	16	Weak
	AS	0.22	0.4	17	Weak	0.2	0.48	15	Weak
T11LI	SBC	0.37	0.13	18	Medium	0.2	0.32	28	Weak
	SBL	0	0.99	23	None	0.12	0.66	15	Weak
	AS	0.24	0.37	16	Weak	-0.16	0.57	15	Weak
T11RI	SBC	0.44	0.07	18	Medium	0.33	0.08	28	Medium
	SBL	0.01	0.98	24	None	0.42	0.11	16	Medium
	AS	-0.17	0.6	12	Weak	-0.29	0.36	12	Weak
T12LS	SBC	0.25	0.33	17	Weak	-0.1	0.64	25	None
	SBL	-0.06	0.8	22	None	-0.39	0.14	16	Medium
	AS	-0.15	0.53	12	Weak	-0.31	0.31	13	Medium
T12RS	SBC	0.21	0.42	17	Weak	-0.05	0.83	25	None
	SBL	-0.04	0.86	22	None	0.2	0.47	16	Weak
	AS	-0.2	0.51	13	Weak	-0.24	0.44	13	Weak
T12LI	SBC	0.25	0.32	18	Weak	0.2	0.32	26	Weak
	SBL	0.16	0.49	22	Weak	0.23	16	-0.37	Weak
	AS	-0.48	0.1	13	Medium	-0.58	0.05	12	**Strong**

Appendix B-10 Correlation between pitting score and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T12RI	SBC	-0.14	0.6	17	Weak	0.23	0.25	26	Weak
	SBL	0.32	0.15	22	Medium	-0.04	0.88	16	None
	AS	-0.38	0.29	10	Medium	-0.02	0.96	12	None
L1LS	SBC	0.02	0.95	19	None	-0.2	0.33	25	Weak
	SBL	0.4	0.07	22	Medium	-0.31	0.31	13	Medium
	AS	-0.23	0.41	15	Weak	-0.07	0.81	15	None
L1RS	SBC	-0.23	0.35	19	Weak	0.03	0.9	23	None
	SBL	-0.13	0.56	24	Weak	0.05	0.88	12	None
	AS	-0.01	0.97	13	None	0.12	0.7	14	Weak
L1LI	SBC	0.34	0.16	19	Medium	0.03	0.87	24	None
	SBL	0.09	0.69	25	None	0.08	0.8	13	None
	AS	-0.4	0.16	13	Medium	-0.23	0.4	16	Weak
L1RI	SBC	-0.28	0.25	19	Weak	0.02	0.94	24	None
	SBL	-0.09	0.68	24	None	-0.4	0.2	12	Medium
	AS	-0.42	0.12	15	Medium	-0.55	0.03	15	**Strong**
L2LS	SBC	0.2	0.38	21	Weak	0.04	0.84	26	None
	SBL	0.36	0.1	22	Medium	0.31	0.3	13	Medium
	AS	-0.16	0.53	18	Weak	-0.4	0.17	13	Medium
L2RS	SBC	0.22	0.35	21	Weak	-0.04	0.83	25	None
	SBL	0.09	0.7	23	None	0.1	0.77	11	Weak
	AS	-0.45	0.08	16	Medium	0.18	0.55	13	Weak
L2LI	SBC	0.16	0.48	21	Weak	-0.13	0.54	25	Weak
	SBL	0.44	0.03	24	Medium	0.56	0.06	12	**Strong**
	AS	-0.31	0.28	14	Medium	0.05	0.87	13	None
L2RI	SBC	0	0.99	20	None	-0.13	0.54	25	Weak
	SBL	-0.04	0.86	24	None	0.38	0.22	12	Medium
	AS	-0.44	0.12	14	Medium	-0.11	0.71	14	Weak
L3LS	SBC	0.11	0.64	20	Weak	0.07	0.72	27	None
	SBL	0.2	0.4	20	Weak	-0.4	0.18	13	Medium
	AS	-0.51	0.04	17	**Strong**	-0.19	0.48	16	Weak
L3RS	SBC	-0.13	0.57	21	Weak	0	0.99	25	None
	SBL	-0.05	0.86	18	None	-0.29	0.35	13	Weak
	AS	-0.07	0.8	15	None	-0.13	0.68	12	Weak
L3LI	SBC	0.23	0.32	20	Weak	0.28	0.14	29	Weak
	SBL	-0.14	0.56	20	Weak	0.3	0.27	15	Medium
	AS	-0.03	0.92	18	None	-0.28	0.32	15	Medium

Appendix B-10 Correlation between pitting score and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
L3RI	SBC	-0.07	0.77	20	None	0.24	0.22	28	Weak
	SBL			20		-0.26	0.37	14	Weak
	AS	-0.03	0.92	15	None	-0.22	0.46	14	Medium
L4LS	SBC	-0.12	0.61	20	Weak	0.06	0.79	25	None
	SBL	-0.07	0.78	19	None			10	
	AS	-0.06	0.83	17	None	-0.25	0.35	16	Medium
L4RS	SBC	-0.11	0.65	20	Weak	0.06	0.77	25	None
	SBL	0.35	0.13	20	Medium	0.14	0.73	9	Weak
	AS	-0.06	0.83	17	None	-0.25	0.35	16	Medium
L4LI	SBC	-0.05	0.84	20	None	-0.25	0.18	30	Weak
	SBL	0.07	0.78	18	None	0.61	0.06	10	**Strong**
	AS	0.23	0.39	16	Weak	-0.67	0.01	13	**Strong**
L4RI	SBC	0.57	0.01	19	**Strong**	-0.32	0.11	26	Medium
	SBL	0.03	0.89	20	None	-0.52	0.12	10	**Strong**
	AS	0.38	0.16	15	Medium	0.07	0.83	13	None
L5LS	SBC	0.23	0.36	19	Weak	0.37	0.1	21	Medium
	SBL	0.02	0.93	24	None	-0.54	0.06	13	**Strong**
	AS	0.04	0.9	14	None	-0.15	0.62	13	Weak
L5RS	SBC	0.12	0.63	19	Weak	0.09	0.69	21	None
	SBL	-0.19	0.42	21	Weak	-0.17	0.58	13	Weak
	AS	-0.15	0.64	13	Weak	0.1	0.75	13	None
L5LI	SBC	0.16	0.53	19	Weak	-0.02	0.93	21	None
	SBL	-0.04	0.84	24	None	-0.17	0.59	13	Weak
	AS	0.22	0.49	12	Weak	0.62	0.03	12	**Strong**
L5RI	SBC	0.14	0.57	19	Weak	0.06	0.81	21	None
	SBL	0.14	0.54	22	Weak	-0.39	0.19	13	Medium
	AS	0.32	0.27	14	Medium	-0.19	0.55	13	Weak

Appendix B-11 Correlation between osteophyte score and facet size

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C1LS	SBC			18		0	1	23	None
	SBL	-0.03	0.92	19	None	0.31	0.28	14	Medium
	AS			12				6	
C1RS	SBC			18		-0.03	0.88	23	None
	SBL	-0.17	0.47	20	Weak			14	
	AS			14				6	
C1LI	SBC	0.12	0.64	18	Weak			23	
	SBL	-0.23	0.35	19	Weak	0.03	0.91	14	None
	AS			10				5	
C1RI	SBC			18				23	
	SBL	-0.18	0.45	20	Weak	-0.1	0.73	14	Weak
	AS	-0.46	0.11	13	Medium			6	
C2LS	SBC	0.26	0.27	20	Weak			25	
	SBL	-0.28	0.24	20	Weak	0	1	13	None
	AS	-0.5	0.12	11	**Strong**			10	
C2RS	SBC			20		-0.26	0.22	25	Weak
	SBL	0.01	0.98	21	None	-0.04	0.89	13	None
	AS			13				9	
C2LI	SBC	0.1	0.69	18	Weak	-0.03	0.89	25	None
	SBL	0.3	0.21	19	Medium	0.1	0.76	13	None
	AS			9				8	
C2RI	SBC	-0.2	0.43	17	Weak	0.01	0.95	25	None
	SBL	0.26	0.26	21	Weak	-0.39	0.19	13	Medium
	AS			9		0.25	0.56	8	Weak
C3LS	SBC	0	1	13	None	0.15	0.52	22	Weak
	SBL	-0.06	0.81	21	None	0.04	0.89	17	None
	AS			15		-0.25	0.55	8	Weak
C3RS	SBC	-0.48	0.1	13	Medium	0.32	0.15	22	Medium
	SBL	0	0.99	21	None	-0.27	0.32	16	Weak
	AS	-0.19	0.51	15	Weak	0.74	0.04	8	**Strong**
C3LI	SBC	-0.39	0.19	13	Medium	0.05	0.85	20	None
	SBL	0.09	0.69	20	None	-0.01	0.96	17	None
	AS	-0.31	0.26	15	Medium	-0.06	0.88	8	None
C3RI	SBC	0.1	0.76	13	Weak	0.08	0.75	20	None
	SBL	0.15	0.52	21	Weak	-0.12	0.67	16	Weak
	AS			13		0.33	0.42	8	Medium

Appendix B-11 Correlation between osteophyte score and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C4LS	SBC	-0.24	0.44	13	Weak	0.13	0.59	21	Weak
	SBL	-0.04	0.85	23	None	0.02	0.94	16	None
	AS	-0.15	0.64	12	Weak			6	
C4RS	SBC	-0.08	0.81	11	None	0.52	0.02	21	**Strong**
	SBL	-0.08	0.72	24	None	0.26	0.36	15	Weak
	AS	0.46	0.12	13	Medium	0.49	0.33	6	Medium
C4LI	SBC	0.19	0.53	13	Weak	-0.06	0.78	23	None
	SBL	-0.44	0.03	24	Medium	0.04	0.89	16	None
	AS	0.22	0.5	12	Weak	0.28	0.59	6	Weak
C4RI	SBC	-0.01	0.97	12	None	-0.18	0.42	23	Weak
	SBL	-0.02	0.93	24	None	-0.31	0.26	15	Medium
	AS	0.13	0.69	12	Weak	0.37	0.47	6	Medium
C5LS	SBC	-0.16	0.51	20	Weak	0.1	0.63	27	Weak
	SBL	-0.26	0.22	24	Weak	-0.09	0.72	20	None
	AS	0.48	0.23	8	Medium	-0.42	0.31	8	Medium
C5RS	SBC	-0.06	0.8	20	None	0.15	0.47	27	Weak
	SBL	0.11	0.59	25	Weak	0.03	0.91	17	None
	AS	0.41	0.31	8	Medium	0.25	0.55	8	Weak
C5LI	SBC	-0.51	0.02	20	**Strong**	0.18	0.37	27	Weak
	SBL	-0.13	0.54	24	Weak	0.1	0.68	20	Weak
	AS	-0.41	0.31	8	Medium			8	
C5RI	SBC	-0.25	0.3	20	Weak	0.28	0.16	27	Weak
	SBL	0.22	0.29	24	Weak	0.06	0.8	20	None
	AS	-0.25	0.56	8	Weak	-0.04	0.93	8	None
C6LS	SBC	0.03	0.92	18	None	0.25	0.24	25	Weak
	SBL	0.12	0.58	23	Weak	0.11	0.66	19	Weak
	AS	0.14	0.73	9	Weak			7	
C6RS	SBC	0.27	0.27	18	Weak	-0.18	0.37	26	Weak
	SBL	0.52	0.01	22	**Strong**	0.12	0.63	19	Weak
	AS	0.1	0.77	11	Weak	0.05	0.91	8	None
C6LI	SBC	0.04	0.88	18	None	0.11	0.61	25	Weak
	SBL	-0.27	0.19	26	Weak	-0.25	0.31	19	Weak
	AS	0.27	0.48	9	Weak	-0.25	0.56	8	Weak
C6RI	SBC	-0.25	0.32	18	Weak	-0.1	0.64	26	Weak
	SBL	-0.16	0.47	22	Weak	-0.28	0.24	19	Weak
	AS			10		-0.25	0.56	8	Weak
C7LS	SBC	-0.17	0.5	18	Weak	0.08	0.66	29	None
	SBL	-0.31	0.12	26	Medium	-0.21	0.37	20	Weak
	AS	-0.1	0.77	11	Weak	-0.41	0.41	6	Medium

Appendix B-11 Correlation between osteophyte score and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C7RS	SBC	-0.25	0.32	18	Weak	0.02	0.94	28	None
	SBL	0.45	0.03	25	Medium	-0.41	0.06	22	Medium
	AS			13		0.2	0.66	7	Weak
C7LI	SBC	-0.06	0.81	18	None	0	0.99	29	None
	SBL	-0.1	0.62	27	Weak	-0.35	0.12	22	Medium
	AS	0.08	0.79	13	None	0.66	0.16	6	**Strong**
C7RI	SBC	0.19	0.46	18	Weak	-0.23	0.24	29	Weak
	SBL	-0.02	0.91	27	None	0.22	0.32	22	Weak
	AS	-0.15	0.62	13	Weak	0.41	0.36	7	Medium
T1LS	SBC	-0.09	0.74	18	None	-0.02	0.93	29	None
	SBL	0.15	0.45	29	Weak	-0.3	0.2	20	Weak
	AS	0	1	13	None	0.44	0.24	9	Medium
T1RS	SBC	-0.31	0.2	19	Medium	-0.24	0.2	31	Weak
	SBL	0.05	0.79	29	None	-0.3	0.18	21	Medium
	AS	0.09	0.75	16	None	0.36	0.31	10	Medium
T1LI	SBC			20		0.06	0.75	31	None
	SBL	-0.06	0.75	30	None	0.02	0.92	22	None
	AS			18		-0.7	0.02	10	**Strong**
T1RI	SBC			20		0.13	0.5	31	Weak
	SBL	0.24	0.21	30	Weak	-0.1	0.66	21	Weak
	AS	-0.2	0.47	16	Weak	0.29	0.42	10	Weak
T2LS	SBC	0.04	0.83	29	None	-0.44	0.07	18	Medium
	SBL	0.04	0.83	29	None	-0.44	0.07	18	Medium
	AS	-0.17	0.48	19	Weak	-0.02	0.94	14	None
T2RS	SBC	-0.1	0.58	34	None	0.41	0.08	19	Medium
	SBL	-0.1	0.58	34	None	0.41	0.08	19	Medium
	AS	-0.3	0.2	21	Medium	0.11	0.72	14	Weak
T2LI	SBC	-0.35	0.1	23	Medium	0.34	0.08	29	Medium
	SBL	-0.03	0.85	33	None	0.11	0.65	19	Weak
	AS	-0.09	0.7	22	None	-0.1	0.73	14	Weak
T2RI	SBC	-0.23	0.29	23	Weak	0	0.99	29	None
	SBL	0.02	0.92	32	None	-0.15	0.52	20	Weak
	AS	-0.37	0.1	21	Medium	0.09	0.75	14	None
T3LS	SBC	-0.04	0.87	21	None	0.24	0.23	27	Weak
	SBL	0.07	0.73	24	None	0.06	0.8	20	None
	AS	-0.35	0.15	19	Medium	-0.42	0.1	16	Medium

Appendix B-11 Correlation between osteophyte score and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T3RS	SBC	-0.29	0.2	22	Weak	0.05	0.8	27	None
	SBL	0.15	0.46	26	Weak	0.28	0.24	20	Weak
	AS			22		0.18	0.48	17	Weak
T3LI	SBC	-0.39	0.07	22	Medium	0.31	0.12	27	Medium
	SBL	-0.14	0.5	24	Weak	0.1	0.67	21	Weak
	AS	0.3	0.21	19	Medium	0.12	0.69	14	Weak
T3RI	SBC	-0.33	0.13	22	Medium	0.32	0.12	26	Medium
	SBL	-0.18	0.38	25	Weak	0.17	0.47	21	Weak
	AS	-0.04	0.86	19	None	-0.14	0.63	15	Weak
T4LS	SBC	-0.14	0.56	19	Weak	0.12	0.57	25	Weak
	SBL	-0.01	0.95	26	None	0.05	0.85	18	None
	AS	-0.5	0.03	20	**Strong**	-0.34	0.19	16	Medium
T4RS	SBC	-0.12	0.63	19	Weak	0.13	0.56	24	Weak
	SBL	0.1	0.65	24	None	0.13	0.61	18	Weak
	AS	0.02	0.93	20	None	0.19	0.48	16	Weak
T4LI	SBC	-0.41	0.08	19	Medium	0.35	0.09	24	Medium
	SBL	0.03	0.88	24	None	0.49	0.05	16	**Strong**
	AS								
T4RI	SBC	-0.16	0.54	17	Weak	0.01	0.98	19	None
	SBL	0.5	0.05	16	**Strong**	0.45	0.14	12	Medium
	AS	-0.08	0.8	13	None	0.24	0.46	12	Weak
T5LS	SBC	-0.18	0.47	19	Weak	0	0.98	25	None
	SBL	0.29	0.19	22	Weak	-0.05	0.83	19	None
	AS	0.04	0.88	19	None	0.23	0.39	16	Weak
T5RS	SBC	-0.05	0.85	19	None	-0.12	0.57	25	Weak
	SBL	0.4	0.07	21	Medium	-0.12	0.63	19	Weak
	AS	-0.31	0.18	20	Medium	0.41	0.11	16	Medium
T5LI	SBC	-0.32	0.21	17	Medium	-0.11	0.63	22	Weak
	SBL	-0.04	0.86	20	None	0.3	0.19	20	Medium
	AS			14		-0.25	0.37	15	Weak
T5RI	SBC	0.07	0.78	18	None	0.1	0.66	22	Weak
	SBL	0.01	0.98	23	None	-0.07	0.78	20	None
	AS	0.29	0.3	15	Weak	-0.2	0.49	15	Weak
T6LS	SBC	-0.69	0	17	**Strong**	-0.02	0.93	26	None
	SBL	-0.1	0.63	25	Weak	-0.18	0.47	19	Weak
	AS	0.2	0.46	16	Weak	0.17	0.56	14	Weak
T6RS	SBC	-0.45	0.07	17	Medium	0.1	0.62	26	Weak
	SBL	0.09	0.67	25	None	-0.14	0.57	19	Weak
	AS	0.3	0.26	16	Medium	-0.06	0.84	14	None

Appendix B-11 Correlation between osteophyte score and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T6LI	SBC			19		-0.2	0.31	27	Weak
	SBL	0.05	0.84	22	None	0.18	0.44	20	Weak
	AS	0.38	0.18	14	Medium	0.32	0.26	14	Medium
T6RI	SBC	0.03	0.92	19	None	-0.19	0.34	28	Weak
	SBL	-0.11	0.61	23	Weak	-0.2	0.43	17	Weak
	AS			14		-0.05	0.86	14	None
T7LS	SBC	-0.17	0.46	20	Weak	0.1	0.6	28	Weak
	SBL	0.04	0.85	25	None	0.25	0.33	18	Weak
	AS	-0.05	0.87	14	None	0.04	0.9	15	None
T7RS	SBC	0.15	0.52	20	Weak	-0.11	0.59	26	Weak
	SBL	-0.12	0.59	24	Weak	-0.17	0.52	16	Weak
	AS	-0.01	0.97	15	None	-0.38	0.17	15	Medium
T7LI	SBC			18		-0.18	0.37	27	Weak
	SBL	-0.04	0.87	22	None	-0.2	0.43	17	Weak
	AS	-0.15	0.62	13	Weak	0.43	0.11	15	Medium
T7RI	SBC			19		0.08	0.71	27	None
	SBL	-0.11	0.61	23	Weak	-0.2	0.43	17	Weak
	AS			13		-0.39	0.19	13	Medium
T8LS	SBC	0	1	21	None	-0.13	0.54	24	Weak
	SBL	0.04	0.85	25	None	0.25	0.33	18	Weak
	AS	0.5	0.07	14	**Strong**	0.57	0.03	15	**Strong**
T8RS	SBC	-0.02	0.94	21	None	0.19	0.37	24	Weak
	SBL	-0.16	0.45	25	Weak	0.16	0.52	18	Weak
	AS	0.54	0.05	14	**Strong**	-0.03	0.92	15	None
T8LI	SBC	-0.33	0.14	21	Medium	-0.09	0.68	24	None
	SBL	-0.12	0.56	25	Weak			16	
	AS			15		-0.25	0.37	15	Weak
T8RI	SBC	-0.22	0.32	22	Weak	0	0.99	24	None
	SBL	0.15	0.49	25	Weak	0.36	0.16	17	Medium
	AS	-0.31	0.26	15	Medium	-0.07	0.8	14	None
T9LS	SBC	-0.08	0.73	21	None	0.11	0.59	29	Weak
	SBL	0.29	0.16	26	Weak	-0.09	0.74	17	None
	AS	-0.22	0.39	18	Weak	0.36	0.18	16	Medium
T9RS	SBC	0.08	0.73	21	None	0.19	0.32	29	Weak
	SBL	0.55	0	26	**Strong**			17	
	AS	0.01	0.98	18	None	-0.11	0.68	16	Weak

Appendix B-11 Correlation between osteophyte score and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T9LI	SBC			19		-0.03	0.9	29	None
	SBL	-0.08	0.72	25	None			17	
	AS	-0.37	0.14	17	Medium	0.18	0.54	14	Weak
T9RI	SBC	-0.09	0.73	19	None	-0.14	0.5	27	Weak
	SBL	-0.22	0.32	22	Weak			17	
	AS			16		-0.16	0.57	15	Weak
T10LS	SBC	-0.07	0.76	20	None	0.03	0.9	28	None
	SBL	0.1	0.65	25	None	0.36	0.17	16	Medium
	AS	0.22	0.38	18	Weak	-0.43	0.15	13	Medium
T10RS	SBC	0.27	0.25	20	Weak	0.01	0.97	28	None
	SBL	0.26	0.21	26	Weak			16	
	AS	0.45	0.07	17	Medium	-0.07	0.82	13	None
T10LI	SBC	-0.22	0.37	19	Weak	0.1	0.63	27	Weak
	SBL	0.07	0.74	26	None			16	
	AS	0.47	0.06	17	Medium	0.27	0.4	12	Weak
T10RI	SBC	-0.12	0.61	19	Weak	-0.02	0.93	27	None
	SBL	-0.28	0.17	26	Weak			15	
	AS	0.41	0.1	17	Medium	0.62	0.03	12	**Strong**
T11LS	SBC	0.19	0.42	20	Weak	0.03	0.87	29	None
	SBL	-0.04	0.85	23	None	0.15	0.13	16	Weak
	AS	0.06	0.83	14	None	-0.28	0.36	13	Medium
T11RS	SBC	-0.06	0.78	21	None	0.08	0.67	29	None
	SBL	-0.01	0.96	24	None	-0.29	0.28	16	Weak
	AS	-0.17	0.51	17	Weak	0.51	0.07	14	**Strong**
T11LI	SBC	0.29	0.22	20	Weak	-0.04	0.84	28	None
	SBL	0	0.99	23	None	0.12	0.66	15	Weak
	AS	-0.02	0.95	17	None	0.07	0.81	14	None
T11RI	SBC	0.14	0.57	20	Weak	0.13	0.51	28	Weak
	SBL	0.01	0.98	24	None	0.42	0.11	16	Medium
	AS			15		0.5	0.12	11	**Strong**
T12LS	SBC	0.03	0.89	18	None	-0.16	0.44	26	Weak
	SBL	-0.06	0.8	22	None	-0.39	0.14	16	Medium
	AS	-0.14	0.63	14	Weak	0.15	0.63	13	Weak
T12RS	SBC	-0.57	0.01	18	**Strong**	0.18	0.39	26	Weak
	SBL	-0.04	0.86	22	None	0.2	0.47	16	Weak
	AS	-0.28	0.34	14	Weak	-0.14	0.65	13	Weak

Appendix B-11 Correlation between osteophyte score and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T12LI	SBC	0.02	0.92	19	None	0.14	0.47	27	Weak
	SBL	0.16	0.49	22	Weak	0.23	16	-0.37	Weak
	AS	-0.18	0.57	12	Weak	-0.37	0.29	10	Medium
T12RI	SBC	-0.18	0.48	18	Weak	0	1	27	None
	SBL	0.32	0.15	22	Medium	-0.04	0.88	16	None
	AS			12		-0.44	0.15	12	Medium
L1LS	SBC	-0.13	0.61	19	Weak	0.09	0.68	25	None
	SBL	0.4	0.07	22	Medium	-0.31	0.31	13	Medium
	AS	-0.08	0.8	14	None	0.18	0.52	15	Weak
L1RS	SBC	-0.22	0.39	18	Weak	-0.04	0.85	23	None
	SBL	-0.13	0.56	24	Weak	0.05	0.88	12	None
	AS	0.06	0.84	13	None	0.07	0.82	14	None
L1LI	SBC	0.12	0.64	19	Weak	-0.08	0.73	24	None
	SBL	0.09	0.69	25	None	0.08	0.8	13	None
	AS			13		-0.1	0.7	16	Weak
L1RI	SBC	-0.14	0.57	19	Weak	0.09	0.68	24	None
	SBL	-0.09	0.68	24	None	-0.4	0.2	12	Medium
	AS	-0.53	0.05	14	**Strong**	-0.05	0.86	15	None
L2LS	SBC	0.17	0.45	21	Weak	0.32	0.11	26	Medium
	SBL	0.36	0.1	22	Medium	0.31	0.3	13	Medium
	AS	0	0.99	17	None	0.24	0.43	13	Weak
L2RS	SBC	-0.17	0.46	21	Weak	-0.01	0.96	25	None
	SBL	0.09	0.7	23	None	0.1	0.77	11	Weak
	AS	-0.36	0.18	16	Medium	0.05	0.88	13	None
L2LI	SBC	0.05	0.82	21	None	0.2	0.34	25	Weak
	SBL	0.44	0.03	24	Medium	0.56	0.06	12	**Strong**
	AS	-0.42	0.13	14	Medium	-0.23	0.45	13	Weak
L2RI	SBC	-0.27	0.24	20	Weak	-0.1	0.63	25	Weak
	SBL	-0.04	0.86	24	None	0.38	0.22	12	Medium
	AS	0.1	0.72	15	Weak	-0.23	0.44	14	Weak
L3LS	SBC	0.16	0.49	20	Weak	-0.06	0.77	28	None
	SBL	0.2	0.4	20	Weak	-0.4	0.18	13	Medium
	AS	-0.08	0.75	17	None	0.13	0.63	17	Weak
L3RS	SBC	0.27	0.26	20	Weak	-0.08	0.71	25	None
	SBL	-0.05	0.86	18	None	-0.29	0.35	13	Weak
	AS	-0.04	0.9	15	None	0.02	0.96	12	None
L3LI	SBC	0.05	0.85	21	None	-0.24	0.22	29	Weak
	SBL	-0.14	0.56	20	Weak	0.3	0.27	15	Medium
	AS	0.32	0.2	18	Medium	-0.31	0.26	15	Medium

Appendix B-11 Correlation between osteophyte score and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
L3RI	SBC	-0.1	0.68	21	Weak	0.08	0.7	27	None
	SBL	-0.22	0.39	17	Weak	-0.08	0.78	15	None
	AS	-0.22	0.44	15	Weak	0.3	0.31	13	Medium
L4LS	SBC	0.17	0.48	20	Weak	0.19	0.36	25	Weak
	SBL	-0.07	0.78	19	None			10	
	AS	-0.22	0.39	17	Weak	-0.08	0.78	15	None
L4RS	SBC	-0.17	0.48	20	Weak	-0.23	0.28	25	Weak
	SBL	0.35	0.13	20	Medium	0.14	0.73	9	Weak
	AS	-0.22	0.39	17	Weak	-0.08	0.78	15	None
L4LI	SBC	0.27	0.26	20	Weak	-0.07	0.73	25	None
	SBL	0.07	0.78	18	None	0.61	0.06	10	**Strong**
	AS	-0.02	0.95	16	None	-0.64	0.02	12	**Strong**
L4RI	SBC	0.59	0.01	20	**Strong**	-0.28	0.16	26	Weak
	SBL	0.03	0.89	20	None	-0.52	0.12	10	**Strong**
	AS	0.25	0.37	15	Weak	0.17	0.59	12	Weak
L5LS	SBC	0.01	0.96	19	None	-0.25	0.27	21	Weak
	SBL	0.02	0.93	24	None	-0.54	0.06	13	**Strong**
	AS	0.27	0.35	14	Weak	-0.47	0.12	12	Medium
L5RS	SBC	0.04	0.88	19	None	0.06	0.8	21	None
	SBL	-0.19	0.42	21	Weak	-0.17	0.58	13	Weak
	AS	0.41	0.17	13	Medium	0.04	0.9	12	None
L5LI	SBC	-0.22	0.36	19	Weak	0.31	0.17	21	Medium
	SBL	-0.04	0.84	24	None	-0.17	0.59	13	Weak
	AS	0.1	0.76	12	Weak	-0.01	0.98	11	None
L5RI	SBC	0.08	0.75	19	None	-0.06	0.81	21	None
	SBL	0.14	0.54	22	Weak	-0.39	0.19	13	Medium
	AS	-0.11	0.72	14	Weak	-0.35	0.26	12	Medium

Appendix B-12 Correlation between vertebral osteophytosis and facet size

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C1LS	SBC								
	SBL								
	AS								
C1RS	SBC								
	SBL								
	AS								
C1LI	SBC								
	SBL								
	AS								
C1RI	SBC								
	SBL								
	AS								
C2LS	SBC	-0.138	0.529	23	Weak	-0.028	0.873	35	None
	SBL	-0.079	0.684	29	None	-0.189	0.426	20	Weak
	AS			11				6	
C2RS	SBC	0.134	0.541	23	Weak	0.041	0.817	35	None
	SBL	-0.019	0.929	29	None	-0.044	0.853	20	None
	AS			10				6	
C2LI	SBC	-0.103	0.65	22	Weak	-0.15	0.391	35	Weak
	SBL	0.171	10.75	29	Weak	0.054	0.821	20	None
	AS			11				6	
C2RI	SBC	-0.179	0.425	22	Weak	-0.207	0.233	35	Weak
	SBL	0.016	0.0932	29	None	0.288	0.218	20	Weak
	AS			10				5	
C3LS	SBC	-0.077	0.754	19	Weak	0.144	0.43	32	Weak
	SBL	0.247	0.205	28	Weak	-0.098	0.671	21	None
	AS	0.058	0.865	11	none			5	
C3RS	SBC	0.189	0.424	20	Weak	0.464	**0.007**	32	Medium
	SBL	0.049	0.803	28	None	-0.038	0.874	20	None
	AS	-0.338	0.309	11	Medium			5	
C3LI	SBC	0.001	0.996	20	None	0.031	0.87	31	None
	SBL	0.055	0.783	27	None	-0.057	0.807	21	None
	AS	0.126	0.711	11	Weak			5	
C3RI	SBC	-0.186	0.43	20	Weak	0.176	0.345	31	Weak
	SBL	0.024	0.903	28	None	-0.171	0.47	20	Weak
	AS	-0.229	0.525	10	Weak			5	

Appendix B-12 Correlation between vertebral osteophytosis and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C4LS	SBC	-0.043	0.86	19	None	0.169	0.39	28	Weak
	SBL	0.429	**0.02**	29	Medium	-0.008	0.971	22	None
	AS			10				7	
C4RS	SBC	-0.207	0.396	19	Medium	0.287	0.139	28	Weak
	SBL	0.095	0.626	29	None	-0.063	0.781	22	None
	AS			11				7	
C4LI	SBC	0.096	0.688	20	None	0.375	**0.045**	29	Medium
	SBL	0.072	0.712	29	None	-0.023	0.919	23	None
	AS			11				7	
C4RI	SBC	-0.155	0.479	23	Weak	0.458	**0.012**	29	Medium
	SBL	0.163	0.397	29	Weak	0.138	0.54	22	Weak
	AS			11				7	
C5LS	SBC	-0.155	0.469	24	Weak	0.158	0.372	34	Weak
	SBL	0.046	0.808	30	None	0.564	**0.004**	24	**Strong**
	AS	0.409	0.24	10	Medium			8	
C5RS	SBC	-0.09	0.677	24	None	0.241	0.17	34	Weak
	SBL	0.278	0.137	30	Weak	0.242	0.256	24	Weak
	AS	0.724	**0.009**	10	**Strong**			8	
C5LI	SBC	-0.204	0.338	24	Weak	-0.019	0.916	34	None
	SBL	0.025	0.898	29	None	-0.136	0.527	24	Weak
	AS	0.088	0.808	10	None			8	
C5RI	SBC	0.046	0.808	30	None	0.106	0.549	34	Weak
	SBL	0.536	**0.003**	29	**Strong**	0.117	0.585	24	Weak
	AS	0.74	**0.014**	10	**Strong**			8	
C6LS	SBC	0.278	0.137	30	Weak	0.153	0.373	34	Weak
	SBL	0.077	0.685	30	None	-0.128	0.562	23	weak
	AS	0.717	**0.013**	11	**Strong**			6	
C6RS	SBC	0.025	0.898	29	None	0.472	**0.004**	36	Medium
	SBL	0.07	0.717	29	None	0.248	0.243	24	Weak
	AS	0.53	0.093	11	**Strong**			7	
C6LI	SBC	0.536	**0.003**	29	**Strong**	-0.109	0.528	36	Weak
	SBL	-0.068	0.715	31	None	0.156	0.476	23	Weak
	AS	0.735	**0.01**	11	**Strong**			7	
C6RI	SBC	-0.222	0.348	20	Weak	0.014	0.937	36	None
	SBL	-0.037	0.846	30	None	0.201	0.359	23	Weak
	AS	0.646	**0.032**	11	**Strong**			7	

Appendix B-12 Correlation between vertebral osteophytosis and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C7LS	SBC	-0.245	0.297	20	Weak	0.056	0.744	37	None
	SBL	-0.008	0.967	32	None	-0.146	0.508	23	Weak
	AS	0.906	**0.001**	11	**Strong**			5	
C7RS	SBC	-0.221	0.35	20	Weak	0.231	0.176	36	Weak
	SBL	-0.295	0.101	32	Weak	-0.146	0.505	23	Weak
	AS	0.124	0.716	11	Weak			5	
C7LI	SBC	0.13	0.544	24	Weak	0.062	0.715	37	None
	SBL	0.129	0.481	32	Weak	-0.077	0.727	23	None
	AS	0.057	0.86	12	None			5	
C7RI	SBC	0.251	0.236	24	Weak	0.116	0.496	37	Weak
	SBL	0.254	0.161	32	Weak	-0.136	0.536	23	Weak
	AS	-0.333	0.29	12	Medium			5	
T1LS	SBC	0.067	0.77	20	None	0.01	0.951	37	None
	SBL	0.365	0.103	21	Medium	0.365	0.103	21	Medium
	AS	0.228	0.587	8	Weak			6	
T1RS	SBC	-0.11	0.636	21	Weak	0.094	0.576	38	None
	SBL	0.215	0.337	22	Weak	0.215	0.337	22	Weak
	AS	-0.218	0.572	9	Weak			7	
T1LI	SBC	0.096	0.68	21	None	0.351	**0.03**	38	Medium
	SBL	0.235	0.293	22	Weak	0.235	0.293	22	Weak
	AS	0.245	0.526	9	Weak			7	
T1RI	SBC	-0.155	0.502	21	Weak	0.209	0.209	38	Weak
	SBL	-0.012	0.957	22	None	-0.012	0.957	22	None
	AS	-0.116	0.766	9	Weak			7	
T2LS	SBC	-0.018	0.937	21	None	0.001	0.998	22	None
	SBL	-0.018	0.937	21	None	0.001	0.998	22	None
	AS	0.075	0.838	10	None	-0.306	0.933	8	Medium
T2RS	SBC	-0.072	0.75	22	None	-0.072	0.75	22	None
	SBL	-0.072	0.75	22	None	-0.072	0.75	22	None
	AS	-0.141	0.698	10	Weak	0.455	0.257	8	Medium
T2LI	SBC	-0.19	0.385	23	Weak	0.086	0.614	37	None
	SBL	-0.133	0.557	22	Weak	-0.133	0.557	22	Weak
	AS	-0.103	0.778	10	Weak	-0.307	0.459	8	Medium
T2RI	SBC	-0.195	0.373	23	Weak	0.249	0.137	37	Weak
	SBL	0.461	**0.031**	22	Medium	0.461	**0.031**	22	Medium
	AS	-0.108	0.767	10	Weak	0.746	**0.034**	8	**Strong**

Appendix B-12 Correlation between vertebral osteophytosis and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T3LS	SBC	-0.021	0.928	22	None	-0.021	0.899	38	None
	SBL	-0.013	0.957	20	None	-0.013	0.957	20	None
	AS	-0.108	0.737	12	Weak	0.033	0.938	8	None
T3RS	SBC	0.234	0.295	22	Weak	0.225	0.174	38	Weak
	SBL	0.35	0.13	20	Medium	0.35	0.13	20	Medium
	AS	-0.179	0.559	13	Weak	0.292	0.445	9	Weak
T3LI	SBC	-0.241	0.279	22	Weak	0.024	0.888	38	None
	SBL	-0.194	0.412	20	Weak	-0.194	0.412	20	Weak
	AS	-0.287	0.343	13	Weak	0.521	0.186	8	**Strong**
T3RI	SBC	0.576	**0.005**	22	**Strong**	0.311	0.057	38	Medium
	SBL	0.048	0.844	19	None	0.239	0.309	20	Weak
	AS	-0.16	0.603	13	Weak	0.19	0.625	9	Weak
T4LS	SBC	0.027	0.902	24	None	0.008	0.964	37	None
	SBL	-0.157	0.52	19	Weak	-0.157	0.52	19	Weak
	AS	-0.314	0.411	9	Medium	-0.26	0.5	9	Weak
T4RS	SBC	0.273	0.197	24	Weak	0.216	0.207	36	Weak
	SBL	0.008	0.973	19	None	0.008	0.973	19	None
	AS	-0.145	0.71	9	Weak	0.261	0.498	9	Weak
T4LI	SBC	0.371	0.074	24	Medium	-0.248	0.145	36	Weak
	SBL	-0.349	0.155	18	Medium	-0.349	0.155	18	Medium
	AS	-0.115	0.769	9	Weak	-0.567	0.143	8	**Strong**
T4RI	SBC	0.403	0.07	21	Medium	0.375	0.065	25	Medium
	SBL	0.14	0.638	12	Weak			12	
	AS	0.319	0.538	6	Medium	0.776	0.123	5	**Strong**
T5LS	SBC	0.245	0.259	23	Weak	-0.33	0.053	35	Medium
	SBL	-0.07	0.775	19	None	-0.07	0.775	19	None
	AS	-0.51	0.197	8	**Strong**	-0.125	0.767	8	Weak
T5RS	SBC	0.417	**0.048**	23	Medium	0.602	**0.001**	35	**Strong**
	SBL	0.257	0.287	19	Weak	0.257	0.287	19	Weak
	AS	0.201	0.633	8	Weak	0.198	0.638	8	Weak
T5LI	SBC	0.257	237	23	Weak	-0.016	0.929	35	None
	SBL	-0.023	0.925	19	None	-0.023	0.925	19	None
	AS	0.269	0.559	7	Weak	-0.28	0.502	8	Weak
T5RI	SBC	0.25	0.25	23	Weak	0.253	0.142	35	Weak
	SBL	0.175	0.473	19	Weak	0.175	0.473	19	Weak
	AS	-0.17	0.715	7	Weak	-0.248	0.553	8	Weak

