University of Southampton

Faculty of Medicine

Human Development and Health

Physically-demanding Work and Leisure Activities following Lower Limb Arthroplasty, and Mid to Long-term Outcomes

by

Elena Zaballa Lasala

Thesis for the degree of Doctor of Philosophy

January 2020

University of Southampton

Abstract

Faculty of Medicine

Human Development and Health

Thesis for the degree of Doctor of Philosophy

Physically-demanding Work and Leisure Activities following Lower Limb Arthroplasty, and Mid to Long-term Outcomes

by

Elena Zaballa Lasala

Lower limb arthroplasty has been a major success. However, it is known that physically-demanding work increases the risk of primary hip and knee OA, therefore it is possible that returning to work involving physical activity could increase the risk of joint failure. This thesis investigated this hypothesis.

In a systematic review we explored whether among people aged over 18 years, who underwent lower limb arthroplasty and had a minimum follow-up of one year, there was an increased risk of revision surgery amongst those undertaking work and non-work related heavy physical activity. We found limited evidence to address the question.

In a longitudinal study we followed-up two cohorts of hip and knee arthroplasty recipients who were aged ≤65 years at the time of operation, and who were followed for a minimum of 5 years post-operation. Participants completed a questionnaire about work and leisure activities post-arthroplasty, symptoms and function since arthroplasty, and other relevant risk factors for joint failure.

An increased risk of revision of hip arthroplasty was found amongst those who reported kneeling/squatting post-operatively at work and those who were highly active at least once a week in their leisure time. Poor function at follow-up after both knee and hip arthroplasty was associated with heavy lifting at work. People needing to do heavy physical work were more likely to stop working post-operation because of a problem with their replaced hip or knee. All levels of leisure activity were beneficial for function after knee arthroplasty.

More research is needed to address this research question. Low and medium impact leisure activities should be encouraged as they are beneficial. However, we found some evidence to suggest that high impact activities increased the risk of hip revision.

Table of Contents

List of tables

List of Figures

Research Thesis: Declaration of Authorship

I, Elena Zaballa Lasala, declare that this thesis and the work presented in it are my own and have been generated by me as the result of my own original research.

Physically demanding work and leisure activities following lower limb arthroplasty, and mid to long-term outcomes

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. None of this work has been published before submission.

Signed:

Date: 30 January 2020

Acknowledgements

This work has been possible with the support of many people along the way, and I would like to express my gratitude to all of them with the hope of not forgetting anyone.

I would like to begin by thanking my supervisors Karen Walker-Bone, Clare Harris and Nigel Arden for their guidance, encouragement and patience in these last few years. Thank you Karen for giving me the opportunity to learn the steps necessary to perform an epidemiological study, teaching me during the process and being always welcoming. Clare, I cannot thank you enough for making things a lot easier for me and transmitting me your knowledge. I am also grateful to David Coggon, who conceived the original idea for the study and provided valuable input to the design of the questionnaire. I would also like to make special mention to Georgia Ntani for her friendship, great patience, support, and help in the understanding of the statistical analyses in the study. Thank you all of you for being always welcoming, transmitting your passion for science, and helping me out on this journey.

I would also like to thank Anne Lübbeke-Wolff and colleagues from the Geneva Arthroplasty Registry for their willingness to collaborate in this study and for performing such thorough work in the Geneva Arthroplasty Registry. This work would have not been possible without your involvement. It has been a pleasure to work with you! Also, thanks to Carol Ball, Lucy Gates and Antonella Delmestri for spending time showing me how to handle the intricacies of the Clinical Outcomes in Arthroplasty study.

Once again, thank you to Vanessa Cox and the IT team from the MRC Lifecourse Epidemiology Unit, for their support in data entering the questionnaires and keeping such a high standard in the quality of the data used in this work, and to Theodosia Salika and Sue Curtis for helping out. And of course, all the colleagues and friends from Southampton that have supported me over the last four years and have made me feel so welcome.

This thesis would not have been possible without the insistence of Sergio Vargas-Prada, who encouraged me, helped me, and made me feel confident enough to put in an application to come to Southampton and begin the work presented in this thesis. It has also been possible thanks to the grant from the Arthritis Research UK/MRC Centre for

Musculoskeletal Health and Work based at the MRC Lifecourse Epidemiology Unit in Southampton.

Por último, este trabajo esta dedicado a mis padres Guillermo y Chelo, y también a Esther, Iván y Martina por apoyarme y animarme en la distancia, no solo desde que comencé esta tesis, si no desde que decidí recorrer el camino de la investigación.

Definitions and Abbreviations

ACR	American College of Rheumatology
ADL	Activities of Daily Living
ALVAL	Aseptic lymphocyte-dominant vasculitis-associated lesion
ASA	American Society of Anesthesiologists
BMI	Body Mass Index
COASt	Clinical Outcomes in Arthroplasty Study
CPRD	Clinical Practice Research Datalink
DALYS	Disability Adjusted Life Years
GAR	Geneva Arthroplasty Register
GBD	The Global Burden of Disease study
HADS	Hospital Anxiety Depression Score
HR	Hazard ratio
HTO	High Tibial Osteotomy
IIAC	Industrial Injuries Advisory Council
IIDB	Industrial Injuries Disablement Benefit
LTPA	Leisure time physical activity
MAQ	Modifiable Activity Questionnaire
MET	Metabolic equivalent per task
NICE	The National Institute for Health and Care Excellence
NJR	National Joint Registry
NOC	Nuffield Orthopaedic Centre
NSAIDs	Non-steroidal anti-inflammatory drugs
OA	Osteoarthritis
OHS	Oxford Hip Score
OKS	Oxford Knee Score
OMB	Oxford Musculoskeletal Biobank
OR	Odds ratio
PCS	Physical Component Summary, from SF-12
PPIs	Proton Pump inhibitors
PROMs	Patient Reported Outcome Measures
RA	Rheumatoid Arthritis
RR	Risk ratio
SF-12	12-item Short Form Survey
SKAR	Swedish Knee Arthroplasty Register
THA	Total Hip Arthroplasty
THR	Total Hip Replacement
TKA	Total Knee Arthroplasty
TKR	Total Knee Replacement
UCLA	University of California at Los Angeles
UHS	University Hospital Southampton NHS Foundation Trust
UKA	Unicompartmental arthroplasty
WHO	The World Health Organization
WOMAC	Western Ontario and McMaster Universities Osteoarthritis Index

Chapter 1 : Osteoarthritis (OA)

1.1 Definition

William Heberden, widely considered the father of rheumatology, was the first physician to distinguish between osteoarthritis (OA) and gout. In 1872 he described the Digitorum Nodi of OA. " What are those little hard knobs, about the size of a small pea, which are frequently seen upon the fingers, particularly a little below the top, near the joint? They have no connexion with the gout, being found in persons who never had it: they continue for life; and being hardly ever attended with pain, or disposed to become psoriasis, are rather unsightly and inconvenient, though they must be some little hindrance to the free use of fingers" [1]. Currently OA is known to be a disorder directed at the synovial joints (diarthrodial joints) that affects the cartilage, subchondral bone, ligaments, synovial membrane and capsule [2]. It is the most common form of arthritis worldwide, characterized by stiffness, pain and functional disability which can affect both the small joints (for example, fingers of the hand) and large joints (e.g. hip and knee).

1.2 Natural history

In a healthy mobile joint the ends of the bones are encased by cartilage. The joint structure is protected by a capsule lined with a synovial membrane, which produces synovial fluid that lubricates the joint. Cartilage along with the fluid act together to provide lubrication and shock absorption allowing a free range of movement of the joint with no pain. When joints are exposed to minor trauma or abnormal biomechanics, there is capacity for the joint to compensate for the damage by triggering a repair mechanism. However, when the process of damage/repair becomes unbalanced, OA can occur. Morphological changes of the joint that follow depend on the severity of the OA and include: gross cartilage loss, growth of bone spurs on the margin (edge) of the bone called osteophytes, inflammation of the synovium, excess synovial fluid, and thickening of the capsule. Thickness of articular cartilage is shown in the figures below [3].

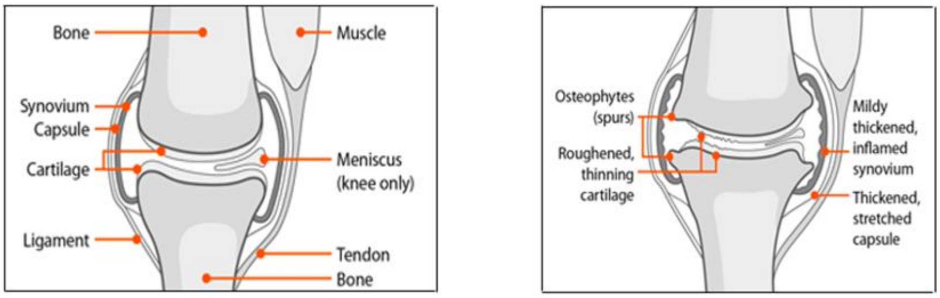

Figure 1. Healthy joint (on the left) and mild OA (on the right)

OA can be diagnosed from clinical symptoms, radiographs (X-rays, MRI) or a combination of both, but no gold standard classification criteria to diagnose OA have been agreed. According to the classification criteria proposed by the American College of Rheumatology (ACR), presence of pain in the affected hip or knee, in addition to another 3 out of 5 parameters described (see Table 1) is enough to make a positive OA diagnosis. In Europe, the National Institute for Health and Care Excellence (NICE) defines a positive case of OA as those patients aged over 45, who have limited morning stiffness (less than 30 minutes) in association with joint pain associated with activity.

Table 1. Clinical symptoms of OA

American College of Rheumatology*	NICE
• Pain (hip or knee)	• Over 45 years of age
• Morning stiffness for less than 30 minutes	• Pain in the joint related to activity
• Over 50 years of age	• Morning stiffness for less than 30 minutes or no morning stiffness
• Crepitus	
• Bony tenderness	
• Bony enlargement	
• No warmth in the synovium	

*Criteria determined by the Committee of the American Rheumatism Association, [4, 5]

Another way to diagnose OA is by assessing morphological and structural changes on X-rays. In 1957, Kellgren and Lawrence (K&L) established a widely used system based on radiological features to grade the severity of OA. The authors examined X-rays of different joints (hip, knee, spine, hand and feet in 85 participants aged between 55 and 64 years. When the X-rays presented: i) osteophytes, ii) periarticular ossicles, iii) narrowing cartilage along with sclerosis iv) pseudocystic areas with sclerotic walls or v) changes in the shape of the bone ends, OA of the joint was suggested. Taking into account these features K&L established a five grade scale (see Table 2), where zero indicates no changes in the joint and higher values indicate a more severe case of OA.