Appendix B-12 Correlation between vertebral osteophytosis and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T6LS	SBC	0.436	**0.033**	24	Medium	-0.004	0.981	35	None
	SBL	0.031	0.893	21	None	0.031	0.893	21	None
	AS	0.258	0.471	10	Weak	-0.256	0.541	8	Weak
T6RS	SBC	0.118	0.582	24	Weak	0.084	0.631	35	None
	SBL	0.013	0.955	21	None	0.013	0.955	21	None
	AS	-0.134	0.713	10	Weak	0.103	0.809	8	Weak
T6LI	SBC	0.469	**0.021**	24	Medium	0.082	0.629	37	None
	SBL	-0.414	0.062	21	Medium	-0.141	0.062	21	Weak
	AS	-0.046	0.906	9	None	-0.624	0.098	8	**Strong**
T6RI	SBC	0.381	0.066	24	Medium	0.164	0.332	37	Weak
	SBL	0.234	0.212	30	Weak	0.007	0.977	20	None
	AS	0.095	0.808	9	None	-0.343	0.406	8	Medium
T7LS	SBC	0.512	**0.008**	26	**Strong**	0.019	0.909	37	None
	SBL	0.06	0.75	31	None	-0.144	0.543	20	Weak
	AS	0.069	0.871	8	None	-0.512	0.158	9	**Strong**
T7RS	SBC	0.14	0.494	26	Weak	0.042	0.803	37	None
	SBL	0.259	0.167	30	Weak	-0.383	0.095	20	Medium
	AS	0.303	0.466	8	Medium	-0.259	0.501	9	None
T7LI	SBC	0.233	0.263	25	Weak	0.077	0.653	37	None
	SBL	0.259	0.175	29	Weak	-0.003	0.989	200	None
	AS	0.296	0.477	8	Weak	0.78	**0.013**	9	**Strong**
T7RI	SBC	-0.145	0.489	25	Weak	0.041	0.811	37	None
	SBL	0.234	0.212	30	Weak	0.007	0.977	20	None
	AS	0.188	0.655	8	Weak	-0.154	0.715	8	Weak
T8LS	SBC	0.332	0.113	24	Medium	-0.017	0.921	37	None
	SBL	0.06	0.75	31	None	-0.144	0.543	20	Weak
	AS	0.274	0.511	8	Weak	0.047	0.904	9	None
T8RS	SBC	0.037	0.863	24	None	-0.015	0.933	35	None
	SBL	0.135	0.468	31	Weak	-0.217	0.357	20	Weak
	AS	0.096	0.822	8	None	-0.13	0.738	9	Weak
T8LI	SBC	0.49	**0.013**	25	Medium	0.03	0.865	35	None
	SBL	0.2	0.28	31	Weak	-0.289	0.245	18	Weak
	AS	-0.163	0.699	8	Weak	-0.345	0.363	9	Medium
T8RI	SBC	0.433	**0.031**	25	Medium	0.011	0.949	35	None
	SBL	0.11	0.555	31	Weak	-0.009	0.972	19	None
	AS	-0.034	0.936	8	None	0.216	0.576	9	Weak

Appendix B-12 Correlation between vertebral osteophytosis and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T9LS	SBC	0.358	0.073	26	Medium	0.34	**0.037**	38	Medium
	SBL	0.104	0.583	30	Weak	-0.025	0.916	20	None
	AS	0.434	0.21	10	Medium	-0.448	0.226	9	Medium
T9RS	SBC	0.24	0.237	26	Weak	0.285	0.083	38	Weak
	SBL	0.093	0.627	30	None	0.005	0.985	20	None
	AS	0.082	0.822	10	None	0.09	0.818	9	None
T9LI	SBC	0.148	0.481	25	Weak	0.066	0.695	38	None
	SBL	-0.099	0.604	30	None	-0.335	0.149	20	Medium
	AS	-0.145	0.689	10	Weak	-0.649	0.059	9	**Strong**
T9RI	SBC	0.17	0.416	25	Weak	0.071	0.675	37	None
	SBL	0.005	0.98	28	None	-0.058	0.808	20	None
	AS	-0.33	0.352	10	None	-0.537	0.136	9	**Strong**
T10LS	SBC	0.082	0.698	25	None	0.153	0.359	38	Weak
	SBL	0.054	0.781	29	None	-0.117	0.622	20	Weak
	AS	0.004	0.991	10	None	-0.488	0.182	9	Medium
T10RS	SBC	0.274	0.185	25	Weak	0.08	0.634	38	None
	SBL	0.039	0.837	30	None	-0.004	0.987	20	None
	AS	0.021	0.953	10	None	-0.011	0.977	9	None
T10LI	SBC	0.155	0.449	26	Weak	0.165	0.322	38	Weak
	SBL	-0.118	0.541	29	Weak	-0.206	0.384	20	Weak
	AS	0.094	0.796	10	None	-0.042	0.915	9	None
T10RI	SBC	0.352	0.077	26	Medium	0.176	0.29	38	Weak
	SBL	-0.155	0.423	29	Weak	-0.124	0.601	20	Weak
	AS	0.004	0.991	10	None	0.227	0.556	9	Weak
T11LS	SBC	0.169	0.408	26	Weak	-0.022	0.894	38	None
	SBL	-0.125	0.534	27	Weak	0.057	0.81	20	None
	AS	-0.225	0.592	8	Weak	0.158	0.685	9	Weak
T11RS	SBC	-0.116	0.573	26	Weak	-0.022	0.896	38	None
	SBL	0.01	0.959	28	None	0.23	0.315	21	Weak
	AS	-0.448	0.227	9	Medium	-0.093	0.812	9	None
T11LI	SBC	0.012	0.956	25	None	-0.093	0.578	38	None
	SBL	-0.053	0.793	27	None	0.408	0.067	21	Medium
	AS	-0.113	0.773	9	Weak	-0.012	0.975	9	None
T11RI	SBC	0.156	0.457	25	Weak	-0.132	0.43	38	Weak
	SBL	0.152	0.44	28	Weak	0.499	**0.021**	21	Medium
	AS	-0.059	0.881	9	None	0.308	0.457	8	Medium

Appendix B-12 Correlation between vertebral osteophytosis and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T12LS	SBC	-0.105	0.624	24	Weak	-0.227	0.19	35	Weak
	SBL	-0.16	0.417	28	None	0.337	0.136	21	Medium
	AS	-0.031	0.942	8	None	0.194	0.617	9	Weak
T12RS	SBC	0.142	0.509	24	Weak	-0.073	0.678	35	None
	SBL	0.067	0.728	29	None	0.51	**0.018**	21	**Strong**
	AS	0.169	0.665	9	Weak	0.552	0.123	9	**Strong**
T12LI	SBC	0.039	0.852	25	None	-0.242	0.162	35	Weak
	SBL	0.21	0.275	29	Weak	0.435	**0.049**	21	Medium
	AS	0.04	0.919	9	None	0.213	0.613	8	Weak
T12RI	SBC	0.238	0.252	25	Weak	-0.356	**0.036**	35	Medium
	SBL	0.105	0.586	29	Weak	0.347	0.123	21	Medium
	AS	-0.266	0.489	9	Weak	0.197	0.612	9	Weak
L1LS	SBC	0.46	**0.021**	25	Medium	-0.105	0.55	35	Weak
	SBL	0.165	0.4	28	Weak	0.478	**0.033**	20	Medium
	AS	-0.361	0.306	10	Medium	0.001	0.998	8	None
L1RS	SBC	0.438	**0.029**	25	Medium	-0.196	0.267	34	Weak
	SBL	-0.14	0.478	28	Weak	0.248	0.292	20	Weak
	AS	-0.231	0.55	9	Weak	0.149	0.725	8	Weak
L1LI	SBC	0.302	0.142	25	Medium	-0.085	0.628	35	None
	SBL	-0.036	0.852	29	None	0.385	0.093	20	Medium
	AS	-0.211	0.559	10	Weak	-0.485	0.186	9	Medium
L1RI	SBC	0.073	0.728	25	None	-0.063	0.722	34	None
	SBL	0.056	0.776	28	None	0.147	0.535	20	Weak
	AS	-0.211	0.559	10	Weak	-0.122	0.754	9	Weak
L2LS	SBC	0.303	0.132	26	Medium	0.092	0.6	35	None
	SBL	0.058	0.764	29	None	0.244	0.3	20	Weak
	AS	-0.156	0.667	10	Weak	-0.027	0.949	8	None
L2RS	SBC	0.267	0.188	26	Weak	0.076	0.664	35	None
	SBL	0.066	0.74	28	None	-0.011	0.964	18	None
	AS	0.388	0.268	10	Medium	-0.255	0.542	8	Weak
L2LI	SBC	0.232	0.252	26	Weak	0.142	0.416	35	Weak
	SBL	-0.092	0.627	30	None	0.146	0.551	19	Weak
	AS	0.507	0.135	10	**Strong**	-0.34	0.409	8	Medium
L2RI	SBC	0.218	0.286	26	Weak	0.009	0.957	35	None
	SBL	-0.071	0.71	30	None	0.103	0.676	19	Weak
	AS	0.162	0.677	9	Weak	-0.238	0.57	8	Weak

Appendix B-12 Correlation between vertebral osteophytosis and facet size continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
L3LS	SBC	-0.086	0.698	23	None	-0.135	0.455	33	Weak
	SBL	0.183	0.141	22	Weak	-0.036	0.898	15	None
	AS	0.153	0.693	9	Weak	0.227	0.529	10	Weak
L3RS	SBC	0.033	0.88	23	None	-0.413	**0.019**	32	Medium
	SBL	-0.038	0.87	21	None	0.126	0.669	14	Weak
	AS	0.035	0.935	8	None	0.244	0.561	8	Weak
L3LI	SBC	0.155	0.602	23	Weak	-0.216	0.228	33	Weak
	SBL	-0.087	0.693	23	None	-0.065	0.811	16	None
	AS	0.6	0.155	7	**Strong**	0.1	0.784	10	Weak
L3RI	SBC	0.267	0.219	23	Weak	-0.022	0.901	33	None
	SBL	0.27	0.517	8	Weak	0.539	0.108	10	**Strong**
	AS	-0.114	0.488	8	Weak	-0.027	0.941	10	None
L4LS	SBC	0.079	0.701	26	None	-0.06	0.723	37	None
	SBL	-0.365	0.42	7	Medium			4	
	AS	0.27	0.517	8	Weak	0.539	0.108	10	**Strong**
L4RS	SBC	-0.021	0.918	26	None	-0.042	0.805	37	None
	SBL	-0.0386	0.393	7	None			3	
	AS	0.27	0.517	8	Weak	0.539	0.108	10	**Strong**
L4LI	SBC	0.347	0.083	26	Medium	-0.269	0.108	37	Weak
	SBL	0.083	0.859	7	None			4	
	AS	0.587	**0.045**	12	**Strong**	0.567	0.111	9	**Strong**
L4RI	SBC	0.577	**0.002**	26	**Strong**	-0.152	0.37	37	Weak
	SBL	0.206	0.658	7	Weak			4	
	AS	-0.079	0.818	11	None	0.29	0.449	9	Weak
L5LS	SBC	0.146	0.488	25	Weak	-0.042	0.815	33	None
	SBL	0.047	0.808	29	None	0.016	19	0.11	None
	AS	0.392	0.234	11	Medium	0.614	0.106	8	**Strong**
L5RS	SBC	0.165	0.43	25	Weak	0.146	0.416	33	Weak
	SBL	0.218	0.274	27	Weak	0.11	**0.653**	19	Weak
	AS	0.313	0.412	9	Medium	0.582	0.13	8	**Strong**
L5LI	SBC	0.708	**0.001**	25	**Strong**	-0.098	0.588	33	None
	SBL	0.061	0.751	29	None	0.697	**0.001**	19	**Strong**
	AS	0.116	0.766	9	Weak	0.492	0.216	8	Medium
L5RI	SBC	0.403	**0.046**	25	Medium	0.062	0.737	32	None
	SBL	-0.022	0.911	28	None	0.739	**0.001**	19	**Strong**
	AS	0.588	0.096	9	**Strong**	0.716	**0.14**	8	**Strong**

Appendix C. Results for Facet Angle

Appendix C-1 Descriptive statistics and SDI for facet angle

Facet Area	Sample	Male			Female			SDI
		N	Mean	Std dev.	N	Mean	Std dev.	
C1LS	SBC	23	29.48	4.52	32	29.53	3.82	99.82
	SBL	26	26.19	1.83	20	26.20	2.28	99.97
	AS	16	26.69	10.11	9	28.56	10.98	93.46
C1RS	SBC	23	30.17	5.97	32	30.19	6.19	99.95
	SBL	26	26.15	1.74	20	26.55	2.74	98.51
	AS	16	27.63	8.79	9	25.56	9.04	108.10
C1LI	SBC	23	35.52	7.43	32	33.50	5.69	106.04
	SBL	26	34.54	6.03	20	33.45	6.39	103.25
	AS	14	38.86	9.84	9	27.89	10.45	139.33
C1RI	SBC	23	37.48	7.11	32	33.44	5.09	112.08
	SBL	26	35.08	5.26	20	33.75	5.86	103.93
	AS	15	38.40	11.02	10	29.60	8.19	129.73
C2LS	SBC	23	49.00	9.84	35	45.94	11.30	106.65
	SBL	29	43.76	8.22	20	43.10	6.03	101.53
	AS	12	54.92	11.92	11	41.27	13.96	133.06
C2RS	SBC	23	48.96	11.92	35	45.06	9.50	108.65
	SBL	29	43.48	5.31	20	40.35	4.65	107.76
	AS	12	49.92	11.29	11	41.82	9.98	119.37
C2LI	SBC	22	64.14	17.46	35	67.80	17.64	94.6
	SBL	29	50.90	8.21	20	56.15	13.04	90.64
	AS	12	77.50	15.20	10	55.70	14.47	139.14
C2RI	SBC	23	64.43	15.77	35	71.29	19.54	90.39
	SBL	29	51.17	7.19	20	57.80	12.60	88.53
	AS	13	74.46	13.68	10	62.90	16.41	118.38
C3LS	SBC	19	89.68	10.24	32	82.50	14.73	108.71
	SBL	28	78.32	13.35	21	81.24	12.05	96.41
	AS	16	72.44	13.62	10	63.60	11.53	113.90

Appendix C-1 Descriptive statistics and SDI for facet angle continued

Facet Area	Sample	Male			Female			SDI
		N	Mean	Std dev.	N	Mean	Std dev.	
C3RS	SBC	20	84.60	11.50	32	80.25	16.14	105.42
	SBL	28	73.64	15.30	20	79.30	12.39	92.87
	AS	16	74.00	17.75	10	56.40	14.77	131.21
C3LI	SBC	20	84.30	6.81	31	83.45	7.19	101.02
	SBL	27	76.44	10.33	21	82.43	6.95	92.74
	AS	16	96.31	12.99	10	82.00	14.86	117.45
C3RI	SBC	20	90.60	9.02	31	87.74	7.63	103.26
	SBL	28	78.54	8.29	20	84.80	4.87	92.61
	AS	14	105.07	12.63	10	84.00	10.93	125.09
C4LS	SBC	19	95.95	8.99	28	90.43	10.24	106.1
	SBL	29	91.45	9.59	22	92.73	8.11	98.62
	AS	14	85.71	10.37	10	88.70	7.06	96.63
C4RS	SBC	20	91.90	8.10	28	89.75	9.72	102.4
	SBL	29	90.45	9.18	22	90.41	10.77	100.04
	AS	14	89.86	12.35	10	84.60	18.43	106.21
C4LI	SBC	20	84.85	8.90	29	85.93	8.34	98.74
	SBL	29	82.79	10.68	23	83.70	5.12	98.92
	AS	13	98.23	12.59	10	91.70	11.74	107.12
C4RI	SBC	20	89.95	9.82	29	91.48	7.69	98.32
	SBL	29	85.97	5.47	22	86.95	6.43	98.86
	AS	13	96.23	18.65	10	100.90	9.78	95.37
C5LS	SBC	23	98.70	9.16	34	97.26	6.36	101.47
	SBL	30	93.33	14.24	24	95.08	6.09	98.16
	AS	11	91.64	14.20	10	97.20	11.69	94.28
C5RS	SBC	24	97.00	8.13	34	93.91	10.43	103.29
	SBL	30	94.67	6.97	24	94.21	7.30	100.49
	AS	11	86.18	11.65	10	99.50	12.28	86.61
C55LI	SBC	24	88.67	9.78	34	88.91	4.30	99.72
	SBL	29	85.90	8.80	24	87.13	5.28	98.59
	AS	11	95.91	10.36	10	99.50	11.28	96.39

Appendix C-1 Descriptive statistics and SDI for facet angle continued

Facet Area	Sample	Male			Female			SDI
		N	Mean	Std dev.	N	Mean	Std dev.	
C5RI	SBC	24	93.00	10.55	34	91.56	6.76	101.57
	SBL	29	87.83	6.29	24	90.38	6.32	97.18
	AS	11	104.18	13.38	10	100.00	10.09	104.18
C6LS	SBC	21	100.33	6.87	37	98.32	9.76	
	SBL	30	98.07	5.31	23	99.30	6.60	98.75
	AS	12	91.83	9.81	9	93.67	10.74	98.04
C6RS	SBC	21	100.05	9.16	37	96.38	8.15	103.81
	SBL	29	97.86	4.74	24	98.83	5.88	99.02
	AS	12	88.00	15.86	9	96.11	18.58	91.56
C6LI	SBC	21	91.81	7.12	37	91.68	6.47	100.15
	SBL	31	88.29	4.58	23	90.96	4.03	97.07
	AS	12	91.33	7.36	9	97.00	11.94	94.16
C6RI	SBC	21	94.05	7.05	37	92.97	8.06	101.16
	SBL	31	89.26	5.27	24	90.79	4.57	98.31
	AS	12	94.17	9.43	9	98.78	7.66	95.33
C7LS	SBC	25	98.64	7.57	39	97.95	6.65	100.71
	SBL	32	95.84	5.32	24	96.04	4.80	99.79
	AS	11	91.18	11.01	6	88.50	9.05	103.03
C7RS	SBC	25	94.40	7.96	38	94.50	6.93	99.89
	SBL	32	92.81	5.90	24	92.58	5.79	100.25
	AS	11	90.73	12.95	6	94.50	9.31	96.01
C7LI	SBC	25	93.68	7.12	39	91.28	5.46	102.63
	SBL	32	89.47	5.02	24	89.17	5.27	100.34
	AS	12	96.00	12.50	6	96.17	12.91	99.83
C7RI	SBC	25	94.40	6.51	39	94.23	6.10	100.18
	SBL	32	90.63	5.24	24	92.79	5.82	97.67
	AS	12	98.83	11.63	6	95.33	9.03	103.67
T1LS	SBC	21	100.90	6.80	40	99.40	6.90	101.51
	SBL	34	99.59	6.08	23	100.61	5.26	98.99
	AS	15	95.00	10.74	12	99.17	11.15	95.80

Appendix C-1 Descriptive statistics and SDI for facet angle continued

Facet Area	Sample	Male			Female			SDI
		N	Mean	Std dev.	N	Mean	Std dev.	
T1RS	SBC	24	97.67	9.02	40	96.90	6.10	100.79
	SBL	34	100.12	5.96	23	98.17	7.15	101.98
	AS	14	99.50	9.57	12	98.17	6.75	101.36
T1LI	SBC	24	95.79	8.58	40	93.20	15.37	102.78
	SBL	35	94.11	5.16	23	92.04	4.24	102.25
	AS	14	108.36	6.52	12	108.42	11.03	99.95
T1RI	SBC	24	102.83	5.96	40	103.85	6.34	99.02
	SBL	35	94.94	7.05	23	97.39	6.74	97.49
	AS	14	110.79	4.46	12	107.25	10.80	103.30
T2LS	SBC	26	105.69	4.61	38	103.16	5.03	102.46
	SBL	34	103.59	5.07	22	105.23	4.07	98.44
	AS	13	102.69	5.34	14	103.86	9.78	98.88
T2RS	SBC	26	104.96	4.65	38	101.00	4.48	103.92
	SBL	35	102.37	5.69	22	103.41	3.46	99.00
	AS	13	106.23	5.99	14	108.79	5.38	97.65
T2LI	SBC	26	99.69	8.72	38	98.42	8.40	101.29
	SBL	34	95.44	4.61	22	93.23	4.08	102.37
	AS	13	111.69	7.66	14	109.86	8.93	101.67
T2RI	SBC	26	105.58	6.59	38	104.34	5.68	101.18
	SBL	34	98.94	5.32	22	98.27	6.57	100.68
	AS	13	109.92	8.46	14	98.07	37.11	112.08
T3LS	SBC	25	106.48	4.39	39	105.08	4.74	101.34
	SBL	28	105.07	3.97	21	104.62	3.09	100.43
	AS	15	105.80	6.21	14	106.50	5.65	99.34
T3RS	SBC	25	104.40	3.54	39	104.79	3.84	99.62
	SBL	29	105.52	3.79	21	105.00	3.08	100.49
	AS	16	110.25	5.89	14	108.00	5.28	102.08
T3LI	SBC	25	97.40	7.33	39	96.62	5.61	100.61
	SBL	29	94.28	4.08	21	94.76	4.65	99.49
	AS	15	111.80	8.49	13	111.62	10.02	100.17

Appendix C-1 Descriptive statistics and SDI for facet angle continued

Facet Area	Sample	Male			Female			SDI
		N	Mean	Std dev.	N	Mean	Std dev.	
T3RI	SBC	25	104.60	6.31	39	105.38	5.71	99.26
	SBL	29	99.59	5.96	21	99.19	6.52	100.40
	AS	16	109.06	7.02	14	109.86	5.05	99.28
T4LS	SBC	26	105.42	4.25	37	104.76	3.93	100.64
	SBL	30	103.63	3.93	19	104.42	3.29	99.25
	AS	15	107.07	5.35	14	106.36	3.82	100.67
T4RS	SBC	26	104.85	3.89	36	105.25	4.30	99.62
	SBL	29	103.76	2.67	19	104.68	3.90	99.12
	AS	15	110.20	5.41	14	106.00	3.98	103.96
T4LI	SBC	26	100.42	7.29	36	96.78	6.80	103.77
	SBL	29	93.34	3.70	18	94.50	4.57	98.78
	AS	16	109.00	6.54	13	106.54	4.91	102.31
T4RI	SBC	26	106.85	5.24	36	104.94	5.84	101.81
	SBL	30	97.50	4.64	18	99.78	7.51	97.72
	AS	16	110.25	6.12	13	108.15	5.61	101.94
T5LS	SBC	25	105.64	3.65	37	105.00	3.18	100.61
	SBL	28	104.29	3.32	20	104.55	3.39	99.75
	AS	16	104.94	5.37	10	105.30	3.95	99.66
T5RS	SBC	25	104.68	3.30	37	103.84	4.98	100.81
	SBL	28	103.93	4.04	20	104.25	3.63	99.69
	AS	16	109.75	6.60	10	106.00	5.19	103.54
T5LI	SBC	25	97.84	7.56	36	97.42	6.17	100.43
	SBL	26	94.88	5.02	20	94.45	4.89	100.46
	AS	14	108.79	5.48	10	107.60	8.25	101.10
T5RI	SBC	25	105.40	4.72	36	105.67	5.76	99.75
	SBL	28	99.39	4.93	20	98.05	5.13	101.37
	AS	14	109.07	7.38	10	108.60	7.17	100.43
T6LS	SBC	26	104.23	3.02	35	104.29	2.98	99.95
	SBL	31	104.19	4.36	21	105.71	3.70	98.56
	AS	14	104.71	5.85	10	105.50	5.25	99.26

Appendix C-1 Descriptive statistics and SDI for facet angle continued

Facet Area	Sample	Male			Female			SDI
		N	Mean	Std dev.	N	Mean	Std dev.	
T6RS	SBC	26	104.73	4.79	35	102.74	5.53	101.93
	SBL	31	103.71	3.47	21	103.71	3.61	100.00
	AS	14	107.64	5.58	10	107.00	7.30	100.60
T6LI	SBC	26	99.12	7.58	37	95.97	5.89	103.27
	SBL	29	94.62	5.56	21	94.29	3.90	100.36
	AS	12	104.42	6.24	10	105.10	8.41	99.35
T6RI	SBC	26	104.19	6.44	37	102.65	6.19	101.5
	SBL	29	98.10	4.19	21	98.81	5.27	99.29
	AS	12	107.67	6.88	10	106.00	6.58	101.57
T7LS	SBC	26	104.96	3.62	38	105.08	4.60	99.89
	SBL	31	104.03	4.00	20	104.75	3.55	99.31
	AS	13	104.15	5.51	13	104.23	6.93	99.93
T7RS	SBC	26	102.92	4.08	38	104.05	4.58	98.91
	SBL	32	103.44	3.93	19	103.37	2.89	100.07
	AS	13	104.38	6.89	13	108.08	5.85	96.58
T7LI	SBC	25	96.32	5.48	38	96.68	5.36	99.62
	SBL	30	94.87	3.55	20	94.40	4.76	100.49
	AS	11	106.27	9.59	12	109.00	6.37	97.50
T7RI	SBC	25	102.56	5.81	38	102.76	6.86	99.8
	SBL	31	98.19	4.97	20	99.35	5.02	98.84
	AS	11	110.73	8.66	13	105.85	5.16	104.61
T8LS	SBC	25	104.36	4.32	36	105.14	4.06	99.26
	SBL	32	103.44	4.13	20	103.95	5.42	99.51
	AS	13	104.54	4.96	14	103.57	6.01	100.93
T8RS	SBC	25	104.08	4.17	36	103.03	5.17	101.02
	SBL	32	104.09	3.63	20	101.80	2.88	102.25
	AS	13	107.46	5.08	14	107.79	5.49	99.70
T8LI	SBC	26	95.35	7.03	36	94.92	6.22	100.45
	SBL	32	96.59	4.88	18	93.22	3.95	103.62
	AS	13	103.38	7.21	14	101.93	7.27	101.43

Appendix C-1 Descriptive statistics and SDI for facet angle continued

Facet Area	Sample	Male			Female			SDI
		N	Mean	Std dev.	N	Mean	Std dev.	
T8RI	SBC	26	102.62	4.96	36	102.22	5.22	100.38
	SBL	32	96.81	5.81	19	97.37	4.40	99.43
	AS	13	104.46	6.96	14	105.93	6.66	98.62
T9LS	SBC	26	103.62	4.84	39	103.08	5.76	100.52
	SBL	31	102.84	4.40	20	102.95	4.05	99.89
	AS	14	102.29	4.41	13	100.69	6.10	101.58
T9RS	SBC	26	101.92	4.04	39	102.44	5.00	99.5
	SBL	31	103.16	3.64	20	101.15	3.08	101.99
	AS	13	108.38	3.40	13	104.23	5.34	103.99
T9LI	SBC	25	95.52	6.21	39	96.10	6.38	99.39
	SBL	31	95.58	4.43	20	93.80	4.02	101.90
	AS	14	100.29	7.35	12	103.00	6.19	97.36
T9RI	SBC	25	102.12	5.22	39	103.23	5.93	98.92
	SBL	30	98.37	5.24	20	96.55	5.56	101.88
	AS	14	101.29	6.34	12	104.08	5.45	97.31
T10LS	SBC	25	101.40	6.50	39	103.28	4.65	98.18
	SBL	30	103.37	3.91	20	103.80	3.04	99.58
	AS	15	104.13	4.47	12	102.08	5.43	102.01
T10RS	SBC	25	103.00	5.59	39	101.33	4.46	101.64
	SBL	31	103.87	3.93	20	102.10	3.77	101.73
	AS	14	107.07	4.12	12	107.42	4.50	99.68
T10LI	SBC	26	93.54	11.69	39	94.92	8.92	98.54
	SBL	30	92.57	8.20	20	95.45	4.91	96.98
	AS	15	104.00	8.25	12	104.67	5.55	99.36
T10RI	SBC	26	97.04	13.49	39	99.41	8.15	97.61
	SBL	30	96.47	6.20	20	98.65	6.91	97.79
	AS	15	104.73	7.45	12	106.75	9.39	98.11
T11LS	SBC	26	101.00	12.21	39	103.51	6.42	97.57
	SBL	29	103.76	5.49	21	104.71	3.66	99.09
	AS	15	104.73	5.57	12	104.75	3.96	99.98

Appendix C-1 Descriptive statistics and SDI for facet angle continued

Facet Area	Sample	Male			Female			SDI
		N	Mean	Std dev.	N	Mean	Std dev.	
T11RS	SBC	26	96.08	14.32	39	100.41	7.33	95.68
	SBL	29	102.97	5.74	21	102.71	3.68	100.24
	AS	15	105.67	8.48	12	108.83	6.18	97.09
T11LI	SBC	25	62.12	23.48	39	72.49	23.94	85.7
	SBL	28	76.39	24.45	21	86.14	18.78	88.68
	AS	14	80.57	25.53	12	78.67	21.77	102.42
T11RI	SBC	25	57.32	30.76	39	75.77	27.70	75.65
	SBL	29	76.79	25.25	21	82.38	21.76	93.22
	AS	14	83.14	25.92	12	85.17	27.03	97.62
T12LS	SBC	24	63.83	29.15	36	77.72	29.37	82.13
	SBL	28	82.71	27.57	21	90.19	21.94	91.71
	AS	13	81.92	27.12	12	80.92	23.96	101.24
T12RS	SBC	24	53.50	29.47	36	72.67	28.83	73.62
	SBL	28	81.50	26.80	21	85.67	24.19	95.14
	AS	13	82.15	24.51	12	81.75	30.63	100.49
T12LI	SBC	25	30.88	7.17	36	36.53	13.62	84.54
	SBL	29	38.90	16.41	21	41.24	20.31	94.32
	AS	13	45.46	33.94	11	44.27	31.04	102.69
T12RI	SBC	25	31.88	8.01	36	33.61	15.22	94.85
	SBL	29	37.55	18.42	21	37.71	14.28	99.57
	AS	12	40.25	32.85	12	29.33	10.42	137.22
L1LS	SBC	25	31.08	10.23	36	37.53	17.57	82.82
	SBL	29	37.62	16.80	20	37.80	19.79	99.53
	AS	16	35.63	29.41	15	31.40	12.03	113.46
L1RS	SBC	25	27.92	7.34	36	33.03	10.42	84.53
	SBL	28	35.96	16.88	20	32.75	11.58	109.81
	AS	14	23.64	6.63	15	31.13	15.02	75.94
L1LI	SBC	25	28.76	6.77	36	26.83	6.38	107.18
	SBL	29	29.86	6.27	20	31.65	10.02	94.35
	AS	15	24.07	9.54	16	29.56	8.52	81.41

Appendix C-1 Descriptive statistics and SDI for facet angle continued

Facet Area	Sample	Male			Female			SDI
		N	Mean	Std dev.	N	Mean	Std dev.	
L1RI	SBC	25	28.04	6.13	35	28.54	7.17	98.24
	SBL	28	28.86	4.32	20	31.40	8.16	91.90
	AS	16	25.88	13.81	15	30.33	9.24	85.30
L2LS	SBC	26	30.50	9.83	37	30.73	9.81	99.25
	SBL	30	29.27	7.30	20	28.70	4.01	101.97
	AS	17	23.12	8.45	13	25.77	11.66	89.71
L2RS	SBC	26	30.12	10.01	37	28.92	8.25	104.14
	SBL	28	27.54	6.72	19	28.63	6.07	96.17
	AS	17	23.88	12.01	13	29.31	13.14	81.49
L2LI	SBC	26	29.50	8.42	37	30.68	8.02	96.17
	SBL	30	32.07	7.03	19	34.05	8.32	94.17
	AS	16	28.25	6.12	11	34.09	9.62	82.87
L2RI	SBC	26	30.46	7.57	37	31.84	8.57	95.68
	SBL	30	32.70	7.12	19	32.00	7.33	102.19
	AS	16	26.94	8.61	12	29.75	8.17	90.55
L3LS	SBC	26	33.42	9.33	36	32.75	8.39	102.06
	SBL	27	34.11	7.13	20	33.30	9.26	102.44
	AS	16	24.38	7.85	16	29.50	8.38	82.63
L3RS	SBC	26	32.23	7.37	36	30.89	8.51	104.34
	SBL	27	33.33	9.38	20	32.50	7.42	102.56
	AS	16	26.06	9.43	16	31.75	7.03	82.09
L3LI	SBC	26	38.73	8.66	36	39.58	10.96	97.85
	SBL	27	40.00	8.20	21	41.19	12.16	97.11
	AS	17	36.82	9.72	16	43.19	9.66	85.26
L3RI	SBC	26	37.85	9.22	36	42.33	12.65	89.4
	SBL	25	41.64	9.90	21	40.33	10.49	103.24
	AS	16	34.75	8.25	14	33.21	7.46	104.62
L4LS	SBC	26	41.31	10.49	38	39.58	11.93	104.37
	SBL	24	42.92	8.38	16	44.38	5.75	96.71
	AS	16	33.44	10.98	14	34.86	9.02	95.93

Appendix C-1 Descriptive statistics and SDI for facet angle continued

Facet Area	Sample	Male			Female			SDI
		N	Mean	Std dev.	N	Mean	Std dev.	
L4RS	SBC	26	38.62	8.41	38	36.76	9.68	105.04
	SBL	25	37.84	7.36	15	40.27	8.15	93.97
	AS	16	33.69	7.98	14	34.86	5.48	96.64
L4LI	SBC	26	46.58	9.77	38	46.97	11.73	99.16
	SBL	24	50.63	12.26	16	52.63	9.99	96.20
	AS	16	46.88	10.22	13	53.77	7.88	87.18
L4RI	SBC	26	49.88	10.52	38	48.63	11.99	102.58
	SBL	25	53.56	14.83	16	53.56	9.55	100.00
	AS	15	41.07	13.47	12	56.83	6.29	72.26
L5LS	SBC	24	51.83	8.33	34	48.71	11.29	106.42
	SBL	29	52.72	12.30	19	52.11	11.14	101.19
	AS	13	47.77	19.97	13	45.23	13.40	105.61
L5RS	SBC	24	47.88	9.39	34	44.35	11.67	107.94
	SBL	27	49.74	10.85	19	50.00	8.14	99.48
	AS	13	43.08	11.91	13	50.08	9.60	86.02
L5LI	SBC	24	51.54	9.50	34	50.35	9.74	102.36
	SBL	29	51.28	12.36	19	52.84	11.68	97.04
	AS	12	50.42	9.89	12	49.50	9.67	101.85
L5RI	SBC	24	53.17	11.04	34	51.35	8.96	103.53
	SBL	28	52.46	10.02	19	55.89	9.52	93.86
	AS	13	44.69	9.29	12	45.92	5.28	97.33

Key: C=Cervical, T=Thoracic, L=Lumbar, Number = Vertebral level, R=Right, L=Left, S=Superior, I = Inferior, Std Dev = Standard Deviation, SDI = Sexual dimorphism Index,

Appendix C-2 Results of Mann-Whitney u test for sex differences in facet angle

Facet Level	SBC		SBL		AS	
	Mann-Whitney U	p	Mann-Whitney U	p	Mann-Whitney U	p
C1LS	361.00	0.90	248.50	0.79	61.50	0.55
C1RS	356.50	0.84	251.00	0.84	68.50	0.84
C1LI	314.50	0.36	230.50	0.51	27.00	0.02
C1RI	258.00	0.06	216.50	0.33	40.00	0.05
C2LS	322.00	0.20	287.00	0.95	30.00	0.03
C2RS	321.00	0.19	198.00	0.06	33.50	0.04
C2LI	335.00	0.41	217.00	0.14	18.00	0.01
C2RI	307.50	0.13	206.00	0.09	33.00	0.05
C3LS	227.00	0.13	258.50	0.47	51.50	0.13
C3RS	264.50	0.30	216.00	0.18	34.00	0.02
C3LI	296.50	0.79	167.00	0.02	36.00	0.02
C3RI	280.00	0.56	150.00	0.01	13.50	**<0.0001**
C4LS	173.50	0.04	296.50	0.67	57.50	0.46
C4RS	229.00	0.28	283.50	0.50	54.50	0.36
C4LI	287.50	0.96	320.00	0.80	33.50	0.05
C4RI	272.00	0.71	280.50	0.46	64.50	0.98
C5LS	342.50	0.43	346.50	0.81	44.00	0.44
C5RS	306.50	0.11	349.50	0.85	21.50	0.02
C55LI	401.00	0.91	338.00	0.86	41.50	0.34
C5RIA	405.00	0.96	304.50	0.44	47.00	0.57
C6LS	349.50	0.53	312.00	0.55	45.50	0.55
C6RS	235.50	0.01	324.50	0.67	39.50	0.30
C6LI	388.00	0.99	242.50	0.04	36.00	0.20
C6RI	365.50	0.71	312.00	0.30	35.00	0.18
C7LS	454.50	0.65	349.00	0.56	28.00	0.61
C7RS	462.50	0.86	382.00	0.97	30.00	0.76
C7LI	404.50	0.25	357.50	0.66	35.50	0.96
C7RI	482.00	0.94	298.50	0.15	30.00	0.57

Appendix C-2 Results of Mann-Whitney u test for sex differences in facet angle continued

Facet Level	SBC		SBL		AS	
	Mann-Whitney U	p	Mann-Whitney U	p	Mann-Whitney U	p
T1LS	380.00	0.54	347.00	0.47	68.50	0.29
T1RS	446.00	0.64	344.50	0.45	66.50	0.37
T1LI	447.00	0.65	314.00	0.16	77.50	0.74
T1RI	466.00	0.85	332.50	0.26	66.50	0.37
T2LS	321.50	0.02	302.50	0.23	77.00	0.50
T2RS	261.50	**<0.000**	368.00	0.78	66.50	0.23
T2LI	437.50	0.44	275.00	0.09	80.00	0.59
T2RI	440.50	0.46	342.50	0.60	90.00	0.96
T3LS	424.50	0.38	280.00	0.77	103.50	0.95
T3RS	468.00	0.79	288.50	0.75	92.00	0.40
T3LI	435.00	0.47	297.00	0.88	94.50	0.89
T3RI	448.50	0.59	302.50	0.97	98.00	0.56
T4LS	442.00	0.58	229.50	0.25	105.00	1.00
T4RS	414.00	0.44	244.50	0.51	53.50	0.02
T4LI	313.50	0.03	233.50	0.54	78.50	0.26
T4RI	356.00	0.11	208.00	0.18	85.50	0.42
T5LS	423.00	0.57	251.50	0.54	72.50	0.69
T5RS	416.50	0.51	277.00	0.95	54.50	0.18
T5LI	445.00	0.94	247.00	0.77	60.00	0.56
T5RI	441.50	0.90	237.00	0.37	68.50	0.93
T6LS	440.00	0.82	254.00	0.18	67.50	0.88
T6RS	361.00	0.17	324.50	0.99	66.00	0.81
T6LI	360.50	0.09	303.00	0.98	58.00	0.89
T6RI	433.00	0.50	289.50	0.77	53.50	0.67
T7LS	472.00	0.76	260.00	0.33	83.00	0.94
T7RS	394.50	0.17	297.50	0.90	58.50	0.18
T7LI	466.50	0.90	272.00	0.58	55.50	0.52
T7RI	463.00	0.87	269.00	0.43	47.00	0.15

Appendix C-2 Results of Mann-Whitney u test for sex differences in facet angle continued

Facet Level	SBC		SBL		AS	
	Mann-Whitney U	p	Mann-Whitney U	p	Mann-Whitney U	p
T8LS	400.50	0.47	256.00	0.22	76.00	0.47
T8RS	395.50	0.42	200.00	0.02	87.00	0.85
T8LI	465.50	0.97	167.00	0.01	82.50	0.68
T8RI	453.00	0.83	284.00	0.70	88.00	0.88
T9LS	487.50	0.79	303.50	0.90	73.50	0.39
T9RS	471.00	0.63	211.50	0.05	34.00	0.01
T9LI	477.00	0.88	233.00	0.14	68.50	0.42
T9RI	441.00	0.52	242.00	0.25	60.00	0.22
T10LS	411.50	0.29	285.00	0.76	70.00	0.33
T10RS	370.00	0.10	223.50	0.09	76.00	0.68
T10LI	506.50	0.99	229.00	0.16	84.00	0.77
T10RI	480.50	0.72	241.50	0.24	78.50	0.57
T11LS	470.00	0.62	268.50	0.48	82.00	0.69
T11RS	422.50	0.26	284.50	0.69	65.50	0.23
T11LI	373.00	0.11	218.50	0.13	69.50	0.45
T11RI	326.50	0.03	262.00	0.40	76.50	0.70
T12LS	313.00	0.07	249.00	0.36	64.00	0.44
T12RS	294.50	0.04	260.50	0.50	66.00	0.51
T12LI	319.00	0.05	301.50	0.95	65.00	0.71
T12RI	414.00	0.60	276.00	0.57	71.50	0.98
L1LS	351.00	0.15	259.00	0.53	101.50	0.46
L1RS	297.00	0.02	246.00	0.48	67.00	0.10
L1LI	389.50	0.37	289.50	0.99	83.00	0.14
L1RI	413.50	0.72	202.50	0.10	78.00	0.10
L2LS	471.00	0.89	280.00	0.69	98.50	0.61
L2RS	464.50	0.82	228.00	0.41	81.00	0.22
L2LI	443.00	0.59	235.50	0.31	53.00	0.08
L2RI	449.50	0.66	259.00	0.59	81.50	0.50

Appendix C-2 Results of Mann-Whitney u test for sex differences in facet angle continued

Facet Level	SBC		SBL		AS	
	Mann-Whitney U	p	Mann-Whitney U	p	Mann-Whitney U	p
L3LS	449.50	0.79	252.00	0.70	78.50	0.06
L3RS	395.00	0.30	260.00	0.83	82.50	0.09
L3LI	458.50	0.89	271.00	0.79	86.50	0.07
L3RI	364.50	0.14	244.00	0.68	106.00	0.80
L4LS	452.50	0.57	172.50	0.59	106.50	0.82
L4RS	433.00	0.40	150.00	0.29	108.50	0.88
L4LI	476.00	0.81	169.50	0.53	61.00	0.06
L4RI	468.00	0.72	199.00	0.98	22.50	0.00
L5LS	337.00	0.26	272.00	0.94	73.50	0.57
L5RS	343.50	0.31	233.00	0.60	53.50	0.11
L5LI	397.50	0.87	259.50	0.74	69.00	0.86
L5RI	382.00	0.68	207.50	0.20	66.50	0.53

Key: C=Cervical, T=Thoracic, L=Lumbar, Number = Vertebral level, R=Right, L=Left, S=Superior, I = Inferior.

Appendix C-3 Kruskal-Wallace test for differences in facet angle with age group

Facet	Sample	Male Size		Female Size	
		Chi-Square	P Value	Chi-Square	P Value
C1LS	SBC	1.60	0.45	0.76	0.68
	SBL	3.57	0.17	0.12	0.94
	AS	2.03	0.36	0.38	0.54
C1RS	SBC	2.63	0.27	0.34	0.84
	SBL	1.23	0.54	3.85	0.15
	AS	1.13	0.57	0.24	0.62
C1L!	SBC	2.57	0.28	0.65	0.72
	SBL	3.41	0.18	0.30	0.86
	AS	2.12	0.35	0.06	0.81
C1RI	SBC	2.65	0.27	0.06	0.97
	SBL	2.76	0.25	1.43	0.49
	AS	2.16	0.34	0.72	0.40
C2LS	SBC	1.14	0.57	1.68	0.43
	SBL	0.28	0.87	2.62	0.27
	AS	2.24	0.33	2.19	0.33
C2RS	SBC	2.69	0.26	1.31	0.52
	SBL	0.01	0.99	1.38	0.50
	AS	1.48	0.48	1.68	0.43
C2LI	SBC	3.39	0.18	1.39	0.50
	SBL	1.61	0.45	1.77	0.41
	AS	4.73	0.09	3.96	0.14
C2RI	SBC	4.31	0.12	1.02	0.60
	SBL	0.73	0.69	3.50	0.17
	AS	0.02	0.99	3.99	0.14
C3LS	SBC	0.53	0.77	4.41	0.11
	SBL	3.40	0.18	3.99	0.14
	AS	0.97	0.62	0.10	0.95

Appendix C-3 Kruskal-Wallace test for differences in facet angle with age group continued

Facet	Sample	Male Size		Female Size	
		Chi-Square	P Value	Chi-Square	P Value
C3RS	SBC	0.43	0.81	2.86	0.24
	SBL	3.31	0.19	6.19	0.05
	AS	1.28	0.53	0.98	0.61
C3LI	SBC	2.15	0.34	5.79	0.06
	SBL	0.29	0.87	1.62	0.44
	AS	0.99	0.61	2.68	0.26
C3RI	SBC	5.01	0.08	1.19	0.55
	SBL	1.35	0.51	5.70	0.06
	AS	2.33	0.31	0.93	0.63
C4LS	SBC	0.97	0.62	0.94	0.63
	SBL	0.81	0.67	0.89	0.64
	AS	0.80	0.67	0.44	0.80
C4RS	SBC	0.34	0.84	5.26	0.07
	SBL	1.17	0.56	2.13	0.34
	AS	1.60	0.45	0.61	0.74
C4LI	SBC	6.32	0.04	5.46	0.07
	SBL	3.41	0.18	1.36	0.51
	AS	2.37	0.31	0.90	0.64
C4RI	SBC	4.28	0.12	8.82	0.01
	SBL	0.46	0.80	1.09	0.58
	AS	0.30	0.86	3.95	0.14
C5LS	SBC	3.33	0.19	2.37	0.31
	SBL	4.67	0.10	1.32	0.52
	AS	2.37	0.31	0.54	0.76
C5RS	SBC	2.08	0.35	3.23	0.20
	SBL	5.84	0.05	1.05	0.59
	AS	1.24	0.54	1.35	0.51
C55LI	SBC	4.12	0.13	6.16	0.05
	SBL	1.20	0.55	1.35	0.51
	AS	1.09	0.58	6.47	0.04

Appendix C-3 Kruskal-Wallace test for differences in facet angle with age group continued

Facet	Sample	Male Size		Female Size	
		Chi-Square	P Value	Chi-Square	P Value
C5RI	SBC	5.97	0.05	2.67	0.26
	SBL	3.94	0.14	1.84	0.40
	AS	2.69	0.26	2.29	0.32
C6LS	SBC	2.15	0.34	2.36	0.31
	SBL	2.06	0.36	0.31	0.86
	AS	0.02	0.99	1.50	0.47
C6RS	SBC	1.66	0.44	3.28	0.19
	SBL	1.44	0.49	0.55	0.76
	AS	1.97	0.37	4.80	0.09
C6LI	SBC	1.64	0.44	1.19	0.55
	SBL	4.41	0.11	0.48	0.79
	AS	0.77	0.68	0.76	0.69
C6RI	SBC	4.04	0.13	3.59	0.17
	SBL	2.27	0.32	1.19	0.55
	AS	1.27	0.53	0.38	0.83
C7LS	SBC	2.69	0.26	0.58	0.75
	SBL	0.50	0.78	0.51	0.77
	AS	0.68	0.71	0.21	0.64
C7RS	SBC	3.10	0.21	0.35	0.84
	SBL	0.26	0.88	0.74	0.69
	AS	1.09	0.58	0.00	1.00
C7LI	SBC	2.04	0.36	4.09	0.13
	SBL	0.14	0.93	0.22	0.90
	AS	2.24	0.33	3.43	0.06
C7RI	SBC	0.46	0.80	8.45	0.01
	SBL	4.66	0.10	6.41	0.04
	AS	2.10	0.35	0.21	0.64
T1LS	SBC	0.45	0.80	0.29	0.86
	SBL	4.67	0.10	0.36	0.83
	AS	3.63	0.16	0.03	0.86

Appendix C-3 Kruskal-Wallace test for differences in facet angle with age group continued

Facet	Sample	Male Size		Female Size	
		Chi-Square	P Value	Chi-Square	P Value
T1RS	SBC	0.72	0.70	0.45	0.80
	SBL	3.91	0.14	5.55	0.06
	AS	2.76	0.25	2.18	0.34
T1LI	SBC	0.82	0.66	1.60	0.45
	SBL	4.29	0.12	0.33	0.85
	AS	0.29	0.87	1.71	0.43
T1RI	SBC	2.22	0.33	1.63	0.44
	SBL	0.97	0.61	0.24	0.89
	AS	2.26	0.32	0.17	0.92
T2LS	SBC	0.42	0.81	6.06	0.05
	SBL	4.41	0.11	1.61	0.45
	AS	3.39	0.18	0.64	0.73
T2RS	SBC	0.42	0.81	6.06	0.05
	SBL	3.34	0.19	2.10	0.35
	AS	4.11	0.13	3.63	0.16
T2LI	SBC	0.73	0.69	2.33	0.31
	SBL	3.64	0.16	1.20	0.55
	AS	0.08	0.96	1.92	0.38
T2RI	SBC	1.02	0.60	0.52	0.77
	SBL	2.16	0.34	1.38	0.50
	AS	2.75	0.25	0.14	0.93
T3LS	SBC	1.93	0.38	0.61	0.74
	SBL	2.70	0.26	0.24	0.89
	AS	2.13	0.34	0.61	0.74
T3RS	SBC	2.80	0.25	0.32	0.85
	SBL	0.24	0.89	1.77	0.41
	AS	0.90	0.64	1.83	0.40
T3LI	SBC	1.62	0.45	1.58	0.45
	SBL	1.42	0.49	1.49	0.47
	AS	1.77	0.41	0.03	0.99

Appendix C-3 Kruskal-Wallace test for differences in facet angle with age group continued

Facet	Sample	Male Size		Female Size	
		Chi-Square	P Value	Chi-Square	P Value
T3RI	SBC	0.66	0.72	3.96	0.14
	SBL	0.55	0.76	0.23	0.89
	AS	0.12	0.94	1.57	0.46
T4LS	SBC	0.43	0.80	2.97	0.23
	SBL	1.39	0.50	2.10	0.35
	AS	1.28	0.53	1.31	0.52
T4RS	SBC	2.59	0.27	0.45	0.80
	SBL	1.08	0.58	0.69	0.71
	AS	0.97	0.62	1.87	0.39
T4LI	SBC	1.84	0.40	2.40	0.30
	SBL	0.09	0.95	4.51	0.11
	AS	0.30	0.86	0.31	0.86
T4RI	SBC	1.83	0.40	0.12	0.94
	SBL	2.72	0.26	0.09	0.96
	AS	3.75	0.15	1.52	0.47
T5LS	SBC	5.68	0.06	0.03	0.98
	SBL	4.14	0.13	1.48	0.48
	AS	1.14	0.57	1.17	0.56
T5RS	SBC	0.20	0.90	0.30	0.86
	SBL	0.14	0.93	2.26	0.32
	AS	2.88	0.24	0.59	0.75
T5LI	SBC	4.92	0.09	4.14	0.13
	SBL	1.17	0.56	1.47	0.48
	AS	2.02	0.36	0.20	0.91
T5RI	SBC	2.77	0.25	0.64	0.72
	SBL	1.47	0.48	0.20	0.91
	AS	2.33	0.31	4.08	0.13
T6LS	SBC	4.92	0.09	0.55	0.76
	SBL	1.19	0.55	1.39	0.50
	AS	1.08	0.58	0.05	0.83

Appendix C-3 Kruskal-Wallace test for differences in facet angle with age group continued

Facet	Sample	Male Size		Female Size	
		Chi-Square	P Value	Chi-Square	P Value
T6RS	SBC	0.06	0.97	3.65	0.16
	SBL	1.97	0.37	1.21	0.55
	AS	1.92	0.38	1.14	0.29
T6LI	SBC	5.38	0.07	2.85	0.24
	SBL	3.71	0.16	5.07	0.08
	AS	1.48	0.48	0.10	0.75
T6RI	SBC	2.37	0.31	1.14	0.57
	SBL	0.20	0.90	1.63	0.44
	AS	0.11	0.95	1.15	0.28
T7LS	SBC	0.86	0.65	0.32	0.85
	SBL	1.70	0.43	6.64	0.04
	AS	0.66	0.72	0.00	1.00
T7RS	SBC	1.98	0.37	1.94	0.38
	SBL	2.08	0.35	1.60	0.45
	AS	0.66	0.72	0.14	0.71
T7LI	SBC	3.86	0.14	2.01	0.37
	SBL	3.81	0.15	0.26	0.88
	AS	1.20	0.55	0.55	0.46
T7RI	SBC	3.44	0.18	2.13	0.34
	SBL	0.77	0.68	0.37	0.83
	AS	2.12	0.35	0.05	0.82
T8LS	SBC	1.06	0.59	0.51	0.77
	SBL	3.35	0.19	0.14	0.93
	AS	1.31	0.52	4.00	0.14
T8RS	SBC	0.04	0.98	0.07	0.97
	SBL	2.87	0.24	0.51	0.78
	AS	1.59	0.45	3.38	0.18
T8LI	SBC	3.37	0.18	0.87	0.65
	SBL	2.23	0.33	0.87	0.65
	AS	2.21	0.33	2.75	0.25

Appendix C-3 Kruskal-Wallace test for differences in facet angle with age group continued

Facet	Sample	Male Size		Female Size	
		Chi-Square	P Value	Chi-Square	P Value
T8RI	SBC	0.83	0.66	2.82	0.24
	SBL	0.40	0.82	0.68	0.71
	AS	0.69	0.71	3.24	0.20
T9LS	SBC	3.11	0.21	1.07	0.59
	SBL	1.80	0.41	1.03	0.60
	AS	0.53	0.77	0.09	0.96
T9RS	SBC	1.59	0.45	0.66	0.72
	SBL	5.41	0.07	4.64	0.10
	AS	0.10	0.95	1.55	0.46
T9LI	SBC	0.51	0.77	2.98	0.22
	SBL	0.42	0.81	0.86	0.65
	AS	2.57	0.28	0.00	1.00
T9RI	SBC	0.95	0.62	1.63	0.44
	SBL	9.00	0.01	6.99	0.03
	AS	3.15	0.21	1.24	0.27
T10LS	SBC	1.76	0.42	0.71	0.70
	SBL	0.93	0.63	1.88	0.39
	AS	0.35	0.84	0.03	0.86
T10RS	SBC	0.33	0.85	3.78	0.15
	SBL	1.85	0.40	0.59	0.74
	AS	0.46	0.80	0.01	0.93
T10LI	SBC	1.15	0.56	0.65	0.72
	SBL	0.18	0.91	0.28	0.87
	AS	2.56	0.28	0.12	0.73
T10RI	SBC	1.85	0.40	0.17	0.92
	SBL	2.50	0.29	1.41	0.50
	AS	1.91	0.38	0.46	0.50
T11LS	SBC	2.19	0.33	2.27	0.32
	SBL	2.51	0.29	0.25	0.88
	AS	0.69	0.41	0.12	0.73

Appendix C-3 Kruskal-Wallace test for differences in facet angle with age group continued

Facet	Sample	Male Size		Female Size	
		Chi-Square	P Value	Chi-Square	P Value
T11RS	SBC	1.62	0.45	0.14	0.93
	SBL	2.67	0.26	1.07	0.59
	AS	0.06	0.81	0.03	0.86
T11LI	SBC	0.80	0.67	5.45	0.07
	SBL	0.66	0.72	0.27	0.87
	AS	0.10	0.75	1.05	0.30
T11RI	SBC	0.37	0.83	2.35	0.31
	SBL	0.48	0.79	0.71	0.70
	AS	0.27	0.61	0.12	0.73
T12LS	SBC	2.16	0.34	0.33	0.85
	SBL	0.39	0.82	0.39	0.82
	AS	2.48	0.12	2.93	0.09
T12RS	SBC	0.97	0.62	3.37	0.19
	SBL	0.24	0.89	0.41	0.82
	AS	0.02	0.89	1.05	0.30
T12LI	SBC	0.34	0.84	1.22	0.54
	SBL	0.10	0.95	0.39	0.82
	AS	0.08	0.78	0.04	0.85
T12RI	SBC	1.40	0.50	0.31	0.86
	SBL	0.57	0.75	0.85	0.65
	AS	0.01	0.94	3.86	0.05
L1LS	SBC	2.82	0.24	1.77	0.41
	SBL	1.35	0.51	1.61	0.45
	AS	0.10	0.75	0.78	0.68
L1RS	SBC	0.26	0.88	1.68	0.43
	SBL	0.65	0.72	0.23	0.89
	AS	0.15	0.70	1.65	0.44
L1LI	SBC	1.04	0.60	6.35	0.04
	SBL	0.03	0.98	3.78	0.15
	AS	5.06	0.02	5.29	0.07

Appendix C-3 Kruskal-Wallace test for differences in facet angle with age group continued

Facet	Sample	Male Size		Female Size	
		Chi-Square	P Value	Chi-Square	P Value
L1RI	SBC	2.59	0.27	13.84	<0.01
	SBL	0.59	0.74	2.59	0.27
	AS	1.02	0.31	0.49	0.78
L2LS	SBC	3.70	0.16	1.25	0.53
	SBL	0.41	0.81	0.86	0.65
	AS	2.16	0.14	0.62	0.73
L2RS	SBC	6.65	0.04	2.52	0.28
	SBL	0.22	0.90	0.73	0.69
	AS	3.30	0.07	1.09	0.58
L2LI	SBC	3.67	0.16	2.28	0.32
	SBL	1.64	0.44	1.93	0.38
	AS	1.57	0.21	1.78	0.41
L2RI	SBC	1.74	0.42	1.28	0.53
	SBL	1.01	0.60	1.84	0.40
	AS	0.96	0.33	2.21	0.33
L3LS	SBC	2.55	0.28	1.01	0.60
	SBL	0.16	0.92	0.44	0.80
	AS	0.84	0.36	1.50	0.47
L3RS	SBC	1.03	0.60	0.42	0.81
	SBL	1.57	0.46	1.05	0.59
	AS	0.05	0.83	0.96	0.62
L3LI	SBC	1.42	0.49	5.09	0.08
	SBL	1.48	0.48	0.60	0.74
	AS	3.65	0.06	0.30	0.86
L3RI	SBC	2.64	0.27	1.26	0.53
	SBL	3.39	0.18	0.82	0.66
	AS	3.45	0.06	0.01	0.94
L4LS	SBC	0.15	0.93	0.38	0.83
	SBL	0.28	0.87	1.84	0.40
	AS	0.76	0.38	0.01	0.94

Appendix C-3 Kruskal-Wallace test for differences in facet angle with age group continued

Facet	Sample	Male Size		Female Size	
		Chi-Square	P Value	Chi-Square	P Value
L4RS	SBC	0.83	0.68	2.33	0.31
	SBL	1.80	0.41	0.56	0.76
	AS	0.05	0.83	0.01	0.94
L4LI	SBC	2.34	0.31	4.06	0.13
	SBL	0.13	0.94	0.39	0.82
	AS	1.57	0.21	0.60	0.44
L4RI	SBC	0.72	0.70	4.25	0.12
	SBL	0.00	1.00	0.31	0.86
	AS	0.50	0.48	0.01	0.93
L5LS	SBC	0.49	0.78	1.47	0.48
	SBL	0.26	0.88	0.74	0.69
	AS	0.86	0.35	0.03	0.87
L5RS	SBC	2.40	0.30	4.27	0.12
	SBL	1.08	0.58	1.31	0.52
	AS	0.62	0.43	0.15	0.70
L5LI	SBC	0.95	0.62	1.43	0.49
	SBL	2.17	0.34	0.60	0.74
	AS	1.91	0.17	0.03	0.86
L5RI	SBC	1.47	0.48	2.05	0.36
	SBL	2.48	0.29	1.35	0.51
	AS	1.33	0.25	2.36	0.12

Key: C=Cervical, T=Thoracic, L=Lumbar, Number = Vertebral level, R=Right, L=Left, S=Superior, I = Inferior,

Appendix C-4 Correlation between facet angle and actual age

Facet	Males				Females			
	C-Coefficient	P	N	Strength of Correlation	C-Coefficient	P	N	Strength of Correlation
C1LS	-0.34	0.11	23	Medium	-0.04	0.84	32	None
C1RS	-0.26	0.23	23	Weak	-0.11	0.56	32	Weak
C1LI	-0.13	0.57	23	Weak	0.07	0.72	32	None
C1RI	-0.02	0.92	23	None	0.08	0.68	32	Weak
C2LS	-0.18	0.42	23	Weak	0.18	0.31	35	Weak
C2RS	-0.28	0.19	23	Weak	0.11	0.52	35	Weak
C2LI	-0.25	0.26	22	Weak	-0.09	0.62	35	None
C2RI	-0.29	0.18	23	Weak	-0.09	0.62	35	None
C3LS	0.00	1.00	19	None	0.32	0.07	32	Medium
C3RS	0.15	0.52	20	Weak	0.00	0.99	32	None
C3LI	-0.23	0.34	20	Weak	-0.15	0.41	31	Weak
C3RI	-0.42	0.06	20	Medium	-0.14	0.45	31	Weak
C4LS	-0.14	0.57	19	Weak	0.06	0.75	28	None
C4RS	0.27	0.25	20	Weak	-0.26	0.18	28	Weak
C4LI	-0.39	0.09	20	Medium	-0.29	0.12	29	Weak
C4RI	-0.28	0.23	20	Weak	-0.39	0.04	29	Medium
C5LS	-0.25	0.25	23	Weak	-0.12	0.49	34	Weak
C5RS	-0.20	0.34	24	Weak	-0.40	0.02	34	Medium
C5LI	-0.22	0.30	24	Weak	-0.39	0.02	34	Medium
C5RI	-0.41	0.05	24	Medium	-0.25	0.15	34	Weak
C6LS	-0.08	0.73	21	None	-0.17	0.31	37	Weak
C6RS	-0.22	0.34	21	Weak	-0.17	0.30	37	Weak
C6LI	-0.18	0.44	21	Weak	-0.16	0.33	37	Weak
C6RI	-0.35	0.12	21	Weak	-0.19	0.27	37	Weak
C7LS	-0.19	0.36	25	Weak	-0.02	0.92	39	None
C7RS	-0.13	0.53	25	Weak	-0.08	0.65	38	None
C7LI	0.16	0.45	25	Weak	-0.13	0.43	39	Weak
C7RI	0.03	0.90	25	None	-0.32	0.04	39	Medium
T1LS	-0.16	0.49	21	Weak	0.07	0.66	40	None
T1RS	0.14	0.53	24	Weak	-0.08	0.64	40	None
T1LI	-0.26	0.22	24	Weak	-0.13	0.44	40	Weak
T1RI	-0.02	0.94	24	None	-0.02	0.93	40	None
T2LS	0.16	0.45	26	Weak	0.19	0.24	38	Weak
T2RS	-0.02	0.91	26	None	0.05	0.76	38	None
T2LI	-0.25	0.21	26	Weak	-0.24	0.15	38	Weak
T2RI	-0.08	0.70	26	None	0.06	0.71	38	None
T3LS	0.32	0.12	25	Medium	0.15	0.37	39	Weak
T3RS	0.33	0.11	25	Medium	0.01	0.96	39	None
T3LI	-0.26	0.22	25	Weak	-0.21	0.21	39	Weak
T3RI	0.00	0.99	25	None	-0.34	0.03	39	Medium

Appendix C-4 Correlation between facet angle and actual age continued

Facet	Males				Females			
	C-Coefficient	P	N	Strength of Correlation	C-Coefficient	P	N	Strength of Correlation
T4LS	0.00	0.99	26	None	-0.11	0.50	37	Weak
T4RS	-0.27	0.19	26	Weak	0.03	0.88	36	None
T4LI	-0.27	0.18	26	Weak	-0.26	0.13	36	Weak
T4RI	-0.19	0.36	26	Weak	-0.01	0.98	36	None
T5LS	-0.19	0.36	25	Weak	0.07	0.66	37	None
T5RS	-0.03	0.88	25	None	-0.07	0.69	37	None
T5LI	-0.27	0.19	25	Weak	-0.34	0.04	36	Medium
T5RI	-0.20	0.33	25	Weak	-0.14	0.41	36	Weak
T6LS	0.39	0.05	26	Medium	0.00	0.99	35	None
T6RS	-0.08	0.71	26	None	0.28	0.11	35	Weak
T6LI	-0.27	0.18	26	Weak	-0.24	0.15	37	Weak
T6RI	-0.04	0.85	26	None	0.20	0.23	37	Weak
T7LS	0.06	0.78	26	Weak	0.04	0.81	38	None
T7RS	-0.21	0.30	26	Weak	0.23	0.17	38	Weak
T7LI	-0.46	0.02	25	Medium	-0.14	0.41	38	Weak
T7RI	-0.08	0.72	25	None	-0.17	0.31	38	Weak
T8LS	0.32	0.12	25	Medium	0.14	0.42	36	Weak
T8RS	-0.05	0.81	25	None	0.05	0.79	36	None
T8LI	-0.42	0.03	26	Medium	-0.12	0.49	36	Weak
T8RI	-0.13	0.51	26	Weak	-0.17	0.32	36	Weak
T9LS	0.11	0.60	26	Weak	0.16	0.33	39	Weak
T9RS	0.05	0.79	26	None	0.10	0.56	39	Weak
T9LI	-0.26	0.20	25	Weak	-0.26	0.11	39	Weak
T9RI	-0.12	0.57	25	Weak	-0.21	0.19	39	Weak
T10LS	0.33	0.11	25	Medium	0.09	0.57	39	None
T10RS	-0.18	0.38	25	Weak	-0.02	0.90	39	None
T10LI	-0.40	0.04	26	Medium	-0.16	0.34	39	Weak
T10RI	-0.38	0.05	26	Medium	0.02	0.92	39	None
T11LS	-0.01	0.98	26	None	-0.10	0.55	39	Weak
T11RS	-0.07	0.73	26	None	0.00	0.99	39	None
T11LI	-0.09	0.67	25	None	0.04	0.80	39	None
T11RI	-0.03	0.88	25	None	0.11	0.50	39	Weak
T12LS	0.02	0.92	24	None	0.18	0.29	36	Weak
T12RS	-0.03	0.89	24	None	0.30	0.07	36	Medium
T12LI	-0.01	0.95	25	None	0.20	0.24	36	Weak
T12RI	-0.20	0.33	25	Weak	-0.09	0.61	36	None
L1LS	0.18	0.40	25	Weak	0.05	0.76	36	None
L1RS	-0.04	0.84	25	None	0.05	0.77	36	None
L1LI	0.16	0.44	25	Weak	0.13	0.44	36	Weak
L1RI	0.38	0.06	25	Medium	-0.03	0.87	35	None

Appendix C-4 Correlation between facet angle and actual age continued

Facet	Males				Females			
	C-Coefficient	P	N	Strength of Correlation	C-Coefficient	P	N	Strength of Correlation
L2LS	0.36	0.07	26	Medium	-0.09	0.58	37	None
L2RS	0.45	0.02	26	Medium	-0.15	0.37	37	Weak
L2LI	0.43	0.03	26	Medium	0.08	0.63	37	None
L2RI	0.23	0.25	26	Weak	0.05	0.79	37	None
L3LS	0.39	0.05	26	Medium	0.07	0.70	36	None
L3RS	0.21	0.31	26	Weak	-0.01	0.96	36	None
L3LI	-0.18	0.38	26	Weak	-0.11	0.51	36	Weak
L3RI	0.04	0.83	26	None	0.05	0.78	36	None
L4LS	0.15	0.48	26	Weak	-0.01	0.97	38	None
L4RS	-0.05	0.82	26	None	0.07	0.66	38	None
L4LI	-0.13	0.53	26	Weak	0.16	0.35	38	Weak
L4RI	-0.06	0.76	26	None	0.16	0.33	38	Weak
L5LS	0.11	0.60	24	Weak	0.13	0.47	34	Weak
L5RS	-0.15	0.47	24	Weak	0.02	0.92	34	None
L5LI	-0.13	0.55	24	Weak	-0.13	0.55	24	Weak
L5RI	0.02	0.92	24	None	-0.18	0.31	34	Weak

Appendix C-5 Kruskal-Wallace test for inter-sample facet angle difference

Facet	Male		Female	
	Chi-Square	p	Chi-Square	p
C1LS	7.247	**0.027**	10.169	0.006
C1RS	9.701	**0.008**	7.65	0.022
C1LI	1.748	0.417	3.761	0.153
C1RI	1.056	0.59	2.311	0.315
C2LS	8.278	**0.016**	1.376	0.503
C2RS	4.049	0.132	3.473	0.176
C2LI	21.119	**<0.0001**	7.232	**0.027**
C2RI	21.025	**<0.0001**	7.54	**0.023**
C3LS	14.801	**0.001**	12.455	**0.002**
C3RS	7.349	**0.025**	14.433	**0.001**
C3LI	21.926	**<0.0001**	0.158	0.924
C3RI	39.371	**<0.0001**	4.816	0.09
C4LS	9.879	**0.007**	2.648	0.266
C4RS	0.471	0.79	3.114	0.211
C4LI	15.146	**0.001**	6.027	**0.049**
C4RI	14.689	**0.001**	17.88	**<0.0001**
C5LS	3.116	0.211	1.501	0.472
C5RS	9.439	**0.009**	3.714	0.156
C5LI	6.129	**0.047**	8.348	**0.015**
C5RI	13.473	**0.001**	12.833	**0.002**
C6LS	6.094	**0.048**	2.223	0.329
C6RS	8.027	**0.018**	0.977	0.613
C6LI	6.33	**0.042**	3.057	0.217
C6RI	6.77	**0.034**	7.852	**0.02**
C7LS	6.233	**0.044**	6.525	**0.038**
C7RS	1.394	0.498	1.326	0.515
C7LI	5.102	0.078	2.647	0.266
C7RI	7.39	**0.025**	1.249	0.535
T1LS	2.813	0.245	0.671	0.715
T1RS	1.39	0.499	0.519	0.771
T1LI	24.764	**<0.0001**	19.042	**<0.0001**
T1RI	37.397	**<0.0001**	11.415	**0.003**
T2LS	3.243	0.198	3.263	0.196
T2RS	5.176	0.075	18.084	**<0.0001**
T2LI	24.726	**<0.0001**	23.962	**<0.0001**
T2RI	23.168	**<0.0001**	22.568	**<0.0001**
T3LS	1.041	0.594	1.483	0.477
T3RS	10.099	**0.006**	4.997	0.082
T3LI	31.009	**<0.0001**	25.215	**<0.0001**
T3RI	17.479	**<0.0001**	18.719	**<0.0001**

Appendix C-5 Kruskal-Wallace test for inter-sample facet angle difference continued

Facet	Male		Female	
	Chi-Square	p	Chi-Square	p
T4LS	4.595	0.101	0.91	0.635
T4RS	15.395	**<0.0001**	2.278	0.32
T4LI	41.31	**<0.0001**	20.7	**<0.0001**
T4RI	40.067	**<0.0001**	8.849	**0.012**
T5LS	1.461	0.482	0.043	0.979
T5RS	11.721	**0.003**	1.059	0.589
T5LI	21.453	**<0.0001**	17.822	**<0.0001**
T5RI	22.444	**<0.0001**	20.669	**<0.0001**
T6LS	0.188	0.91	2.255	0.324
T6RS	5.629	0.06	2.483	0.289
T6LI	16.336	**<0.0001**	12.954	**0.002**
T6RI	21.216	**<0.0001**	9.702	**0.008**
T7LS	1.242	0.537	0.545	0.761
T7RS	1.016	0.602	4.865	0.088
T7LI	13.258	**0.001**	24.941	**<0.0001**
T7RI	24.259	**<0.0001**	7.519	**0.023**
T8LS	0.842	0.656	2.299	0.317
T8RS	4.921	0.085	9.171	**0.01**
T8LI	11.581	**0.003**	10.97	**0.004**
T8RI	18.074	**<0.0001**	15.224	**<0.0001**
T9LS	0.654	0.721	3.459	0.177
T9RS	18.602	**<0.0001**	3.266	0.195
T9LI	4.879	0.087	12.186	**0.002**
T9RI	7.69	**0.021**	14.87	**0.001**
T10LS	2.974	0.226	2.281	0.32
T10RS	6.503	**0.039**	11.534	**0.003**
T10LI	16.184	**<0.0001**	13.854	**0.001**
T10RI	14.896	**0.001**	4.75	0.093
T11LS	0.399	0.819	0.308	0.857
T11RS	9.778	**0.008**	10.763	0.005
T11LI	7.044	**0.03**	5.354	0.069
T11RI	7.123	**0.028**	0.83	0.66
T12LS	6.883	**0.032**	1.583	0.453
T12RS	10.465	**0.005**	4.089	0.129
T12LI	3.435	0.18	0.155	0.926
T12RI	1.264	0.532	3.742	0.154
L1LS	4.424	0.109	1.68	0.432
L1RS	7.797	**0.02**	1.756	0.416
L1LI	3.685	0.158	3.286	0.193
L1RI	5.991	0.05	2.051	0.359

Appendix C-5 Kruskal-Wallace test for inter-sample facet angle difference continued

Facet	Male		Female	
	Chi-Square	p	Chi-Square	p
L2LS	7.768	**0.021**	3.974	0.137
L2RS	7.966	**0.019**	0.482	0.786
L2LI	4.024	0.134	3.25	0.197
L2RI	3.73	0.155	0.538	0.764
L3LS	14.974	**0.001**	1.585	0.453
L3RS	5.752	0.056	1.052	0.591
L3LI	2.27	0.321	1.105	0.576
L3RI	5.339	0.069	5.569	0.062
L4LS	7.029	**0.03**	5.39	0.068
L4RS	2.66	0.265	2.734	0.255
L4LI	1.201	0.549	6.24	**0.044**
L4RI	6.994	**0.03**	8.074	**0.018**
L5LS	1.046	0.593	2.14	0.343
L5RS	1.981	0.371	5.461	0.065
L5LI	0.061	0.97	0.47	0.791
L5RI	5.782	0.056	8.038	**0.018**

Appendix C-6 Mann- Whitney test for inter-sample variation in facet angle

Facet	Male						Female					
	SBC/SBL		SBC/AS		SBL/AS		SBC/SBL		SBC/AS		SBL/AS	
	Z	p	Z	p	Z	p	Z	p	Z	p	Z	p
C1LS	-2.758	**0.006**	-1.634	0.102	-0.984	0.325	-3.394	**0.001**	-0.538	0.591	-1.307	0.191
C1RS	-3.42	**0.001**	-1.117	0.264	-0.824	0.41	-2.878	**0.004**	-1.011	0.312	-0.311	0.755
C1LI	-0.251	0.802	-0.99	0.322	-1.324	0.186	-0.208	0.836	-1.912	0.056	-1.611	0.107
C1RI	-1.075	0.282	-0.285	0.776	-0.448	0.654	-0.227	0.821	-1.437	0.151	-1.327	0.185
C2LS	-1.818	0.069	-1.55	0.121	-2.584	**0.01**	-0.368	0.713	-1.134	0.257	-0.875	0.382
C2RS	-1.829	0.067	-0.296	0.767	-1.424	0.154	-1.815	0.07	-1.033	0.301	-0.042	0.967
C2LI	-2.713	**0.007**	-2.073	**0.038**	-4.417	**<0.001**	-2.338	**0.019**	-1.926	0.054	-0.132	0.895
C2RI	-3.008	**0.003**	-1.897	0.058	-4.254	**<0.001**	-2.698	**0.007**	-1.285	0.199	-0.683	0.495
C3LS	-2.984	**0.003**	-3.432	**0.001**	-1.502	0.133	-0.665	0.506	-3.312	**0.001**	-3.088	**0.002**
C3RS	-2.648	**0.008**	-1.912	0.056	-0.098	0.922	-0.283	0.778	-3.534	**<0.001**	-3.461	**0.001**
C3LI	-2.703	**0.007**	-3.011	**0.003**	-4.137	**<0.001**	-0.253	0.801	-0.183	0.855	-0.403	0.687
C3RI	-4.515	**<0.001**	-3.578	**<0.001**	-5.141	**<0.001**	-2.209	**0.027**	-0.974	0.33	-0.464	0.643
C4LS	-1.778	0.075	-3.029	**0.002**	-1.884	0.06	-0.696	0.487	-0.997	0.319	-1.737	0.082
C4RS	-0.765	0.444	-0.298	0.766	-0.039	0.969	-0.883	0.377	-1.198	0.231	-1.69	0.091
C4LI	-0.877	0.38	-3.322	**0.001**	-3.572	**<0.001**	-1.447	0.148	-1.47	0.142	-2.321	**0.02**
C4RI	-2.46	**0.014**	-2.214	**0.027**	-3.328	**0.001**	-2.634	**0.008**	-2.771	**0.006**	-3.714	**<0.001**
C5LS	-1.683	0.092	-1.183	0.237	-0.251	0.802	-1.203	0.229	-0.323	0.747	-0.701	0.483
C5RS	-1.204	0.229	-2.797	**0.005**	-2.521	**0.012**	-0.325	0.745	-1.743	0.081	-1.819	0.069
C5LI	-0.743	0.457	-1.761	0.078	-2.504	**0.012**	-0.972	0.331	-2.439	**0.015**	-2.69	**0.007**
C5RI	-1.809	0.07	-2.356	**0.018**	-3.497	**<0.001**	-1.31	0.19	-3.261	**0.001**	-3.046	**0.002**
C6LS	-1.344	0.179	-2.362	**0.018**	-1.579	0.114	-0.252	0.801	-1.431	0.152	-1.303	0.193
C6RS	-2.286	**0.022**	-2.119	**0.034**	-1.622	0.105	-0.957	0.339	-0.514	0.607	-0.101	0.919
C6LI	-2.27	**0.023**	-0.038	0.97	-1.782	0.075	-1.153	0.249	-1.309	0.191	-1.348	0.178
C6RI	-2.58	**0.01**	-0.075	0.94	-1.483	0.138	-1.575	0.115	-1.89	0.059	-2.641	**0.008**

Appendix C-6 Mann- Whitney test for inter-sample variation in facet angle continued