Table 2. Kellgren and Lawrence's radiographic classification system for OA

Grade	Description
0	No space narrowing present
1	Doubtful joint space narrowing (JSN) and possible osteophytic lipping
2	Possible JSN, definite osteophytes
3	Definite JSN, moderate osteophytes, sclerosis, possible bony deformity
4	Marked JSN, large osteophytes, severe sclerosis and definite bony deformity

A joint with a K&L ≥ 2 grade is considered to be an osteoarthritic joint [6].

1.3 Burden of the disease

OA can progress over time and may eventually affect the ability of the individual to perform daily living activities. The Global Burden of Disease study (GBD) described changes in morbidity and mortality levels between 1990 and 2010 for 291 conditions across 187 countries. Among other outcomes, GBD reported years lived with disability as an indicator of loss of health caused by diseases, and thus how different diseases contributed to global disability. Globally, OA of the hip and knee was ranked the 15th most disabling condition contributing to global disability at baseline in 1990 and this became the 11th most disabling condition by 2010 [7]. Another study specifically looked at the global burden of disease in the UK and showed no changes in the burden of lower limb OA between 1990 and 2010 [8].

Patients tend to seek medical advice when they have symptoms from the joint (often pain), so a different approach to assess the burden of hip and knee OA is to use medical consultations at GP surgeries. Analysis from the Consultations in Primary Care Archive in the UK estimated that 8.7 million people aged 45 and over sought treatment due to OA between 2004 and 2010. Of the total consultations, 2.12 million were related to hip OA and 4.75 million to knee OA [9].

1.3.1 Prevalence of OA

Prevalence rates of OA as estimated across population-based studies vary depending on the case definition used (radiographic, symptomatic or both). Table 3 shows that the highest prevalence rates of OA are seen in those studies using case definitions based on radiographs (15.7% to 19.6% for the hip and 27.2% to 61.9% for the knee), with lower rates estimated when symptoms are used (7.2% to 16.4% for the knee). The combination of radiographic and symptomatic assessment yields the lowest estimated rates.

Table 3. Prevalence rates of the hip and knee OA in population-based studies

Hip					
Country	**Authors**	**Sample**	**Radiographic**	**Symptomatic**	**Radiographic and symptomatic**
USA[10]	Kim C (2014)	Framingham study (2000-2005)	19.6%	4.2%	_
Japan[11]	Iiaka T (2016)	ROAD study	15.7%	_	_
France[12]	Guillemin F (2011)	Multiregional representative sample in France	_	_	0.9-3.9% men, 0.7-5.1% women
Global[7]	Cross M (2014)	Systematic reviews	_	_	0.85% (95% UI 0.74% to1.02%)
Knee					
Country	**Authors**	**Sample**	**Radiographic**	**Symptomatic**	**Radiographic and symptomatic**
USA [13]	Dillon C.F (2006)	NHANES III	27.2% CI(25.0-29.4) K&L≥2	12.1% (10.1-13.5) Over 60%	_
USA [14]	Felson D.T. (1987)	Framingham	33% No K&L grade	_	_
USA [15]	Jordan JM (2007)	Johnston County OA project	27.8%	16.4 %	_
Japan [11]	Iiaka T (2016)	ROAD study ≥60 years	61.9%	_	
China [16]	Zhang Y (2001)	Beijing ≥65	27.1% men 46.6% women	7.15% men 15.4% women	_
France[12]	Guillemin F (2011)	Multiregional representative sample in France	_	_	2.1%-10.1% men, 1.6-14.9% women
Global [7]	Cross M (2014)	Systematic reviews	_	_	3.8% (95% UI 3.6% to 4.1%)

However, even among studies using radiographs there is still wide variation in estimated rates, probably because of differences in anatomical sites and ages of the populations studied.

1.3.2 Incidence of OA

Not many studies have described the incidence rates of new cases of OA in the population. The period of time over which participants were followed up and the methods used to estimate the incidence vary between studies. Oliveria et al found 88 incident cases of hip OA and 240 incident cases of knee OA per 100,000 person-years between 1988 and 1991 among members of the Fallon Community Health Plan [17]. In another study participants reported at baseline whether they had been diagnosed with OA by X ray or by a GP. At 10 years follow-up 5.8% of the individuals developed hip OA and 7.3% knee OA (self-reported) [18]. A more recent study (ROAD study) reported a similar incidence of radiographically confirmed knee OA (9.7% cases) over three years of follow-up in Japan [19].

Another study based on registry data estimated the overall incidence rate of OA in British Columbia at 11.7 per 1,000 person years [20].

1.4 Classification of OA

OA can be classified according to the aetiology (primary OA or secondary OA) or according to the number of joints affected. Primary or idiopathic OA occurs when the cause or causes that trigger joint degeneration are not known. Conversely, OA is classified as secondary when there is an attributable cause that leads to OA of the joint. Among these causes there are metabolic conditions (e.g. acromegaly), anatomic causes (e.g. congenital) and any inflammatory arthropathy [21].

1.5 Risk factors

In most cases, OA has a multifactorial aetiology. Many different risk factors have been described as contributing to the onset or development of the disease. These risk factors can be classified following different criteria, but for the purpose of this study we will distinguish between non-occupational and occupational risk factors.

1.5.1 Non-occupational risk factors

1.5.1.1 Age and sex

Ageing is an important risk factor for OA. Lower limb OA increases progressively from younger ages (mid-forties) to 70-79 years of age [17, 22] regardless of whether the case definition is based on radiographic or symptomatic diagnostic criteria. Oliveria and colleagues studied hip and knee OA among participants from The Fallon Community Health Care Plan by examining radiographs [17]. The incidence rate of knee OA in women increased from 276 cases per 100,000 person years between 50-59 years of age to 1,082 cases per 100,000 per person years at ages 70-79 years. A similar pattern was found among men, but the incidence of knee OA was lower than in women especially at older ages, rising from 248 cases at ages 50-59 years, to 619 cases per 100,000 person years at age 70-79 years. Approximately 15 years later, Prieto-Alhambra et al performed a similar study in Catalonia, this time using clinical symptoms for diagnosis of OA [22]. Their results also showed an increase in the incidence of hip and knee OA with increasing age.

The epidemiological evidence reported in relation to sex as a risk factor is not consistent. Several studies have shown higher rates of OA in women than in men [7, 17, 22]. For example the GBD study estimated that the global standardised prevalence of radiographic knee OA was 3.8% (95% uncertainty interval (UI) 3.6% to 4.1%) with the mean prevalence lower in men (2.8%; 95% UI 2.6% to 3.1%), than in women (mean 4.8%; 95% UI 4.4% to 5.2%). Contrastingly, a Japanese population-based study known as the ROAD study [19] showed that the incidence of knee OA in men was higher than in women; 6.9% vs 11.9% for K&L≥2 and 8.4% vs 13.9% for K&L≥3. In another population-based study from Norway, where participants self-reported their diagnosis with OA between 1994 and 2004, no significant differences between men and women were found [18]. The differences in incidence reported in the studies might be due to differences in case definitions, study methodology and differences in the populations studied.

1.5.1.2 Body Mass Index

The World Health Organization (WHO) categorises BMI into 6 groups that are widely used in epidemiological studies (underweight, normal weight, overweight, obese type I, obese type II and obese type III). Obesity, assessed through BMI, is a well-recognised risk factor for OA development [23]. In the epidemiological literature cross-sectional, case-control and cohort studies have shown an increased risk of hip and knee OA with increasing BMI [24]. A recent population-based study by Reyes et al [25] showed 1.7 incident cases of hip OA and 3.7 cases of knee OA per 1,000 person-years in normal weight participants versus 3.8 cases of hip OA and 19.5 cases of knee OA per 1,000 person-years in obese class II participants. The excess risk of having OA due to higher BMI was more marked for knee OA than for hip OA, with obese class II individuals having a 4.7 fold higher risk of being diagnosed with knee OA when compared with normal weight individuals [25]. Moreover, subjects with knee OA are at higher risk of undergoing knee replacement as BMI increases [26]. In the case of the hip, a meta-analysis which pooled data from over two million participants estimated that an increase of BMI by 5 units results in an 11% higher risk of hip OA [27].

1.5.1.3 Ethnicity

Not many population-based studies are available that study ethnicity as a risk factor for OA. Jordan et al assessed the prevalence estimates of hip and knee OA in the Johnston County Osteoarthritis project [28]. OA cases were defined by: joint symptoms, symptomatic OA, radiographs with a K&L grade ≥2 or a K&L grade of 3 or 4. The results showed a similar pattern for hip and knee, where African-Americans were found to have a higher prevalence of hip and knee OA than Caucasians. Specifically, hip OA was higher in African-Americans for K&L grade ≥ 2 32.1% (95%CI 29.9 –34.4) than in Caucasians 26.6% (95%CI 25.1- 28.1), and for hip symptoms 12.0% (95%CI 10.3-13.9) in African-Americans versus 9.0% (95%CI 8.3-10.2) in Caucasians [28]. For the knee joint, the prevalence estimates were also higher in African-Americans than in Caucasians [15]. Another study used the third National Health and Nutrition Examination Survey, a cross-sectional survey, to estimate the prevalence of radiographic knee OA. The authors found that people of black ethnicity were at higher risk of developing radiographic knee OA (65%) and symptomatic knee OA (52%) when compared with non-Hispanic whites [13].

1.5.1.4 History of joint injuries

Having a previous joint injury has been suggested as contributing to the progression of OA at both the hip and knee [23]. A meta-analysis including 24 observational studies showed that the risk of knee OA was 4 times higher in patients with a previous knee injury than in those without a prior knee injury. The association was found regardless of the variation in the risk estimates of each of the studies [29]. Additionally, having a meniscectomy procedure has been shown to raise the risk of knee OA [30].