Facet	Male						Female					
	SBC/SBL		SBC/AS		SBL/AS		SBC/SBL		SBC/AS		SBL/AS	
	Z	p	Z	p	Z	p	Z	p	Z	p	Z	p
C7LS	-1.797	0.072	-2.207	**0.027**	-1.215	0.224	-1.099	0.272	-2.394	**0.017**	-1.951	0.051
C7RS	-1.114	0.265	-0.741	0.459	-0.434	0.664	-1.173	0.241	-0.325	0.745	-0.156	0.876
C7LI	-2.142	**0.032**	-0.261	0.794	-1.44	0.15	-0.784	0.433	-1.325	0.185	-1.46	0.144
C7RI	-2.315	**0.021**	-0.862	0.388	-2.038	**0.042**	-0.943	0.345	-0.452	0.651	-0.831	0.406
T1LS	-0.643	0.52	-1.607	0.108	-1.274	0.203	-0.501	0.616	-0.711	0.477	-0.498	0.618
T1RS	-1.038	0.299	-0.925	0.355	-0.331	0.741	-0.688	0.491	-0.417	0.677	-0.052	0.958
T1LI	-0.845	0.398	-3.878	**<0.001**	-4.905	**<0.001**	-1.605	0.108	-3.734	**<0.001**	-3.917	**<0.001**
T1RI	-3.941	**<0.001**	-3.717	**<0.001**	-5.229	**<0.001**	-3.09	**0.002**	-0.772	0.44	-2.523	**0.012**
T2LS	-1.709	0.087	-1.241	0.215	-0.155	0.876	-1.81	0.07	-0.987	0.324	-0.411	0.681
T2RS	-1.548	0.122	-0.96	0.337	-2.037	**0.042**	-2.048	**0.041**	-3.835	**<0.001**	-3.089	0.002
T2LI	-1.933	0.053	-3.476	**0.001**	-4.836	**<0.001**	-2.094	**0.036**	-3.647	**<0.001**	-4.758	**<0.001**
T2RI	-3.947	**<0.001**	-1.764	0.078	-3.733	**<0.001**	-3.213	**0.001**	-3.249	**0.001**	-3.866	**<0.001**
T3LS	-0.995	0.32	-0.28	0.779	-0.59	0.555	-0.459	0.646	-0.912	0.362	-1.23	0.219
T3RS	-0.768	0.443	-3.031	**0.002**	-2.548	**0.011**	-0.164	0.87	-2.111	**0.035**	-1.942	0.052
T3LI	-2.112	**0.035**	-4.307	**<0.001**	-5.132	**<0.001**	-1.176	0.24	-4.578	**<0.001**	-4.449	**<0.001**
T3RI	-2.699	**0.007**	-1.85	0.064	-3.908	**<0.001**	-3.212	**0.001**	-2.426	**0.015**	-3.641	**<0.001**
T4LS	-1.601	0.109	-0.802	0.422	-1.867	0.062	-0.191	0.848	-0.889	0.374	-0.811	0.418
T4RS	-0.876	0.381	-3.129	**0.002**	-3.77	**<0.001**	-1.167	0.243	-0.559	0.576	-1.408	0.159
T4LI	-4.32	**<0.001**	-3.757	**<0.001**	-5.516	**<0.001**	-1.139	0.255	-3.875	**<0.001**	-4.319	**<0.001**
T4RI	-5.251	**<0.001**	-1.573	0.116	-5.19	**<0.001**	-1.954	0.051	-1.649	0.099	-2.844	**0.004**
T5LS	-1.221	0.222	-0.738	0.461	-0.061	0.951	-0.22	0.826	-0.026	0.979	-0.089	0.929
T5RS	-0.619	0.536	-2.785	**0.005**	-3.246	**0.001**	-0.21	0.833	-1.073	0.283	-0.687	0.492
T5LI	-1.021	0.307	-3.855	**<0.001**	-4.331	**<0.001**	-1.829	0.067	-3.43	**0.001**	-3.844	**<0.001**
T5RI	-3.788	**<0.001**	-1.575	0.115	-3.935	**<0.001**	-4.138	**<0.001**	-1.042	0.297	-3.424	**0.001**

Appendix C-6 Mann- Whitney test for inter-sample variation in facet angle continued

Facet	Male						Female					
	SBC/SBL		SBC/AS		SBL/AS		SBC/SBL		SBC/AS		SBL/AS	
	Z	p	Z	p	Z	p	Z	p	Z	p	Z	p
T6LS	-0.379	0.704	-0.357	0.721	-0.086	0.931	-1.566	0.117	-0.041	0.967	-0.679	0.497
T6RS	-1.077	0.281	-1.522	0.128	-2.304	**0.021**	-0.34	0.734	-1.533	0.125	-1.273	0.203
T6LI	-2.373	**0.018**	-2.235	**0.025**	-3.791	**<0.001**	-1.017	0.309	-3.01	**0.003**	-3.524	**<0.001**
T6RI	-3.729	**<0.001**	-1.102	0.27	-3.865	**<0.001**	-2.459	**0.014**	-1.239	0.215	-2.74	**0.006**
T7LS	-1.088	0.277	-0.24	0.811	-0.621	0.534	-0.443	0.657	-0.639	0.523	-0.469	0.639
T7RS	-0.622	0.534	-0.927	0.354	-0.593	0.553	-0.903	0.366	-1.724	0.085	-2.115	**0.034**
T7LI	-0.865	0.387	-3.166	**0.002**	-3.383	**0.001**	-1.546	0.122	-4.498	**<0.001**	-4.351	**<0.001**
T7RI	-2.718	**0.007**	-3.308	**0.001**	-4.429	**<0.001**	-2.018	**0.044**	-1.093	0.274	-2.669	**0.008**
T8LS	-0.635	0.526	-0.264	0.792	-0.859	0.391	-0.086	0.932	-1.534	0.125	-1.133	0.257
T8RS	-0.259	0.796	-1.995	0.046	-2.041	**0.041**	-0.699	0.484	-2.365	**0.018**	-3.15	**0.002**
T8LI	-1.247	0.212	-3.049	**0.002**	-2.874	**0.004**	-0.786	0.432	-2.784	**0.005**	-3.185	**0.001**
T8RI	-3.691	**<0.001**	-1.181	0.238	-3.164	**0.002**	-3.224	**0.001**	-1.286	0.199	-3.426	**0.001**
T9LS	-0.523	0.601	-0.185	0.853	-0.814	0.415	-0.105	0.917	-1.85	0.064	-1.465	0.143
T9RS	-1.098	0.272	-3.979	**<0.001**	-3.711	**<0.001**	-1.387	0.165	-0.77	0.442	-1.649	0.099
T9LI	-0.066	0.947	-1.878	0.06	-2.12	**0.034**	-1.086	0.278	-2.76	**0.006**	-3.587	**<0.001**
T9RI	-2.772	**0.006**	-0.793	0.428	-1.365	0.172	-3.588	**<0.001**	-0.153	0.879	-2.986	**0.003**
T10LS	-1.385	0.166	-1.523	0.128	-0.448	0.654	-1.143	0.253	-0.765	0.445	-1.313	0.189
T10RS	-0.72	0.471	-2.333	**0.02**	-2.17	**0.03**	-0.727	0.467	-3.299	**0.001**	-2.695	**0.007**
T10LI	-0.835	0.404	-3.081	**0.002**	-3.972	**<0.001**	-0.104	0.917	-3.378	**0.001**	-3.577	**<0.001**
T10RI	-1.68	0.093	-2.496	**0.013**	-3.764	**<0.001**	-0.842	0.4	-1.842	0.065	-1.967	0.049
T11LS	-0.575	0.565	-0.435	0.664	-0.236	0.813	-0.521	0.602	-0.259	0.796	-0.279	0.78
T11RS	-2.502	**0.012**	-2.716	**0.007**	-0.881	0.378	-0.988	0.323	-3.124	**0.002**	-2.597	**0.009**
T11LI	-2.183	**0.029**	-2.182	**0.029**	-0.907	0.364	-2.295	**0.022**	-0.68	0.497	-1.112	0.266
T11RI	-2.152	**0.031**	-2.212	**0.027**	-1.024	0.306	-0.628	0.53	-0.773	0.439	-0.417	0.677

Appendix C-6 Mann- Whitney test for inter-sample variation in facet angle continued

Facet	Male						Female					
	SBC/SBL		SBC/AS		SBL/AS		SBC/SBL		SBC/AS		SBL/AS	
	Z	p	Z	p	Z	p	Z	p	Z	p	Z	p
T12LS	-2.471	**0.013**	-1.768	**0.077**	-0.575	0.565	-1.15	0.25	-0.163	0.87	-0.973	0.331
T12RS	-2.911	**0.004**	-2.515	**0.012**	-0.182	0.855	-1.938	0.053	-1.157	0.247	-0.159	0.874
T12LI	-2.072	**0.038**	-0.463	0.643	-0.286	0.775	-0.373	0.709	-0.04	0.968	-0.275	0.783
T12RI	-0.583	0.56	-0.731	0.465	-1.048	0.295	-1.628	0.103	-0.668	0.504	-1.597	0.11
L1LS	-1.608	0.108	-0.724	0.469	-1.817	0.069	-0.343	0.732	-1.212	0.226	-1.052	0.293
L1RS	-2.322	**0.02**	-0.823	0.41	-2.245	**0.025**	-0.471	0.637	-1.277	0.202	-0.913	0.361
L1LI	-0.678	0.497	-1.373	0.17	-1.861	0.063	-1.774	0.076	-0.601	0.548	-1.039	0.299
L1RI	-0.431	0.666	-1.689	0.091	-2.548	**0.011**	-1.449	0.147	-0.189	0.85	-0.843	0.399
L2LS	-0.239	0.811	-2.49	**0.013**	-2.497	**0.013**	-1.209	0.227	-1.564	0.118	-1.725	0.085
L2RS	-1.295	0.195	-2.465	**0.014**	-2.22	**0.026**	-0.174	0.862	-0.501	0.616	-0.876	0.381
L2LI	-1.564	0.118	-0.364	0.716	-1.779	0.075	-1.6	0.11	-1.226	0.22	-0.115	0.908
L2RI	-0.924	0.356	-1.129	0.259	-1.896	0.058	-0.104	0.917	-0.642	0.521	-0.716	0.474
L3LS	-0.357	0.721	-3.313	**0.001**	-3.603	**<0.001**	-0.086	0.932	-1.171	0.241	-1.086	0.278
L3RS	-0.312	0.755	-2.246	**0.025**	-2.029	**0.042**	-0.865	0.387	-0.787	0.431	-0.234	0.815
L3LI	-0.615	0.538	-1.158	0.247	-1.366	0.172	-0.605	0.545	-1.015	0.31	-0.402	0.688
L3RI	-1.162	0.245	-1.233	0.218	-2.33	**0.02**	-0.332	0.74	-2.313	**0.021**	-1.864	0.062
L4LS	-0.584	0.559	-1.973	**0.049**	-2.65	**0.008**	-1.576	0.115	-1.039	0.299	-2.426	**0.015**
L4RS	-0.416	0.677	-1.583	0.113	-1.234	0.217	-1.19	0.234	-0.5	0.617	-1.843	0.065
L4LI	-1.051	0.293	-0.117	0.907	-0.76	0.447	-1.736	0.083	-2.206	**0.027**	-0.395	0.693
L4RI	-0.981	0.326	-2.102	**0.036**	-2.407	**0.016**	-1.737	0.082	-2.532	0.011	-1.339	0.181
L5LS	-0.331	0.74	-0.733	0.463	-1.008	0.314	-1.134	0.257	-0.778	0.437	-1.198	0.231
L5RS	-0.397	0.691	-0.877	0.381	-1.503	0.133	-1.831	0.067	-1.866	0.062	-0.794	0.427
L5LI	-0.116	0.907	-0.202	0.84	-0.215	0.83	-0.576	0.565	-0.066	0.947	-0.669	0.503
L5RI	-0.156	0.876	-2.296	**0.022**	-2.076	**0.038**	-1.469	0.142	-1.945	0.052	-2.739	**0.006**

Appendix C-7 Correlation between femoral robusticity and facet angle

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
C1LS	SBC	0.37	0.27	11	Medium	0.28	0.43	10	Weak	0.29	0.25	17	Weak	0.37	0.18	15	Medium
	SBL	-0.29	0.25	18	Weak	-0.23	0.35	19	Weak	-0.03	0.92	11	None	-0.48	0.16	10	Medium
	AS	0.10	0.75	12	Weak	0.30	0.31	13	Medium	0.00	1.00	6	None	-0.13	0.76	8	Weak
C1RS	SBC	0.53	0.09	11	**Strong**	0.44	0.20	10	Medium	0.43	0.08	17	Medium	0.14	0.62	15	Weak
	SBL	-0.17	0.51	18	Weak	-0.14	0.57	19	Weak	0.09	0.78	11	None	-0.34	0.34	10	Medium
	AS	-0.12	0.71	12	Weak	0.15	0.61	13	Weak	0.71	0.12	6	**Strong**	0.34	0.41	8	Medium
C1LI	SBC	0.08	0.81	11	None	0.28	0.43	10	Weak	-0.20	0.43	17	Weak	0.38	0.16	15	Medium
	SBL	-0.08	0.76	18	None	-0.13	0.60	19	Weak	0.28	0.41	11	Weak	-0.46	0.19	10	Medium
	AS	0.02	0.96	10	None	-0.12	0.74	11	Weak	0.27	0.61	6	Weak	0.16	0.70	8	Weak
C1RI	SBC	0.06	0.86	11	None	0.29	0.42	10	Weak	-0.23	0.38	17	Weak	0.41	0.13	15	Medium
	SBL	-0.08	0.76	18	None	0.00	1.00	19	None	0.21	0.54	11	Weak	-0.38	0.27	10	Medium
	AS	0.11	0.75	11	Weak	0.04	0.89	12	None	0.51	0.25	7	**Strong**	0.18	0.64	9	Weak
C2LS	SBC	0.11	0.74	12	Weak	0.12	0.73	11	Weak	-0.28	0.25	19	Weak	-0.29	0.27	17	Weak
	SBL	-0.12	0.61	20	Weak	-0.11	0.61	22	Weak	0.00	1.00	11	None	-0.32	0.37	10	Medium
	AS	0.65	0.08	8	**Strong**	0.71	0.03	9	**Strong**	0.57	0.18	7	**Strong**	0.39	0.31	9	Medium

Appendix C-7 Correlation between femoral robusticity and facet angle continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
C2RS	SBC	0.13	0.68	12	Weak	0.20	0.56	11	Weak	-0.16	0.50	19	Weak	-0.23	0.38	17	Weak
	SBL	-0.22	0.34	20	Weak	-0.24	0.29	22	Weak	0.08	0.83	11	None	-0.25	0.49	10	Weak
	AS	0.22	0.60	8	Weak	0.37	0.32	9	Medium	0.62	0.13	7	**Strong**	0.42	0.26	9	Medium
C2LI	SBC	0.00	0.99	12	None	-0.08	0.80	11	None	-0.08	0.74	19	None	-0.19	0.47	17	Weak
	SBL	0.04	0.88	20	None	-0.08	0.73	22	None	0.03	0.93	11	None	-0.13	0.71	10	Weak
	AS	-0.67	0.07	8	**Strong**	-0.65	0.06	9	**Strong**	0.52	0.23	7	**Strong**	0.59	0.12	8	**Strong**
C2RI	SBC	0.25	0.43	12	Weak	-0.06	0.86	11	None	0.25	0.30	19	Weak	-0.25	0.34	17	Weak
	SBL	0.14	0.55	20	Weak	0.02	0.92	22	None	0.15	0.67	11	Weak	-0.10	0.78	10	Weak
	AS	0.24	0.57	8	Weak	0.20	0.59	10	Weak	0.46	0.30	7	Medium	0.55	0.16	8	**Strong**
C3LS	SBC	0.24	0.49	11	Weak	0.26	0.47	10	Weak	-0.31	0.22	17	Medium	-0.39	0.14	16	Medium
	SBL	0.02	0.93	20	None	-0.08	0.72	22	None	0.18	0.58	12	Weak	0.03	0.91	12	None
	AS	0.00	0.99	10	None	-0.13	0.71	11	Weak	0.08	0.85	8	None	-0.22	0.57	9	Weak
C3RS	SBC	0.08	0.81	12	None	0.33	0.32	11	Medium	-0.28	0.28	17	Weak	-0.21	0.43	16	Weak
	SBL	0.06	0.81	20	None	-0.18	0.41	22	Weak	0.31	0.35	11	Medium	0.14	0.69	11	Weak
	AS	-0.23	0.52	10	Weak	-0.29	0.38	11	Weak	0.25	0.56	8	Weak	-0.13	0.74	9	Weak

Appendix C-7 Correlation between femoral robusticity and facet angle continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coeffi	P	N	Strength of	C Coeffici	P	N	Strength of	C Coeffici	P	N	Strength of	C Coeffi	P	N	Strength of Correlation
C3LI	SBC	-0.18	0.58	12	Weak	0.13	0.70	11	Weak	0.04	0.87	17	None	-0.02	0.95	16	None
	SBL	-0.09	0.72	19	None	0.29	0.20	21	Weak	0.32	0.31	12	Medium	0.35	0.26	12	Medium
	AS	0.21	0.57	10	Weak	0.22	0.52	11	Weak	-0.47	0.24	8	Medium	-0.50	0.17	9	**Strong**
C3RI	SBC	0.38	0.22	12	Medium	0.41	0.21	11	Medium	0.19	0.46	17	Weak	0.32	0.23	16	Medium
	SBL	-0.52	0.02	20	**Strong**	-0.53	0.01	22	**Strong**	0.16	0.63	11	Weak	-0.13	0.70	11	Weak
	AS	-0.15	0.68	10	Weak	-0.11	0.77	10	Weak	-0.10	0.81	8	Weak	-0.22	0.56	9	Weak
C4LS	SBC	0.28	0.37	12	Weak	-0.10	0.78	11	Weak	0.25	0.37	15	Weak	0.31	0.25	15	Medium
	SBL	-0.17	0.46	21	Weak	-0.26	0.24	23	Weak	-0.68	0.01	14	**Strong**	-0.02	0.94	11	None
	AS	0.19	0.62	9	Weak	0.24	0.47	11	Weak	-0.03	0.94	7	None	-0.06	0.88	8	None
C4RS	SBC	-0.30	0.35	12	Medium	-0.01	0.97	11	None	0.50	0.06	15	**Strong**	0.53	0.04	15	**Strong**
	SBL	-0.24	0.30	21	Weak	-0.24	0.26	23	Weak	-0.96	0.00	14	**Strong**	0.07	0.84	11	None
	AS	0.08	0.84	9	None	0.14	0.67	11	Weak	-0.20	0.67	7	Weak	-0.18	0.67	8	Weak
C4LI	SBC	0.55	0.06	12	**Strong**	0.30	0.38	11	Medium	0.56	0.03	15	**Strong**	0.47	0.08	15	Medium
	SBL	0.06	0.80	21	None	0.07	0.75	23	None	-0.45	0.09	15	Medium	-0.13	0.70	12	Weak
	AS	0.43	0.29	8	Medium	0.47	0.17	10	Medium	0.69	0.09	7	**Strong**	0.63	0.09	8	**Strong**

Appendix C-7 Correlation between femoral robusticity and facet angle continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
C4RI	SBC	0.36	0.24	12	Medium	0.17	0.62	11	Weak	0.48	0.07	15	Medium	0.49	0.06	15	Medium
	SBL	-0.12	0.62	21	Weak	-0.06	0.77	23	None	-0.64	0.01	14	**Strong**	0.30	0.37	11	Medium
	AS	0.12	0.78	8	Weak	0.14	0.70	10	Weak	0.62	0.14	7	**Strong**	0.68	0.06	8	**Strong**
C5LS	SBC	0.21	0.49	13	Weak	0.04	0.90	12	None	0.16	0.54	17	Weak	0.14	0.63	14	Weak
	SBL	0.21	0.37	21	Weak	0.21	0.36	22	Weak	-0.46	0.08	15	Medium	0.55	0.05	13	**Strong**
	AS	0.24	0.57	8	Weak	0.32	0.41	9	Medium	-0.30	0.51	7	Medium	-0.29	0.45	9	Weak
C5RS	SBC	-0.20	0.52	13	Weak	-0.31	0.32	12	Medium	0.26	0.32	17	Weak	0.33	0.25	14	Medium
	SBL	0.18	0.44	21	Weak	0.15	0.51	22	Weak	-0.65	0.01	15	**Strong**	0.47	0.10	13	Medium
	AS	-0.04	0.92	8	None	-0.11	0.78	9	Weak	-0.35	0.45	7	Medium	-0.32	0.40	9	Medium
C5LI	SBC	0.26	0.38	13	Weak	0.14	0.66	12	Weak	0.27	0.29	17	Weak	-0.07	0.82	14	None
	SBL	0.04	0.85	20	None	0.11	0.64	21	Weak	-0.29	0.30	15	Weak	0.23	0.44	13	Weak
	AS	0.29	0.48	8	Weak	0.01	0.99	9	None	-0.77	0.04	7	**Strong**	-0.70	0.03	9	**Strong**
C5RI	SBC	0.13	0.68	13	Weak	0.32	0.31	12	Medium	0.22	0.40	17	Weak	0.22	0.45	14	Weak
	SBL	0.11	0.65	20	Weak	0.27	0.24	21	Weak	-0.26	0.35	15	Weak	0.03	0.92	13	None
	AS	0.09	0.83	8	None	0.18	0.65	9	Weak	-0.47	0.29	7	Medium	-0.39	0.30	9	Medium

Appendix C-7 Correlation between femoral robusticity and facet angle continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C.coefficient	P	N	Strength of Correlation
C6LS	SBC	0.64	0.05	10	**Strong**	-0.28	0.44	10	Weak	0.08	0.71	22	None	0.15	0.53	19	Weak
	SBL	-0.04	0.85	23	None	0.07	0.74	24	None	0.08	0.78	14	None	0.02	0.95	13	None
	AS	0.34	0.37	9	Medium	0.23	0.52	10	Weak	-0.09	0.84	7	None	-0.05	0.91	8	None
C6RS	SBC	0.28	0.43	10	Weak	-0.19	0.59	10	Weak	0.07	0.76	22	None	0.03	0.91	19	None
	SBL	-0.17	0.44	22	Weak	-0.07	0.74	23	None	0.59	0.02	15	**Strong**	0.11	0.73	13	Weak
	AS	0.29	0.45	9	Weak	0.38	0.29	10	Medium	-0.47	0.28	7	Medium	-0.47	0.25	8	Medium
C6LI	SBC	0.52	0.12	10	**Strong**	0.06	0.88	10	None	-0.26	0.24	22	Weak	-0.20	0.41	19	Weak
	SBL	0.20	0.34	24	Weak	0.12	0.56	25	Weak	-0.02	0.94	14	None	0.09	0.77	13	None
	AS	-0.14	0.72	9	Weak	-0.01	0.99	10	None	0.50	0.26	7	**Strong**	0.36	0.38	8	Medium
C6RI	SBC	0.45	0.19	10	Medium	0.20	0.58		Weak	0.17	0.44	22	Weak	0.09	0.71	19	None
	SBL	0.13	0.54	24	Weak	0.11	0.60	25	Weak	0.10	0.73	15	None	0.15	0.62	13	Weak
	AS	0.16	0.69	9	Weak	0.27	0.45	10	Weak	0.19	0.69	7	Weak	-0.01	0.99	8	None
C7LS	SBC	0.33	0.30	12	Medium	0.08	0.82	11	None	-0.09	0.68	21	None	0.13	0.60	18	Weak
	SBL	-0.12	0.56	25	Weak	-0.15	0.47	25	Weak	-0.38	0.16	15	Medium	0.05	0.86	13	None
	AS	-0.34	0.40	8	Medium	-0.22	0.57	9	Weak	-0.12	0.83	6	Weak	-0.11	0.84	6	Weak

Appendix C-7 Correlation between femoral robusticity and facet angle continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
C7RS	SBC	0.49	0.11	12	Medium	0.44	0.17	11	Medium	-0.13	0.59	20	Weak	-0.08	0.76	17	None
	SBL	0.02	0.93	24	None	-0.05	0.82	25	None	-0.14	0.61	15	Weak	-0.05	0.87	13	None
	AS	0.25	0.52	9	Weak	0.35	0.32	10	Medium	0.13	0.81	6	Weak	0.14	0.79	6	Weak
C7LI	SBC	-0.01	0.99	12	None	-0.67	0.03	11	**Strong**	0.08	0.73	21	None	0.03	0.90	18	None
	SBL	-0.02	0.94	24	None	0.01	0.95	26	None	0.16	0.58	15	Weak	0.17	0.57	13	Weak
	AS	-0.23	0.55	9	Weak	0.00	1.00	10	None	-0.86	0.03	6	**Strong**	-0.87	0.02	6	**Strong**
C7RI	SBC	0.15	0.63	12	Weak	-0.38	0.25	11	Medium	-0.09	0.71	21	None	0.32	0.20	18	Medium
	SBL	0.06	0.77	24	None	0.00	0.99	26	None	0.15	0.60	15	Weak	0.13	0.67	13	Weak
	AS	-0.52	0.16	9	**Strong**	-0.25	0.49	10	Weak	0.14	0.79	6	Weak	0.14	0.79	6	Weak
T1LS	SBC	0.25	0.46	11	Weak	-0.08	0.83	10	None	0.23	0.28	23	Weak	0.08	0.75	19	None
	SBL	-0.12	0.57	25	Weak	0.03	0.89	26	None	0.20	0.49	14	Weak	0.28	0.39	12	Weak
	AS	0.08	0.82	11	None	0.26	0.39	13	Weak	-0.28	0.40	11	Weak	-0.24	0.48	11	Weak
T1RS	SBC	-0.07	0.82	12	None	0.14	0.68	11	Weak	0.12	0.60	22	Weak	0.31	0.21	18	Medium
	SBL	0.00	0.99	25	None	0.11	0.58	26	Weak	0.20	0.49	14	Weak	-0.30	0.35	12	Medium
	AS	-0.05	0.88	11	None	0.14	0.67	12	Weak	0.41	0.31	8	Medium	0.38	0.28	10	Medium

Appendix C-7 Correlation between femoral robusticity and facet angle continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
T1LI	SBC	-0.27	0.39	12	Weak	-0.08	0.82	11	None	0.23	0.31	22	Weak	0.12	0.64	18	Weak
	SBL	-0.05	0.79	26	None	0.06	0.79	26	None	0.67	0.01	14	**Strong**	0.61	0.04	12	**Strong**
	AS	0.41	0.21	11	Medium	0.39	0.22	12	Medium	-0.17	0.68	8	Weak	-0.19	0.60	10	Weak
T1RI	SBC	-0.04	0.89	12	None	0.04	0.92	11	None	0.10	0.66	22	None	-0.05	0.84	18	None
	SBL	0.10	0.62	26	Weak	0.10	0.61	26	Weak	0.23	0.42	14	Weak	0.64	0.02	12	**Strong**
	AS	-0.25	0.46	11	Weak	-0.28	0.38	12	Weak	0.25	0.54	8	Weak	0.28	0.44	10	Weak
T2LS	SBC	0.32	0.29	13	Medium	0.17	0.59	12	Weak	0.20	0.39	21	Weak	0.19	0.47	17	Weak
	SBL	-0.07	0.73	25	None	0.00	0.99	25	None	0.34	0.25	13	Medium	0.37	0.24	12	Medium
	AS	0.50	0.14	10	**Strong**	0.62	0.06	10	**Strong**	0.10	0.77	11	None	0.04	0.91	13	None
T2RS	SBC	0.03	0.93	13	None	0.29	0.37	12	Weak	-0.16	0.50	21	Weak	0.14	0.58	17	Weak
	SBL	-0.08	0.69	26	None	0.04	0.86	26	None	-0.11	0.72	13	Weak	0.66	0.02	12	**Strong**
	AS	0.53	0.12	10	**Strong**	0.51	0.14	10	**Strong**	-0.31	0.36	11	Medium	-0.38	0.20	13	Medium
T2LI	SBC	0.03	0.91	13	None	-0.03	0.94	12	None	0.38	0.09	21	Medium	0.17	0.52	17	Weak
	SBL	0.02	0.93	25	None	0.07	0.74	25	None	-0.23	0.45	13	Weak	0.63	0.03	12	**Strong**
	AS	0.09	0.80	10	None	0.07	0.84	10	None	-0.44	0.17	11	Medium	-0.46	0.12	13	None

Appendix C-7 Correlation between femoral robusticity and facet angle continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
T2RI	SBC	-0.29	0.34	13	Weak	0.34	0.28	12	Medium	0.20	0.38	21	Weak	-0.03	0.91	17	None
	SBL	0.18	0.40	25	Weak	0.20	0.34	25	Weak	0.19	0.54	13	Weak	0.33	0.30	12	Medium
	AS	0.05	0.89	10	None	0.11	0.76	10	Weak	-0.07	0.84	11	None	-0.04	0.88	13	None
T3LS	SBC	-0.37	0.21	13	Medium	-0.02	0.95	12	None	0.05	0.82	21	None	0.22	0.39	17	Weak
	SBL	0.17	0.47	21	Weak	0.23	0.34	20	Weak	-0.26	0.41	12	Weak	0.44	0.15	12	Medium
	AS	-0.25	0.46	11	Weak	-0.40	0.23	11	Medium	-0.43	0.19	11	Medium	-0.34	0.25	13	Medium
T3RS	SBC	-0.32	0.29	13	Medium	0.12	0.70	12	Weak	0.19	0.41	21	Weak	0.19	0.48	17	Weak
	SBL	0.05	0.82	22	None	0.10	0.67	21	None	0.28	0.39	12	Weak	0.51	0.09	12	**Strong**
	AS	-0.09	0.78	11	None	-0.08	0.80	12	None	-0.34	0.30	11	Medium	-0.41	0.16	13	Medium
T3LI	SBC	-0.28	0.35	13	Weak	-0.03	0.93	12	None	0.33	0.14	21	Medium	-0.05	0.85	17	None
	SBL	0.13	0.56	22	Weak	-0.05	0.82	21	None	-0.40	0.20	12	Medium	0.84	0.00	12	**Strong**
	AS	-0.12	0.74	10	Weak	-0.16	0.63	11	Weak	-0.31	0.36	11	Medium	-0.16	0.61	12	Weak
T3RI	SBC	-0.13	0.68	13	Weak	-0.18	0.58	12	Weak	0.42	0.06	21	Medium	0.15	0.57	17	Weak
	SBL	0.03	0.90	22	None	0.03	0.88	21	None	-0.42	0.18	12	Medium	0.42	0.17	12	Medium
	AS	0.01	0.98	11	None	0.00	0.99	12	None	0.19	0.58	11	Weak	0.22	0.48	13	Weak

Appendix C-7 Correlation between femoral robusticity and facet angle continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
T4LS	SBC	-0.20	0.52	13	Weak	-0.02	0.95	12	None	-0.11	0.66	20	Weak	-0.28	0.30	16	Weak
	SBL	-0.02	0.92	23	None	-0.01	0.98	22	None	-0.65	0.04	10	**Strong**	0.17	0.63	10	Weak
	AS	0.07	0.83	12	None	0.08	0.82	12	None	-0.13	0.68	12	Weak	-0.09	0.77	13	None
T4RS	SBC	0.02	0.95	13	None	0.16	0.63	12	Weak	-0.22	0.36	19	Weak	-0.37	0.18	15	Medium
	SBL	-0.22	0.33	22	Weak	-0.24	0.30	21	Weak	0.11	0.76	10	Weak	0.21	0.56	10	Weak
	AS	0.21	0.52	12	Weak	0.20	0.53	12	Weak	0.16	0.61	12	Weak	0.19	0.53	13	Weak
T4LI	SBC	0.04	0.91	13	None	0.03	0.92	12	None	0.28	0.24	19	Weak	0.13	0.64	16	Weak
	SBL	-0.11	0.63	22	Weak	-0.07	0.77	21	None	-0.19	0.63	9	Weak	0.60	0.09	9	**Strong**
	AS	0.15	0.64	13	Weak	-0.03	0.92	13	None	-0.33	0.33	11	Medium	-0.18	0.57	12	Weak
T4RI	SBC	0.26	0.39	13	Weak	0.29	0.35	12	Weak	-0.10	0.70	19	Weak	-0.30	0.26	16	Medium
	SBL	-0.07	0.76	23	None	-0.23	0.30	22	Weak	-0.13	0.74	9	Weak	0.51	0.17	9	**Strong**
	AS	0.14	0.64	13	Weak	0.17	0.58	13	Weak	-0.02	0.96	11	None	-0.09	0.79	12	None
T5LS	SBC	-0.09	0.78	12	None	0.18	0.57	12	Weak	-0.20	0.40	20	Weak	-0.01	0.98	17	None
	SBL	-0.03	0.88	21	None	-0.04	0.87	20	None	-0.28	0.40	11	Weak	0.29	0.42	10	Weak
	AS	-0.15	0.62	13	Weak	-0.22	0.48	13	Weak	-0.05	0.91	8	None	0.22	0.57	9	Weak

Appendix C-7 Correlation between femoral robusticity and facet angle continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
T5RS	SBC	-0.18	0.57	12	Weak	0.06	0.85	12	None	-0.10	0.67	20	Weak	-0.24	0.35	17	Weak
	SBL	-0.11	0.65	21	Weak	-0.20	0.40	20	Weak	-0.04	0.91	11	None	0.51	0.13	10	**Strong**
	AS	-0.08	0.81	13	None	-0.15	0.62	13	Weak	-0.48	0.22	8	Medium	-0.24	0.54	9	Weak
T5LI	SBC	0.27	0.40	12	Weak	0.11	0.74	12	Weak	0.38	0.10	20	Medium	0.24	0.34	17	Weak
	SBL	-0.20	0.40	20	Weak	-0.07	0.79	18	None	-0.23	0.48	12	Weak	0.43	0.21	10	Medium
	AS	0.36	0.28	11	Medium	0.33	0.32	11	Medium	-0.27	0.52	8	Weak	0.15	0.71	9	Weak
T5RI	SBC	0.21	0.52	12	Weak	-0.17	0.59	12	Weak	0.41	0.07	20	Medium	0.14	0.58	17	Weak
	SBL	0.12	0.61	21	Weak	0.24	0.31	20	Weak	-0.15	0.65	12	Weak	0.37	0.29	10	Medium
	AS	0.23	0.50	11	Weak	0.20	0.55	11	Weak	0.48	0.23	8	Medium	0.59	0.09	9	**Strong**
T6LS	SBC	-0.13	0.67	13	Weak	-0.32	0.32	12	Medium	0.17	0.48	19	Weak	0.24	0.36	16	Weak
	SBL	0.05	0.82	24	None	0.10	0.67	23	None	0.01	0.99	12	None	0.23	0.50	11	Weak
	AS	0.31	0.41	9	Medium	0.11	0.75	11	Weak	-0.22	0.58	9	Weak	-0.04	0.90	10	None
T6RS	SBC	-0.14	0.66	13	Weak	-0.05	0.87	12	None	-0.18	0.47	19	Weak	-0.24	0.36	16	Weak
	SBL	-0.24	0.25	24	Weak	-0.20	0.37	23	Weak	0.14	0.65	12	Weak	0.20	0.56	11	Weak
	AS	0.17	0.66	9	Weak	0.11	0.74	11	Weak	-0.63	0.07	9	**Strong**	-0.43	0.21	10	Medium

Appendix C-7 Correlation between femoral robusticity and facet angle continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
T6LI	SBC	0.48	0.10	13	Medium	-0.12	0.71	12	Weak	0.07	0.78	20	None	0.01	0.98	16	None
	SBL	-0.19	0.38	23	Weak	-0.16	0.48	22	Weak	0.57	0.05	12	**Strong**	0.39	0.24	11	Medium
	AS	0.61	0.14	7	**Strong**	0.44	0.23	9	Medium	-0.47	0.20	9	Medium	-0.21	0.56	10	Weak
T6RI	SBC	-0.29	0.34	13	Weak	0.06	0.85	12	None	-0.09	0.70	20	None	-0.12	0.65	16	Weak
	SBL	-0.02	0.92	23	None	0.11	0.63	22	Weak	0.14	0.66	12	Weak	0.19	0.58	11	Weak
	AS	0.59	0.16	7	**Strong**	0.06	0.89	9	None	-0.61	0.08	9	**Strong**	-0.35	0.32	10	Medium
T7LS	SBC	0.58	0.04	13	**Strong**	0.19	0.56	12	Weak	-0.16	0.50	21	Weak	-0.04	0.87	17	None
	SBL	0.08	0.73	23	None	0.19	0.39	23	Weak	0.07	0.83	12	None	0.53	0.09	11	**Strong**
	AS	0.39	0.29	9	Medium	0.23	0.52	10	Weak	-0.08	0.80	12	None	0.02	0.95	13	None
T7RS	SBC	0.60	0.03	13	**Strong**	0.40	0.20	12	Medium	0.07	0.77	21	None	-0.13	0.61	17	Weak
	SBL	-0.04	0.84	24	None	-0.02	0.94	24	None	-0.34	0.29	12	Medium	0.20	0.58	10	Weak
	AS	0.21	0.58	9	Weak	0.16	0.66	10	Weak	-0.10	0.75	12	Weak	0.01	0.97	13	None
T7LI	SBC	0.46	0.13	12	Medium	0.05	0.89	11	None	0.09	0.70	21	None	-0.12	0.66	17	Weak
	SBL	-0.31	0.15	23	Medium	-0.16	0.48	22	Weak	-0.26	0.42	12	Weak	-0.32	0.33	11	Medium
	AS	0.45	0.31	7	Medium	0.42	0.30	8	Medium	-0.17	0.63	11	Weak	-0.04	0.91	12	None

Appendix C-7 Correlation between femoral robusticity and facet angle continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
T7RI	SBC	0.58	0.05	12	**Strong**	0.28	0.40	11	Weak	0.37	0.10	21	Medium	-0.10	0.69	17	Weak
	SBL	-0.33	0.12	23	Medium	-0.25	0.25	23	Weak	0.03	0.94	12	None	0.19	0.57	11	Weak
	AS	0.67	0.10	7	**Strong**	0.72	0.04	8	**Strong**	0.12	0.70	12	Weak	0.14	0.66	13	Weak
T8LS	SBC	0.16	0.61	12	Weak	-0.12	0.73	11	Weak	-0.32	0.19	19	Medium	0.07	0.79	16	None
	SBL	0.07	0.75	24	None	0.06	0.78	23	None	0.09	0.77	12	None	0.35	0.27	12	Medium
	AS	-0.17	0.65	9	Weak	-0.05	0.88	11	None	-0.33	0.30	12	Medium	-0.05	0.87	13	None
T8RS	SBC	-0.11	0.74	12	Weak	0.18	0.60	11	Weak	-0.13	0.61	19	Weak	-0.22	0.42	16	Weak
	SBL	-0.12	0.57	24	Weak	-0.18	0.42	23	Weak	-0.72	0.01	12	**Strong**	-0.05	0.88	12	None
	AS	-0.09	0.82	9	None	-0.27	0.43	11	Weak	0.32	0.31	12	Medium	0.40	0.17	13	Medium
T8LI	SBC	0.19	0.53	13	Weak	-0.10	0.75	12	Weak	0.21	0.40	19	Weak	0.15	0.57	16	Weak
	SBL	0.03	0.91	24	None	-0.07	0.76	23	None	0.73	0.02	10	**Strong**	-0.01	0.97	10	None
	AS	0.16	0.67	9	Weak	0.13	0.70	11	Weak	-0.24	0.45	12	Weak	-0.13	0.67	13	Weak
T8RI	SBC	0.28	0.36	13	Weak	-0.41	0.18	12	Medium	-0.07	0.78	19	None	0.33	0.21	16	Medium
	SBL	-0.03	0.88	24	None	-0.04	0.84	23	None	-0.10	0.77	11	Weak	-0.25	0.46	11	Weak
	AS	0.06	0.89	9	None	-0.10	0.77	11	Weak	-0.04	0.89	12	None	0.02	0.94	13	None

Appendix C-7 Correlation between femoral robusticity and facet angle continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
T9LS	SBC	0.02	0.94	13	None	0.61	0.04	12	**Strong**	-0.12	0.61	21	Weak	0.09	0.73	18	None
	SBL	0.00	1.00	24	None	0.02	0.92	24	None	0.24	0.45	12	Weak	0.50	0.09	12	**Strong**
	AS	0.42	0.22	10	Medium	0.18	0.58	12	Weak	-0.13	0.69	11	Weak	-0.03	0.92	12	None
T9RS	SBC	0.13	0.67	13	Weak	-0.26	0.42	12	Weak	-0.28	0.22	21	Weak	-0.05	0.84	18	None
	SBL	0.20	0.34	24	Weak	0.15	0.50	24	Weak	-0.13	0.69	12	Weak	0.08	0.80	12	None
	AS	0.38	0.31	9	Medium	0.26	0.45	11	Weak	-0.34	0.30	11	Medium	-0.07	0.84	12	None
T9LI	SBC	0.46	0.13	12	Medium	-0.47	0.15	11	Medium	0.07	0.76	21	None	0.30	0.23	18	Medium
	SBL	-0.17	0.43	24	Weak	-0.23	0.27	24	Weak	-0.09	0.77	12	None	-0.14	0.66	12	Weak
	AS	-0.15	0.69	10	Weak	-0.24	0.46	12	Weak	-0.05	0.89	11	None	0.07	0.82	12	None
T9RI	SBC	0.06	0.85	12	None	0.14	0.69	11	Weak	0.16	0.50	21	Weak	0.29	0.25	18	Weak
	SBL	0.53	0.01	23	**Strong**	0.54	0.01	23	**Strong**	-0.31	0.33	12	Medium	-0.43	0.16	12	None
	AS	-0.39	0.27	10	Medium	-0.39	0.21	12	Medium	-0.19	0.57	11	Weak	-0.18	0.58	12	Weak
T10LS	SBC	-0.22	0.49	12	Weak	0.50	0.12	11	**Strong**	-0.11	0.63	21	Weak	0.05	0.85	18	None
	SBL	0.02	0.92	23	None	0.06	0.79	22	None	0.14	0.67	12	Weak	0.28	0.37	12	Weak
	AS	0.34	0.33	10	Medium	0.33	0.28	13	Medium	0.13	0.70	11	Weak	0.13	0.68	12	Weak

Appendix C-7 Correlation between femoral robusticity and facet angle continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
T10RS	SBC	0.06	0.85	12	None	-0.01	0.99	11	None	-0.20	0.38	21	Weak	-0.22	0.38	18	Weak
	SBL	0.11	0.63	23	Weak	0.09	0.69	23	None	0.24	0.45	12	Weak	0.18	0.58	12	Weak
	AS	0.04	0.92	10	None	0.26	0.42	12	Weak	0.15	0.66	11	Weak	0.22	0.50	12	Weak
T10LI	SBC	-0.49	0.09	13	Medium	-0.08	0.81	12	None	-0.09	0.70	21	None	0.08	0.77	18	None
	SBL	0.12	0.58	23	Weak	0.10	0.64	23	Weak	0.06	0.86	12	None	0.13	0.68	12	Weak
	AS	0.13	0.71	10	Weak	0.01	0.97	13	None	-0.02	0.95	11	None	0.14	0.67	12	Weak
T10RI	SBC	-0.51	0.08	13	**Strong**	0.20	0.53	12	Weak	-0.30	0.19	21	Medium	-0.25	0.32	18	Weak
	SBL	0.50	0.02	23	**Strong**	0.59	0.00	23	**Strong**	-0.21	0.52	12	Weak	-0.22	0.49	12	Weak
	AS	-0.44	0.20	10	Medium	-0.39	0.19	13	Medium	-0.30	0.38	11	Medium	-0.13	0.68	12	Weak
T11LS	SBC	-0.42	0.15	13	Medium	-0.27	0.40	12	Weak	-0.40	0.08	21	Medium	-0.13	0.60	18	Weak
	SBL	0.20	0.35	23	Weak	0.14	0.53	22	Weak	0.02	0.96	13	None	0.63	0.03	12	**Strong**
	AS	-0.19	0.59	10	Weak	-0.17	0.61	12	Weak	0.10	0.77	11	None	0.14	0.66	12	Weak
T11RS	SBC	-0.51	0.07	13	**Strong**	-0.17	0.59	12	Weak	-0.40	0.07	21	Medium	-0.31	0.22	18	Medium
	SBL	0.30	0.17	23	Medium	0.32	0.15	22	Medium	0.11	0.73	13	Weak	0.37	0.24	12	Medium
	AS	-0.04	0.91	10	None	0.00	1.00	12	None	-0.23	0.49	11	Weak	0.04	0.90	12	None

Appendix C-7 Correlation between femoral robusticity and facet angle continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
T11LI	SBC	-0.39	0.19	13	Medium	-0.23	0.48	12	Weak	-0.37	0.10	21	Medium	-0.39	0.11	18	Medium
	SBL	0.21	0.34	23	Weak	0.25	0.27	21	Weak	0.25	0.41	13	Weak	0.06	0.84	12	None
	AS	-0.12	0.75	10	Weak	-0.04	0.90	12	None	0.33	0.32	11	Medium	0.39	0.20	12	Medium
T11RI	SBC	-0.08	0.79	13	None	0.00	1.00	12	None	-0.42	0.06	21	Medium	-0.42	0.08	18	Medium
	SBL	-0.02	0.92	23	None	0.05	0.83	22	None	0.10	0.74	13	Weak	-0.06	0.86	12	None
	AS	0.13	0.71	10	Weak	0.22	0.48	12	Weak	-0.04	0.91	11	None	0.02	0.95	12	None
T12LS	SBC	-0.39	0.19	13	Medium	-0.37	0.24	12	Medium	-0.33	0.17	19	Medium	-0.38	0.14	16	Medium
	SBL	0.19	0.40	21	Weak	0.10	0.68	20	None	0.18	0.55	13	Weak	0.12	0.72	12	Weak
	AS	0.28	0.46	9	Weak	0.33	0.32	11	Medium	0.44	0.17	11	Medium	0.50	0.10	12	**Strong**
T12RS	SBC	-0.39	0.19	13	Medium	-0.15	0.64	12	Weak	-0.52	0.02	19	**Strong**	-0.56	0.03	16	**Strong**
	SBL	0.12	0.61	21	Weak	0.06	0.79	20	None	0.16	0.59	13	Weak	0.03	0.93	12	None
	AS	-0.15	0.69	9	Weak	-0.01	0.97	11	None	0.28	0.41	11	Weak	0.34	0.28	12	Medium
T12LI	SBC	-0.10	0.75	13	Weak	0.24	0.45	12	Weak	-0.19	0.44	19	Weak	-0.22	0.41	16	Weak
	SBL	-0.13	0.57	22	Weak	-0.12	0.59	21	Weak	0.78	0.00	13	**Strong**	0.39	0.21	12	Medium
	AS	0.39	0.30	9	Medium	0.42	0.19	11	Medium	-0.18	0.62	10	Weak	-0.15	0.67	11	Weak

Appendix C-7 Correlation between femoral robusticity and facet angle continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
T12RI	SBC	0.11	0.72	13	Weak	0.55	0.07	12	**Strong**	-0.16	0.53	19	Weak	-0.05	0.85	16	None
	SBL	-0.17	0.45	22	Weak	-0.16	0.48	21	Weak	0.50	0.08	13	**Strong**	0.18	0.59	12	Weak
	AS	-0.12	0.76	9	Weak	-0.16	0.67	10	Weak	0.62	0.04	11	**Strong**	0.65	0.02	12	**Strong**
L1LS	SBC	-0.13	0.68	12	Weak	-0.20	0.53	12	Weak	-0.11	0.64	20	Weak	-0.09	0.72	17	None
	SBL	-0.21	0.35	23	Weak	-0.19	0.38	23	Weak	0.95	0.00	12	**Strong**	0.43	0.16	12	Medium
	AS	0.22	0.53	10	Weak	0.00	0.99	13	None	0.01	0.97	11	None	0.17	0.60	12	Weak
L1RS	SBC	0.11	0.73	12	Weak	0.38	0.22	12	Medium	-0.23	0.32	20	Weak	-0.26	0.31	17	Weak
	SBL	-0.13	0.55	22	Weak	-0.10	0.65	22	Weak	0.93	0.00	12	**Strong**	0.27	0.40	12	Weak
	AS	0.50	0.21	8	**Strong**	0.09	0.80	11	None	0.15	0.66	11	Weak	0.52	0.09	12	**Strong**
L1LI	SBC	0.31	0.32	12	Medium	-0.02	0.95	12	None	-0.42	0.06	20	Medium	-0.35	0.17	17	Medium
	SBL	-0.22	0.31	23	Weak	-0.39	0.07	23	Medium	0.02	0.96	12	None	-0.34	0.28	12	Medium
	AS	-0.48	0.19	9	Medium	-0.54	0.07	12	**Strong**	-0.10	0.75	12	Weak	0.02	0.95	13	None
L1RI	SBC	0.19	0.55	12	Weak	-0.39	0.20	12	Medium	-0.43	0.07	19	Medium	-0.37	0.14	17	Medium
	SBL	-0.09	0.69	22	None	-0.05	0.83	22	None	-0.68	0.01	12	**Strong**	-0.11	0.73	12	Weak
	AS	-0.32	0.37	10	Medium	-0.26	0.39	13	Weak	0.22	0.50	12	Weak	0.31	0.30	13	Medium

Appendix C-7 Correlation between femoral robusticity and facet angle continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
L2LS	SBC	-0.09	0.76	13	None	-0.25	0.43	12	Weak	-0.31	0.17	21	Medium	-0.16	0.52	19	Weak
	SBL	0.12	0.59	23	Weak	-0.05	0.83	23	None	-0.30	0.35	12	Medium	-0.30	0.34	12	Medium
	AS	-0.09	0.79	11	None	-0.19	0.52	14	Weak	-0.05	0.89	10	None	0.27	0.42	11	Weak
L2RS	SBC	-0.10	0.74	13	Weak	-0.73	0.01	12	**Strong**	-0.19	0.41	21	Weak	-0.29	0.23	19	Weak
	SBL	-0.13	0.56	21	Weak	-0.18	0.43	21	Weak	-0.60	0.04	12	**Strong**	-0.29	0.38	11	Weak
	AS	0.00	0.99	11	None	-0.07	0.83	14	None	0.45	0.19	10	Medium	0.53	0.09	11	**Strong**
L2LI	SBC	-0.06	0.84	13	None	-0.23	0.47	12	Weak	-0.33	0.14	21	Medium	-0.23	0.35	19	Weak
	SBL	0.02	0.91	23	None	0.04	0.85	23	None	-0.65	0.03	11	**Strong**	-0.32	0.34	11	Medium
	AS	-0.04	0.92	10	None	-0.17	0.57	13	Weak	0.27	0.52	8	Weak	0.38	0.32	9	Medium
L2RI	SBC	0.40	0.18	13	Medium	0.23	0.47	12	Weak	-0.20	0.39	21	Weak	-0.46	0.05	19	Medium
	SBL	0.01	0.97	23	None	-0.20	0.35	23	Weak	-0.54	0.07	12	**Strong**	-0.25	0.44	12	Weak
	AS	0.02	0.96	10	None	-0.16	0.59	13	Weak	0.54	0.13	9	**Strong**	0.48	0.16	10	Medium
L3LS	SBC	0.31	0.30	13	Medium	0.15	0.65	12	Weak	0.06	0.80	20	None	-0.23	0.37	17	Weak
	SBL	0.08	0.74	21	None	-0.05	0.82	21	None	-0.40	0.18	13	Medium	-0.03	0.92	11	None
	AS	-0.25	0.44	12	Weak	-0.36	0.21	14	Medium	0.06	0.85	13	None	0.12	0.68	14	Weak

Appendix C-7 Correlation between femoral robusticity and facet angle continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
L3RS	SBC	0.19	0.54	13	Weak	0.08	0.80	12	None	0.12	0.61	20	Weak	-0.11	0.66	17	Weak
	SBL	-0.21	0.36	22	Weak	-0.31	0.17	21	Medium	-0.55	0.05	13	**Strong**	-0.10	0.77	11	Weak
	AS	0.40	0.22	11	Medium	0.09	0.75	14	None	0.03	0.93	13	None	0.14	0.62	14	Weak
L3LI	SBC	0.12	0.70	13	Weak	0.52	0.08	12	**Strong**	-0.26	0.26	20	Weak	0.00	0.99	17	None
	SBL	-0.14	0.53	21	Weak	0.01	0.95	21	None	-0.42	0.16	13	Medium	0.02	0.94	12	None
	AS	-0.13	0.69	12	Weak	-0.27	0.32	15	Weak	0.20	0.52	13	Weak	0.11	0.71	14	Weak
L3RI	SBC	0.56	0.04	13	**Strong**	0.39	0.21	12	Medium	-0.22	0.34	20	Weak	-0.08	0.75	17	None
	SBL	0.27	0.26	19	Weak	0.11	0.63	20	Weak	-0.50	0.09	13	**Strong**	-0.27	0.40	12	Weak
	AS	-0.19	0.58	11	Weak	-0.28	0.32	14	Weak	0.18	0.57	12	Weak	0.13	0.66	13	Weak
L4LS	SBC	-0.03	0.92	13	None	0.40	0.20	12	Medium	-0.21	0.37	21	Weak	-0.09	0.73	18	None
	SBL	-0.04	0.87	19	None	0.07	0.78	18	None	0.17	0.63	10	Weak	-0.33	0.32	11	Medium
	AS	-0.37	0.27	11	Medium	-0.31	0.29	14	Medium	0.16	0.62	12	Weak	0.12	0.69	13	Weak
L4RS	SBC	0.24	0.42	13	Weak	0.20	0.54	12	Weak	-0.26	0.26	21	Weak	-0.02	0.92	18	None
	SBL	-0.19	0.42	20	Weak	-0.29	0.22	19	Weak	-0.18	0.62	10	Weak	0.01	0.98	10	None
	AS	-0.02	0.95	11	None	-0.16	0.57	14	Weak	-0.14	0.66	12	Weak	-0.14	0.65	13	Weak

Appendix C-7 Correlation between femoral robusticity and facet angle continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coeffi cient	P	N	Strength of Correlation	C Coeffi cient	P	N	Strength of Correlation	C Coeffi cient	P	N	Strength of Correlat ion	C Coeffici ent	P	N	Strength of Correlati on
L4LI	SBC	-0.22	0.47	13	Weak	0.13	0.69	12	Weak	-0.51	0.02	21	**Strong**	-0.11	0.68	18	Weak
	SBL	-0.10	0.70	19	Weak	-0.04	0.86	18	None	0.27	0.45	10	Weak	-0.01	0.97	11	None
	AS	-0.50	0.12	11	**Strong**	-0.52	0.05	14	**Strong**	-0.32	0.33	11	Medium	-0.38	0.22	12	Medium
L4RI	SBC	-0.36	0.23	13	Medium	-0.04	0.90	12	None	-0.58	0.01	21	**Strong**	-0.17	0.51	18	Weak
	SBL	0.02	0.95	20	None	0.01	0.95	19	None	0.47	0.17	10	Medium	-0.22	0.51	11	Weak
	AS	-0.37	0.26	11	Medium	-0.27	0.37	13	Weak	-0.31	0.39	10	Medium	-0.30	0.37	11	Medium
L5LS	SBC	-0.44	0.18	11	Medium	0.15	0.65	11	Weak	-0.53	0.02	18	**Strong**	-0.06	0.81	16	None
	SBL	0.11	0.64	22	Weak	0.10	0.65	22	Weak	-0.55	0.07	12	**Strong**	-0.32	0.33	11	Medium
	AS	0.30	0.48	8	Medium	0.22	0.52	11	Weak	0.05	0.88	11	None	0.04	0.89	12	None
L5RS	SBC	0.22	0.51	11	Weak	-0.05	0.87	11	None	-0.46	0.05	18	Medium	-0.20	0.46	16	Weak
	SBL	0.18	0.46	20	Weak	0.22	0.35	20	Weak	-0.44	0.15	12	Medium	0.12	0.73	11	Weak
	AS	-0.07	0.88	8	None	-0.02	0.95	11	None	0.00	0.99	11	None	-0.09	0.79	12	None
L5LI	SBC	0.13	0.70	11	Weak	-0.06	0.86	11	None	0.10	0.68		Weak	0.17	0.54	16	Weak
	SBL	0.17	0.45	22	Weak	0.17	0.45	22	Weak	-0.31	0.33	12	Medium	0.30	0.37	11	Medium
	AS	-0.59	0.17	7	**Strong**	-0.45	0.19	10	Medium	-0.07	0.84	10	None	0.03	0.93	11	None

Appendix C-7 Correlation between femoral robusticity and facet angle continued

Facet	Sample	Male								Female							
		Left Femoral Robusticity				Right Femoral Robusticity				Left Femoral Robusticity				Right Femoral Robusticity			
		C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation	C Coefficient	P	N	Strength of Correlation
L5RI	SBC	-0.19	0.57	11	Weak	0.15	0.66	11	Weak	0.16	0.53	18	Weak	0.19	0.48	16	Weak
	SBL	0.10	0.68	21	None	0.05	0.85	21	None	-0.31	0.32	12	Medium	0.30	0.38	11	Medium
	AS	-0.45	0.26	8	Medium	-0.42	0.20	11	Medium	-0.38	0.27	10	Medium	-0.32	0.34	11	Medium

Appendix C-8 Correlation between humeral and facet angle directional asymmetry

Facet	Sample	Male				Female			
		Continuity Coefficient	P	Phi	Phi correlation Strength	Continuity Coefficient	P	Phi	Phi correlation Strength
C1S	SBC	1.02	0.31	0.38	Medium	0.00	0.96	-0.09	Weak
	SBL	3.33	0.07	0.56	**Strong**	0.00	1.00	-0.07	None
	AS	0.31	0.58	0.67	**Strong**				
C1I	SBC	1.07	0.30	0.45	Medium	0.00	1.00	-0.01	None
	SBL	0.00	1.00	0.09	None	0.00	1.00	0.14	Weak
	AS	0.00	1.00	-0.41	Medium				
C2S	SBC	0.01	0.91	-0.19	Weak	0.00	1.00	-0.07	None
	SBL	0.00	1.00	0.06	None	0.55	0.46	0.33	Medium
	AS	0.00	1.00	0.58	**Strong**				
C2I	SBC	0.00	1.00	-0.04	None	0.13	0.72	-0.14	Weak
	SBL	0.00	1.00	0.01	None	5.66	0.02	-0.76	**Strong**
	AS	0.31	0.58	-0.67	**Strong**				
C3S	SBC	0.00	1.00	0.17	Weak	0.17	0.68	-0.17	Weak
	SBL	0.65	0.42	0.18	Weak	0.25	0.62	-0.25	Weak
	AS	0.00	1.00	0.33	Medium				
C3I	SBC	0.00	1.00	-0.27	Weak	0.05	0.82	0.14	Weak
	SBL	1.32	0.25	-0.36	Medium	0.20	0.66	0.24	Weak
	AS	0.00	1.00	0.33	Medium				
C4S	SBC	0.05	0.83	0.22	Weak	0.44	0.51	-0.26	Weak
	SBL	0.01	0.91	0.16	Weak	0.14	0.71	0.20	Weak
	AS	0.05	0.82	0.61	**Strong**				
CC4I	SBC	0.00	1.00	0.14	Weak	0.00	1.00	0.05	None
	SBL	1.09	0.60	-0.38	Medium	0.00	1.00	-0.01	None
	AS	0.00	1.00	0.25	Weak				
C5S	SBC	0.00	1.00	0.08	None	2.85	0.09	-0.40	Medium
	SBL	0.00	1.00	-0.03	None	0.00	1.00	0.01	None
	AS	0.05	0.82	0.61	**Strong**				

Appendix C-8 Correlation between humeral and facet angle directional asymmetry continued

Facet	Sample	Male				Female			
		Continuity Coefficient	P	Phi	Phi correlation Strength	Continuity Coefficient	P	Phi	Phi correlation Strength
C5I	SBC	0.03	0.87	0.16	Weak	0.15	0.70	0.23	Weak
	SBL	0.32	0.57	0.23	Weak	0.00	1.00	-0.14	Weak
	AS	0.00	1.00	0.25	Weak				
C6S	SBC	0.00	1.00	0.07	None	0.03	0.87	0.13	Weak
	SBL	0.00	1.00	0.09	None	0.00	1.00	-0.12	Weak
	AS	0.05	0.82	0.61	**Strong**				
C6I	SBC	1.24	0.27	-0.45	Medium	0.00	1.00	0.07	None
	SBL	1.06	0.30	-0.36	Medium	0.00	1.00	0.10	None
	AS	0.00	1.00	-0.41	Medium				
C7S	SBC	0.00	1.00	-0.14	Weak	0.01	0.93	-0.10	Weak
	SBL	0.54	0.46	-0.29	Weak	0.00	1.00	0.05	None
	AS	0.00	1.00	-0.41	Medium				
C7!	SBC	3.15	0.08	0.63	**Strong**	0.00	0.97	0.12	Weak
	SBL	0.01	0.94	0.13	Weak	0.35	0.85	0.18	Weak
	AS	0.00	1.00	0.50	**Strong**				
T1S	SBC	1.64	0.20	0.47	Medium	0.00	1.00	0.06	None
	SBL	3.00	0.58	-0.22	Weak	1.43	0.23	0.40	Medium
	AS	0.32	0.57	0.47	Medium	0.00	1.00	0.41	Medium
T1I	SBC	0.00	1.00	0.00	None	0.00	0.96	0.11	Weak
	SBL	0.00	1.00	0.08	None	1.82	0.18	0.44	Medium
	AS	0.00	1.00	0.26	Weak				
T2S	SBC	0.62	0.43	0.39	Medium	0.00	1.00	-0.05	None
	SBL	0.00	1.00	0.06	None	0.19	0.67	-0.21	Weak
	AS	0.00	1.00	0.26	Weak				
T2I	SBC	2.12	0.15	0.51	**Strong**	0.00	1.00	-0.07	None
	SBL	0.00	1.00	0.02	None	0.75	0.39	0.36	Medium
	AS	0.00	1.00	-0.32	Medium	0.00	1.00	0.50	**Strong**

Appendix C-8 Correlation between humeral and facet angle directional asymmetry continued

Facet	Sample	Male				Female			
		Continuity Coefficient	P	Phi	Phi correlation Strength	Continuity Coefficient	P	Phi	Phi correlation Strength
T3S	SBC	0.06	0.81	0.22	Weak	0.02	0.89	0.10	None
	SBL	0.00	1.00	-0.03	None	0.00	1.00	-0.14	Weak
	AS	0.00	1.00	0.15	Weak	0.00	1.00	-0.58	**Strong**
T3I	SBC					0.09	0.77	0.20	Weak
	SBL	0.00	1.00	-0.15	Weak	1.50	0.22	-0.43	Medium
	AS	0.00	1.00	-0.29	Weak	0.00	1.00	0.00	None
T4S	SBC	0.83	0.36	0.36	Medium	0.61	0.43	0.23	Weak
	SBL	0.01	0.92	-0.17	Weak	0.85	0.36	0.42	Medium
	AS	0.00	1.00	0.07	None	0.03	0.58	0.67	**Strong**
T4I	SBC	0.00	1.00	0.24	Weak	0.13	0.71	0.22	Weak
	SBL	0.00	1.00	0.02	None	0.00	0.96	0.18	Weak
	AS	1.74	0.57	-0.47	Medium	0.00	1.00	0.00	None
T5S	SBC	0.00	1.00	-0.14	Weak	0.13	0.72	-0.16	Weak
	SBL	0.00	1.00	0.00	None	0.00	1.00	0.00	None
	AS	1.47	0.23	-1.00	**Strong**	0.00	1.00	0.50	**Strong**
T5I	SBC	0.35	0.56	0.32	Medium	0.00	1.00	0.14	Weak
	SBL	1.25	0.26	-0.37	Medium	0.00	1.00	0.07	None
	AS	0.08	0.78	0.49	Medium	0.00	1.00	-0.33	Medium
T6S	SBC	0.00	0.96	0.13	Weak	0.02	0.88	0.12	Weak
	SBL	0.00	1.00	-0.08	None	0.00	1.00	0.12	Weak
	AS	0.00	1.00	-0.58	**Strong**	0.00	1.00	-0.58	**Strong**
T6I	SBC	0.00	1.00	0.13	Weak	0.53	0.47	0.26	Weak
	SBL	0.00	1.00	0.07	None	0.00	1.00	0.23	Weak
	AS					0.19	0.67	-1.00	**Strong**
T7S	SBC	0.00	1.00	0.07	None	2.87	0.09	-0.40	Medium
	SBL	0.01	0.91	0.13	Weak	0.49	0.49	0.31	Medium
	AS	0.00	1.00	0.00	None	0.00	1.00	-0.41	Medium

Appendix C-8 Correlation between humeral and facet angle directional asymmetry continued

Facet	Sample	Male				Female			
		Continuity Coefficient	P	Phi	Phi correlation Strength	Continuity Coefficient	P	Phi	Phi correlation Strength
T7I	SBC	0.02	0.90	-0.29	Weak	0.21	0.65	-0.20	Weak
	SBL					1.07	0.30	-0.44	Medium
	AS	0.00	1.00	-0.17	None	0.00	1.00	0.17	Weak
T8S	SBC	0.00	1.00	0.06	None	0.64	0.42	0.23	Weak
	SBL	1.49	0.22	-0.35	Medium	0.00	1.00	0.00	None
	AS	0.02	0.88	-0.47	Medium				
T8I	SBC					0.00	1.00	0.05	None
	SBL	1.44	0.23	0.37	Medium	0.00	1.00	0.15	Weak
	AS	0.37	0.55	-0.55	**Strong**	0.00	1.00	-0.41	Medium
T9S	SBC	1.86	0.17	-0.54	**Strong**	0.09	0.76	0.13	Weak
	SBL	0.21	0.65	0.21	Weak	0.00	1.00	0.15	Weak
	AS	0.00	1.00	0.45	Medium	0.05	0.82	0.61	**Strong**
T9I	SBC	0.00	1.00	0.13	Weak	0.00	1.00	0.03	None
	SBL	0.15	0.70	0.19	Weak	2.40	0.12	0.52	**Strong**
	AS	0.00	1.00	0.00	None	0.00	1.00	-0.41	Medium
T10S	SBC	0.85	0.36	-0.42	Medium	0.62	0.43	-0.23	Weak
	SBL	1.16	0.28	0.36	Medium	0.08	0.78	0.25	Weak
	AS	0.00	1.00	0.00	None	0.00	1.00	-0.33	Medium
T10I	SBC	0.00	1.00	0.16	Weak	0.00	1.00	0.05	None
	SBL	0.00	1.00	-0.10	None	1.38	0.24	0.40	Medium
	AS	0.00	1.00	0.33	Medium	0.00	1.00	0.17	Weak
T11S	SBC	0.00	1.00	0.05	None	0.09	0.77	-0.13	Weak
	SBL	0.00	1.00	-0.11	Weak	0.00	0.95	-0.15	Weak
	AS	2.67	0.10	1.00	**Strong**	0.00	1.00	0.17	Weak
T11I	SBC	0.00	1.00	-0.07	None	0.17	0.68	-0.15	Weak
	SBL	0.00	1.00	-0.02	None	0.00	1.00	0.06	None
	AS	0.37	0.55	-0.55	**Strong**	0.00	1.00	-0.41	Medium

Appendix C-8 Correlation between humeral and facet angle directional asymmetry continued

Facet	Sample	Male				Female			
		Continuity Coefficient	P	Phi	Phi correlation Strength	Continuity Coefficient	P	Phi	Phi correlation Strength
T12S	SBC	0.02	0.90	0.20	Weak	0.00	1.00	-0.05	None
	SBL	0.00	1.00	0.08	None	0.02	0.90	0.14	Weak
	AS	0.75	0.39	0.71	**Strong**	0.05	0.82	0.61	**Strong**
T12I	SBC	5.69	0.02	-0.75	**Strong**	0.97	0.32	0.27	Weak
	SBL	1.68	0.20	-0.38	Medium	0.00	1.00	-0.03	None
	AS	0.00	1.00	0.25	Weak	0.00	1.00	0.41	Medium
L1S	SBC	0.09	0.77	0.19	Weak	0.04	0.84	0.12	Weak
	SBL	0.11	0.74	0.20	Weak	0.00	1.00	-0.05	None
	AS	0.11	0.74	-0.42	Medium	0.00	1.00	0.41	Medium
L1I	SBC	0.70	0.40	0.32	Medium	0.00	1.00	-0.07	None
	SBL	0.00	1.00	0.06	None	0.02	0.90	0.16	Weak
	AS	0.11	0.74	-0.42	Medium	0.00	1.00	0.33	Medium
L2S	SBC	0.02	0.90	0.16	Weak	0.58	0.45	0.23	Weak
	SBL	0.07	0.79	0.17	Weak	2.85	0.09	0.53	**Strong**
	AS	0.89	0.35	-0.60	**Strong**	0.31	0.58	0.67	**Strong**
L2I	SBC	0.00	0.96	0.13	Weak	2.18	0.14	-0.35	Medium
	SBL	0.03	0.85	-0.15	Weak	0.00	1.00	-0.13	Weak
	AS	0.18	0.67	-0.45	Medium	0.00	1.00	-0.17	Weak
L3S	SBC	2.52	0.11	-0.52	**Strong**	1.20	0.27	-0.29	Weak
	SBL	0.01	0.91	-0.15	Weak	0.55	0.46	0.33	Medium
	AS	0.00	1.00	0.26	Weak	0.00	1.00	-0.41	Medium
L3I	SBC	0.14	0.71	0.20	Weak	0.00	1.00	0.05	None
	SBL	0.02	0.88	0.15	Weak	0.00	1.00	-0.08	None
	AS	0.00	1.00	-0.45	Weak	0.05	0.82	-0.61	**Strong**
L4S	SBC	2.46	0.12	-0.48	Medium	0.97	0.32	0.27	Weak
	SBL	0.00	1.00	0.13	Weak	1.31	0.25	-0.47	Medium
	AS	0.75	0.39	-0.71	**Strong**	0.31	0.58	-0.67	**Strong**

Appendix C-8 Correlation between humeral and facet angle directional asymmetry continued

Facet	Sample	Male				Female			
		Continuity Coefficient	P	Phi	Phi correlation Strength	Continuity Coefficient	P	Phi	Phi correlation Strength
L4I	SBC	0.00	0.96	0.18	Weak	0.61	0.43	0.23	Weak
	SBL	0.00	1.00	0.09	None	0.04	0.84	-0.24	Weak
	AS	0.00	1.00	-0.26	Weak	0.00	1.00	-0.17	Weak
L5S	SBC	0.02	0.90	-0.16	Weak	0.00	1.00	0.02	None
	SBL	0.00	1.00	-0.09	None	0.51	0.47	-0.29	Weak
	AS	0.75	0.39	0.71	**Strong**	0.00	1.00	0.33	Medium
L5I	SBC	0.00	1.00	0.00	None	0.00	1.00	0.02	None
	SBL	0.00	1.00	-0.09	None	0.24	0.27	-0.45	Medium
	AS	0.09	0.76	0.50	**Strong**				

Appendix C-9 Correlation between eburnation and facet angle

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C1LS	SBC	0.39	0.1	19	Medium			21	
	SBL	0.09	0.72	19	None			15	
	AS	0.22	0.54	10	Weak			6	
C1RS	SBC	-0.11	0.66	19	Weak	0.15	0.5	22	Weak
	SBL	0.4	0.09	19	Medium			15	
	AS	0.26	0.42	12	Weak			6	
C1LI	SBC	0.05	0.86	18	None	-0.14	0.55	21	Weak
	SBL	-0.12	0.62	19	Weak	0.06	0.83	15	None
	AS	-0.7	0.04	9	**Strong**			5	
C1RI	SBC			19				22	
	SBL	0.2	0.41	19	Weak	-0.28	0.31	15	Weak
	AS	-0.23	0.48	12	Weak			6	
C2LS	SBC	-0.15	0.52	20	Weak	0.13	0.56	23	Weak
	SBL	0.48	0.03	21	Medium	0	1	14	None
	AS	0.38	0.29	10	Medium	-0.61	0.14	7	**Strong**
C2RS	SBC	-0.32	0.16	21	Medium	-0.23	0.29	24	Weak
	SBL	0.46	0.04	21	Medium	-0.04	0.91	14	None
	AS	-0.08	0.84	10	None			7	
C2LI	SBC	0.35	0.15	18	Medium	0.14	0.53	23	Weak
	SBL	0.28	0.23	20	Weak	-0.46	0.11	13	Medium
	AS	-0.6	0.09	9	**Strong**	-0.66	0.16	6	**Strong**
C2RI	SBC			18		-0.14	0.51	24	Weak
	SBL	0.34	0.14	21	Medium	-0.45	0.11	14	Medium
	AS	-0.18	0.62	10	Weak	0.13	0.81	6	Weak
C3LS	SBC	-0.24	0.44	13	Weak	-0.1	0.66	23	Weak
	SBL	0.01	0.97	22	None	0.06	0.83	15	None
	AS	-0.49	0.07	14	Medium	-0.12	0.8	7	Weak
C3RS	SBC	0.26	0.4	13	Weak	0.13	0.56	23	Weak
	SBL	0.43	0.04	22	Medium	0	1	14	None
	AS	-0.44	0.12	14	Medium	-0.22	0.63	7	Weak
C3LI	SBC	0.53	0.07	13	**Strong**	-0.37	0.1	21	Medium
	SBL	-0.21	0.35	21	Weak	0.22	0.44	15	Weak
	AS	0.03	0.92	14	None	-0.12	0.8	7	Weak
C3RI	SBC			13		-0.26	0.24	22	Weak
	SBL	-0.19	0.4	22	Weak	-0.28	0.34	14	Weak
	AS	-0.16	0.61	12	Weak	0.27	0.56	7	Weak

Appendix C-9 Correlation between eburnation and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C4LS	SBC	0.09	0.76	14	None	0.06	0.8	21	None
	SBL			24				17	
	AS	0.31	0.32	12	Medium	0.11	0.84	6	Weak
C4RS	SBC	-0.39	0.19	13	Medium	-0.08	0.74	20	None
	SBL	-0.01	0.97	25	None	-0.08	0.77	16	None
	AS	0.15	0.63	12	Weak	0.11	0.84	6	Weak
C4LI	SBC	-0.5	0.08	13	**Strong**	-0.1	0.67	21	Weak
	SBL	0.17	0.41	25	Weak	0.41	0.1	17	Medium
	AS	0.39	0.24	11	Medium	0.84	0.04	6	**Strong**
C4RI	SBC	-0.31	0.33	12	Medium	-0.1	0.68	21	Weak
	SBL	0.07	0.73	25	None	0.31	0.24	16	Medium
	AS	0.67	0.02	11	**Strong**	0.66	0.15	6	**Strong**
C5LS	SBC	-0.02	0.93	20	None	0.07	0.75	26	None
	SBL	0.48	0.02	24	Medium	0.51	0.02	20	**Strong**
	AS	0.81	0.02	8	**Strong**	-0.41	0.49	5	Medium
C5RS	SBC	0.12	0.63	20	Weak	0.19	0.36	26	Weak
	SBL	0.15	0.46	25	Weak	0.34	0.14	20	Medium
	AS	0.26	0.53	8	Weak	-0.78	0.12	5	**Strong**
C5LI	SBC			20		-0.19	0.36	26	Weak
	SBL	-0.18	0.41	24	Weak			20	
	AS	0.06	0.9	8	None	-0.89	0.04	5	**Strong**
C5RI	SBC	0.09	0.7	20	None			26	
	SBL	0	0.99	24	None	0.18	0.45	20	Weak
	AS	0.26	0.54	8	Weak	-0.11	0.86	5	Weak
C6LS	SBC	0.43	0.06	20	Medium	-0.29	0.17	24	Weak
	SBL	0.46	0.02	25	Medium	0.42	0.08	18	Medium
	AS	0.32	0.41	9	Medium	-0.22	0.63	7	Weak
C6RS	SBC	0.27	0.24	20	Weak	0.27	0.2	25	Weak
	SBL	0.01	0.97	24	None	0.12	0.64	18	Weak
	AS	0.34	0.38	9	Medium	-0.79	0.04	7	**Strong**
C6LI	SBC	-0.29	0.21	20	Weak			24	
	SBL	0.2	0.32	26	Weak	0.38	0.12	18	Medium
	AS	0	1	9	None	-0.36	0.43	7	Medium
C6RI	SBC			20				25	
	SBL	-0.19	0.37	25	Weak			19	
	AS	0.46	0.22	9	Medium	-0.62	0.14	7	**Strong**
C7LS	SBC	0.12	0.63	20	Weak	-0.21	0.29	28	Weak
	SBL	-0.27	0.19	26	Weak	-0.07	0.77	21	None
	AS	0.14	0.72	9	Weak	0.05	0.94	5	None

Appendix C-9 Correlation between eburnation and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C7RS	SBC	-0.02	0.93	20	None			27	
	SBL	0	1	27	None	-0.04	0.87	21	None
	AS	0.61	0.06	10	**Strong**	-0.21	0.74	5	Weak
C7LI	SBC	0.3	0.21	19	Medium	0.31	0.11	28	Medium
	SBL	-0.14	0.46	28	Weak	0.37	0.1	21	Medium
	AS	-0.2	0.58	10	Weak	-0.71	0.18	5	**Strong**
C7RI	SBC			19				25	
	SBL	-0.27	0.17	28	Weak	0.38	0.2	21	Medium
	AS	0.27	0.45	10	Weak	-0.71	0.18	5	**Strong**
T1LS	SBC	0.26	0.32	17	Weak	-0.04	0.83	29	None
	SBL	-0.01	0.96	30	None	0.35	0.1	21	Medium
	AS	0.11	0.71	14	Weak	0.34	0.37	9	Medium
T1RS	SBC	0.17	0.49	19	Weak	0.14	0.47	30	Weak
	SBL	0.01	0.95	29	None	0.13	0.58	20	Weak
	AS	0.03	0.93	13	None	0.29	0.42	10	Weak
T1LI	SBC			20		0.09	0.65	31	None
	SBL	0.11	0.55	31	Weak	-0.02	0.94	21	None
	AS	0.25	0.42	13	Weak	0.14	0.7	10	Weak
T1RI	SBC			20		-0.05	0.82	29	None
	SBL			31		-0.07	0.75	21	None
	AS	-0.03	0.93	13	None	-0.23	0.53	10	Weak
T2LS	SBC			23		0.19	0.34	28	Weak
	SBL	-0.1	0.6	32	Weak	-0.32	0.17	20	Medium
	AS	0.36	0.25	12	Medium	-0.39	0.18	13	Medium
T2RS	SBC	0.27	0.21	23	Weak	-0.31	0.1	29	Medium
	SBL	0.09	0.63	33	None			19	
	AS	0.42	0.18	12	Medium	-0.13	0.68	13	Weak
T2LI	SBC			23		0.29	0.12	29	Weak
	SBL			33				20	
	AS	0.6	0.04	12	**Strong**	-0.17	0.58	13	Weak
T2RI	SBC	0.16	0.46	23	Weak	0.14	0.44	31	Weak
	SBL	0.34	0.06	31	Medium			19	
	AS	0.38	0.22	12	Medium	-0.43	0.15	13	Medium
T3LS	SBC	0.08	0.73	21	None	0.16	0.43	26	Weak
	SBL	0.19	0.4	22	Weak	0.31	0.2	19	Medium
	AS	0.1	0.73	14	Weak	0.07	0.81	14	None