1.5.1.5 Structural factors

Anatomical abnormalities might predispose individuals to hip OA in later life. More recently, a group of 3,620 individuals, who were part of the Copenhagen Osteoarthritis Substudy, had anteroposterior weight-bearing radiographs to examine the association between hip anatomical deformities and development of hip OA. The results showed that participants who had a deep acetabular socket had a relative risk of 2.4 (95%CI 2.0-2.9) and those with pistol grip deformity had a relative risk of 2.2 (95%CI 1.7-2.8) for subsequent development of hip OA compared with people with no hip abnormalities. However, in this study, no statistical association was found between acetabular dysplasia and hip OA (RR: 1.6; 95%CI 0.9 -2.5) [31]. Similarly, Croft and colleagues found no association between hip OA and acetabular dysplasia in men [32], and Smith et al suggested that acetabular dysplasia in elderly women (60 to 75 years of age) was not a cause of hip OA [33].

1.5.1.6 Leisure time physical activity

Public health programmes encourage the population to undertake regular physical activity related to leisure activities as a way of promoting health, but it is important to understand the relationship between physical activity and OA. Two important features need to be considered to assess the impact of activity on the lower limb; i) how particular activities load the hips and knees differently and ii) the duration, frequency and intensity of the activity performed.

A study, in which patients from a clinic in Dallas (USA) were examined, reported their physical activity performed since the beginning of the study and whether a doctor had diagnosed hip or knee OA at follow-up [34]. The results showed that men who walked or jogged more than 20 miles per week had a relative risk of 2.4 (95%CI 1.5- 3.9) of developing OA when compared with those who did not regularly exercise [34]. Other authors took into account duration and intensity of the physical activity to look at the relationship between the strain posed by physical activity on the joint and lower limb OA.

Cases and controls were selected from the Aerobics Center Longitudinal Study (Dallas) and the physical activity was classified into none, low and moderate/high according to the duration, intensity, impact and torsional loading. Among men in the sample, those doing sports that posed a moderate/high stress on the joint had a protective effect against hip and knee OA as compared with sedentary men (OR: 0.62 95%C 0.43-0.89). A more marked protective effect was observed in women defined as doing moderate to high activities when compared with sedentary women (OR: 0.24 95%CI 0.11-0.52) [35]. A meta-analysis studied pooled data from 24 studies to assess whether running had an effect on lower limb OA. The meta-analysis suggested that people running as amateurs were less likely to have hip or knee OA compared with sedentary people, in contrast to professional runners who were more prone to hip or knee OA [36].

1.5.1.7 Role of genetics in OA

Over the last approximately ten years, genetics is continuously being shown to be an important risk factor for OA. With the arrival of the Genome Wide Association Studies [37] it has been possible to assess associations between single nucleotide polymorphisms (SNPs) and OA. These studies concern genotyping large samples of cases and controls to find biological susceptibility of individuals to develop a disease. According to the European Bioinformatics Institute [38], between 2008 and 2019, and mainly during the last three years of this period, ten studies have identified associations between SNPs located in different genes and hip/knee OA.

1.5.2 Occupational risk factors

Occupation is a well-recognised risk factor for hip and knee OA. This section summarises the evidence from recent systematic reviews and meta-analyses, and an update of the literature.

1.5.2.1 Knee OA

Epidemiological studies have examined the relation between occupational activities or types of work, and knee OA. Despite the different study designs or limitations in the design of some studies, there is strong evidence supporting a higher risk of knee OA in certain types of occupations [39].

Two recent systematic reviews [40, 41] have examined the existing evidence on the association between knee OA and occupation or occupational activities (heavy lifting, kneeling, combined heavy lifting and kneeling and climbing stairs). Both reviews retrieved cross-sectional, case-control and cohort studies published until 2011 (see Table 4) and agreed that there is reasonable evidence suggesting that kneeling, lifting [40, 41], squatting and climbing [41] are risk factors for initiating or developing knee OA.

Table 4. Summary of positive associations between occupational activities and risk of knee OA.

Occupational activity	Study design	Positive association with knee OA*	Estimated risk range (RR, OR)
Kneeling or squatting	C	0 out of 1 (0%)	_
	CC	7 out of 10 (70%)	(1.1- 6.9)
	CS	3 out of 6 (50%)	(2.4-4.92)
Climbing stairs	CC	4 out of 8 (50%)	(2.3-5.1)
	CS	1 out of 3 (33%)	1.61
Lifting	C	0 out of 1 (0%)	_
	CC	7 out of 12 (59%)	(2.0-7.31)
	CS	3 out of 3 (100%)	(1.23-2.72)
Walking	C	0 out of 1 (0%)	_
	CC	1 out 8 (12.5%)	2.1
	CS	1 out of 3 (33%)	1.46
Standing	C	1 out of 1 (100%)	3.8
	CC	0 out of 6 (0%)	_
	CS	2 out of 4 (50%)	(1.36-1.38)
Physical workload and combined exposures	C	2 out of 4 (50%)	(2.2-18.3)
	CC	6 out of 8 (75%)	(2.02-14.3)
	CS	2 out of 3 (66%)	(1.32-3.49)

*Adapted from Palmer KT 2012 [41]. C: cohort, CC: case-control, CS: cross-sectional

The occupational activities included in Table 4 are typical of certain types of jobs and therefore people employed in these jobs are more likely to suffer from knee OA. The following list comprises occupations that were included in the reviewed studies and found a positive association with an increased risk of knee OA:

- Agriculture
- Asphalt worker
- Bricklayers
- Chemical & plastic processors (men)

- Cleaners (women)
- Concrete workers
- Construction workers, construction (men)
- Craft workers
- Farm workers (men / women)
- Firefighters (men)
- Floor layers / carpet layers
- Forestry workers
- Fishery workers
- Machine fitters, assemblers, mechanics (men)
- Metal workers
- Painters, carpet layers (men)
- Plasterers, insulators, glaziers, construction carpenters, upholsterers (men)
- Plumbers
- Rock workers
- Sheet-metal workers
- Tile setters
- Transportation and traffic workers
- Wood workers

More recently, two meta-analyses have been carried out. The first one identified 51 studies (8 longitudinal, 25 cross-sectional and 18 case-control studies) accounting for 500,000 individuals [42]. The review looked at the pooled risk ratio for knee OA in occupations involving knee joint loading such as kneeling, knee-bending and carrying weights compared with those activities not involving knee joint loading. They showed a 60% higher risk of knee OA in occupations involving knee joint loading in the studies overall, but this varied by study design from 38% in cohort studies, 57% in cross-sectional studies, and up to 80% in case-control studies.

There was a wide variation in the risk estimate across the studies (OR: 0.95 to 18.09). Most of the findings were consistent with a positive association between occupational activities and knee OA, except for a few studies which showed a protective effect [43-45].

In addition to the type of occupational activities carried out, it is important to consider the period of time that workers are exposed to those occupational activities. Andersen et al found a dose-response pattern between time exposed to certain occupations and future risk of knee surgery. For instance, women employed as health care assistants for between 1 and 5 years had a 5% higher risk of knee replacement as compared with office workers. The risk rose to 27% when employed for between 6 and 10 years, and up to 92% (compared with office workers) for women who remained in the same type of job for more than 10 years [46].

In 2017 a second meta-analysis [47] compared workers exposed to occupational tasks that load the knee joint with those who had no or only low exposure to these demanding tasks. For the case-control studies included, knee OA cases were defined as having K&L grade over 2. The results, summarised in Table 5, are similar to those shown in the previous meta-analysis; suggesting around a 70% higher risk of knee OA in occupations involving kneeling or squatting, 69% higher risk with lifting, and 55% higher risk with climbing stairs.

Table 5. Meta-analysis results from occupational tasks and risk of knee OA

Occupational task	Study design (N)	Odds Ratio (95%CI)
Kneeling or squatting	Case-control (12)	1.70 (1.35-2.13)
Lifting	Case-control (11)	1.69 (1.43-2.00)
Climbing stairs **	Case-control (7)	1.55 (1.25-1.91)

*Table adapted from Verbeek et al 2017 [47] ** Climbing stairs, ladders or flights of stairs

Only two prospective cohort studies were included in the systematic review performed by Verbeek et al, and these two longitudinal studies reported contradictory results. In one of them no association was found between kneeling, squatting and crawling and risk of knee OA [48], whereas the other study found a positive association between kneeling and squatting and knee OA [49]. Because of the possibility of having a greater risk of knee OA with cumulative exposure to knee loading Verbeek and colleagues performed a further meta-analysis with 8 case-control studies. This revealed that being exposed to kneeling or squatting for over 5,000 hours (i.e. approximately equivalent to kneeling on average 4 hours a day over a 5 year period) increased the risk of having/developing knee OA by 26%. However, a third meta-analysis pooling data from two case-control studies that included lifting did not show a dose response effect for lifting activities.

In the light of the findings summarised, the evidence suggests a moderate to strong link between work and occupational activities that load the knee and risk of developing knee OA. In addition cumulative exposure to such demanding tasks poses an even greater risk.

Prescribed diseases

Some jobs can cause deleterious health effects in the long-term. In the UK the law entitles workers to receive benefits when a disease has developed during or after employment in certain jobs. These diseases are known as prescribed diseases, and the diseases and job combinations have been listed in Government Regulations. The Industrial Injuries Advisory Council (IIAC) is a non-departmental public body which advises the Minister for Work and Pensions on which diseases should be covered by the Industrial Injury Scheme, based on the following criteria [50];

- Workers are at greater risk of a disease in an occupation, and
- There is reasonable evidence to attribute a disease to an occupational exposure.

For some diseases occupational history and/or clinical features can be used to attribute a disease to a type of work. Such is the case for diseases where exposure outside of work is very rare and therefore the disease is more frequent in people who carry out particular jobs. An example is occupational asthma, where the symptoms improve when the person is not at work for a period of time (e.g. annual leave) and symptoms get worse when returning to work. However, in many diseases such as OA, it is more difficult to demonstrate that an occupation has caused the disease. For these diseases epidemiological studies have to not only show that people exposed to certain jobs are more likely to develop OA, but also that the workers have at least double the risk of having the disease. This last criteria is based on the fact that OA cases observed in a population exposed to a hazard have a 50% chance to occur because of the exposure and a 50% chance not to be related to the exposure. Several studies have shown such a two or more fold risk of knee OA in specific occupations (Table 6).