Appendix C-9 Correlation between eburnation and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T3RS	SBC	0.16	0.48	22	Weak	0.21	0.3	27	Weak
	SBL	0.11	0.59	25	Weak	0.17	0.46	21	Weak
	AS	0.29	0.3	15	Weak	-0.42	0.14	14	Medium
T3LI	SBC			22		-0.16	0.44	27	Weak
	SBL			25		-0.19	0.42	21	Weak
	AS	0.49	0.09	13	Medium	0.16	0.61	13	Weak
T3RI	SBC	-0.29	0.2	22	Weak	-0.03	0.87	25	None
	SBL	0.14	0.51	25	Weak	0.34	0.14	20	Medium
	AS	0.58	0.03	14	**Strong**	0.31	0.28	14	Medium
T4LS	SBC	0.08	0.75	19	None	-0.11	0.6	24	Weak
	SBL	0.17	0.41	26	Weak	-0.15	0.56	18	Weak
	AS	0.01	0.98	13	None	-0.11	0.7	14	Weak
T4RS	SBC	-0.21	0.4	19	Weak	0.23	0.29	24	Weak
	SBL	0.27	0.2	25	Weak	0.35	0.14	19	Medium
	AS	0.32	0.28	13	Medium	-0.18	0.53	14	Weak
T4LI	SBC	0.02	0.93	19	None	-0.07	0.74	24	None
	SBL			25		-0.27	0.29	18	Weak
	AS	0.31	0.3	13	Medium	0.12	0.71	13	Weak
T4RI	SBC	0.04	0.86	19	None	0.3	0.14	25	Medium
	SBL	0.26	0.21	25	Weak			16	
	AS	0.36	0.23	13	Medium	0.18	0.55	13	Weak
T5LS	SBC	-0.04	0.86	19	None	0.14	0.49	25	Weak
	SBL	-0.35	0.11	22	Medium	-0.26	0.28	19	Weak
	AS	0	1	14	None	0.33	0.36	10	Medium
T5RS	SBC	-0.37	0.12	19	Medium	-0.34	0.1	24	Medium
	SBL	-0.2	0.39	21	Weak	0.09	0.72	19	None
	AS	0.11	0.71	14	Weak	-0.07	0.84	10	None
T5LI	SBC	-0.15	0.56	17	Weak	0.33	0.14	22	Medium
	SBL			20		-0.22	0.37	19	Weak
	AS	0.5	0.12	11	**Strong**	0.17	0.64	10	Weak
T5RI	SBC	-0.36	0.15	18	Medium	0.12	0.6	21	Weak
	SBL			23				19	
	AS	0.18	0.61	11	Weak	0.41	0.24	10	Medium
T6LS	SBC	0.34	0.19	17	Medium	-0.07	0.73	25	None
	SBL	0.3	0.16	24	Medium	-0.13	0.6	19	Weak
	AS	0.57	0.07	11	**Strong**	0.21	0.55	10	Weak
T6RS	SBC	0.05	0.86	17	None	0.01	0.98	27	None
	SBL	0.07	0.74	24	None	0.06	0.81	19	None
	AS	0.1	0.77	12	Weak	0.17	0.64	10	Weak

Appendix C-9 Correlation between eburnation and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T6LI	SBC			19		-0.18	0.38	27	Weak
	SBL			23		-0.33	0.16	20	Medium
	AS	0.28	0.47	9	Weak	0.52	0.12	10	**Strong**
T6RI	SBC			19				27	
	SBL			23				20	
	AS	-0.06	0.88	10	None	0.1	0.78	10	Weak
T7LS	SBC			20		-0.27	0.18	27	Weak
	SBL	0.28	0.2	23	Weak	0.38	0.12	18	Medium
	AS	-0.06	0.87	12	None	0.4	0.18	13	Medium
T7RS	SBC			20		-0.18	0.39	26	Weak
	SBL	0.33	0.12	24	Medium	0.43	0.1	16	Medium
	AS	0.13	0.68	12	Weak	-0.22	0.47	13	Weak
T7LI	SBC			19		0.36	0.16	17	Medium
	SBL			19		0.36	0.16	17	Medium
	AS	0.37	0.3	10	Medium	-0.08	0.81	12	None
T7RI	SBC			19				25	
	SBL			22				17	
	AS	0.04	0.91	10	None	0.08	0.8	13	None
T8LS	SBC	-0.24	0.29	21	Weak	0	1	24	None
	SBL			25				17	
	AS	0.02	0.94	13	None	0.22	0.48	13	Weak
T8RS	SBC			21		0	1	24	None
	SBL	0.02	0.91	25	None	0.06	0.82	16	None
	AS	-0.14	0.66	13	Weak	0.33	0.27	13	Medium
T8LI	SBC	-0.22	0.33	21	Weak	0.11	0.62	24	Weak
	SBL	-0.03	0.89	24	None	-0.04	0.91	14	None
	AS	-0.17	0.57	13	Weak	-0.23	0.45	13	Weak
T8RI	SBC			22		0.32	0.1	27	Medium
	SBL	0.06	0.78	24	None			15	
	AS	-0.2	0.52	13	Weak	0	1	13	None
T9LS	SBC	0.03	0.91	21	None	0.02	0.91	29	None
	SBL	-0.13	0.54	26	Weak	0.03	0.92	16	None
	AS	-0.14	0.64	14	Weak	-0.57	0.05	12	**Strong**
T9RS	SBC	0.05	0.82	21	None	-0.35	0.06	29	Medium
	SBL	-0.01	0.97	26	None	-0.45	0.11	14	Medium
	AS	0.32	0.29	13	Medium	-0.15	0.64	12	Weak

Appendix C-9 Correlation between eburnation and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T9LI	SBC			19		0.27	0.17	29	Weak
	SBL	0.01	0.95	25	None	-0.13	0.67	14	Weak
	AS	0.29	0.32	14	Weak	-0.41	0.22	11	Medium
T9RI	SBC			19		-0.05	0.8	29	None
	SBL			24		-0.42	0.14	14	Medium
	AS	-0.22	0.45	14	Weak	-0.5	0.12	11	**Strong**
T10LS	SBC	-0.05	0.82	20	None	0.06	0.78	28	None
	SBL	0.34	0.09	26	Medium	-0.03	0.93	14	None
	AS	-0.57	0.03	14	**Strong**	0.29	0.39	11	Weak
T10RS	SBC			20		0.32	0.11	27	Medium
	SBL			27				14	
	AS	-0.11	0.72	13	Weak	-0.07	0.84	11	None
T10LI	SBC			20		0.06	0.76	28	None
	SBL			27		0.14	0.63	14	Weak
	AS	-0.52	0.06	14	**Strong**	-0.43	0.19	11	Medium
T10RI	SBC			20		0.19	0.33	28	Weak
	SBL			27		-0.08	0.8	13	None
	AS	-0.5	0.07	14	**Strong**	-0.34	0.31	11	Medium
T11LS	SBC	0.01	0.96	21	None	0.02	0.94	28	None
	SBL	-0.07	0.72	25	None			15	
	AS	-0.23	0.42	14	Weak	0.29	0.39	11	Weak
T11RS	SBC	0.15	0.51	21	Weak	0.05	0.81	28	None
	SBL	-0.14	0.52	24	Weak	-0.31	0.27	14	Medium
	AS	0.22	0.44	14	Weak	-0.05	0.9	11	None
T11LI	SBC	0.38	0.1	20	Medium	-0.03	0.9	27	None
	SBL			23				14	
	AS	-0.37	0.21	13	Medium	0.3	0.37	11	Medium
T11RI	SBC			20		-0.34	0.1	25	Medium
	SBL			25				14	
	AS	-0.34	0.25	13	Medium	0.08	0.82	11	None
T12LS	SBC	-0.12	0.64	18	Weak	-0.23	0.28	25	Weak
	SBL	0.08	0.72	23	None			14	
	AS	0.04	0.91	13	None	0.41	0.21	11	Medium
T12RS	SBC	-0.35	0.15	18	Medium	0.06	0.76	25	None
	SBL			23				14	
	AS	-0.07	0.81	13	None	0.28	0.41	11	Weak
T12LI	SBC	0.07	0.77	19	None	-0.09	0.65	26	None
	SBL	-0.05	0.83	23	None			14	
	AS	0.14	0.66	12	Weak	0.23	0.53	10	Weak

Appendix C-9 Correlation between eburnation and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T12RI	SBC	0.29	0.25	18	Weak			24	
	SBL	-0.1	0.66	23	Weak			14	
	AS	0.07	0.84	12	None	0.32	0.33	11	Medium
L1LS	SBC	-0.01	0.97	19	None			25	
	SBL			24				12	
	AS	-0.07	0.81	14	None	-0.2	0.53	12	Weak
L1RS	SBC	0.42	0.08	19	Medium			24	
	SBL	0.21	0.32	24	Weak			13	
	AS	-0.22	0.49	12	Weak	0.04	0.9	13	None
L1LI	SBC	-0.33	0.17	19	Medium			23	
	SBL	0.07	0.74	25	None			12	
	AS	-0.39	0.19	13	Medium	-0.17	0.56	15	Weak
L1RI	SBC	-0.38	0.11	19	Medium			24	
	SBL	0.23	0.27	25	Weak			13	
	AS	-0.16	0.58	14	Weak	0.37	0.19	14	Medium
L2LS	SBC	-0.19	0.42	21	Weak	0.28	0.17	26	Weak
	SBL			23				13	
	AS	-0.09	0.75	15	None	0.43	0.19	11	Medium
L2RS	SBC			21				25	
	SBL			23				12	
	AS	-0.09	0.75	15	None	0.43	0.19	11	Medium
L2LI	SBC			21				25	
	SBL			24				13	
	AS	-0.12	0.69	14	Weak	0.23	0.52	10	Weak
L2RI	SBC			20				24	
	SBL	0.12	0.57	24	Weak			13	
	AS	-0.36	0.23	13	Medium	0.43	0.22	10	Medium
L3LS	SBC	-0.24	0.31	20	Weak			27	
	SBL	0.24	0.29	21	Weak	0.31	0.28	14	Medium
	AS	-0.15	0.59	16	Weak	-0.07	0.81	15	None
L3RS	SBC	0.2	0.38	21	Weak			26	
	SBL	-0.02	0.93	20	None			13	
	AS	-0.15	0.58	16	Weak	0.03	0.92	15	None
L3LI	SBC	0.15	0.52	21	Weak	-0.16	0.41	28	Weak
	SBL	0.06	0.8	20	None	0.17	0.56	14	Weak
	AS	-0.19	0.46	17	Weak	-0.31	0.26	15	Medium

Appendix C-9 Correlation between eburnation and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
L3RI	SBC	0.42	0.06	21	Medium			29	
	SBL			19		0.17	0.56	14	Weak
	AS	-0.02	0.95	15	None	-0.22	0.46	13	Weak
L4LS	SBC			20				25	
	SBL			19				10	
	AS	0.32	0.23	16	Medium	-0.11	0.71	13	Weak
L4RS	SBC	0.23	0.33	20	Weak	0.06	0.79	25	None
	SBL			20		0.48	0.19	9	Medium
	AS	-0.07	0.79	16	None	-0.01	0.98	13	None
L4LI	SBC	-0.16	0.5	20	Weak			25	
	SBL			18				10	
	AS	-0.17	0.55	15	Weak	0.31	0.33	12	Medium
L4RI	SBC	0.34	0.14	20	Medium	-0.02	0.94	23	None
	SBL			20		0.18	0.63	10	Weak
	AS	0.39	0.18	13	Medium	-0.32	0.34	11	Medium
L5LS	SBC	0.24	0.35	18	Weak	0.26	0.27	20	Weak
	SBL	-0.09	0.66	24	None			13	
	AS	0.08	0.82	11	None	0.27	0.42	11	Weak
L5RS	SBC	0.51	0.03	18	**Strong**			20	
	SBL	-0.21	0.36	22	Weak	-0.08	0.74	18	None
	AS	0.4	0.22	11	Medium	-0.5	0.12	11	**Strong**
L5LI	SBC	0.11	0.65	18	Weak			18	
	SBL	0.08	0.71	24	None	-0.24	0.33	18	Weak
	AS	-0.48	0.19	9	Medium	0.35	0.32	10	Medium
L5RI	SBC	-0.12	0.64	18	Weak			18	
	SBL	0.1	0.66	23	Weak	0.28	0.27	18	Weak
	AS	-0.65	0.03	11	**Strong**	-0.33	0.35	10	Medium

Appendix C-10 Correlation between pitting scores and facet angle

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C1LS	SBC	-0.02	0.95	18	None	0.12	0.6	23	Weak
	SBL	-0.03	0.92	19	None	0.31	0.28	14	Medium
	AS	0	0.99	11	None	-0.42	0.35	7	Medium
C1RS	SBC	0.48	0.04	18	Medium	0.07	0.75	23	None
	SBL	-0.17	0.47	20	Weak			14	
	AS	-0.05	0.88	12	None	0.05	0.92	7	None
C1LI	SBC	0.32	0.2	18	Medium	-0.2	0.36	23	Weak
	SBL	-0.23	0.35	19	Weak	0.03	0.91	14	None
	AS	-0.44	0.24	9	Medium	-0.45	0.38	6	Medium
C1RI	SBC	0.34	0.16	18	Medium	0.22	0.31	23	Weak
	SBL	-0.18	0.45	20	Weak	-0.1	0.73	14	Weak
	AS	-0.2	0.53	12	Weak	-0.1	0.83	7	Weak
C2LS	SBC	-0.07	0.78	20	None	-0.41	0.04	25	Medium
	SBL	-0.28	0.24	20	Weak	0	1	13	None
	AS	0.24	0.5	10	Weak	0.73	0.04	8	**Strong**
C2RS	SBC	-0.02	0.95	20	None	-0.13	0.53	25	Weak
	SBL	0.01	0.98	21	None	-0.04	0.89	13	None
	AS	-0.17	0.64	10	Weak	0.4	0.33	8	Medium
C2LI	SBC	0.31	0.21	18	Medium	-0.07	0.74	25	None
	SBL	0.3	0.21	19	Medium	0.1	0.76	13	None
	AS	-0.07	0.86	9	None	0.61	0.15	7	**Strong**
C2RI	SBC	0.36	0.15	18	Medium	-0.12	0.56	25	Weak
	SBL	0.26	0.26	21	Weak	-0.39	0.19	13	Medium
	AS	-0.09	0.8	10	None	0.67	0.1	7	**Strong**
C3LS	SBC	-0.04	0.89	13	None	-0.23	0.3	22	Weak
	SBL	-0.06	0.81	21	None	0.04	0.89	17	None
	AS	-0.06	0.85	14	None	0.6	0.21	6	**Strong**
C3RS	SBC	-0.42	0.15	13	Medium	-0.31	0.17	22	Medium
	SBL	0	0.99	21	None	-0.27	0.32	16	Weak
	AS	-0.06	0.85	14	None	-0.52	0.3	6	**Strong**
C3LI	SBC	0.14	0.66	13	Weak	0.06	0.79	20	None
	SBL	0.09	0.69	20	None	-0.01	0.96	17	None
	AS	0.22	0.45	14	Weak	-0.93	0.01	6	**Strong**
C3RI	SBC	-0.22	0.47	13	Weak	-0.07	0.78	20	None
	SBL	0.15	0.52	21	Weak	-0.12	0.67	16	Weak
	AS	0.15	0.65	12	Weak	-0.46	0.36	6	Medium

Appendix C-10 Correlation between pitting scores and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C4LS	SBC	-0.44	0.13	13	Medium	-0.04	0.88	20	None
	SBL	-0.04	0.85	23	None	0.02	0.94	16	None
	AS	0.31	0.32	12	Medium	-0.4	0.43	6	Medium
C4RS	SBC	-0.5	0.1	12	**Strong**	0.13	0.57	21	Weak
	SBL	-0.08	0.72	24	None	0.26	0.36	15	Weak
	AS	0.25	0.43	12	Weak	-0.75	0.09	6	**Strong**
C4LI	SBC	0.29	0.34	13	Weak	0.17	0.44	23	Weak
	SBL	-0.44	0.03	24	Medium	0.04	0.89	16	None
	AS	0.26	0.44	11	Weak	0.45	0.37	6	Medium
C4RI	SBC	0.23	0.46	12	Weak	-0.13	0.54	23	Weak
	SBL	-0.02	0.93	24	None	-0.31	0.26	15	Medium
	AS	-0.13	0.72	11	Weak	0.34	0.51	6	Medium
C5LS	SBC	0.02	0.95	20	None	-0.13	0.53	27	Weak
	SBL	-0.26	0.22	24	Weak	-0.09	0.72	20	None
	AS	0.42	0.3	8	Medium	-0.89	0.04	5	**Strong**
C5RS	SBC	0.02	0.94	20	None	0.31	0.12	27	Medium
	SBL	0.11	0.59	25	Weak	0.03	0.91	17	None
	AS	-0.13	0.75	8	Weak	-0.79	0.11	5	**Strong**
C5LI	SBC	0.5	0.02	20	**Strong**	-0.05	0.79	27	None
	SBL	-0.13	0.54	24	Weak	0.1	0.68	20	Weak
	AS	0.1	0.81	8	Weak	-0.35	0.56	5	Medium
C5RI	SBC	0.01	0.97	20	None	0.05	0.82	27	None
	SBL	0.22	0.29	24	Weak	0.06	0.8	20	None
	AS	0.46	0.26	8	Medium	-0.71	0.18	5	**Strong**
C6LS	SBC	0.08	0.76	19	None	-0.05	0.83	25	None
	SBL	0.12	0.58	23	Weak	0.11	0.66	19	Weak
	AS	0.06	0.88	9	None	-0.13	0.78	7	Weak
C6RS	SBC	0.22	0.37	19	Weak	-0.12	0.56	26	Weak
	SBL	0.52	0.01	22	**Strong**	0.12	0.63	19	Weak
	AS	0.07	0.86	9	None	-0.16	0.74	7	Weak
C6LI	SBC	-0.26	0.29	19	Weak	0.12	0.58	25	Weak
	SBL	-0.27	0.19	26	Weak	-0.25	0.31	19	Weak
	AS	-0.04	0.92	9	None	0.19	0.69	7	Weak
C6RI	SBC	-0.21	0.39	19	Weak	0.23	0.25	26	Weak
	SBL	-0.16	0.47	22	Weak	-0.28	0.24	19	Weak
	AS	0.02	0.96	9	None	-0.06	0.9	7	None
C7LS	SBC	-0.14	0.57	19	Weak	0.12	0.54	28	Weak
	SBL	-0.31	0.12	26	Medium	-0.21	0.37	20	Weak
	AS	0.16	0.66	10	Weak	0.95	0.01	5	**Strong**

Appendix C-10 Correlation between pitting scores and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C7RS	SBC	0.09	0.72	19	None	-0.14	0.47	28	Weak
	SBL	0.45	0.03	25	Medium	-0.41	0.06	22	Medium
	AS	-0.03	0.95	8	None	0.45	0.45	5	Medium
C7LI	SBC	0.58	0.01	18	**Strong**	0.21	0.28	29	Weak
	SBL	-0.1	0.62	27	Weak	-0.35	0.12	22	Medium
	AS	0.72	0.03	9	**Strong**	-0.71	0.18	5	**Strong**
C7RI	SBC	0.23	0.36	18	Weak	0.05	0.79	29	None
	SBL	-0.02	0.91	27	None	0.22	0.32	22	Weak
	AS	0.37	0.33	9	Medium	0.71	0.18	5	**Strong**
T1LS	SBC	0.41	0.13	15	Medium	-0.18	0.32	32	Weak
	SBL	0.15	0.45	29	Weak	-0.3	0.2	20	Weak
	AS	0.4	0.18	13	Medium	-0.36	0.31	10	Medium
T1RS	SBC	0.29	0.24	18	Weak	-0.2	0.26	32	Weak
	SBL	0.05	0.79	29	None	-0.3	0.18	21	Medium
	AS	0.6	0.04	12	**Strong**	0.35	0.29	11	Medium
T1LI	SBC	0.08	0.74	19	None	-0.1	0.6	32	Weak
	SBL	-0.06	0.75	30	None	0.02	0.92	22	None
	AS	0	1	12	None	0.06	0.87	11	None
T1RI	SBC	-0.25	0.3	19	Weak	-0.02	0.91	32	None
	SBL	0.24	0.21	30	Weak	-0.1	0.66	21	Weak
	AS	-0.18	0.58	12	Weak	-0.3	0.38	11	Medium
T2LS	SBC	0.04	0.83	29	None	-0.44	0.07	18	Medium
	SBL	0.04	0.83	29	None	-0.44	0.07	18	Medium
	AS	0.44	0.15	12	Medium	0.21	0.49	13	Weak
T2RS	SBC	-0.1	0.58	34	None	0.41	0.08	19	Medium
	SBL	-0.1	0.58	34	None	0.41	0.08	19	Medium
	AS	0.39	0.21	12	Medium	-0.11	0.72	13	Weak
T2LI	SBC	0.38	0.09	21	Medium	-0.13	0.5	31	Weak
	SBL	-0.03	0.85	33	None	0.11	0.65	19	Weak
	AS	0.03	0.93	12	None	0.05	0.87	13	None
T2RI	SBC	-0.36	0.11	21	Medium	0.16	0.41	30	Weak
	SBL	0.02	0.92	32	None	-0.15	0.52	20	Weak
	AS	0.36	0.25	12	Medium	-0.26	0.39	13	Weak
T3LS	SBC	0.03	0.9	20	None	0.15	0.44	28	Weak
	SBL	0.07	0.73	24	None	0.06	0.8	20	None
	AS	-0.26	0.39	13	Weak	-0.39	0.19	13	Medium

Appendix C-10 Correlation between pitting scores and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T3RS	SBC	-0.08	0.75	20	None	0.13	0.51	29	Weak
	SBL	0.15	0.46	26	Weak	0.28	0.24	20	Weak
	AS	-0.14	0.61	15	Weak	0.07	0.83	13	None
T3LI	SBC	0.04	0.85	20	None	-0.22	0.25	29	Weak
	SBL	-0.14	0.5	24	Weak	0.1	0.67	21	Weak
	AS	0.23	0.43	14	Weak	-0.06	0.87	12	None
T3RI	SBC	-0.2	0.4	20	Weak	-0.03	0.89	29	None
	SBL	-0.18	0.38	25	Weak	0.17	0.47	21	Weak
	AS	0.46	0.09	15	Medium	-0.25	0.41	13	Weak
T4LS	SBC	0.03	0.9	16	None	-0.04	0.84	28	None
	SBL	-0.01	0.95	26	None	0.05	0.85	18	None
	AS	0.04	0.9	15	None	-0.28	0.35	13	Weak
T4RS	SBC	0	0.99	16	None	0.05	0.81	27	None
	SBL	0.1	0.65	24	None	0.13	0.61	18	Weak
	AS	0.08	0.78	14	None	-0.23	0.45	13	Weak
T4LI	SBC	0.2	0.45	16	Weak	0.19	0.35	27	Weak
	SBL	0.03	0.88	24	None	0.49	0.05	16	**Strong**
	AS	-0.27	0.34	14	Weak	-0.33	0.29	12	Medium
T4RI	SBC	-0.26	0.32	16	Weak	-0.29	0.14	27	Weak
	SBL	0.5	0.05	16	**Strong**	0.45	0.14	12	Medium
	AS	0.01	0.97	15	None	0.07	0.83	12	None
T5LS	SBC	-0.22	0.42	16	Weak	0.11	0.58	28	Weak
	SBL	0.29	0.19	22	Weak	-0.05	0.83	19	None
	AS	0.03	0.92	16	None	-0.33	0.39	9	Medium
T5RS	SBC	-0.16	0.54	18	Weak	-0.09	0.66	25	None
	SBL	0.4	0.07	21	Medium	-0.12	0.63	19	Weak
	AS	0.09	0.75	16	None	-0.56	0.1	10	**Strong**
T5LI	SBC	-0.19	0.49	15	Weak	0.02	0.93	24	None
	SBL	-0.04	0.86	20	None	0.3	0.19	20	Medium
	AS	0.53	0.06	13	**Strong**	0.64	0.06	9	**Strong**
T5RI	SBC	0.01	0.97	16	None	0.31	0.14	24	Medium
	SBL	0.01	0.98	23	None	-0.07	0.78	20	None
	AS	-0.03	0.92	13	None	0.64	0.06	9	**Strong**
T6LS	SBC	0.26	0.31	18	Weak	0.3	0.15	25	Medium
	SBL	-0.1	0.63	25	Weak	-0.18	0.47	19	Weak
	AS	0.17	0.58	13	Weak	-0.37	0.33	9	Medium
T6RS	SBC	-0.42	0.08	18	Medium	-0.32	0.12	25	Medium
	SBL	0.09	0.67	25	None	-0.14	0.57	19	Weak
	AS	0.26	0.39	13	Weak	-0.6	0.09	9	**Strong**

Appendix C-10 Correlation between pitting scores and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T6LI	SBC	0.47	0.05	19	Medium	-0.08	0.71	26	None
	SBL	0.05	0.84	22	None	0.18	0.44	20	Weak
	AS	0.82	0	11	**Strong**	.	.	8	
T6RI	SBC	-0.17	0.5	19	Weak	-0.22	0.28	27	Weak
	SBL	-0.11	0.61	23	Weak	-0.2	0.43	17	Weak
	AS	0.31	0.36	11	Medium	-0.23	0.58	8	Weak
T7LS	SBC	0.41	0.09	19	Medium	-0.17	0.39	29	Weak
	SBL	0.04	0.85	25	None	0.25	0.33	18	Weak
	AS	0	1	13	None	0.3	0.34	12	Medium
T7RS	SBC	0.13	0.58	19	Weak	-0.18	0.36	27	Weak
	SBL	-0.12	0.59	24	Weak	-0.17	0.52	16	Weak
	AS	-0.19	0.55	13	Weak	0.02	0.96	12	None
T7LI	SBC	0.37	0.13	18	Medium	0.15	0.45	28	Weak
	SBL	-0.04	0.87	22	None	-0.2	0.43	17	Weak
	AS	0.22	0.54	10	Weak	-0.1	0.78	11	Weak
T7RI	SBC	0.02	0.95	18	None	-0.01	0.98	28	None
	SBL	-0.11	0.61	23	Weak	-0.2	0.43	17	Weak
	AS	0.23	0.53	10	Weak	-0.23	0.48	12	Weak
T8LS	SBC	-0.15	0.55	19	Weak	-0.15	0.45	28	Weak
	SBL	0.04	0.85	25	None	0.25	0.33	18	Weak
	AS	0.3	0.38	11	Medium	-0.08	0.8	13	None
T8RS	SBC	-0.21	0.38	19	Weak	0.09	0.64	28	None
	SBL	-0.16	0.45	25	Weak	0.16	0.52	18	Weak
	AS	-0.25	0.46	11	Weak	0.25	0.41	13	Weak
T8LI	SBC	-0.09	0.72	19	None	-0.14	0.48	28	Weak
	SBL	-0.12	0.56	25	Weak			16	
	AS	0.33	0.32	11	Medium	0.11	0.73	13	Weak
T8RI	SBC	-0.2	0.41	20	Weak	0.24	0.22	28	Weak
	SBL	0.15	0.49	25	Weak	0.36	0.16	17	Medium
	AS	0.09	0.79	11	None	-0.19	0.54	13	Weak
T9LS	SBC	0.35	0.15	19	Medium	0.04	0.84	30	None
	SBL	0.29	0.16	26	Weak	-0.09	0.74	17	None
	AS	0.06	0.85	13	None	-0.09	0.76	13	None
T9RS	SBC	0.16	0.53	19	Weak	-0.1	0.6	30	Weak
	SBL	0.55	0	26	**Strong**			17	
	AS	0.16	0.63	11	Weak	-0.47	0.11	13	Medium

Appendix C-10 Correlation between pitting scores and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T9LI	SBC	0.44	0.07	18	Medium	-0.61	0	29	**Strong**
	SBL	-0.08	0.72	25	None			17	
	AS	-0.3	0.34	12	Medium	-0.02	0.95	12	None
T9RI	SBC	-0.07	0.79	18	None	0.13	0.49	29	Weak
	SBL	-0.22	0.32	22	Weak			17	
	AS	-0.61	0.04	12	**Strong**	-0.28	0.38	12	Weak
T10LS	SBC	0.06	0.8	18	None	-0.07	0.71	28	None
	SBL	0.1	0.65	25	None	0.36	0.17	16	Medium
	AS	0.01	0.99	12	None	0.23	0.47	12	Weak
T10RS	SBC	0.26	0.31	18	Weak	0.17	0.39	28	Weak
	SBL	0.26	0.21	26	Weak			16	
	AS	-0.23	0.48	12	Weak	0.17	0.6	12	Weak
T10LI	SBC	0.01	0.98	18	None	0.16	0.4	29	Weak
	SBL	0.07	0.74	26	None			16	
	AS	-0.13	0.7	11	Weak	0.25	0.43	12	Weak
T10RI	SBC	-0.42	0.08	18	Medium	-0.09	0.64	29	None
	SBL	-0.28	0.17	26	Weak			15	
	AS	-0.28	0.38	12	Weak	-0.18	0.57	12	Weak
T11LS	SBC	0.09	0.71	19	None	-0.03	0.87	28	None
	SBL	-0.04	0.85	23	None	0.15	0.13	16	Weak
	AS	-0.27	0.37	13	Weak	-0.2	0.54	12	Weak
T11RS	SBC	-0.52	0.02	19	**Strong**	0.25	0.19	29	Weak
	SBL	-0.01	0.96	24	None	-0.29	0.28	16	Weak
	AS	0.08	0.79	13	None	-0.18	0.58	12	Weak
T11LI	SBC	-0.22	0.38	18	Weak	-0.23	0.23	28	Weak
	SBL	0	0.99	23	None	0.12	0.66	15	Weak
	AS	-0.14	0.67	12	Weak	0.41	0.19	12	Medium
T11RI	SBC	-0.2	0.43	18	Weak	-0.02	0.92	28	None
	SBL	0.01	0.98	24	None	0.42	0.11	16	Medium
	AS	-0.54	0.11	10	**Strong**	-0.07	0.83	12	None
T12LS	SBC	-0.18	0.48	17	Weak	0.14	0.53	24	Weak
	SBL	-0.06	0.8	22	None	-0.39	0.14	16	Medium
	AS	-0.16	0.61	12	Weak	0.28	0.4	11	Weak
T12RS	SBC	-0.46	0.06	17	Medium	-0.08	0.71	24	None
	SBL	-0.04	0.86	22	None	0.2	0.47	16	Weak
	AS	-0.61	0.04	12	**Strong**	0.59	0.06	11	**Strong**
T12LI	SBC	0.07	0.8	18	None	-0.13	0.54	25	Weak
	SBL	0.16	0.49	22	Weak	0.23	16	-0.37	Weak
	AS	-0.07	0.84	11	None	0.16	0.65	11	Weak

Appendix C-10 Correlation between pitting scores and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T12RI	SBC	0.22	0.4	17	Weak	0	0.99	25	None
	SBL	0.32	0.15	22	Medium	-0.04	0.88	16	None
	AS	-0.11	0.77	10	Weak	0.4	0.23	11	Medium
L1LS	SBC	-0.08	0.75	19	None	0.04	0.86	25	None
	SBL	0.4	0.07	22	Medium	-0.31	0.31	13	Medium
	AS	0.15	0.59	15	Weak	0.01	0.97	13	None
L1RS	SBC	0.04	0.88	19	None	-0.06	0.79	24	None
	SBL	-0.13	0.56	24	Weak	0.05	0.88	12	None
	AS	0.18	0.58	12	Weak	0.5	0.07	14	**Strong**
L1LI	SBC	-0.12	0.62	19	Weak	-0.03	0.89	24	None
	SBL	0.09	0.69	25	None	0.08	0.8	13	None
	AS	-0.3	0.3	14	Medium	0.08	0.78	15	None
L1RI	SBC	0.36	0.13	19	Medium	-0.41	0.05	24	Medium
	SBL	-0.09	0.68	24	None	-0.4	0.2	12	Medium
	AS	-0.11	0.7	15	Weak	0.52	0.06	14	**Strong**
L2LS	SBC	-0.05	0.82	21	None	-0.08	0.69	27	None
	SBL	0.36	0.1	22	Medium	0.31	0.3	13	Medium
	AS	-0.26	0.33	16	Weak	0.33	0.29	12	Medium
L2RS	SBC	-0.07	0.78	21	None	0.15	0.45	26	Weak
	SBL	0.09	0.7	23	None	0.1	0.77	11	Weak
	AS	0.1	0.74	14	Weak	0.32	0.31	12	Medium
L2LI	SBC	0.15	0.52	21	Weak	0.13	0.52	26	Weak
	SBL	0.44	0.03	24	Medium	0.56	0.06	12	**Strong**
	AS	-0.12	0.69	14	Weak	0.29	0.42	10	Weak
L2RI	SBC	0	1	20	None	0	0.99	26	None
	SBL	-0.04	0.86	24	None	0.38	0.22	12	Medium
	AS	-0.03	0.93	13	None	0.1	0.77	11	Weak
L3LS	SBC	-0.06	0.81	20	None	0.13	0.53	26	Weak
	SBL	0.2	0.4	20	Weak	-0.4	0.18	13	Medium
	AS	-0.45	0.08	16	Medium	-0.2	0.49	14	Weak
L3RS	SBC	-0.01	0.98	21	None	0.06	0.78	26	None
	SBL	-0.05	0.86	18	None	-0.29	0.35	13	Weak
	AS	-0.02	0.95	16	None	-0.26	0.38	14	Weak
L3LI	SBC	0.31	0.18	20	Medium	-0.33	0.08	28	Medium
	SBL	-0.14	0.56	20	Weak	0.3	0.27	15	Medium
	AS	-0.37	0.14	17	Medium	-0.06	0.83	14	None

Appendix C-10 Correlation between pitting scores and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
L3RI	SBC	-0.01	0.96	20	None	0.01	0.95	27	None
	SBL	0.19	0.49	16	Weak	-0.31	0.3	13	Medium
	AS	-0.37	0.17	15	Medium	-0.67	0.02	12	**Strong**
L4LS	SBC	0.02	0.94	20	None	0.1	0.63	25	Weak
	SBL	-0.07	0.78	19	None			10	
	AS	0.19	0.49	16	Weak	-0.31	0.3	13	Medium
L4RS	SBC	0.35	0.13	20	Medium	0.47	0.02	25	Medium
	SBL	0.35	0.13	20	Medium	0.14	0.73	9	Weak
	AS	0.19	0.49	16	Weak	-0.31	0.3	13	Medium
L4LI	SBC	0.41	0.07	20	Medium	-0.33	0.1	25	Medium
	SBL	0.07	0.78	18	None	0.61	0.06	10	**Strong**
	AS	-0.39	0.16	15	Medium	-0.06	0.85	12	None
L4RI	SBC	-0.01	0.98	19	None	0.12	0.55	26	Weak
	SBL	0.03	0.89	20	None	-0.52	0.12	10	**Strong**
	AS	0	1	13	None	-0.09	0.8	11	None
L5LS	SBC	-0.44	0.07	18	Medium	-0.3	0.18	21	Medium
	SBL	0.02	0.93	24	None	-0.54	0.06	13	**Strong**
	AS	0.51	0.11	11	**Strong**	0.06	0.87	11	None
L5RS	SBC	0.16	0.54	18	Weak	0	0.99	21	None
	SBL	-0.19	0.42	21	Weak	-0.17	0.58	13	Weak
	AS	0.4	0.22	11	Medium	-0.3	0.37	11	Medium
L5LI	SBC	0.01	0.97	18	None	0.16	0.49	21	Weak
	SBL	-0.04	0.84	24	None	-0.17	0.59	13	Weak
	AS	-0.47	0.17	10	Medium	0.3	0.4	10	Medium
L5RI	SBC	-0.15	0.56	18	Weak	-0.18	0.44	21	Weak
	SBL	0.14	0.54	22	Weak	-0.39	0.19	13	Medium
	AS	-0.56	0.07	11	**Strong**	-0.21	0.57	10	Weak

Appendix C-11 Correlation between osteophyte score and facet angle

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C1LS	SBC			18		0.13	0.56	23	Weak
	SBL	-0.03	0.92	19	None	0.31	0.28	14	Medium
	AS			11				6	
C1RS	SBC			18		0.24	0.26	23	Weak
	SBL	-0.17	0.47	20	Weak			14	
	AS			12				6	
C1LI	SBC	0.28	0.26	18	Weak			23	
	SBL	-0.23	0.35	19	Weak	0.03	0.91	14	None
	AS			9				5	
C1RI	SBC			18				23	
	SBL	-0.18	0.45	20	Weak	-0.1	0.73	14	Weak
	AS	-0.13	0.68	12	Weak			6	
C2LS	SBC	-0.16	0.5	20	Weak			25	
	SBL	-0.28	0.24	20	Weak	0	1	13	None
	AS	0.18	0.63	10	Weak			8	
C2RS	SBC			20		-0.17	0.42	25	Weak
	SBL	0.01	0.98	21	None	-0.04	0.89	13	None
	AS			10				8	
C2LI	SBC	0.29	0.24	18	Weak	0.01	0.98	25	None
	SBL	0.3	0.21	19	Medium	0.1	0.76	13	None
	AS			9				7	
C2RI	SBC	-0.05	0.85	18	None	-0.11	0.62	25	Weak
	SBL	0.26	0.26	21	Weak	-0.39	0.19	13	Medium
	AS			10		0	1	7	None
C3LS	SBC	-0.06	0.85	13	None	-0.01	0.95	22	None
	SBL	-0.06	0.81	21	None	0.04	0.89	17	None
	AS			14		-0.66	0.16	6	**Strong**
C3RS	SBC	-0.18	0.56	13	Weak	0.23	0.31	22	Weak
	SBL	0	0.99	21	None	-0.27	0.32	16	Weak
	AS	0.38	0.18	14	Medium	-0.68	0.14	6	**Strong**
C3LI	SBC	0.23	0.45	13	Weak	0.52	0.02	20	**Strong**
	SBL	0.09	0.69	20	None	-0.01	0.96	17	None
	AS	0.14	0.64	14	Weak	-0.44	0.38	6	Medium
C3RI	SBC	-0.06	0.84	13	None	0.27	0.24	20	Weak
	SBL	0.15	0.52	21	Weak	-0.12	0.67	16	Weak
	AS			12		-0.21	0.69	6	Weak

Appendix C-11 Correlation between osteophyte score and facet angle

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C4LS	SBC	-0.37	0.22	13	Medium	0.23	0.33	21	Weak
	SBL	-0.04	0.85	23	None	0.02	0.94	16	None
	AS	0.47	0.12	12	Medium			6	
C4RS	SBC	-0.61	0.04	12	**Strong**	-0.1	0.68	21	Weak
	SBL	-0.08	0.72	24	None	0.26	0.36	15	Weak
	AS	-0.42	0.17	12	Medium	-0.89	0.02	6	**Strong**
C4LI	SBC	-0.09	0.78	13	None	0.31	0.15	23	Medium
	SBL	-0.44	0.03	24	Medium	0.04	0.89	16	None
	AS	0.35	0.29	11	Medium	0.69	0.13	6	**Strong**
C4RI	SBC	-0.1	0.77	12	Weak	-0.05	0.81	23	None
	SBL	-0.02	0.93	24	None	-0.31	0.26	15	Medium
	AS	0.5	0.12	11	**Strong**	0.67	0.15	6	**Strong**
C5LS	SBC	-0.07	0.77	20	None	0.31	0.11	27	Medium
	SBL	-0.26	0.22	24	Weak	-0.09	0.72	20	None
	AS	0.23	0.58	8	Weak	-0.71	0.18	5	**Strong**
C5RS	SBC	-0.15	0.52	20	Weak	-0.13	0.51	27	Weak
	SBL	0.11	0.59	25	Weak	0.03	0.91	17	None
	AS	0.25	0.55	8	Weak	-0.71	0.18	5	**Strong**
C5LI	SBC	0.05	0.82	20	None	-0.12	0.56	27	Weak
	SBL	-0.13	0.54	24	Weak	0.1	0.68	20	Weak
	AS	-0.08	0.85	8	None			5	
C5RI	SBC	-0.18	0.44	20	Weak	-0.08	0.68	27	None
	SBL	0.22	0.29	24	Weak	0.06	0.8	20	None
	AS	0.25	0.55	8	Weak	-0.71	0.18	5	**Strong**
C6LS	SBC	0.26	0.28	19	Weak	-0.14	0.52	25	Weak
	SBL	0.12	0.58	23	Weak	0.11	0.66	19	Weak
	AS	-0.55	0.13	9	**Strong**			7	
C6RS	SBC	-0.21	0.4	19	Weak	-0.04	0.86	26	None
	SBL	0.52	0.01	22	**Strong**	0.12	0.63	19	Weak
	AS	0	1	9	None	-0.27	0.56	7	Weak
C6LI	SBC	-0.18	0.46	19	Weak	0.24	0.25	25	Weak
	SBL	-0.27	0.19	26	Weak	-0.25	0.31	19	Weak
	AS	0	1	9	None	0.41	0.36	7	Medium
C6RI	SBC	-0.1	0.68	19	Weak	0.05	0.81	26	None
	SBL	-0.16	0.47	22	Weak	-0.28	0.24	19	Weak
	AS			9		-0.1	0.83	7	Weak
C7LS	SBC	-0.06	0.81	19	None	-0.02	0.91	29	None
	SBL	-0.31	0.12	26	Medium	-0.21	0.37	20	Weak
	AS	-0.06	0.87	10	None	0.87	0.06	5	**Strong**