Table 6. Risk ratio of knee OA by type of job

Author	Occupation	Risk estimates (95% CI)
Cohort studies		
Jarvholm B (2007)	Asphalt worker	2.81 (1.11 – 7.13)
	Brick layers	2.14 (1.08 – 4.25)
	Floor layers	4.72 (1.80 – 12.33)
	Plumbers	2.29 (1.19 – 4.43)
	Rock workers	2.59 (1.18 – 5.69)
	Sheet-metal workers	2.60 (1.06 – 5.37)
	Wood workers	2.02 (1.11 – 3.69)
*Sandmark H (2000)	PE teachers (vs. matched population referents)	Men 2.7 (1.6 - 4.6)
		Women 4.0 (2.0 - 8.2)
Vingard (1991)	Firefighters – Men	2.93 (1.32 - 5.46)
	Cleaners – Women	2.18 (1.26 - 3.00)
Case-control studies		
Franklin J (2010)	Technicians/clerks – Men	2.0 (0.71 – 5.7)
	Farmers – Men	5.1 (2.1 – 12.4)
	Fishermen – Men	3.3 (1.3 – 8.4)
	Craft workers – Men	2.5 (1.0 – 6.2)
*Holmberg S (2004)	Farm work 11-30 vs. <1 yr – Women	2.1 (1.0 - 4.5)
	Farm work >30 vs. <1 yr – Women	2.0 (0.7 – 5.5)
	Building & construction 11-30 vs <1 yr – Men	3.7 (1.2 - 11.3)
Manninen (2002)	Transportation & traffic (vs. professional workers)	3.07 (1.19-7.90
*Sandmark H (2000)	Farmers (vs. non-heavy jobs) – Men	3.2 (2.0 - 5.2)
	Farmers (vs. non-heavy jobs) – Women	2.4 (1.4 - 4.1)
	Construction workers – Men	3.1 (1.5 - 6.4)
	Forestry workers – Men	2.1 (1.0 - 4.6)
Seidler A (2008) Men >10 yrs in job	Chemical & plastics processors	16.1 (3.1 – 84.4)
	Machine fitters, assemblers, mechanics	3.0 (1.5 – 6.2)
	Plasterers, insulators, glaziers, Construction, carpenters, upholsterers	5.7 (1.2 – 28.0)
	Storemen, nurses, refuse collectors	4.3 (1.6 – 11.7)
Vingard E (1992)	(vs. jobs with low physical workload)	
	Farmers – Men	5.3 (1.4 - 19.7)
	Painters, carpet layers	23.1 (3.0 – 178.3)
	Construction workers	5.1 (2.6 – 10.0)
	Metal workers	3.2 (1.7 – 5.9)
*Yoshimura N (2006)	Work in factory, construction, agriculture or fishery (vs. not)	6.2 (1.40 – 27.5)
Cross-sectional studies		
Thun M (1987)	Tile setters (vs. controls)	2.0 (90%CI: 1.2 - 3.3)
Lawrence JS (1955)	Coalminers (vs. dockers and light manual workers)	2.6 (1.3 - 5.9) †
	Coalminers (vs. dockers, light manual & office workers)	3.0 (1.6-6.1) †

Reproduced from Palmer KT 2012 [41] * Tibiofemoral knee OA † Derived OR and 95%CI

Based on some of the findings shown in Table 6, IIAC recognised OA of the knee for prescription among underground miners in 2008 and among carpet and floor layers in 2010 [51].

1.5.2.2 Hip OA

Similarly to the knee, numerous epidemiological studies have assessed the association between work and hip OA. A systematic review examined the relationship between physically-demanding jobs or occupational tasks, and risk of hip OA [52]. Thirty studies published up to and including 2009 met the inclusion criteria, of which 12 were of cross-sectional design, 12 were case-control and 6 were cohort studies.

Within the same review Sulsky et al described the conclusions drawn in previous systematic reviews published between 1999 and March 2011 which had looked at hip OA and work. Although the body of literature supported a positive association between work load and hip OA, there was some variation between the studies in the strength of the association, with some authors finding a strong association and others finding a more moderate association.

A more recent review summarised associations reported in the literature between occupation or occupational activities and the risk for hip OA [53]. The positive associations with estimated risks over 2.0 are shown in Table 7.

Table 7. Associations between occupation or occupational activities and risk of hip OA

Case-control studies	
Farming > 10 vs. < 1 year	OR 3.2 (95%CI 1.8-5.5)
Work >5 hours/day in animal barns since age 30 vs. no work in animal barns	OR 13.3 (95%CI 1.22-144.98)
Work on farm > 30 vs. 0 years	OR 4.45 (95%CI 2.90-6.83)
Heavy lifting (weights of ≥50 kg) vs. no lifting	OR 4.41 (95%CI 1.1-15.2)
Lifting >25 kg for ≥ 20 vs. 0 years	OR 2.3 (95%CI 1.3-4.4) in men
Cohort studies	
Intensive vs. sedentary physical activity at work	RR 2.1 (95%CI 1.5-3.0) in men RR 2.1 (95%CI 1.3-2.3) in women
Heavy manual vs. light sedentary at work followed up 22 years	OR 6.7 (95%CI 2.3-19.5)

Since this review by Harris et al, we only found one additional original study looking at the association between occupation and lower limb OA. Using the Korea National Health and

Nutrition Examination Survey, almost 10,000 participants over 50 years old described their occupations and these were grouped into four clusters according to the physical demands. The findings showed that the more physical load a job implied, the more likely individuals were to develop hip or knee OA [54].

Another way of examining the association between hip OA and occupation is by exploring the more severe OA cases, which are generally referred to surgery. Accordingly, Rubak et al published two studies that assessed the relationship between cumulative exposure to physically-demanding jobs or occupational activities, and total hip replacement, using two different study designs. For the first study [55] the authors studied a population-based cohort of Danish workers which included people who had been employed for at least 10 years. Participants were grouped into three categories relating to the load on the hip for each type of industry. Cumulative exposure to workload was found to contribute to the risk of having a hip replacement in men but not in women. The second report [56] described a nested case-control study in the working age population where individuals reported their job title. The authors found that cumulative exposure to heavy lifting was a risk factor for having a hip replaced in men (lifting more than 20 ton-year OR:1.35 95%CI 1.05-1.74) , whereas standing for more than 6 hours per day or being exposed to whole body vibration was not associated with hip arthroplasty.

Prescribed diseases

The published literature has consistently indicated that the risk of hip OA is double in farm workers or farmers when compared with the general population, and these findings have been similar across studies carried out in both the UK and in other countries [50]. On the basis of the epidemiologic studies the Industrial Injuries Disablement Benefit covers OA of the hip in farmers or workers employed in farm work for more than ten years [45].

1.6 Impact of OA

1.6.1 On individuals

Longer life expectancy coupled with lower birth rates is modifying the shape of the population towards an increase in the number of people who are retired and a decrease in the number of people of working age. At the same time, the number of workers aged between 50 years and state pension age in the UK, increased by 6.8% between 1994 and 2014 [57]. Over the next decades supporting the retired population, both in financial terms and in health-care, will pose a major challenge across European countries. To face this scenario, similar strategies have been adopted across different countries. In 1995 and again in 2011 the UK government reformed the law to gradually increase the state pension age as a way of encouraging workers to stay in the labour market. Within this context of an ageing working force, the impact of OA on the capacity to work due to a deterioration in physical function is an increasing concern.

Physical function is the ability to move around and look after yourself, and progressive OA is known to have a negative impact on it. There are different methods to assess physical function, but it is not clear to what extent OA alters the ability of people to perform daily activities because there is no consensus about what measures should be included when testing people with OA [58]. On the one hand function can be assessed objectively using performance-based tests, or subjectively using patient reported outcome measures (PROMs). Also one or more joints can be affected by OA. There are validated questionnaires to measure the functional impact at specific areas of the body such as hip or knee (e.g. Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)) or hands (arthritis hand function test). However, it has been estimated that there is a high prevalence of individuals with multisite OA amongst people with advanced stage hip and/or knee OA [59, 60]. Therefore when studies assess function based on answers to PROMs, they may well underestimate functional limitations.

1.6.2 On society

OA of the lower limb is associated with loss of productivity, reduced ability to work and lost working years due to a premature retirement. Pain is a key symptom in individuals with OA which generally leads to work productivity loss. It can be assessed in terms of working days lost due to sick leave episodes, being at the workplace while feeling unwell (presenteeism) or experiencing limitations in coping with occupational activities. Different surveys conducted in several countries have described the effect of OA on daily living activities, including occupational activities. In the UK, 17.3% of respondents to a UK survey of people with self-reported OA indicated that their work was affected by OA [61].

A French study surveyed patients who sought physician advice due to OA. The average age of the participants was 66 years but approximately 20% of them were still part of the workforce. Among the workers 18.6% reported missing a day of work because of an arthritic hip and 20.5% because of an arthritic knee. In addition, this group of participants reported more frequent occupational limitations due to their hip (60.5%) and knee (65.7%) than the general population (14.3%) whose limitations were attributed to other health-related conditions [62]. Another American cross-sectional survey not unexpectedly reported higher productivity loss in employees with pain caused by OA as compared with those who did not report pain. More interestingly, this survey also found that presenteeism was 4 times higher than absenteeism (30.7% and 8.1% in those with OA pain vs 15.7% and 3.9% in those with no OA pain) [63].

Although longitudinal studies are scarce, a prospective study found that the association between pain in OA patients at the beginning of the study and reduced work productivity 3 years later at follow-up was mediated by physical function [64]. This suggests that OA has a significant functional impact over three years and that this significantly impacts the ability to work effectively.

In some cases workers have lost their jobs while being on waiting lists for hip or knee replacement. The proportion of individuals in this situation varies across studies. Bohm et al reported that 20% of individuals waiting for hip replacement were off work and hip functional limitation was a predictor of this [65]. Palmer et al found a higher prevalence of 37% off work amongst people waiting for hip or knee surgery [66]. A further study found that 15% of almost 2,000 respondents retired an average of 7.8 years prematurely due to OA [61].