Appendix C-11 Correlation between osteophyte score and facet angle

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C7RS	SBC	-0.39	0.1	19	Medium	0.03	0.87	28	None
	SBL	0.45	0.03	25	Medium	-0.41	0.06	22	Medium
	AS			10		-0.71	0.18	5	**Strong**
C7LI	SBC	0.3	0.23	18	Medium	-0.07	0.73	29	None
	SBL	-0.1	0.62	27	Weak	-0.35	0.12	22	Medium
	AS	0.46	0.19	10	Medium	-0.71	0.18	5	**Strong**
C7RI	SBC	-0.21	0.41	18	Weak	0.17	0.39	29	Weak
	SBL	-0.02	0.91	27	None	0.22	0.32	22	Weak
	AS	0.52	0.12	10	**Strong**	0.71	0.18	5	**Strong**
T1LS	SBC	0.4	0.11	17	Medium	0.2	0.29	30	Weak
	SBL	0.15	0.45	29	Weak	-0.3	0.2	20	Weak
	AS	0.02	0.94	14	None	0.17	0.67	9	Weak
T1RS	SBC	-0.1	0.69	19	Weak	0.07	0.7	31	None
	SBL	0.05	0.79	29	None	-0.3	0.18	21	Medium
	AS	0.26	0.4	13	Weak	0.23	0.53	10	Weak
T1LI	SBC			20		-0.02	0.91	31	None
	SBL	-0.06	0.75	30	None	0.02	0.92	22	None
	AS			13		-0.23	0.53	10	Weak
T1RI	SBC			20		0.16	0.39	31	Weak
	SBL	0.24	0.21	30	Weak	-0.1	0.66	21	Weak
	AS	-0.46	0.11	13	Medium	0.06	0.87	10	None
T2LS	SBC	0.04	0.83	29	None	-0.44	0.07	18	Medium
	SBL	0.04	0.83	29	None	-0.44	0.07	18	Medium
	AS	0.13	0.69	12	Weak	0.16	0.6	13	Weak
T2RS	SBC	-0.1	0.58	34	None	0.41	0.08	19	Medium
	SBL	-0.1	0.58	34	None	0.41	0.08	19	Medium
	AS	0.18	0.58	12	Weak	-0.74	0	13	**Strong**
T2LI	SBC	-0.13	0.56	23	Weak	0.11	0.57	29	Weak
	SBL	-0.03	0.85	33	None	0.11	0.65	19	Weak
	AS	0.18	0.59	12	Weak	-0.31	0.3	13	Medium
T2RI	SBC	-0.04	0.86	23	None	0.19	0.34	29	Weak
	SBL	0.02	0.92	32	None	-0.15	0.52	20	Weak
	AS	0.27	0.41	12	Weak	-0.35	0.24	13	Medium
T3LS	SBC	-0.02	0.92	21	None	0.13	0.53	27	Weak
	SBL	0.07	0.73	24	None	0.06	0.8	20	None
	AS	0.04	0.88	14	None	-0.43	0.12	14	Medium
T3RS	SBC	0.09	0.7	22	None	0.17	0.41	27	Weak
	SBL	0.15	0.46	26	Weak	0.28	0.24	20	Weak
	AS			15		-0.02	0.96	14	None

Appendix C-11 Correlation between osteophyte score and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T3LI	SBC	-0.32	0.14	22	Medium	-0.08	0.7	27	None
	SBL	-0.14	0.5	24	Weak	0.1	0.67	21	Weak
	AS	-0.02	0.95	14	None	0.12	0.69	13	Weak
T3RI	SBC	-0.29	0.2	22	Weak	-0.01	0.98	26	None
	SBL	-0.18	0.38	25	Weak	0.17	0.47	21	Weak
	AS	0.06	0.83	15	None	-0.29	0.34	13	Weak
T4LS	SBC	0.08	0.74	19	None	-0.1	0.65	25	Weak
	SBL	-0.01	0.95	26	None	0.05	0.85	18	None
	AS	-0.09	0.78	13	None	0.14	0.65	13	Weak
T4RS	SBC	0.05	0.83	19	None	0.08	0.73	24	None
	SBL	0.1	0.65	24	None	0.13	0.61	18	Weak
	AS			13		-0.3	0.32	13	Medium
T4LI	SBC	-0.09	0.71	19	None	0.23	0.27	24	Weak
	SBL	0.03	0.88	24	None	0.49	0.05	16	**Strong**
	AS			13				12	
T4RI	SBC	-0.61	0.01	19	**Strong**	0.16	0.47	24	Weak
	SBL	0.5	0.05	16	**Strong**	0.45	0.14	12	Medium
	AS			13		0.22	0.49	12	Weak
T5LS	SBC	-0.35	0.14	19	Medium	0.06	0.8	25	None
	SBL	0.29	0.19	22	Weak	-0.05	0.83	19	None
	AS	0.1	0.73	14	Weak	0.06	0.86	10	None
T5RS	SBC	-0.11	0.66	19	Weak	0.56	0	25	**Strong**
	SBL	0.4	0.07	21	Medium	-0.12	0.63	19	Weak
	AS	-0.14	0.63	14	Weak	0.28	0.43	10	Weak
T5LI	SBC	-0.26	0.32	17	Weak	0.03	0.9	22	None
	SBL	-0.04	0.86	20	None	0.3	0.19	20	Medium
	AS			9		0.06	0.87	10	None
T5RI	SBC	-0.03	0.9	18	None	0.22	0.32	22	Weak
	SBL	0.01	0.98	23	None	-0.07	0.78	20	None
	AS	-0.55	0.13	9	Strong	0.48	0.16	10	Medium
T6LS	SBC	0.17	0.51	17	Weak	0.35	0.09	25	Medium
	SBL	-0.1	0.63	25	Weak	-0.18	0.47	19	Weak
	AS	0.62	0.03	12	Strong	-0.46	0.18	10	Medium
T6RS	SBC	-0.16	0.55	17	Weak	-0.26	0.2	25	Weak
	SBL	0.09	0.67	25	None	-0.14	0.57	19	Weak
	AS	0.4	0.2	12	Medium	-0.24	0.5	10	Weak
T6LI	SBC			19		-0.11	0.6	26	Weak
	SBL	0.05	0.84	22	None	0.18	0.44	20	Weak
	AS			10		-0.81	0	10	**Strong**

Appendix C-11 Correlation between osteophyte score and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T6RI	SBC	0.08	0.75	19	Medium	0.02	0.93	27	None
	SBL	-0.11	0.61	23	Weak	-0.2	0.43	17	Weak
	AS			10		0.22	0.54	10	Weak
T7LS	SBC	-0.2	0.39	20	Weak	0.3	0.12	28	Medium
	SBL	0.04	0.85	25	None	0.25	0.33	18	Weak
	AS	-0.21	0.51	12	Weak	-0.44	0.15	12	Medium
T7RS	SBC	-0.13	0.58	20	Weak	0.09	0.68	26	None
	SBL	-0.12	0.59	24	Weak	-0.17	0.52	16	Weak
	AS	0.48	0.11	12	Medium	-0.09	0.78	12	None
T7LI	SBC			18		-0.03	0.89	27	None
	SBL	-0.04	0.87	22	None	-0.2	0.43	17	Weak
	AS	0.41	0.24	10	Medium	-0.1	0.77	11	Weak
T7RI	SBC			19		0.15	0.45	27	Weak
	SBL	-0.11	0.61	23	Weak	-0.2	0.43	17	Weak
	AS			10		0.04	0.89	12	None
T8LS	SBC	-0.03	0.9	21	None	-0.08	0.72	24	None
	SBL	0.04	0.85	25	None	0.25	0.33	18	Weak
	AS	0.18	0.58	12	Weak	-0.06	0.85	12	None
T8RS	SBC	-0.14	0.55	21	Weak	0.14	0.52	24	Weak
	SBL	-0.16	0.45	25	Weak	0.16	0.52	18	Weak
	AS	-0.06	0.86	12	None	0.07	0.83	12	None
T8LI	SBC	-0.08	0.75	21	None	-0.27	0.2	24	Weak
	SBL	-0.12	0.56	25	Weak			16	
	AS			12		-0.22	0.49	12	Weak
T8RI	SBC	-0.08	0.74	22	None	0.23	0.27	24	Weak
	SBL	0.15	0.49	25	Weak	0.36	0.16	17	Medium
	AS	0.48	0.11	12	Medium	0.22	0.49	12	Weak
T9LS	SBC	0.05	0.83	21	None	0.02	0.93	29	None
	SBL	0.29	0.16	26	Weak	-0.09	0.74	17	None
	AS	0.33	0.25	14	Medium	-0.17	0.61	11	Weak
T9RS	SBC	-0.19	0.41	21	Weak	0.12	0.52	29	Weak
	SBL	0.55	0	26	**Strong**			17	
	AS	-0.07	0.83	13	None	0.02	0.94	11	None
T9LI	SBC			19		-0.34	0.07	29	Medium
	SBL	-0.08	0.72	25	None			17	
	AS	0.21	0.48	14	Weak	-0.53	0.11	10	**Strong**
T9RI	SBC	0.26	0.28	19	Weak	0.15	0.45	28	Weak
	SBL	-0.22	0.32	22	Weak			17	
	AS			14		0.12	0.73	11	Weak

Appendix C-11 Correlation between osteophyte score and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T10LS	SBC	-0.21	0.37	20	Weak	-0.2	0.3	28	Weak
	SBL	0.1	0.65	25	None	0.36	0.17	16	Medium
	AS	0.08	0.78	14	None	0.56	0.07	11	**Strong**
T10RS	SBC	-0.07	0.77	20	None	-0.21	0.28	28	Weak
	SBL	0.26	0.21	26	Weak			16	
	AS	0.21	0.48	13	Weak	0.4	0.23	11	Medium
T10LI	SBC	0.09	0.72	19	None	-0.09	0.65	27	None
	SBL	0.07	0.74	26	None			16	
	AS	0.4	0.18	13	Medium	-0.32	0.37	10	Medium
T10RI	SBC	0.62	0	19	**Strong**	-0.26	0.18	27	Weak
	SBL	-0.28	0.17	26	Weak			15	
	AS	-0.35	0.24	13	Medium	-0.56	0.09	10	**Strong**
T11LS	SBC	0.4	0.09	20	Medium	0.18	0.36	29	Weak
	SBL	-0.04	0.85	23	None	0.15	0.13	16	Weak
	AS	-0.26	0.38	14	Weak	0.05	0.89	11	None
T11RS	SBC	-0.06	0.8	21	None	-0.02	0.92	29	None
	SBL	-0.01	0.96	24	None	-0.29	0.28	16	Weak
	AS	-0.04	0.89	14	None	-0.56	0.07	11	**Strong**
T11LI	SBC	-0.01	0.95	20	None	-0.2	0.31	28	Weak
	SBL	0	0.99	23	None	0.12	0.66	15	Weak
	AS	0.23	0.45	13	Weak	0.26	0.44	11	Weak
T11RI	SBC	0.2	0.41	20	Weak	-0.23	0.25	28	Weak
	SBL	0.01	0.98	24	None	0.42	0.11	16	Medium
	AS			13		0.04	0.9	11	None
T12LS	SBC	-0.27	0.27	18	Weak	-0.06	0.77	25	None
	SBL	-0.06	0.8	22	None	-0.39	0.14	16	Medium
	AS	0.45	0.13	13	Medium	0.32	0.34	11	Medium
T12RS	SBC	0.65	0	18	**Strong**	-0.43	0.03	25	Medium
	SBL	-0.04	0.86	22	None	0.2	0.47	16	Weak
	AS	0.28	0.36	13	Weak	0.22	0.52	11	Weak
T12LI	SBC	0.23	0.35	19	Weak	0.1	0.64	26	Weak
	SBL	0.16	0.49	22	Weak	0.23	16	-	Weak
	AS	0.06	0.87	12	None	0.24	0.51	10	Weak
T12RI	SBC	0.34	0.17	18	Medium	-0.02	0.93	26	None
	SBL	0.32	0.15	22	Medium	-0.04	0.88	16	None
	AS			12		0.5	0.12	11	**Strong**
L1LS	SBC	0.15	0.53	19	Weak	0.19	0.37	25	Weak
	SBL	0.4	0.07	22	Medium	-0.31	0.31	13	Medium
	AS	-0.43	0.12	14	Medium	-0.27	0.38	13	Weak

Appendix C-11 Correlation between osteophyte score and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
L1RS	SBC	0.59	0.01	18	**Strong**	-0.01	0.97	24	None
	SBL	-0.13	0.56	24	Weak	0.05	0.88	12	None
	AS	-0.36	0.25	12	Medium	0.17	0.55	14	Weak
L1LI	SBC	-0.25	0.3	19	Weak	-0.17	0.44	24	Weak
	SBL	0.09	0.69	25	None	0.08	0.8	13	None
	AS			13		-0.27	0.33	15	Weak
L1RI	SBC	-0.24	0.32	19	Weak	-0.4	0.05	24	Medium
	SBL	-0.09	0.68	24	None	-0.4	0.2	12	Medium
	AS	0.27	0.35	14	Weak	0.15	0.6	14	Weak
L2LS	SBC	0.01	0.96	21	None	-0.11	0.59	27	Weak
	SBL	0.36	0.1	22	Medium	0.31	0.3	13	Medium
	AS	0.07	0.8	15	None	-0.3	0.35	12	Medium
L2RS	SBC	0.27	0.23	21	Weak	-0.41	0.04	26	Medium
	SBL	0.09	0.7	23	None	0.1	0.77	11	Weak
	AS	-0.13	0.65	14	Weak	-0.22	0.49	12	Weak
L2LI	SBC	0.53	0.01	21	**Strong**	-0.45	0.02	26	Medium
	SBL	0.44	0.03	24	Medium	0.56	0.06	12	**Strong**
	AS	0.04	0.9	14	None	-0.13	0.72	10	Weak
L2RI	SBC	-0.01	0.97	20	None	-0.33	0.1	26	Medium
	SBL	-0.04	0.86	24	None	0.38	0.22	12	Medium
	AS	0.07	0.81	14	None	0.51	0.11	11	**Strong**
L3LS	SBC	-0.19	0.42	20	Weak	-0.05	0.79	27	None
	SBL	0.2	0.4	20	Weak	-0.4	0.18	13	Medium
	AS	-0.16	0.55	16	Weak	-0.13	0.66	14	Weak
L3RS	SBC	0.32	0.17	20	Medium	-0.01	0.98	26	None
	SBL	-0.05	0.86	18	None	-0.29	0.35	13	Weak
	AS	0.21	0.45	16	Weak	-0.18	0.54	14	Weak
L3LI	SBC	0.47	0.03	21	Medium	-0.05	0.79	28	None
	SBL	-0.14	0.56	20	Weak	0.3	0.27	15	Medium
	AS	-0.42	0.09	17	Medium	0.22	0.45	14	Weak
L3RI	SBC	0.28	0.23	21	Weak	-0.04	0.83	26	None
	SBL	0.04	0.89	16	None	-0.4	0.2	12	Medium
	AS	-0.39	0.16	15	Medium	-0.46	0.16	11	Medium
L4LS	SBC	0.1	0.68	20	Weak	-0.02	0.93	25	None
	SBL	-0.07	0.78	19	None			10	
	AS	0.04	0.89	16	None	-0.4	0.2	12	Medium
L4RS	SBC	0.4	0.08	20	Weak	-0.1	0.63	25	Weak
	SBL	0.35	0.13	20	Medium	0.14	0.73	9	Weak
	AS	0.04	0.89	16	None	-0.4	0.2	12	Medium

Appendix C-11 Correlation between osteophyte score and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
L4LI	SBC	0.28	0.22	20	Weak	0.18	0.39	25	Weak
	SBL	0.07	0.78	18	None	0.61	0.06	10	**Strong**
	AS	0.1	0.73	15	Weak	0.01	0.97	11	None
L4RI	SBC	0.22	0.34	20	Weak	0.25	0.23	26	Weak
	SBL	0.03	0.89	20	None	-0.52	0.12	10	**Strong**
	AS	0.14	0.65	13	Weak	0.3	0.4	10	Medium
L5LS	SBC	0.02	0.94	18	None	0.38	0.09	21	Medium
	SBL	0.02	0.93	24	None	-0.54	0.06	13	**Strong**
	AS	0.24	0.48	11	Weak	0.01	0.97	10	None
L5RS	SBC	0.47	0.05	18	Medium	-0.39	0.08	21	Medium
	SBL	-0.19	0.42	21	Weak	-0.17	0.58	13	Weak
	AS	-0.46	0.15	11	Medium	-0.67	0.04	10	**Strong**
L5LI	SBC	-0.25	0.33	18	Weak	-0.11	0.64	21	Weak
	SBL	-0.04	0.84	24	None	-0.17	0.59	13	Weak
	AS	0.25	0.48	10	Weak	-0.18	0.64	9	Weak
L5RI	SBC	0.13	0.61	18	Weak	0.17	0.46	21	Weak
	SBL	0.14	0.54	22	Weak	-0.39	0.19	13	Medium
	AS	-0.06	0.87	11	None	-0.15	0.71	9	Weak

Appendix C-12 Correlation between vertebral osteophytosis and facet angle

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C1LS	SBC								
	SBL								
	AS								
C1RS	SBC								
	SBL								
	AS								
C1LI	SBC								
	SBL								
	AS								
C1RI	SBC								
	SBL								
	AS								
C2LS	SBC	-0.076	0.731	23	None	0.155	0.375	35	Weak
	SBL	0.399	**0.032**	29	Medium	-0.176	0.459	20	Weak
	AS			9				6	
C2RS	SBC	-0.146	0.505	23	Weak	0.173	0.321	35	Weak
	SBL	-0.028	0.885	29	None	-0.173	0.466	20	Weak
	AS			9				6	
C2LI	SBC	-0.373	0.088	22	Medium	0.007	0.968	35	None
	SBL	0.028	0.887	29	None	0.403	0.078	20	Medium
	AS			9				6	
C2RI	SBC	-0.271	0.211	23	Weak	0.081	0.643	35	None
	SBL	-0.303	0.117	28	Medium	0.29	0.214	20	Weak
	AS			9				5	
C3LS	SBC	-0.011	0.966	19	None	-0.095	0.605	32	None
	SBL	-0.185	0.347	28	Weak	-0.151	0.513	21	Weak
	AS	0.194	0.591	10	Weak			5	
C3RS	SBC	0.115	0.629	20	Weak	0.03	0.869	32	None
	SBL	0.002	0.993	27	None	0.066	0.782	20	None
	AS	-0.055	0.88	10	Weak			5	
C3LI	SBC	0.049	0.839	20	None	-0.056	0.766	31	None
	SBL	0.08	0.684	28	None	0.228	0.319	21	Weak
	AS	-0.225	0.531	10	Weak			5	
C3RI	SBC	-0.139	0.56	20	Weak	0.217	0.241	31	Weak
	SBL	-0.096	0.628	28	None	0.24	0.308	20	Weak
	AS	-0.375	0.325	9	Medium			5	

Appendix C-12 Correlation between vertebral osteophytosis and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C4LS	SBC	0.03	0.903	19	None	0.211	0.28	28	Weak
	SBL	-0.148	0.445	29	Weak	-0.025	0.911	22	None
	AS			10				7	
C4RS	SBC	0.214	0.366	20	Weak	-0.022	0.91	28	None
	SBL	-0.032	0.868	29	None	0.007	0.975	22	None
	AS			10				7	
C4LI	SBC	-0.259	0.271	20	Weak	-0.172	0.372	29	Weak
	SBL	0.075	0.699	29	None	0.052	0.813	23	None
	AS			10				7	
C4RI	SBC	-0.212	0.369	20	Weak	-0.031	0.874	29	None
	SBL	0.019	0.923	28	None	0.148	0.511	22	Weak
	AS			10				7	
C5LS	SBC	-0.127	0.562	23	Weak	0.052	0.771	34	None
	SBL	-0.126	0.507	30	Weak	0.055	0.797	24	None
	AS	-0.127	0.727	10	Weak			8	
C5RS	SBC	-0.263	0.215	24	Weak	-0.094	0.598	34	None
	SBL	-0.087	0.654	29	None	0.131	0.541	24	Weak
	AS	0.265	0.46	10	Weak			8	
C5LI	SBC	0.036	0.866	24	None	-0.195	0.268	34	Weak
	SBL	0.125	0.518	29	Weak	0.067	0.756	24	None
	AS	0.58	0.079	10	**Strong**			8	
C5RI	SBC	-0.514	**0.01**	24	**Strong**	0.039	0.827	34	None
	SBL	0.134	0.506	27	Weak	-0.122	0.569	24	Weak
	AS	0.628	0.052	10	**Strong**			8	
C6LS	SBC	0.149	0.531	20	Weak	-0.09	0.601	36	None
	SBL	-0.181	0.347	29	Weak	-0.059	0.789	23	None
	AS	0.4	0.222	11	Medium			7	
C6RS	SBC	-0.525	**0.017**	20	**Strong**	-0.101	0.558	36	Weak
	SBL	-0.316	0.083	31	Medium	-0.028	0.895	24	None
	AS	-0.196	0.563	11	Weak			7	
C6LI	SBC	-0.165	0.488	20	Weak	0.032	0.852	36	None
	SBL	0.003	0.988	31	None	-0.082	0.71	23	None
	AS	0.374	0.257	11	Medium			7	
C6RI	SBC	-0.355	0.125	20	Medium	0.023	0.893	36	None
	SBL	-0.027	0.888	30	None	-0.153	0.475	24	Weak
	AS	0.436	0.18	11	Medium			7	
C7LS	SBC	-0.233	0.273	24	Weak	-0.128	0.45	37	Weak
	SBL	-0.245	0.176	32	Weak	-0.009	0.968	23	None
	AS	0.673	**0.033**	10	**Strong**			5	

Appendix C-12 Correlation between vertebral osteophytosis and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
C7RS	SBC	0.061	0.776	24	None	0.049	0.777	36	None
	SBL	0.025	0.893	32	None	0.24	0.271	23	Weak
	AS	0.469	0.172	10	Medium			5	
C7LI	SBC	0.028	0.897	24	None	0.046	0.785	37	None
	SBL	-0.14	0.443	32	None	0.3	0.164	23	Medium
	AS	-0.425	0.192	11	Medium			5	
C7RI	SBC	0.034	0.876	24	None	-0.027	0.876	37	None
	SBL	0.023	0.9	32	None	0.378	0.075	23	Medium
	AS	-0.003	0.993	11	None			5	
T1LS	SBC	0.007	0.76	18	None	0.347	**0.035**	37	Medium
	SBL	-0.036	0.842	34	None	0.226	0.312	22	Weak
	AS	-0.736	0.095	6	**Strong**			6	
T1RS	SBC	0.003	0.99	21	None	0.049	0.771	38	None
	SBL	-0.285	0.102	34	Weak	-0.076	0.736	22	None
	AS	0.457	0.217	9	Medium			7	
T1LI	SBC	-0.24	0.294	21	Weak	0.054	0.474	38	None
	SBL	0.096	0.585	35	None	-0.137	0.543	22	Weak
	AS	-0.267	0.488	9	Weak			7	
T1RI	SBC	0.008	0.972	21	None	0.066	0.694	38	None
	SBL	0.235	0.174	35	Weak	-0.267	0.23	22	Weak
	AS	-0.447	0.227	9	Medium			7	
T2LS	SBC	-0.049	0.783	34	None	0.21	0.347	22	Weak
	SBL	-0.049	0.783	34	None	0.21	0.347	22	Weak
	AS	-0.597	0.069	10	**Strong**	-0.286	0.493	8	Weak
T2RS	SBC	-0.055	0.757	34	None	0.03	0.894	22	None
	SBL	-0.055	0.757	34	None	0.03	0.894	22	None
	AS	-0.471	0.169	10	Medium	0.224	0.593	8	Weak
T2LI	SBC	0.026	0.908	23	None	-0.185	0.273	37	Weak
	SBL	-0.109	0.541	34	None	0.077	0.733	22	None
	AS	-0.494	0.147	10	Medium	-0.608	0.11	8	**Strong**
T2RI	SBC	0.028	0.9	23	None	0.027	0.874	37	None
	SBL	-0.046	0.801	33	None	0.272	0.221	22	Weak
	AS	0.667	**0.035**	10	**Strong**	0.991	**0.001**	8	**Strong**
T3LS	SBC	0.077	0.73	22	None	0.073	0.664	38	None
	SBL	-0.408	**0.031**	28	Medium	0.024	0.919	20	None
	AS	0.075	0.828	11	None	0.013	0.973	9	None
T3RS	SBC	0.175	0.436	22	Weak	0.359	**0.027**	38	Medium
	SBL	0.218	0.256	29	Weak	0.018	0.941	20	None
	AS	-0.361	0.275	11	Medium	0.028	0.942	9	None

Appendix C-12 Correlation between vertebral osteophytosis and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T3LI	SBC	-0.015	0.948	22	None	-0.021	0.901	38	None
	SBL	-0.146	0.45	29	Weak	0.116	0.625	20	Weak
	AS	-0.39	0.265	10	Medium	-0.356	0.386	8	Medium
T3RI	SBC	0.05	0.826	22	None	0.002	0.99	38	None
	SBL	-0.157	0.415	29	Weak	-0.021	0.931	20	None
	AS	-0.307	0.359	11	Medium	-0.16	0.681	9	None
T4LS	SBC	0.162	0.449	24	Weak	0.027	0.874	37	None
	SBL	-0.078	0.681	30	None	-0.463	0.046	19	Medium
	AS	-0.439	0.238	9	Medium	0.133	0.733	9	Weak
T4RS	SBC	0.036	0.868	24	None	0.179	0.297	36	Weak
	SBL	-0.027	0.89	29	None	0.188	0.441	19	Weak
	AS	0.696	**0.037**	9	**Strong**	-0.374	0.321	9	Medium
T4LI	SBC	-0.095	0.659	24	None	0.029	0.868	36	None
	SBL	-0.026	0.894	29	None	-0.279	0.263	18	Weak
	AS	-0.396	0.292	9	Medium	-0.058	0.892	8	None
T4RI	SBC	-0.167	0.435	24	Weak	0.003	0.987	36	None
	SBL	0.059	0.759	30	None	-0.062	0.807	18	None
	AS	-0.257	0.504	9	Weak	-0.189	0.654	8	Weak
T5LS	SBC	0.042	0.85	23	None	0.165	0.343	35	Weak
	SBL	-0.019	0.923	28	None	0.032	0.895	19	None
	AS	-0.26	0.5	9	Weak	-0.316	0.49	7	Medium
T5RS	SBC	0.173	0.43	23	Weak	0.055	0.753	35	None
	SBL	-0.18	0.359	28	Weak	0.107	0.663	19	Weak
	AS	0.088	0.822	9	None	-0.068	0.885	7	None
T5LI	SBC	0.03	0.894	23	None	-0.179	0.304	35	Weak
	SBL	-0.095	0.645	26	None	0.3	0.212	19	Medium
	AS	0.232	0.616	7	Weak	0.206	0.657	7	Weak
T5RI	SBC	-0.031	0.89	23	None	-0.216	0.212	35	Weak
	SBL	0.26	0.182	28	Weak	0.033	0.894	19	None
	AS	-0.029	0.95	7	None	-0.546	0.205	7	**Strong**
T6LS	SBC	0.187	0.383	24	Weak	-0.17	0.338	34	Weak
	SBL	-0.08	0.667	31	None	0.069	0.765	21	None
	AS	-0.086	0.826	9	None	-0.196	0.641	8	Weak
T6RS	SBC	-0.002	0.994	24	None	0.105	0.556	34	Weak
	SBL	0.081	0.664	31	None	-0.243	0.288	21	Weak
	AS	0.186	0.632	9	Weak	0.318	0.442	8	Medium
T6LI	SBC	-0.197	0.357	24	Weak	0.158	0.358	36	Weak
	SBL	-0.267	0.162	29	Weak	-0.049	0.833	21	None
	AS	-0.515	0.237	7	**strong**	0.318	0.443	8	Medium

Appendix C-12 Correlation between vertebral osteophytosis and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T6RI	SBC	0.108	0.635	24	Weak	0.083	0.631	36	None
	SBL	0.142	0.447	31	Weak	0.126	0.596	20	Weak
	AS	-0.411	0.36	7	**None**	0.224	0.594	8	Weak
T7LS	SBC	0.042	0.839	26	None	-0.008	0.96	37	None
	SBL	-0.001	0.995	32	None	0.004	0.988	20	None
	AS	0.323	0.435	8	Medium	0.207	0.593	9	Weak
T7RS	SBC	-0.016	0.936	26	None	0.158	0.35	37	Weak
	SBL	0.091	0.627	31	None	-0.056	0.813	20	None
	AS	-0.027	0.949	8	None	0.223	0.565	9	Weak
T7LI	SBC	0.463	**0.019**	25	Medium	0.038	0.825	37	None
	SBL	-0.111	0.558	30	Weak	-0.074	0.756	20	None
	AS	-0.092	0.828	8	None	-0.233	0.579	8	None
T7RI	SBC	0.269	0.193	25	Weak	0.178	0.291	37	Weak
	SBL	0.142	0.447	31	Weak	0.126	0.596	20	Weak
	AS	-0.321	0.439	8	Medium	0.032	0.935	9	None
T8LS	SBC	0.188	0.379	24	Weak	-0.122	0.485	35	Weak
	SBL	-0.001	0.995	32	None	0.004	0.988	20	None
	AS	0.444	0.27	8	Medium	0.598	0.089	9	**Strong**
T8RS	SBC	-0.161	0.453	24	Weak	-0.018	0.917	35	None
	SBL	0.06	0.743	32	None	-0.042	0.861	20	None
	AS	0.242	0.563	8	Weak	0.252	0.513	9	Weak
T8LI	SBC	-0.402	**0.046**	25	Medium	-0.203	0.243	35	Weak
	SBL	-0.142	0.437	32	Weak	0.085	0.739	18	None
	AS	-0.313	0.45	8	Medium	0.492	0.179	9	Medium
T8RI	SBC	-0.084	0.69	25	None	-0.072	0.681	35	None
	SBL	0.155	0.397	32	Weak	-0.294	0.221	19	Weak
	AS	0.088	0.836	8	None	0.744	**0.022**	9	**Strong**
T9LS	SBC	-0.009	0.966	26	None	0.037	0.826	38	None
	SBL	-0.106	0.57	31	Weak	0.123	0.605	20	Weak
	AS	-0.259	0.47	10	Medium	0.391	0.298	9	Medium
T9RS	SBC	0.122	0.552	26	Weak	0.179	0.282	38	Weak
	SBL	-0.165	0.374	31	Weak	0.016	0.945	20	None
	AS	0.022	0.951	10	None	0.264	0.493	9	Weak
T9LI	SBC	-0.028	0.869	25	None	-0.054	0.75	38	None
	SBL	0.032	0.865	31	None	-0.034	0.885	20	None
	AS	-0.508	0.134	10	**Strong**	0.519	0.152	9	**Strong**
T9RI	SBC	-0.088	0.675	25	None	0.006	0.971	38	None
	SBL	0.422	**0.02**	30	Medium	-0.238	0.312	20	Weak
	AS	0.005	0.989	10	None	0.421	0.259	9	Medium

Appendix C-12 Correlation between vertebral osteophytosis and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
T10LS	SBC	-0.013	0.949	25	None	0.087	0.603	38	None
	SBL	-0.231	0.219	30	Weak	0.242	0.304	20	Weak
	AS	-0.544	0.104	10	**Strong**	0.184	0.653	9	Weak
T10RS	SBC	0.026	0.902	25	None	0.023	0.889	38	None
	SBL	0.229	0.214	31	Weak	0.231	0.324	20	Weak
	AS	-0.386	0.271	10	**None**	0.414	0.268	9	Medium
T10LI	SBC	-0.015	0.941	26	None	-0.058	0.728	38	None
	SBL	0.623	**0.001**	30	**Strong**	-0.275	0.24	20	Weak
	AS	0.481	0.159	10	Medium	-0.1	0.798	9	Weak
T10RI	SBC	-0.023	0.913	26	None	0.167	0.317	38	Weak
	SBL	-0.406	0.026	30	Medium	-0.19	0.423	20	Weak
	AS	-0.029	0.936	10	None	0.124	0.75	9	Weak
T11LS	SBC	0.165	0.421	26	Weak	0.09	0.59	38	None
	SBL	-0.174	0.366	29	Weak	0.201	0.382	21	Weak
	AS	0.32	0.401	9	Medium	0.013	0.973	9	None
T11RS	SBC	0.103	0.618	26	Weak	0.074	0.658	38	None
	SBL	-0.094	0.626	29	None	-0.142	0.538	21	Weak
	AS	0.014	0.972	9	None	0.455	0.219	9	Medium
T11LI	SBC	0.132	0.528	25	Weak	-0.045	0.791	38	None
	SBL	0.1	0.614	28	Weak	0.234	0.308	21	Weak
	AS	-0.078	0.842	9	None	0.14	0.719	9	Weak
T11RI	SBC	0.066	0.753	25	None	0.012	0.943	38	None
	SBL	0.164	0.396	29	Weak	0.301	0.185	21	Medium
	AS	0.382	0.31	9	Medium	0.113	0.772	9	Weak
T12LS	SBC	0.166	0.437	24	Weak	0.149	0.393	35	Weak
	SBL	0.091	0.646	28	None	0.09	0.697	21	None
	AS	0.084	0.83	9	None	-0.532	0.14	9	**Strong**
T12RS	SBC	-0.003	0.989	24	None	0.143	0.413	35	Weak
	SBL	0.238	0.222	28	Weak	0.147	0.526	21	Weak
	AS	0.324	0.395	9	Medium	-0.366	0.333	9	Medium
T12LI	SBC	-0.047	0.822	25	None	-0.017	0.924	35	None
	SBL	-0.057	0.769	29	None	-0.149	0.52	21	Weak
	AS	0.18	0.644	9	Weak	0.036	0.932	8	None
T12RI	SBC	0.306	0.137	25	Medium	-0.087	0.62	35	None
	SBL	0.003	0.989	29	None	-0.122	0.598	21	Weak
	AS	0.272	0.479	9	Weak	-0.146	0.708	9	Weak
L1LS	SBC	0.249	0.23	25	Weak	-0.018	0.92	35	None
	SBL	0.02	0.918	29	None	-0.199	0.401	20	Weak
	AS	0.422	0.224	10	Medium	-0.017	0.968	8	None

Appendix C-12 Correlation between vertebral osteophytosis and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
L1RS	SBC	-0.066	0.753	25	None	-0.085	0.628	35	None
	SBL	0.161	0.412	28	Weak	-0.152	0.523	20	Weak
	AS	0.472	0.2	9	Medium	0.191	0.651	8	Weak
L1LI	SBC	-0.011	0.958	25	None	0.194	0.265	35	Weak
	SBL	0.282	0.138	29	Weak	0.001	0.998	20	None
	AS	0.591	0.072	10	**Strong**	0.573	0.107	9	**Strong**
L1RI	SBC	0.302	0.142	25	Medium	0.037	0.835	34	None
	SBL	-0.061	0.757	28	None	0.067	0.779	20	None
	AS	0.683	**0.029**	10	**Strong**	0.291	0.447	9	Weak
L2LS	SBC	0.342	0.088	26	Medium	-0.037	0.828	36	None
	SBL	0.128	0.499	30	Weak	-0.227	0.336	20	Weak
	AS	-0.236	0.512	10	None	-0.062	0.884	8	None
L2RS	SBC	0.025	0.903	26	None	0.026	0.881	36	None
	SBL	0.466	**0.012**	28	Medium	-0.383	0.105	19	Medium
	AS	0.075	0.836	10	None	-0.069	0.871	8	None
L2LI	SBC	0.364	0.067	26	Medium	0.118	0.493	36	Weak
	SBL	-0.084	0.659	30	None	-0.507	**0.027**	19	**Strong**
	AS	0.047	0.904	9	None	0.307	0.503	7	Medium
L2RI	SBC	0.286	0.157	26	Weak	0.206	0.229	36	Weak
	SBL	0.279	0.135	30	Weak	-0.483	**0.036**	19	Medium
	AS	0.283	0.461	9	Weak	0.032	0.945	7	None
L3LS	SBC	0.439	**0.036**	23	Medium	0.019	0.918	33	None
	SBL	0.341	0.112	25	Medium	-0.409	0.131	15	Medium
	AS	0.725	**0.042**	8	**Strong**	0.567	0.111	9	**Strong**
L3RS	SBC	0.369	0.083	23	Medium	-0.075	0.678	33	None
	SBL	0.502	**0.015**	23	**Strong**	-0.599	**0.018**	15	**Strong**
	AS	0.254	0.543	8	Weak	0.262	0.496	9	Weak
L3LI	SBC	0.132	0.549	23	Weak	-0.066	0.713	33	None
	SBL	0.395	0.062	23	Medium	-0.452	0.079	16	Medium
	AS	-0.207	0.623	8	Weak	-0.011	0.978	9	None
L3RI	SBC	-0.067	0.76	23	None	-0.029	0.871	33	None
	SBL	0.025	0.938	12	None	-0.502	0.169	9	**Strong**
	AS	0.001	0.999	8	None	0.411	0.272	9	Medium
L4LS	SBC	0.157	0.443	26	Weak	0.16	0.344	37	Weak
	SBL	0.379	0.402	7	Medium			4	
	AS	0.025	0.938	12	None	-0.502	0.169	9	**Strong**
L4RS	SBC	0.103	0.615	26	Weak	-0.021	0.901	37	None
	SBL	0.068	0.885	7	None			3	
	AS	0.025	0.938	12	None	-0.502	0.169	9	**Strong**

Appendix C-12 Correlation between vertebral osteophytosis and facet angle continued

Facet	Sample	Male				Female			
		Correlation Coefficient	p	N	Strength of Correlation	Correlation Coefficient	p	N	Strength of Correlation
L4LI	SBC	0.14	0.497	26	Weak	0.154	0.362	37	Weak
	SBL	0.636	0.125	7	**Strong**			4	
	AS	0.578	**0.049**	12	**Strong**	0.299	0.434	9	Weak
L4RI	SBC	0.076	0.714	26	None	0.149	0.38	37	Weak
	SBL	0.348	0.444	7	Medium			4	
	AS	0.394	0.231	11	Medium	0.539	0.168	8	**Strong**
L5LS	SBC	0.482	0.017	24	Medium	-0.015	0.934	33	None
	SBL	0.281	0.139	29	Weak	0.388	0.101	19	Medium
	AS	0.771	**0.015**	9	**Strong**	-0.11	0.796	8	None
L5RS	SBC	-0.024	0.911	24	None	-0.093	0.595	33	None
	SBL	0.178	0.374	27	Weak	0.446	0.056	19	Medium
	AS	0.5	0.17	9	**Strong**	0.09	0.832	8	None
L5LI	SBC	-0.077	0.722	24	None	0.002	0.99	33	None
	SBL	0.343	0.068	29	Medium	-0.225	0.354	19	Weak
	AS	-0.118	0.762	9	None	0.071	0.868	8	None
L5RI	SBC	-0.002	0.991	24	None	-0.1	0.581	33	Weak
	SBL	0.254	0.192	28	Weak	0.053	0.829	19	None
	AS	0.051	0.895	9	None	0.31	0.499	7	Medium