1.6.3 On the economy

The economic burden of OA can be divided into direct, indirect and intangible costs [67]. Direct costs are the expenditure arising from pharmacological and non-pharmacological treatment, hospital resources and physician consultations. The Arthritis Research UK charity estimated that the cost of lower limb arthroplasty (79,399 hip and knee replacements) in 2000 amounted to 405 million pounds [68]. Other figures available are the 2007-2008 NHS costs breakdown, which rated the surgical cost of each hip and knee replacement at 7,800 and 4,471 pounds respectively [69]. Generally the costs associated with joint replacement vary across the UK depending on hospital length of stay and the implant used for the surgery. As Figure 2 shows [67], the greatest expenditure in the management of OA is that due to joint replacement surgery (85%) whereas medical prescriptions (Non-steroidal anti-inflammatory drugs (NSAIDS), NSAIDS iatrogenic and PPIs) represent approximately 10-14% of the budget [70]. However, it is likely that the total of direct costs are higher than the figures presented in this section since the number of hip and knee replacements have been increasing over the past few years.

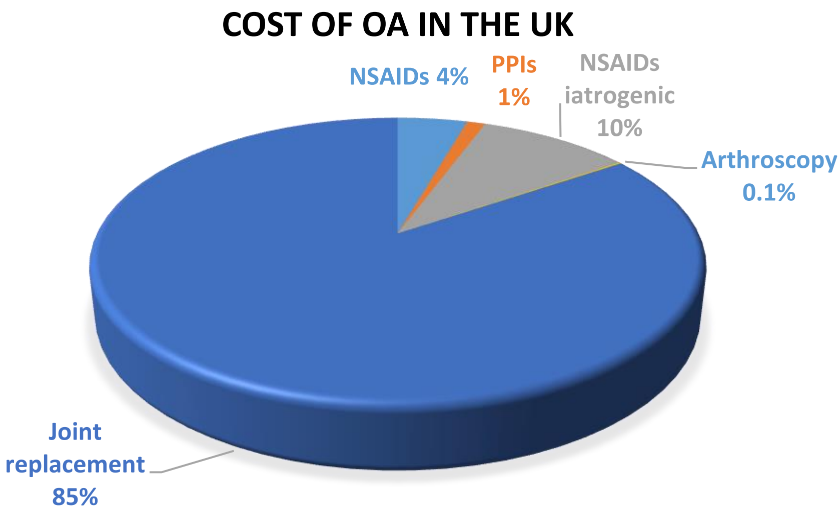

Figure 2. Expenditure on OA treatments

A report based on data from 2008 estimated the total direct cost attributable to OA in the UK at 5.2 billion pounds per year [71].

A second category of economic burden arises from the indirect costs. These do not relate to payments, but to loss of resources, and can be subdivided into costs related to work disability and costs related to informal caregiving. Work disability covers different areas; the number of days on sick leave due to the joint condition, work presenteeism, and reduction in the number of hours worked. Some studies have estimated figures for these costs in the UK. During 1999-2000 the loss of productivity caused by working days lost due to OA generated economic losses was estimated at 18 million pounds [68]. A more recent report estimated total indirect costs in patients with OA and rheumatoid arthritis at 14.8 billion pounds. Permanent retirement was the category that contributed most to the economic loss, but other types of costs included: reduced productivity; informal caregiving; and absenteeism [71].

A third category of economic costs are the intangible costs. They include expenses that cannot be quantified, for example pain and suffering experienced by the patient or the loss of quality of life. It is difficult to estimate intangible costs, such that few studies have attempted to do so. In the GBD study the WHO promotes the Disability Adjusted Life Years (DALYS) as way of measuring health status in a population. Although this measure does not provide numbers, a group of researchers transformed the healthy life lost resulting from OA during 2008 into a monetary value of 7.1 billion pounds [71].

1.7 Treatment options

The NICE guidelines recommend a set of measures to manage patients with OA on the basis of the best evidence available. These proposed strategies follow a hierarchy (Figure 3), aim to reduce pain and stiffness of the joint, enhance the function and improve health related quality of life [72]. A first approach to OA management comprises a set of core measures intended to modify a patient's behaviour. These are: i) education related to the disease to provide better understanding of the condition, ii) physical activity or exercises to strengthen muscles supporting the affected joint, and iii) weight loss in overweight and obese patients as it a strong risk factor for OA. Other non-pharmacological treatments that can be offered alongside the core treatments are thermotherapy, electrotherapy, assistive devices, and manual therapy (for hip) [73].

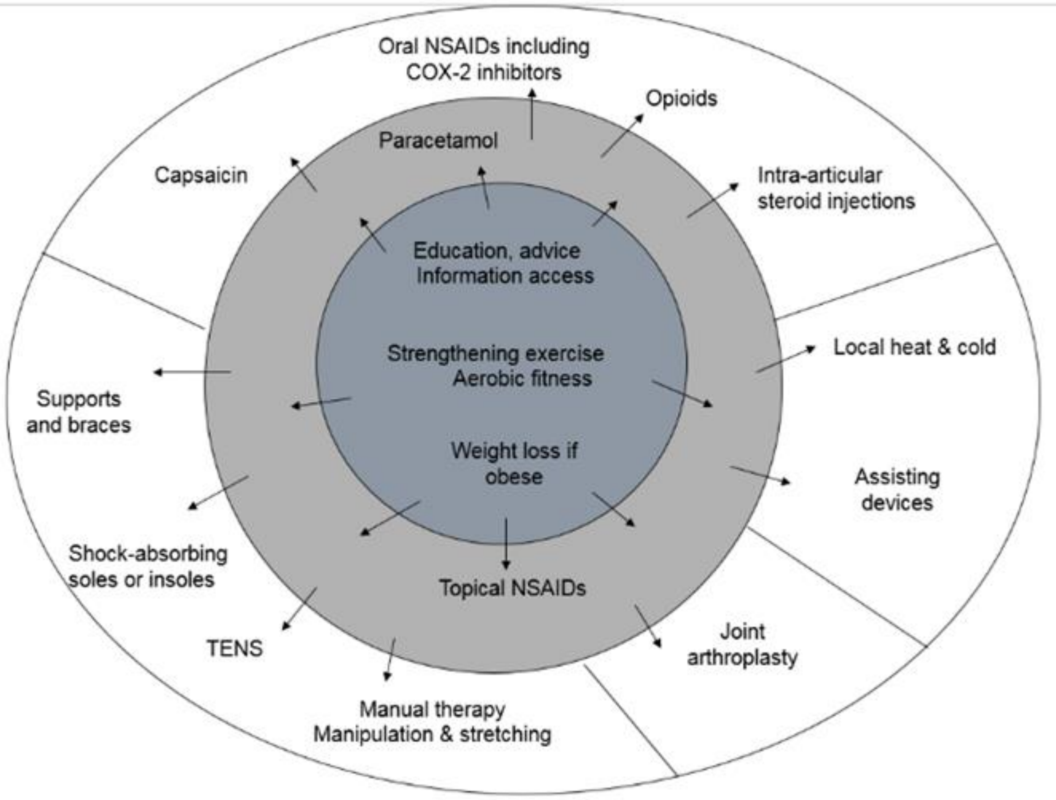

Figure 3. Strategies for OA management

A further level in OA treatment involves prescribing pharmacological treatment (paracetamol, NSAIDs, COX inhibitors or opioids) which is administered topically ahead of taking the same drugs orally. Another option to relieve pain are intraarticular injections. Non-pharmacological and pharmacological methods are not always effective in managing the condition. In cases where patients have been provided with core treatment but still suffer from severe stiffness, pain and functional limitation, clinicians may opt to refer the patient to be considered for joint surgery.

1.8 History of arthroplasty

1.8.1 Total hip replacement

Total hip replacement (THR) is the most effective orthopaedic operation developed in the 20th century that modified the treatment of the arthritic hip joint. The first attempt recorded was in 1891, when Themistocles Glück used ivory to replace the femoral head (hemiarthroplasty). In the following years surgeons performed a technique known as interpositional arthroplasty which consisted of interposing soft materials (such as fascia lata, skin or pig bladders submucosa) between the head of the femur and the socket to avoid contact with the inflamed surfaces [74].

In 1925, Marius Smith-Petersen created a mould of glass suitable to fit over the femoral head which allowed movement of the joint. However the mould cracked because the resistance of the bearing surface was not appropriate to the hip contact forces [75]. A few years later, Smith-Petersen and Philip Wiles successfully replaced glass with stainless steel, creating the first total hip replacement that was fixed to the femur through screws and bolts [75, 76]. The product was improved in the fifties by McKee [77].

In 1952 Drs Robert and Jean Judet described a new technique to perform a hip arthroplasty which was widely used [78]. After undergoing this procedure some of the patients had a squeaky hip, which indicated mechanical friction between the plastic of the original Judet prosthesis and the bone. In response to this problem and to extend the lifespan of the hip implants John Charnley investigated the mechanism underlying joint lubrication. He used different materials (i.e. metal and plastic) to successfully recreate an artificial cartilage characterised by low friction. This revolutionary concept and how to perform the surgery using a stem inserted in the femur and a head inserted in the socket was first documented in 1961 [79].

Currently multiple hip implant designs are available for use by surgeons. In parallel to prosthesis development, bearing surfaces of the implant progressed to achieve low friction, avoid wear of the bearing surface and enhance lubrication. Different options are available for surgeons; metal-on-plastic (low friction concept), ceramic on ceramic, ceramic on crosslinked polyethylene [80] and metal on metal, in order to reduce the wear of the implant and prevent failure of the hip. Metal on metal implants are no longer used because of the poor survival rate of these type of implants.

1.8.2 Unicompartmental and Total knee replacement

The early stages of knee arthroplasty development were similar to hip arthroplasty. In 1860, Verneuil suggested interposition arthroplasty using soft tissues to cover joint condyles but obtained poor results by applying this technique [81]. The next step took place in the late 1930s when the soft tissue was replaced by metal materials, given that Smith-Petersen had obtained positive results using these materials for the hip joint.

A few years later two TKA designs anchored to the bones through intramedullary stems, were constructed by Walldius (in 1953) and Shiers (in 1954); the hinge prosthesis and the gliding joints [82]. The hinge design improved progressively and the results obtained were better than when other TKA designs were used, however long term complications such as early loosening or infection remained a common complication [83].

In parallel to the development of TKA, an alternative procedure was developed to treat the compartment of the joint affected by the disease rather than the whole joint. This next generation of implants consisted of the bicompartmental prosthesis designed to treat arthritis in two compartments: the patellofemoral and either the medial or the lateral compartment. Following the low friction hip arthroplasty concept, in 1971 Frank Gunston described the polycentric knee arthroplasty design. This consisted of a flat surface of high density polyethylene and a round surface component surrounding the femoral head [84]. One year later, in 1972, Coventry described how to perform a geometric TKA. Among other objectives, this design was created to improve knee motion, retain cruciate and collateral ligaments to absorb the stress and avoid bone removal [85]. However it showed high rates of loosening [81].

Also over the seventies designs for the total condylar prosthesis were developed. The most relevant design was the Insalls Total condylar prosthesis, considered the first modern TKA prosthesis, which aimed to improve the mobility range of the knee. In the 1970s-1980s, new implant designs emerged but complications with the femoro-patellar joint were frequently observed during the 1980s and 1990s [81]. In the early eighties (1982) a significant implant, designed by John Goodfellow and John O'Connor, was used as an alternative to TKA to treat compartments of the joint [86]. This design evolved over time from phase I to phase III to improve the survival rate. Recent results of the medial Oxford Phase 3 Unicompartmental Arthroplasty (UKA) have described a survival rate of 93% at 10 year follow-up [87].

1.8.3 Orthopaedic registries

Hip and knee surgery methods and implants developed quickly. The orthopaedic surgeon Göran Bauer realised that it was not ideal that surgeons chose the best operative treatment for patients based on their experience. Additionally the evidence available in the orthopaedic literature was mainly focused on specific methods or implants used [88]. Thus in 1975 he promoted the first knee arthroplasty register known as the Swedish Knee Arthroplasty Register (SKAR) in which prospective data about surgical techniques and implant designs were collected. All such data, longitudinally collected, would provide quality information to allow surgeons to make an informed decision, as well as to the industry. Currently, there are 16 well-established joint registries in different countries or regions that record all information that relates to arthroplasty procedures performed in a country or region. Their main goal is to monitor patients who receive a joint replacement, examine long-term function, detect possible implant failures of new prosthesis in the market and to monitor the quality and outcomes of surgery. For example, using unpublished data from the National Joint Registry (NJR), the company DePuy Orthopaedics recalled the ASR XL implant in 2010 (metal on metal) because the data showed a revision rate of 13% at 5 years follow-up for this device [89]. The NJR of England and Wales was set up following a recommendation made by the Royal College of Surgeons of England in the light of the investigation on the 3M Capital Hip. This prosthesis started to be commercialised in 1991 and during the following six years it was implanted in more than 4,500 patients across 79 centres over the UK. The first signs suggesting concern about the poor performance of the prosthesis were raised at an orthopaedic conference four years after the prosthesis was first commercialised, but the evidence available was not consistent. In 1997 the prosthesis ceased to be marketed and the relevant authorities began detailed research into the problem which was summarised in a report published in 2001 by the Royal College of Surgeons of England [90]. From this report it was clear that the revision rate of the 3M Capital Hip was higher than the revision rate for other hip prostheses. At the time the report was being drafted the revision rate benchmark for failure in a new prosthesis was 10% at 10 years and 8.6% of patients with 3M Capital Hip had undergone revision surgery at 5 years follow-up [90]. To avoid a similar scenario occurring again the NJR has been collecting information on all hip, knee, ankle, elbow and shoulder replacement operations performed in England and Wales since 2002, since 2013 in Northern Ireland and since 2015 in the Isle of Man.

According to the most recent NJR report [91] a total of 890,681 total hip replacements and 975,739 knee replacements were performed between 1 April 2003 and 31 December 2016, with OA being the most common indication to have these operations. The vast majority of patients have unilateral joint replacement, however 15.4% of hip patients and 20.6% of knee patients have both joint sites done at different points in time and approximately 1% have a bilateral replacement. The average age to undergo hip arthroplasty was 68 years and to undergo knee arthroplasty 69 years.

The data collected over these years show an increase in the annual number of lower limb arthroplasties performed in the UK. Part of this growth is due to increasing numbers of operations among those aged under 60 years old. Recent data show that 14,611 hip replacements were done among people aged 59 and below in 2008, with that number increasing to 18,027 in 2016. Despite the absolute numbers reflecting an increase in total hip replacement, the proportion of the population aged 59 and below has remained stable representing 14% of the people who had THA [92]. Similarly knee replacements in this age group raised from 11,737 in 2008 to 17,182 in 2016 [93].

1.9 Going back to work

Besides the pain relief and functional improvement of the joint, another important outcome of the arthroplasty, especially for those in the working age population, is to regain their work ability to perform the occupational activities inherent to their job post-operation. Following a period of recovery, patients who are younger at the time of the surgery are more likely to return to work. Some of these patients will have a long working life after arthroplasty and before retirement. Thus it is important that these patients receive advice in relation to how their occupation might affect the replaced joint both in the mid or long-term, and in a positive or negative way. As shown in Table 8 there are currently no published guidelines available to clinicians, surgeons, rheumatologists, occupational health specialists or general practitioners. However, a leaflet published by the Royal College of Surgeons suggests that the time taken to resume work after hip or knee replacement depends on the type of the job. For example, patients returning to heavy work (e.g. doing a lot of heavy lifting by hand) need a longer period of time to recover than patients returning to light work [94, 95]. These same documents also mention that in the long-term some workers might feel that they need to undertake less physically-demanding tasks. In this situation the document encourages workers to contact occupational health in the first instance or their GP.

This guidance has the benefit of eminence and consensus from surgeons and occupational health physicians but was not underpinned by evidence.

Table 8. Recommendations available to advise patients regarding their occupation after arthroplasty

Guidelines	Long-term clinical outcomes
Occupational Health guidelines	No
The British Society of Rheumatology	No
The British Orthopaedic Association	No
Royal College of Surgeons of England	Yes
Royal College of Occupational Therapists	No
The National Institute for Health and Care Excellence	No

Although there is no scientific evidence to include recommendations in guidelines, a study from 2014 showed that the ability to perform certain occupational activities after TKA entailed difficulty for some patients. In this, a sample of 172 workers, who continued working two years after TKA, reported how difficult they perceived occupational tasks that strained the replaced joint were to carry out. Despite improvement following the arthroplasty those activities which posed higher levels of stress on the knee improved to a lesser extent (kneeling and crouching) [96].

1.10 Long-term outcomes after arthroplasty

1.10.1 Physical Function and pain

The main reasons to undergo lower limb arthroplasty are to relieve pain and improve function. To measure how these parameters (e.g. stiffness or general health) change over time following replacement, it is common to use self-administered questionnaires such as WOMAC, SF-36 or KOOS, pre and post-surgery, and at different points in time. It appears that there is a common pattern in the recovery of function and pain following lower limb arthroplasty. In the first few months after surgery function and pain tend to improve steadily [97] until people reach a peak that corresponds with the best results obtained after surgery. Afterwards there tends to be a plateau followed by a slow deterioration in physical function and pain [98]. However most of the studies that follow-up patients pre and post-surgery continue the follow-up for no longer than one or two years [99, 100], so that developing longer-term evidence on function and pain post-operatively is more challenging.

One prospective study looking at self-reported outcomes pre- and post-TKA using the Knee Injury and Osteoarthritis Outcome Score (KOOS) and SF-36, amongst a group of 102 participants with a mean age of 71 years at the time of the operation, found a continuous improvement at both 6 and 12 months after surgery in: i) pain, ii) function related to activities of daily living (ADL) and sport and recreation, iii) knee-related quality of life, iv) vitality, v) general health perceptions, vi) emotional and social role functioning and vii) mental health. However at 5 years, physical function, body pain and vitality had declined [101]. A similar deterioration in function has also been observed in another small group of young patients who underwent knee replacement between 1977 and 1992. When they were followed up in 1997 the Knee Society Functional Score was 92.9 (SD ± 13.4), but fifteen years later it had decreased to 62.1 (SD ± 32.2) [102]. The pattern of improvement is somewhat different for hip replacements. In a group of 75 patients with THA, levels of physical function were similar at 1 and 7 years post-surgery (WOMAC function: 79 (SD ± 16.7) vs 76 (SD ± 1.1), p=0.56) and also similar for pain at 1 and 7 years after surgery (WOMAC pain: 85.6 (SD ± 16.4) vs 78.2 (SD ± 22.1), p=0.63). Interestingly, the level of physical function attained was similar in patients who underwent replacement and in patients who had no replacement and additionally did not report pain or diminished range of motion [103]. Consistent with the function improvement post-arthroplasty, the results of another study in a small group of patients who underwent THA or TKA, Bruyere et al observed their function to be better at 7 years than at 6 months follow-up [104].

Traditionally the success of joint arthroplasty has been measured using revision surgery as a proxy of implant failure. When considering survival rates there is no doubt about the success of the operation, but is not so clear when different outcomes, such as pain or physical function, are taken into account, especially in the younger population. For example, after lower limb arthroplasty, there is evidence that a significant group of patients continue to report pain. Beswick et al performed a systematic review identifying prospective studies reporting the proportion of patients that experienced long-term pain after THA (6 studies) and TKA (11 studies). The authors estimated that long term pain occurred in 7% to 23% for patients with THR and 10 to 34% for patients with TKA after operation [105].

Another alternative measure of outcomes consists of using self-reported outcome measures after arthroplasty, especially in the younger population as Price et al suggested in the light of the findings of their study [106]. These authors investigated a small sample of patients (53 patients with 60 TKA) who were aged under 60 years at the time of knee replacement. At 15 years after the surgery survival for TKA was 82%, but in contrast, the Oxford Knee Score (OKS) results showed that 41% of the patients reported moderate or severe pain.

1.10.2 Complications

Lower limb arthroplasty is a highly successful procedure but complications may be expected in a small number of patients. They can be broadly divided into short-term and long-term complications. In the early post-operative stage possible short-term complications are:

- post-operative bleeding,
- wound complications,
- deep vein thrombosis,
- pulmonary embolism,
- cardiorespiratory complications,
- early dislocation (within three months of the operation),
- infection originated at the time of the surgery
- and leg length discrepancy that in the more severe cases leads to nerve palsy (in the case of hips) [107].