Appendix D. True prevalence rates

Appendix D-1 True prevalence rates for eburnation, pitting, osteophytes and vertebral osteophytosis

481-508	Sex	True Eburnation	True Pitting	True Osteophytes	True Vertebral Osteophytosis
GC1	F	42.42	52.78	55.56	85.71
GC9	F	54.35	80.43	29.35	0.00
GC14	F	55.43	89.01	55.43	39.13
GC32	F	74.16	95.12	21.35	0.00
GC37	F	42.59	93.65	46.30	69.23
GC81	F	100.00	88.14	26.79	53.85
GC92	F	65.63	79.17	51.04	63.64
GC100	F	44.21	77.66	13.68	0.00
GC103	F	20.43	46.97	25.53	36.36
GC152	F	31.43	60.98	26.47	55.56
B250	F	55.56	88.57	32.14	0.00
B288	F	29.49	86.79	19.48	0.00
B309	F	0.00	79.75	18.64	0.00
B420	F	7.35	78.43	17.65	0.00
A56	F	30.43	86.96	13.04	0.00
A64	F	0.00	52.00	33.33	0.00
A447	F	1.92	70.18	17.24	0.00
A765	F	0.00	27.08	0.00	0.00
A780	F	0.00	57.14	3.70	0.00
A640	F	0.00	44.44	10.00	0.00
A270	F	0.00	10.00	28.26	0.00
SBC8	F	25.00	3.80	7.14	0.00
SBC10	F	27.08	15.63	28.72	0.00
SBC13	F	50.00	37.50	28.13	0.00
SBC17	F	11.96	44.57	38.04	31.82
SCB29	F	7.29	16.67	26.04	56.52
SBC33	F	27.08	13.54	28.13	39.13
SBC43	F	0.00	0.00	4.55	0.00
SBC44	F	4.17	2.94	2.08	0.00
SBC45	F	10.00	5.00	21.25	5.00
SBC52	F	0.00	4.55	2.27	0.00
SBC63	F	11.27	23.21	16.90	0.00
SBC66	F	10.00	15.22	21.05	47.06
SBC67	F	12.50	18.75	15.63	0.00
SBC72	F	5.26	2.78	3.95	0.00
SBC106	F	8.05	27.27	6.90	0.00
SBC117	F	2.27	22.73	3.41	0.00

Appendix D-1 True prevalence rates for eburnation, pitting, osteophytes and vertebral osteophytosis continued

ID	Sex	True Eburnation	True Pitting	True Osteophytes	True Vertebral Osteophytosis
SBC120	F	3.41	23.96	10.23	5.00
SBC122	F	2.38	10.00	3.57	0.00
SBC129	F	20.00	8.33	15.19	80.00
SBC130	F	42.39	57.95	51.14	45.45
SBC133	F	0.00	34.72	6.94	16.67
SBC144	F	7.37	31.25	7.29	0.00
SBC152	F	1.09	22.83	1.09	0.00
SBC153	F	1.09	11.96	6.52	0.00
SBC154	F	7.61	20.65	16.48	0.00
SBC101	F	29.17	20.65	26.09	27.27
SBC98	F	8.33	17.71	11.46	0.00
SBC93	F	2.78	50.00	27.78	44.44
SBC156	F	10.29	26.47	22.06	0.00
SBC113	F	3.41	14.94	8.05	0.00
SBC167	F	4.55	21.59	4.55	19.05
SBC177	F	0.00	0.00	2.08	0.00
SBC178	F	1.04	5.21	10.42	4.35
SBC182	F	21.74	30.43	30.43	0.00
SBC203	F	1.04	0.00	18.75	0.00
SBC209	F	4.05	34.67	17.11	21.05
SBC214	F	1.27	0.00	12.66	0.00
SBC215	F	0.00	6.25	17.50	5.26
SBC219	F	6.25	33.33	11.46	0.00
SBC220	F	5.95	27.38	44.05	100.00
SBC225	F	8.70	14.13	7.61	0.00
FAO901641	F	0.00	45.78	16.87	5.26
FAO901755	F	3.13	30.21	14.58	0.00
FAO901703	F	4.76	46.43	19.05	9.52
FAO901417	F	8.33	43.75	28.42	21.74
FAO901874	F	13.16	24.00	28.00	38.89
FAO901152	F	4.05	29.73	32.43	58.82
FAO901207	F	3.70	17.28	7.41	0.00
FAO901369	F	0.00	15.87	22.22	40.00
FAO901946	F	18.75	37.50	31.25	40.91
FAO901793	F	7.29	27.37	13.68	0.00
FAO901608	F	7.14	10.71	28.57	0.00
FAO901123	F	20.83	47.92	51.04	78.95
FAO901954	F	0.00	13.54	36.46	0.00
FAO901913	F	13.25	10.84	51.81	52.94
FAO901653	F	1.05	11.58	21.05	0.00
FAO901343	F	17.31	36.54	39.22	75.00

Appendix D-1 True prevalence rates for eburnation, pitting, osteophytes and vertebral osteophytosis continued

ID	Sex	True Eburnation	True Pitting	True Osteophytes	True Vertebral Osteophytosis
FAO901376	F	0.00	25.00	5.43	0.00
FAO901809	F	0.00	22.92	17.71	0.00
FAO901887	F	0.00	2.17	15.22	4.55
FAO901799	F	0.00	1.14	21.59	40.91
FAO901409	F	14.58	43.75	54.00	100.00
FAO901278	F	0.00	7.37	1.04	0.00
FAO901519	F	0.00	23.96	21.88	0.00
FAO901893	F	1.30	15.38	10.39	0.00
GC2A	M	13.68	13.83	4.21	0.00
GC5	M	79.69	85.71	62.50	18.75
GC8	M	7.50	44.78	58.33	12.50
GC22	M	94.68	97.78	29.79	26.09
GC80	M	95.00	100.00	36.25	85.00
GC84	M	19.12	95.95	11.76	18.75
GC90	M	95.74	85.42	20.21	21.74
GC117	M	50.00	66.13	10.53	11.11
GC121	M	16.30	79.55	11.96	0.00
GC149	M	18.48	56.84	3.26	0.00
B282B	M	52.83	94.29	7.55	0.00
B311	M	8.00	49.09	45.95	0.00
B338	M	0.00	83.53	30.65	0.00
B385L	M	4.26	72.92	20.21	0.00
A49	M	0.00	93.33	0.00	0.00
A43	M	0.00	83.33	0.00	0.00
A747	M	0.00	20.34	31.51	0.00
A777	M	0.00	40.00	36.36	0.00
A768	M	4.55	16.67	27.27	0.00
A591	M	0.00	57.89	12.50	0.00
A821	M	0.00	65.12	8.82	0.00
A53	M	0.00	88.16	12.96	72.22
A111	M	2.82	69.05	34.55	50.00
A315	M	0.00	0.00	30.77	0.00
A644	M	0.00	45.45	0.00	0.00
A812	M	0.00	10.81	36.36	0.00
A334	M	0.00	0.00	5.56	0.00
A783	M	0.00	34.62	10.53	0.00
A453	M	0.00	26.92	20.00	0.00
A309	M	0.00	12.00	11.11	0.00
A444	M	0.00	5.26	0.00	0.00
A481	M	0.00	17.31	3.57	0.00

Appendix D-1 True prevalence rates for eburnation, pitting, osteophytes and vertebral osteophytosis continued

ID	Sex	True Eburnation	True Pitting	True Osteophytes	True Vertebral Osteophytosis
SBC2	M	16.30	0.00	20.00	0.00
SBC12	M	44.57	22.83	15.96	0.00
SBC31	M	3.26	7.61	17.39	0.00
SBC58	M	7.61	12.50	22.83	72.73
SBC61	M	13.92	26.83	10.13	0.00
SBC67	M	4.17	9.72	1.39	0.00
SBC75	M	2.38	2.27	11.90	0.00
SBC84	M	5.21	5.26	2.08	13.04
SBC108	M	1.04	4.17	4.17	0.00
SBC110	M	3.13	20.83	11.46	11.76
SBC119	M	1.04	20.45	7.29	0.00
SBC124	M	3.41	10.00	22.73	71.43
SBC131	M	6.25	20.00	8.42	26.09
SBC143	M	8.70	40.22	14.13	22.73
SBC94	M	31.82	13.64	23.86	86.36
SBC158	M	27.17	52.17	39.13	68.18
SBC107	M	39.47	48.05	55.26	70.00
SBC112	M	4.88	12.35	4.88	0.00
SBC170	M	6.52	17.58	5.43	0.00
SBC171	M	8.70	50.00	44.57	5.88
SBC179	M	18.18	30.68	12.50	47.62
SBC196	M	1.06	6.25	6.25	17.39
SBC205	M	5.21	8.33	33.33	95.65
SBC221	M	4.35	39.13	18.95	0.00
SBC227	M	7.87	17.98	25.84	0.00
SBC224	M	0.00	3.13	20.83	4.35
FAO901860	M	0.00	44.94	17.98	0.00
FAO901635	M	15.12	57.47	29.07	54.55
FAO901546	M	8.51	44.68	26.60	33.33
FAO901338	M	3.95	9.21	28.95	25.00
FAO901549	M	8.57	48.57	38.57	93.33
FAO901390	M	3.26	36.96	32.61	17.39
FAO901991	M	17.71	34.38	27.08	61.90
FAO901819	M	1.06	26.60	14.89	0.00
FAO901420	M	0.00	6.25	22.50	0.00
FAO901845	M	23.96	17.71	27.08	0.00
FAO901591	M	6.25	38.54	19.79	42.86
FAO901767	M	1.04	17.71	11.46	0.00
FAO901578	M	1.25	35.00	13.75	0.00
FAO901116	M	0.00	33.78	17.81	5.56

Appendix D-1 True prevalence rates for eburnation, pitting, osteophytes and vertebral osteophytosis continued

ID	Sex	True Eburnation	True Pitting	True Osteophytes	True Vertebral Osteophytosis
FAO901925	M	0.00	36.25	22.50	0.00
FAO901454	M	0.00	8.33	4.17	4.55
FAO901932	M	3.57	17.86	28.57	0.00
FAO901606	M	2.08	20.83	46.88	38.10
FAO901155	M	8.93	16.07	28.57	30.77
FAO901589	M	2.27	6.98	30.23	18.18
FAO901721	M	3.13	25.00	22.92	0.00
FAO901745	M	26.32	46.32	56.84	90.91
FAO901827	M	1.64	13.11	8.20	46.67
FAO901885	M	3.49	11.76	17.65	95.00
FAO901785	M	0.00	18.39	14.94	0.00
FAO901251	M	3.33	16.67	6.67	7.14
FAO901200	M	1.32	3.95	9.21	44.44
FAO901751	M	0.00	16.18	14.71	0.00
FAO901825	M	2.13	3.19	23.40	13.64
FAO901345	M	0.00	53.06	30.61	81.82
FAO901521	M	1.61	12.70	7.94	0.00
FAO902001	M	2.17	5.43	30.43	0.00
FAO901449	M	0.00	10.00	1.67	0.00
FAO901500	M	9.47	26.32	29.47	36.36
FAO901868	M	0.00	41.46	17.07	20.00

Appendix D-2 True prevalence rates for osteoarthritis (OA) by individual

ID	Sex	True OA
GC1	F	36.92
GC9	F	79.37
GC14	F	52.75
GC32	F	54.95
GC37	F	42.59
GC81	F	59.1
GC92	F	65.26
GC100	F	51.35
GC103	F	55.56
GC152	F	27.37
B250	F	12.09
B288	F	3.3
B309	F	26.32
B420	F	4.17
A56	F	10
A64	F	7.69
A447	F	14.1
A765	F	8.86
A780	F	3.16
A640	F	2.3
A270	F	1.05
SBC8	F	8.6
SBC10	F	13.83
SBC13	F	7.69
SBC17	F	94.62
SCB29	F	73.86
SBC33	F	94.94
SBC43	F	19.12
SBC44	F	95.7
SBC45	F	44.68
SBC52	F	20.43
SBC63	F	15.22
SBC66	F	18.68
SBC67	F	30.43
SBC72	F	53.85
SBC106	F	29.87
SBC117	F	0
SBC120	F	6.67
SBC122	F	0
SBC129	F	45.05

Appendix D-2 True prevalence rates for osteoarthritis (OA) by individual continued

ID	Sex	True OA
SBC130	F	50.53
SBC133	F	7.37
SBC144	F	0
SBC152	F	0
SBC153	F	11.43
SBC154	F	4.23
SBC101	F	12.63
SBC98	F	5.33
SBC93	F	2.41
SBC156	F	5.26
SBC113	F	8.05
SBC167	F	1.05
SBC177	F	0
SBC178	F	14.12
SBC182	F	0
SBC203	F	0
SBC209	F	0
SBC214	F	0
SBC215	F	0
SBC219	F	16.48
SBC220	F	25.35
SBC225	F	4.94
FAO901641	F	4.6
FAO901755	F	8.7
FAO901703	F	0
FAO901417	F	6.02
FAO901874	F	0
FAO901152	F	17.31
FAO901207	F	26.6
FAO901369	F	1.67
FAO901946	F	3.53
FAO901793	F	0
FAO901608	F	3.33
FAO901123	F	1.32
FAO901954	F	0
FAO901913	F	2.15
FAO901653	F	2.2
FAO901343	F	0
FAO901376	F	0
FAO901809	F	0
FAO901887	F	0
FAO901799	F	27.47
FAO901409	F	38.67
FAO901278	F	3.45

Appendix D-2 True prevalence rates for osteoarthritis (OA) by individual continued

ID	Sex	True OA
FAO901519	F	6.59
FAO901893	F	1.05
GC2A	M	18.39
GC5	M	21.98
GC8	M	1.05
GC22	M	1.05
GC80	M	5.26
GC84	M	4
GC90	M	1.27
GC117	M	0
GC121	M	6.32
GC149	M	4.4
B282B	M	7.95
B311	M	8.79
B338	M	2.33
B385L	M	3.16
A49	M	0
A43	M	0
A747	M	0
A777	M	0
A768	M	14.89
A591	M	0
A821	M	0
A53	M	1.64
A111	M	0
A315	M	9.57
A644	M	0
A812	M	1.3
A334	M	4.21
A783	M	7.6
A453	M	0
A309	M	0
A444	M	0
A481	M	0
SBC2	M	0
SBC12	M	0
SBC31	M	0
SBC58	M	2.82
SBC61	M	0
SBC67	M	0
SBC75	M	0
SBC84	M	0
SBC108	M	2.41
SBC110	M	42.39

Appendix D-2 True prevalence rates for osteoarthritis (OA) by individual continued

ID	Sex	True OA
SBC119	M	6.32
SBC124	M	0
SBC131	M	8.79
SBC143	M	7.37
SBC94	M	1.1
SBC158	M	29.47
SBC107	M	8.42
SBC112	M	32.18
SBC170	M	0
SBC171	M	3.16
SBC179	M	4.82
SBC196	M	8.42
SBC205	M	4.11
SBC221	M	3.7
SBC227	M	0
SBC224	M	18.95
FAO901860	M	4.21
FAO901635	M	0
FAO901546	M	7.14
FAO901338	M	1.27
FAO901549	M	0
FAO901390	M	0
FAO901991	M	0
FAO901819	M	3.61
FAO901420	M	2.11
FAO901845	M	4.3
FAO901591	M	30.43
FAO901767	M	4.55
FAO901578	M	0
FAO901116	M	1.92
FAO901925	M	0
FAO901454	M	20.25
FAO901932	M	3.45
FAO901606	M	1.1
FAO901155	M	6.59
FAO901589	M	2.86
FAO901721	M	10.45
FAO901745	M	4
FAO901827	M	8.7
FAO901885	M	13.16
FAO901785	M	3.3
FAO901251	M	17.89

Appendix D-2 True prevalence rates for osteoarthritis (OA) by individual continued

ID	Sex	True OA
FAO901200	M	1.08
FAO901751	M	24.21
FAO901825	M	21.05
FAO901345	M	6.32
FAO901521	M	1.05
FAO902001	M	12.2
FAO901449	M	1.06
FAO901500	M	8.93
FAO901868	M	4.6

Appendix E. Overall summary of extrinsic variables strongly correlated to facet size and angle

Appendix Table E-1 Statistically significant results from Mann-Witney U test for sex and age with facet size and angle, cervical region

Predictor Variable	Sample	Sex	C1 LS	C1 RS	C1 LI	C1 RI	C2 LS	C2 RS	C2 LI	C2 RI	C3 LS	C3 RS	C3 LI	C3 RI	C4 LS	C4 RS	C4 LI	C4 RI	C5 LS	C5 RS	C5 LI	C5 RI	C6 LS	C6 RS	C6 LI	C6 RI	C7 LS	C7 RS	C7 LI	C7 RI
Sex/facet size	SBC																													
	SBL																													
	AS																													
Sex/facet angle	SBC																													
	SBL																													
	AS																													
Age/facet size	SBC	M																												
		F																												
	SBL	M																												
		F																												
	AS	M																												
		F																												
Age/facet angle	SBC	M																												
		F																												
	SBL	M																												
		F																												
	AS	M																												
		F																												

Appendix Table E-2 Strong correlation between femoral robusticity and facet size and angle, cervical region

Predictor Variable	Sample	Sex	C1 LS	C1 RS	C1 LI	C1 RI	C2 LS	C2 RS	C2 LI	C2 RI	C3 LS	C3 RS	C3 LI	C3 RI	C4 LS	C4 RS	C4 LI	C4 RI	C5 LS	C5 RS	C5 LI	C5 RI	C6 LS	C6 RS	C6 LI	C6 RI	C7 LS	C7 RS	C7 LI	C7 RI
femoral robusticity/facet size	SBC	M																												
		F																L				R								
	SBL	M																												
		F															L													
	AS	M																LR												
		F								LR	R	LR			LR			L			LR	LR	L	LR		R	LR	LR	LR	
femoral robusticity/facet angle	SBC	M					LR		LR																					L
		F	L			L	L	L	LR	R			R				LR	LR			LR				L				LR	
	SBL	M												LR																
		F													L	L		L	R	L				L						
	AS	M					LR		LR																					L
		F		L		L	L	L	LR	R			R				LR	LR			LR				L				LR	

Appendix Table E-3 Facets with strong correlation between humeral and facet size and angle asymmetry, cervical region

Predictor Variable	Sample	Sex	C1 LS	C1 RS	C1 LI	C1 RI	C2 LS	C2 RS	C2 LI	C2 RI	C3 LS	C3 RS	C3 LI	C3 RI	C4 LS	C4 RS	C4 LI	C4 RI	C5 LS	C5 RS	C5 LI	C5 RI	C6 LS	C6 RS	C6 LI	C6 RI	C7 LS	C7 RS	C7 LI	C7 RI
Humeral/facet size asymmetry	SBC	M																												
		F																												
	SBL	M																												
		F																												
	AS	M																												
		F																												
Humeral/facet angle asymmetry	SBC	M																												
		F																												
	SBL	M																												
		F																												
	AS	M																												
		F																												

Appendix Table E-4 Facets with strong correlation between ebtot and facet size and angle, cervical region

Predictor Variable	Sample	Sex	C1 LS	C1 RS	C1 LI	C1 RI	C2 LS	C2 RS	C2 LI	C2 RI	C3 LS	C3 RS	C3 LI	C3 RI	C4 LS	C4 RS	C4 LI	C4 RI	C5 LS	C5 RS	C5 LI	C5 RI	C6 LS	C6 RS	C6 LI	C6 RI	C7 LS	C7 RS	C7 LI	C7 RI
Ebtot/facet size	SBC	M																												
		F																												
	SBL	M																												
		F																												
	AS	M																												
		F																												
Ebtot/facet angle	SBC	M																												
		F																												
	SBL	M																												
		F																												
	AS	M																												
		F																												

Appendix Table E-5 Facets with strong correlation between pitot and facet size and angle, cervical region

Predictor Variable	Sample	Sex	C1 LS	C1 RS	C1 LI	C1 RI	C2 LS	C2 RS	C2 LI	C2 RI	C3 LS	C3 RS	C3 LI	C3 RI	C4 LS	C4 RS	C4 LI	C4 RI	C5 LS	C5 RS	C5 LI	C5 RI	C6 LS	C6 RS	C6 LI	C6 RI	C7 LS	C7 RS	C7 LI	C7 RI
Pitot/ facet size	SBC	M																												
		F																												
	SBL	M																												
		F																												
	AS	M																												
		F																												
Pitot/ facet angle	SBC	M																												
		F																												
	SBL	M																												
		F																												
	AS	M																												
		F																												

Appendix Table E-6 Facets with strong correlation between ostot and facet size and angle, cervical region

Predictor Variable	Sample	Sex	C1 LS	C1 RS	C1 LI	C1 RI	C2 LS	C2 RS	C2 LI	C2 RI	C3 LS	C3 RS	C3 LI	C3 RI	C4 LS	C4 RS	C4 LI	C4 RI	C5 LS	C5 RS	C5 LI	C5 RI	C6 LS	C6 RS	C6 LI	C6 RI	C7 LS	C7 RS	C7 LI	C7 RI
Ostot/ facet size	SBC	M																												
		F																												
	SBL	M																												
		F																												
	AS	M																												
		F																												
Ostot/ facet angle	SBC	M																												
		F																												
	SBL	M																												
		F																												
	AS	M																												
		F																												

Appendix Table E-7 Facets with strong correlation between cvostot and facet size and angle, cervical region

Predictor Variable	Sample	Sex	C1 LS	C1 RS	C1 LI	C1 RI	C2 LS	C2 RS	C2 LI	C2 RI	C3 LS	C3 RS	C3 LI	C3 RI	C4 LS	C4 RS	C4 LI	C4 RI	C5 LS	C5 RS	C5 LI	C5 RI	C6 LS	C6 RS	C6 LI	C6 RI	C7 LS	C7 RS	C7 LI	C7 RI
Cvostot/ Facet size	SBC	M																												
		F																												
	SBL	M																												
		F																												
	AS	M																												
		F																												
Cvostot/ facet angle	SBC	M																												
		F																												
	SBL	M																												
		F																												
	AS	M																												
		F																												

Appendix Table E-8 Facets with statistically significant results from Mann-Whitney U test for sex and age with facet size and angle, thoracic region

Predictor Variable	Sample	T1 LS	T1 RS	T1 LI	T1 RI	T2 LS	T2 RS	T2 LI	T2 RI	T3 LS	T3 RS	T3 LI	T3 RI	T4 LS	T4 RS	T4 LI	T4 RI	T5 LS	T5 RS	T5 LI	T5 RI	T6 LS	T6 RS	T6 LI	T6 RI
Sex/facet size	SBC																								
	SBL																								
	AS																								
Sex/facet angle	SBC																								
	SBL																								
	AS																								
Age/facet size	SBC																								
	SBL																								
	AS																								
Age/facet angle	SBC																								
	SBL																								
	AS																								

Appendix Table E-8 Facets with statistically significant results from Mann-Whitney U test for sex and age with facet size and angle, thoracic region continued

Predictor Variable	Sample	T7 LS	T7 RS	T7 LI	T7 RI	T8 LS	T8 RS	T8 LI	T8 RI	T9 LS	T9 RS	T9 LI	T9 RI	T10 LS	T10 RS	T10 LI	T10 RI	T11 LS	T11 RS	T11 LI	T11 RI	T12 LS	T12 RS	T12 LI	T12 RI
Sex/facet size	SBC																								
	SBL																								
	AS																								
Sex/facet angle	SBC																								
	SBL																								
	AS																								
Age/facet size	SBC																								
	SBL																								
	AS																								
Age/facet angle	SBC																								
	SBL																								
	AS																								

Appendix Table E-9 Facets with strong correlation between femoral robusticity and facet size and angle, thoracic region

Predictor Variable	Sample	Sex	T1 LS	T1 RS	T1 LI	T1 RI	T2 LS	T2 RS	T2 LI	T2 RI	T3 LS	T3 RS	T3 LI	T3 RI	T4 LS	T4 RS	T4 LI	T4 RI	T5 LS	T5 RS	T5 LI	T5 RI	T6 LS	T6 RS	T6 LI	T6 RI
Femoral robusticity/facet size	SBC	M														R										
		F						R										R								
	SBL	M																								
		F							L	L	L			L		L		R	L							
	AS	M								L												L		L		
		F																LR								
Femoral robusticity/facet angle	SBC	M					LR	LR																	L	L
		F																				R		L		L
	SBL	M																								
		F			LR	R		R	R			R	R		L		R	R		R					L	
	AS	M					LR	LR																	L	L
		F	LR																			R		L		L

Appendix Table E-9 Facets with strong correlation between femoral robusticity and facet size and angle, thoracic region continued

Predictor Variable	Sample	Sex	T7 LS	T7 RS	T7 LI	T7 RI	T8 LS	T8 RS	T8 LI	T8 RI	T9 LS	T9 RS	T9 LI	T9 RI	T10 LS	T10 RS	T10 LI	T10 RI	T11 LS	T11 RS	T11 LI	T11 RI	T12 LS	T12 RS	T12 LI	T12 RI
Femoral robusticity/facet size	SBC	M						R				R														R
		F			L	L																				
	SBL	M																								
		F																		R			L			
	AS	M				LR																				
		F																								
Femoral robusticity/facet angle	SBC	M				LR																				
		F			L	L																	R			LR
	SBL	M												LR				LR								
		F	R				L	L		R									R						L	L
	AS	M																								
		F																					R			LR

Appendix Table E-10 Facets showing strong correlation between humeral and facet size and angle, thoracic region

Predictor Variable	Sample	Sex	T1 LS	T1 RS	T1 LI	T1 RI	T2 LS	T2 RS	T2 LI	T2 RI	T3 LS	T3 RS	T3 LI	T3 RI	T4 LS	T4 RS	T4 LI	T4 RI	T5 LS	T5 RS	T5 LI	T5 RI	T6 LS	T6 RS	T6 LI	T6 RI
humeral/facet size asymmetry	SBC	M																								
		F																								
	SBL	M																								
		F																								
	AS	M																								
		F																								
humeral/facet angle asymmetry	SBC	M																								
		F																								
	SBL	M																								
		F																								
	AS	M																								
		F																								

Appendix Table E-10 Facets showing strong correlation between humeral and facet size and angle, thoracic region

Predictor Variable	Sample	Sex	T7 LS	T7 RS	T7 LI	T7 RI	T8 LS	T8 RS	T8 LI	T8 RI	T9 LS	T9 RS	T9 LI	T9 RI	T10 LS	T10 RS	T10 LI	T10 RI	T11 LS	T11 RS	T11 LI	T11 RI	T12 LS	T12 RS	T12 LI	T12 RI
humeral/facet size asymmetry	SBC	M																								
		F																								
	SBL	M																								
		F																								
	AS	M																								
		F																								
humeral/facet angle asymmetry	SBC	M																								
		F																								
	SBL	M																								
		F																								
	AS	M																								
		F																								

Appendix Table E-11 Facets with strong correlation between ebtot and facet size and angle, thoracic region

Predictor Variable	Sample	Sex	T1 LS	T1 RS	T1 LI	T1 RI	T2 LS	T2 RS	T2 LI	T2 RI	T3 LS	T3 RS	T3 LI	T3 RI	T4 LS	T4 RS	T4 LI	T4 RI	T5 LS	T5 RS	T5 LI	T5 RI	T6 LS	T6 RS	T6 LI	T6 RI
Ebtot/facet size	SBC	M	■									■			■											
		F																								
	SBL	M																								
		F																								
	AS	M							■													■				
		F																							■	
Ebtot/facet angle	SBC	M																								
		F																								
	SBL	M																								
		F																								
	AS	M							■					■							■		■			
		F																							■	

Appendix Table E-11 Facets with strong correlation between ebtot and facet size and angle, thoracic region continued

Predictor Variable	Sample	Sex	T7 LS	T7 RS	T7 LI	T7 RI	T8 LS	T8 RS	T8 LI	T8 RI	T9 LS	T9 RS	T9 LI	T9 RI	T10 LS	T10 RS	T10 LI	T10 RI	T11 LS	T11 RS	T11 LI	T11 RI	T12 LS	T12 RS	T12 LI	T12 RI
Ebtot/facet size	SBC	M																								
		F																								
	SBL	M																								
		F																								
	AS	M																								
		F																								
Ebtot/facet angle	SBC	M																								
		F																								
	SBL	M																								
		F																								
	AS	M																								
		F																								

Appendix Table E-12 Facets with strong correlation between pitot and facet size and angle, thoracic region

Predictor Variable	Sample	Sex	T1 LS	T1 RS	T1 LI	T1 RI	T2 LS	T2 RS	T2 LI	T2 RI	T3 LS	T3 RS	T3 LI	T3 RI	T4 LS	T4 RS	T4 LI	T4 RI	T5 LS	T5 RS	T5 LI	T5 RI	T6 LS	T6 RS	T6 LI	T6 RI
Pitot/facet size	SBC	M																								
		F																								
	SBL	M																								
		F																								
	AS	M																								
		F																								
Pitot/facet angle	SBC	M																								
		F																								
	SBL	M																								
		F																								
	AS	M																								
		F																								

Appendix Table E-12 Facets with strong correlation between pitot and facet size and angle, thoracic region continued

Predictor Variable	Sample	Sex	T7 LS	T7 RS	T7 LI	T7 RI	T8 LS	T8 RS	T8 LI	T8 RI	T9 LS	T9 RS	T9 LI	T9 RI	T10 LS	T10 RS	T10 LI	T10 RI	T11 LS	T11 RS	T11 LI	T11 RI	T12 LS	T12 RS	T12 LI	T12 RI
Pitot/facet size	SBC	M																								
		F																								
	SBL	M																								
		F																								
	AS	M																								
		F																								
Pitot/facet angle	SBC	M																								
		F																								
	SBL	M																								
		F																								
	AS	M																								
		F																								

Appendix Table E-13 Facets with strong correlation between ostot and facet size and angle, thoracic region

Predictor Variable	Sample	Sex	T1 LS	T1 RS	T1 LI	T1 RI	T2 LS	T2 RS	T2 LI	T2 RI	T3 LS	T3 RS	T3 LI	T3 RI	T4 LS	T4 RS	T4 LI	T4 RI	T5 LS	T5 RS	T5 LI	T5 RI	T6 LS	T6 RS	T6 LI	T6 RI
Ostot/facet size	SBC	M																								
		F																								
	SBL	M																								
		F																								
	AS	M																								
		F																								
Ostot/facet angle	SBC	M																								
		F																								
	SBL	M																								
		F																								
	AS	M																								
		F																								

Appendix Table E-13 Facets with strong correlation between ostot and facet size and angle, thoracic region continued

Predictor Variable	Sample	Sex	T7 LS	T7 RS	T7 LI	T7 RI	T8 LS	T8 RS	T8 LI	T8 RI	T9 LS	T9 RS	T9 LI	T9 RI	T10 LS	T10 RS	T10 LI	T10 RI	T11 LS	T11 RS	T11 LI	T11 RI	T12 LS	T12 RS	T12 LI	T12 RI
Ostot/facet size	SBC	M																								
		F																								
	SBL	M																								
		F																								
	AS	M																								
		F																								
Ostot/facet angle	SBC	M																								
		F																								
	SBL	M																								
		F																								
	AS	M																								
		F																								

Appendix Table E-14 Facets with strong correlation between cvostot and facet size and angle, thoracic region

Predictor Variable	Sample	Sex	T1 LS	T1 RS	T1 LI	T1 RI	T2 LS	T2 RS	T2 LI	T2 RI	T3 LS	T3 RS	T3 LI	T3 RI	T4 LS	T4 RS	T4 LI	T4 RI	T5 LS	T5 RS	T5 LI	T5 RI	T6 LS	T6 RS	T6 LI	T6 RI
Cvostot/facet size	SBC	M																								
		F																								
	SBL	M																								
		F																								
	AS	M																								
		F																								
Cvostot/facet angle	SBC	M																								
		F																								
	SBL	M																								
		F																								
	AS	M																								
		F																								

Appendix Table E-14 Facets with strong correlation between cvostot and facet size and angle, thoracic region continued

Predictor Variable	Sample	Sex	T7 LS	T7 RS	T7 LI	T7 RI	T8 LS	T8 RS	T8 LI	T8 RI	T9 LS	T9 RS	T9 LI	T9 RI	T10 LS	T10 RS	T10 LI	T10 RI	T11 LS	T11 RS	T11 LI	T11 RI	T12 LS	T12 RS	T12 LI	T12 RI
Cvostot/facet size	SBC	M																								
		F																								
	SBL	M																								
		F																								
	AS	M																								
		F																								
Cvostot/facet angle	SBC	M																								
		F																								
	SBL	M																								
		F																								
	AS	M																								
		F																								

Appendix Table E-15 Facets with statistically significant results from Mann-Whitney U test for sex and age with facet size and angle, lumbar region

Predictor Variable	Sample	L1 LS	L1 RS	L1 LI	L1 RI	L2 LS	L2 RS	L2 LI	L2 RI	L3 LS	L3 RS	L3 LI	L3 RI	L4 LS	L4 RS	L4 LI	L4 RI	L5 LS	L5 RS	L5 LI	L5 RI
Sex/facet size	SBC																				
	SBL																				
	AS																				
Sex/facet angle	SBC																				
	SBL																				
	AS																				
Age/facet size	SBC																				
	SBL																				
	AS																				
Age/facet angle	SBC																				
	SBL																				
	AS																				

Appendix Table E-16 Facets with strong correlation between femoral robusticity and facet size and angle, lumbar region

Predictor Variable	Sample	Sex	L1 LS	L1 RS	L1 LI	L1 RI	L2 LS	L2 RS	L2 LI	L2 RI	L3 LS	L3 RS	L3 LI	L3 RI	L4 LS	L4 RS	L4 LI	L4 RI	L5 LS	L5 RS	L5 LI	L5 RI
Femoral robusticity/facet size	SBC	M									R											
		F																				
	SBL	M																				
		F													L	L	L					
	AS	M	R		L		L					R										
		F																				
Femoral robusticity/facet angle	SBC	M		L	R												LR				L	
		F		R				R		L												
	SBL	M																				
		F	L	L		L		L	L	L		L		L					L			
	AS	M		L	R												LR				L	
		F		R				R		R												

Appendix Table E-17 Facets with strong correlation between humeral and facet size and angle asymmetry, lumbar region

Predictor Variable	Sample	Sex	L1 LS	L1 RS	L1 LI	L1 RI	L2 LS	L2 RS	L2 LI	L2 RI	L3 LS	L3 RS	L3 LI	L3 RI	L4 LS	L4 RS	L4 LI	L4 RI	L5 LS	L5 RS	L5 LI	L5 RI
Humeral/facet size asymmetry	SBC	M																				
		F																				
	SBL	M																				
		F																				
	AS	M																				
		F																				
Humeral/facet angle asymmetry	SBC	M																				
		F																				
	SBL	M																				
		F																				
	AS	M																				
		F																				

Appendix Table E-18 Facets with strong correlation between ebtot and facet size and angle, lumbar region

Predictor Variable	Sample	Sex	L1 LS	L1 RS	L1 LI	L1 RI	L2 LS	L2 RS	L2 LI	L2 RI	L3 LS	L3 RS	L3 LI	L3 RI	L4 LS	L4 RS	L4 LI	L4 RI	L5 LS	L5 RS	L5 LI	L5 RI
Ebtot/facet size	SBC	M																				
		F																				
	SBL	M																				
		F																				
	AS	M																				
		F																				
Ebtot/facet angle	SBC	M																				
		F																				
	SBL	M																				
		F																				
	AS	M																				
		F																				

Appendix Table E-19 Facets with strong correlation between pitot and facet size and angle, lumbar region

Predictor Variable	Sample	Sex	L1 LS	L1 RS	L1 LI	L1 RI	L2 LS	L2 RS	L2 LI	L2 RI	L3 LS	L3 RS	L3 LI	L3 RI	L4 LS	L4 RS	L4 LI	L4 RI	L5 LS	L5 RS	L5 LI	L5 RI
Pitot/facet size	SBC	M																				
		F																				
	SBL	M																				
		F																				
	AS	M																				
		F																				
Pittot/facet angle	SBC	M																				
		F																				
	SBL	M																				
		F																				
	AS	M																				
		F																				

Appendix Table E-20 Facets with strong correlation between ostot and facet size and angle, lumbar region

Predictor Variable	Sample	Sex	L1 LS	L1 RS	L1 LI	L1 RI	L2 LS	L2 RS	L2 LI	L2 RI	L3 LS	L3 RS	L3 LI	L3 RI	L4 LS	L4 RS	L4 LI	L4 RI	L5 LS	L5 RS	L5 LI	L5 RI
Ostot/facet size	SBC	M																				
		F																				
	SBL	M																				
		F																				
	AS	M																				
		F																				
Ostot/facet angle	SBC	M																				
		F																				
	SBL	M																				
		F																				
	AS	M																				
		F																				

Appendix Table E-21 Facets with strong correlation between cvostot and facet size and angle, lumbar region

Predictor Variable	Sample	Sex	L1 LS	L1 RS	L1 LI	L1 RI	L2 LS	L2 RS	L2 LI	L2 RI	L3 LS	L3 RS	L3 LI	L3 RI	L4 LS	L4 RS	L4 LI	L4 RI	L5 LS	L5 RS	L5 LI	L5 RI
Cvostot/facet size	SBC	M	.																			
		F																				
	SBL	M																				
		F																				
	AS	M																				
		F																				
Cvostot/facet angle	SBC	M																				
		F																				
	SBL	M																				
		F																				
	AS	M																				
		F																				

Appendix F. Sample Data Sheet

Appendix Table F-1 Sample Data Sheet

Site		**Context**	
Age Data:			
Pubic symphysis	L R	**Auricular surface**	L R
Todd (1-10)		(1-8)	
Suchey-Brooks (1-6)			
Sex Data			
Pelvis	L R	**Skull**	L M R
Ventral arc (1-3)		Nuchal crest (1-5)	
Sub-pubic cavity (1-3)		Mastoid process (1-5)	
Ischiopubic ramus bridge (1-3)		Supra-orbital margin (1-5)	
Greater sciatic notch (1-5)		Supra-orbital ridge (1-5)	

Osteometrics	L	R	Average
Femoral head Diam			
XLF			
LCT			
XLH			
XLR			
XLU			
XLG			
Femur A/P			
Femur M/L			
Humerus A/P			
Humerus M/L			
PUM			
SPU			
DCOX			
IIMT			
ISMM			
SCOX			
SS			
SA			
SIS			
VEAC			

Cemetery ID																							
Level	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**	**L1**	**L2**	**L3**	**L4**	**L5**
L sup facet width																								
R sup facet width																								
L sup facet height																								
R sup facet height																								
L inf facet width																								
R inf facet width																								
L inf facet height																								
R inf facet height																								
L sup eburnation S/E																								
R sup eburnation S/E																								
L inf eburnation S/E																								
R inf eburnation																								

Appendix F Sample data sheet

Level	C1	C2	C3	C4	C5	C6	C7	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	L1	L2	L3	L4	L5
L sup pitting																								
R sup pitting																								
L inf pitting																								
R inf pitting																								
L sup osteophyte																								
R sup osteophyte																								
L inf osteophyte																								
R inf osteophyte																								
L sup sag angle																								
R sup sag angle																								
L inf sagittal angle																								
R inf sagittal angle																								
VOP sup																								
VOP Inf																								

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