Other complications specific to knee replacement procedures are; neural deficit related to the index TKA, instability, malalignment, and disruption of the extensor mechanism [108].

Long-term complications differ from short-term complications and may necessitate patients to undergo reoperation or revision procedures (see Table 9). Reoperation surgery is performed when one or more components of the prosthesis are required to be exchanged (e.g. wires) and a revision is a more complicated procedure that consists of removing and replacing the prosthesis in a single-stage or two-stage approach.

Within the first year after a hip arthroplasty, dislocation and infection are the main reasons to undergo revision. However, in the mid to long-term generally the trend changes and aseptic loosening and pain become the main causes recorded for revision. In the case of knee arthroplasty, an infected prosthesis is the most frequent cause of revision in the short-term and as with hip replacement, aseptic loosening is the main reason for revision in the long-term

Table 9. Revision rates of hip and knee replacement per 1,000 persons per year by cause

HIP										
Years	**Aseptic loosening**	**Pain**	**Dislocation**	**Infection**	**Peri-prosthetic fracture**	**Mal-alignment**	**Lysis**	**Implant wear**	**Implant fracture**	**Other indication**
< 1	1.13 (1.06-1.20)	0.66 (0.61-0.72)	2.37 (2.27-2.48)	1.54 (1.46-1.63)	1.67 (1.59-1.76)	0.77 (0.71-0.83)	0.08 (0.06-0.10)	0.35 (0.31-0.39)	0.23 (0.20-0.27)	0.72 (0.67-0.78)
5 to 7	1.40 (1.32-1.49)	1.20 (1.12-1.28)	0.46 (0.41-0.51)	0.40 (0.36-0.45)	0.52 (0.47-0.58)	0.28 (0.25-0.33)	0.44 (0.39-0.49)	0.32 (0.28-0.37)	0.16 (0.13-0.20)	0.54 (0.49-0.60)
KNEE										
Years	**Aseptic loosening**	**Pain**	**Dislocation**	**Infection**	**Peri-prosthetic fracture**	**Mal-alignment**	**Lysis**	**Implant wear**	**Implant fracture**	**Other indication**
< 1	0.62 (0.57-0.67)	0.59 (0.54-0.64)	0.38 (0.34-0.42)	1.64 (1.56-1.73)	0.27 (0.23-0.30)	0.35 (0.31-0.39)	0.11 (0.09-0.13)	0.19 (0.16-0.22)	0.01 (0.01-0.02)	0.69 (0.64-0.74)
5 to 7	1.20 (1.13-1.29)	0.53 (0.48-0.59)	0.09 (0.07-0.12)	0.50 (0.45-0.55)	0.11 (0.09-0.13)	0.27 (0.24-0.31)	0.26 (0.23-0.30)	0.31 (0.28-0.36)	0.03 (0.02-0.04)	0.98 (0.90-1.05)

Table partially reproduced from the 14th Annual National Joint Registry report [91]

1.11 Risk factors for revision surgery

Implant revision is a more complex procedure than primary hip or knee arthroplasty due to the damaged bone stock and soft tissue surrounding the joint once primary surgery has been performed. The increasing number of primary arthroplasties will inevitably lead to a higher demand for revision procedures in the future, thus it is important to know what risk factors contribute to failure. There is a growing body of literature looking at associations between implant failure and demographic factors, comorbidities, implant related factors, health services, physical activity and other risk factors. Nevertheless revision is not defined homogeneously across studies; in some studies it is defined as the replacement of some or all components of the prosthesis whereas other studies define revision as removal of the whole prosthesis. In addition, some studies consider all causes of revision while others consider revision limited to specific reasons, such as aseptic loosening or infection. This section discusses risk factors that may lead to a revision procedure.

1.11.1 Age

Studies consistently show that failure of primary hip replacements and partial or total knee replacements is higher when the primary operation took place at younger ages. A collaboration between Swedish, Norwegian and Danish national registries showed a higher failure of hip replacement in people aged below 60 years. At 10 years after hip replacement 93-95% of cemented implants in patients older than 60 years at the time of the surgery were free from revision as compared with 87% to 91% of the patients who were operated when younger than 60 years old [109]. Similarly, knee replacements carried out at younger ages are more likely to be revised (HR 2.30 95%CI 1.96,2.69) [110]. A recent study using data from the Clinical Practice Research Datalink (CPRD) calculated the lifetime risk of revision for total primary hip or knee replacement and found that between 4.4% and 7.7% of the patients who had the index surgery over the age of 70 will have an implant failure. This risk of failure increases to 15% in patients who had the index surgery aged 60 years or less [111]. Likewise, undergoing UKA surgery at a younger age has been shown to be a risk factor for revision across different registries. The age at which people were more likely to have an implant failure differed across the data collected in different countries, for instance in the NJR for England, Wales, Northern Ireland and Isle of Man patients who underwent arthroplasty below 55 years of age were more prone to have a revision procedure, but in the Register of Orthopaedic Prosthetic Implants (RITO) which covers the Emilia-Romagna region (over 4 million people), this was associated with people younger than 60 years of age at the time of the operation [112].

A possible explanation for higher failure rates in the younger population might be that younger people tend to be more physically active after their surgery so that the durability of the prosthesis is reduced due to wear and tear.

1.11.2 Sex

Sex is associated with implant failure but the relationship varies depending on the type of arthroplasty. For hip replacement, a meta-analysis pooling data from three studies reported that men were 39% more likely to undergo revision surgery due to aseptic loosening than were women (OR 1.39; 95%CI, 1.22,1.58) [113]. Conversely women who underwent knee replacement showed higher failure rates compared with men with odds ratios from four out of five studies ranging from 1.51 (95%CI 1.11,2.05) to 2.77 (99%CI 1.66,4.62) [114-116]. An exception to this came from a study by Blum et al who found that women were at 19% lower risk of knee revision than men (OR 0.81 95%CI 0.71,0.92) [110].

1.11.3 Ethnicity

Few studies have looked at associations between ethnicity and risk of revision. Blum et al studied 17,385 patients who underwent knee replacement and reported that patients of Black ethnicity were at higher risk of revision compared with those of White ethnicity (HR 1.39 95%CI 1.08,1.80) [110].

More recently a meta-analysis in which the effect of race on TKA in the United States was studied, used pooled data from 4 studies. The analysis of 451,960 participants showed that people of Black ethnicity were at greater risk of revision than Caucasians (HR 1.38 95%CI, 1.20,1.58) [117]. Contrary to this finding a study by Dy et al found that Black ethnicity was not significantly associated with hip revision when compared with white Caucasians, and other ethnicities seemed to have a protective effect for revision when compared with the risk among white Caucasians (HR 0.79 95%CI 0.70,0.89) [118].

1.11.4 Obesity

The effect of obesity on hip or knee revision surgery is controversial. A recent study, based on data from the CPRD, suggested BMI to have a small effect on the risk of hip or knee revision following lower limb arthroplasty (THA, TKA) [119], whereas pooled data from 9 studies showed a higher risk of TKA revision surgery in obese patients (OR: 1.79 95%CI 1.15,2.78) [120]. A case-control study that included 67 failures of total hip arthroplasty (THA) or total knee arthroplasty (TKA) due to aseptic loosening showed that patients with a BMI over 28 kg/m^2 had 2.29 times higher risk of failure (95%CI 1.19,4.41) when compared with patients with a BMI between 18.5-28 kg/m^2 [121]. Also a study by Dy et al found that obesity was associated with septic (HR 1.68 95%CI 1.34,2.09), but not with aseptic failure of the hip replacement [118].
A further two cohort studies suggested that body weight and BMI had no effect on UKA prosthesis survival. One of these studies followed prospectively a group of over 3,500 people for a period of 5.5 years post-operation with no significant association between BMI and implant failure [122]. Likewise, another retrospective study found a similar prosthesis survival rate at 10 year follow-up in people with a BMI < 30kg/m^2 and people with a BMI ≥ 30kg/m^2 [123].

1.11.5 Comorbidities

Epidemiological studies have examined the influence of comorbid conditions on revision rates heterogeneously. Some authors assess comorbid diseases using scores, for example the Charles comorbidity index or ASA score [124, 125]. Other authors such as Jamsen et al examined the relationship between specific medical conditions and risk of revision [126]. In their study, Jamsen and colleagues found that hip and knee replacements due to OA were at higher risk of failure in patients who presented with other medical conditions; subjects with psychotic disorders were 41% more likely to have hip and knee revision, whilst those with cardiovascular diseases were 19% and 29% more likely to have hip and knee failure respectively when compared with those not having the disease examined [126]. Only a few studies have examined whether depression has an effect on implant revision. Two studies reported this comorbidity to be associated with hip revision [118, 126]. Additionally suffering from depression pre-arthroplasty has been suggested to be related with poor outcome post hip arthroplasty [127]. Diabetes has also been suggested to be associated with total knee revision due to aseptic loosening, but the American Society of Anesthesiologists (ASA) grade did not show any association between comorbidities and revision [128]. Kreder et al found no higher risk of revision after TKA in subjects with comorbidities [129].

In a THA cohort it was observed that having a Deyo-Charlson comorbidity score of 2 (HR 1.74 95%CI 1.25,2.43) or 3 or higher (HR: 1.71 95%CI 1.26,2.32), as well as having an increased ASA score, were associated with a higher risk of post peri-prosthetic fracture [130].

1.11.6 Tobacco

Over recent years the role of smoking on implant survival has been examined. A meta-analysis identified six cohort studies published before August 2014 which looked at the relationship between smoking and the risks of complications after THR. The pooled risk ratio showed that smokers had over 3 times higher risk of aseptic loosening (RR 3.05 95%CI 1.42,6.58), 3.71 times higher risk of deep infection (RR 3.71 95%CI 1.86,7.41) and 2.58 higher risk of exchange or removal of the component for any reason (RR 2.58 95%CI 1.27,5.22) as compared with patients who never smoked [131]. Additionally Kapadia et al reported poorer survival of knee prostheses in smokers than in non-smokers (90% versus 99%) [132]. In contrast to these findings, a more recent study based on a sample of more than 10,000 hip and knee arthroplasty recipients assessed the effect of smoking on the risk of hip and knee revision surgery. Burn et al found that current smokers were at lower risk of revision compared with non-smokers. However, these findings were non-statistically significant HR:0.71 95%CI 0.39,1.29 for the knee, and HR: 0.76 95%CI 0.44,1.32 for the hip [119].

1.11.7 Surgical related factors

Fixation technique (cemented, uncemented or hybrid), implant design and surgical approach all influence the risk of revision. A meta-analysis published recently (2017) assessed the relationship between cemented, uncemented or hybrid implant with risk of revision due to any reason and due to aseptic loosening. The analyses pooled data from randomised control trials, cohort and registry studies retrieved since January 2000 onwards. The authors found no differences in the risk of revision in cemented versus non-cemented implants regardless of whether revision was recorded for any reason (RR 0.47 95%CI 0.45, 0.48) or due to aseptic loosening (RR 0.90 95%CI 0.84, 0.95) [133].

Paxton et al used data from national and regional registries to estimate the differences in risk of revision between different bearing surfaces. A total of 16,571 total hip replacements from six national and regional registries in patients aged between 45 and 64 years showed a non-statistically significant risk of revision in excess of 20% in metal on conventional polyethylene when compared with metal on highly cross-linked polyethylene [134]. A more recent network meta-analysis found that, between 2 and 10 years post hip arthroplasty, metal-on-metal, small heads, cemented implants were almost four times more likely to undergo hip revision surgery compared with metal-on-polyethylene (not highly cross-linked), small head, cemented implants (HR 3.94 95%CI 1.21,13.20) [135].

1.11.8 Health services

Revision rates are higher in hospitals that perform a lower volume of arthroplasties. Hospitals where less than 200 THA are performed annually have been shown to be at 33% greater risk of aseptic revision when compared with hospitals where over 400 THA are performed each year (HR 1.33 95%CI 1.16,1.52) and those where 201 to 400 THA are performed per year were at 42% greater risk compared with the higher volume arthroplasty hospitals (HR 1.42 95%CI 1.24,1.64) [118]. In the case of knee arthroplasty, centres with 201 to 400 TKA per year showed 9% lower risk of revision (HR 0.91 95%CI 0.83, 0.99) compared with centres performing 200 or less TKA per year [136]. Using information on patients receiving the Oxford III UKA implant, the Nordic Arthroplasty

Register Association (NARA) showed that at ten year follow-up they are more likely to undergo partial knee revision when the primary operation was performed in hospitals where less than 11 operations per year were carried out compared with hospitals with more than 44 procedures (HR 0.82 95%CI 0.70,0.94) [137].

1.11.9 Previous surgery

According to one study, a greater risk of revision of a TKA was found amongst individuals who had previously had other knee surgery, finding that, at 15 years of follow-up, no revisions had been performed in patients with no other knee surgery but 3% of patients with a TKA and a previous high tibial osteotomy (HTO) had been revised [138]. Other studies have used data from national joint registries to examine whether surgery prior to knee arthroplasty is a risk factor for revision. The Finnish Arthroplasty Register found that HTO prior to TKA had a hazard ratio of 1.40 (95%CI 1.09,1.81) compared with TKA alone [139]. In a more recent study Badawy and colleagues compared prosthesis survival in patients with and without prior HTO. Both groups, identified from the Norwegian Arthroplasty Registry, were diagnosed with OA and were comparable in terms of age, sex, number of revisions, surgery time and implants. At 10 years after TKA cumulative survival was similar for both, TKA 93.8% (95%CI 93.4,94.2) and TKA with prior HTO 92.6 % (95%CI 91.0,94.2) [140].

1.11.10 Physical activity

It is less clear whether physical activity has a positive or negative effect on implant survival in the long-term. Ritter et al found no correlation between sports played before and after hip replacement and implant loosening assessed radiographically in a group of 214 hips [141]. Another study reported results of a small group of young patients (25 years old at the time of THR) followed after arthroplasty. At five years, 7 patients had required revision surgery, of whom 5 reported their level of activity as being heavy and 2 sedentary. A further 5 patients who presented with migration of the acetabular or femoral component had levels of activity; sedentary in three cases, moderate in one case and heavy in the last case [142]. More recently, Lübbeke et al assessed the effect of a patient’s activity on femoral osteolysis at five and ten years post-THR. The authors used the UCLA activity scale, where patients indicate their activity level between 0 and 10, and found an increase of femoral osteolysis with increasing levels of physical activity [143]. However, these findings are contrary to those reported by Majewski and colleagues, who observed signs of osteolysis more frequently in non-active patients than in moderately active or active patients [144].

Currently there is not much evidence available to guide health professionals as to what type of physical activity should be advised for patients after lower limb arthroplasty. Therefore, the recommendations are based on surgeons' opinions. They generally agree that sports that pose low stress to the hip or knee (low impact sports) can be performed safely, but that contact sports (e.g. football or jogging) should be discouraged. In addition, there is a third group of sports that are generally recommended only for people with previous experience in this sport (e.g. tennis). A systematic review [145] identified studies published before January 2010, and used the evidence available about the effect of physical activity on rate of joint revision to make clinical recommendations. Since physical activities load the joints differently, some of the recommendations made by Vogel et al varied according to the joint replaced. For example, doubles tennis and hiking were recommended after THA, but only encouraged after TKA amongst those patients with previous experience of the sport. The list of activities below shows recommendations for both THA and TKA:

a) Recommended: golf, swimming and bowling
b) With experience: cycling, rowing and cross country skiing
c) Not recommended: squash/racquetball, jogging/running, singles tennis, martial arts, baseball, waterskiing.

Few studies have focused on the relationship between physical activity and TKA failure. In a recent study carried out in Austria, 16 subjects with TKA and willing to ski took part in an intervention which consisted of skiing regularly two or three times per week for 12 weeks and during 3 seasons. The patients were asked to ski a certain distance a day and with a specific incline. The control group also skied, but they were not willing to do it regularly. Approximately two years after the intervention the authors did not find radiolucent lines or osteolysis in either the intervention group or the control group [146].

In chapter 2, all published epidemiological evidence (using specific criteria) regarding physical activity and revision will be described, distinguishing between physical activity at work and that related to sports.

1.11.11 Other risk factors

Over the last decade the use of three groups of medication have been linked to an improvement in prosthesis survival: hormone replacement therapy (HRT), bisphosphonates and statins. There are a small number of studies which have looked at whether the use of these drugs impact implant survival (mainly hip prosthesis) and the results consistently suggest a protective effect.

Hormone replacement therapy (HRT). One study assessed the relationship between HRT and implant failure and showed a protective effect of HRT intake on prosthesis failure despite heterogeneity of the sample studied. Prieto-Alhambra et al used data from the CPRD to assess women, who had THA or TKA, at a mean time of 3.3 years after surgery. The authors found that hip and knee implant survival was better among women who had taken HRT for 6 months or less as compared with women who had not taken HRT (HR 0.62 95%CI 0.41,0.94). The improvement in prosthesis survival was even greater in HRT users for a period of ≥12 months compared with non HRT users (HR 0.48 95%CI 0.29,0.78) [147].

Bisphosphonates. Another study used an approach similar to that used by Prieto-Alhambra et al. The authors identified patients who had a primary THA in California and showed that 8 years after arthroplasty patients treated with bisphosphonate were 47% less likely to have an aseptic failure of the implant (HR 0.53 95%CI 034,0.81) compared with patients not treated with bisphosphonate. However, patients treated with bisphosphonate were 92% more likely to have a peri-prosthetic fracture (HR 1.92 95CI% 1.13,3.27) compared with those not treated [148].

Statins. The use of statins to avoid hip arthroplasty failure has been suggested by Lübbeke et al, since rates of femoral osteolysis in statin users was found to be lower than in non-users after 5 years of follow-up after the index surgery [149]. An earlier case-control study identified 2,349 revised hip arthroplasties and the same number of controls, among the Danish Hip Arthroplasty Registry. The results showed that the risk of revision from all causes was 67% lower in patients who had at least one statin prescription after replacement as compared with non-statin users (RR 0.34 95CI% 0.28,0.41). A similar pattern was observed when the analysis focused on the risk of revision due to specific causes; i.e. deep infection, aseptic loosening, dislocation or peri-prosthetic fracture but not in cases where the revision cause recorded was pain or implant failure [150].

1.12 Hypothesis and objectives

As described, there is moderate to strong evidence suggesting that work contributes to the development of primary OA of the lower limb. Specifically the cumulative exposure to heavy occupations which involve tasks that mechanically load the hips (e.g. farming) or knees (e.g. carpet fitting) have been shown to increase the risk of OA. For younger patients who undergo hip or knee replacement and who often go back to work, it is possible that these same exposures post-operatively might lead to premature failure of the joint or impairment of long-term function. It is therefore important to know the extent of any risk, so that patients can make informed choices about their activities after surgery and therefore the main objectives of this thesis are to:

1. Carry out a systematic review to explore whether there is any existing data to suggest an increased risk of post-operative joint failure associated with occupation or occupational activities, and sports
2. Examine to what extent the mid- to long-term risk of joint failure is increased by exposure to physically-demanding activities that stress the joint
3. Examine to what extent the level of physical disability is increased by exposure to physically-demanding activities that stress the joint
4. Examine to what extent physically-demanding activities post-arthroplasty influence the work ability of people following arthroplasty.

Chapter 2 : Work and leisure activities as risk factors for revision of hip and knee arthroplasty: a systematic review

2.1 Introduction

Lower limb arthroplasty has been one of the most successful orthopaedic procedures of the late 20th century. Such is the success of this type of operation that it is increasingly being offered to adults at younger ages. For example UK data show that in 2004-5 there were 10,145 hip replacements done among people aged 59 and below, and that this number had increased to 17,883 in 2014-15 [151]. Additionally, future projections point towards an even greater increase in these type of surgical procedures by 2030 and 2035 [152-154].

Although highly effective interventions, hip and knee replacements may fail over time necessitating revision surgery to the replaced joint. Revision surgery is a more complex procedure than primary arthroplasty with poorer outcomes [155] and a greater economic burden [156, 157] on health services. Therefore, it is important to study what risk factors contribute to reoperation or revision surgery in order to develop strategies to prevent the need for revision surgery following a lower limb arthroplasty. Moreover, a better understanding of modifiable risk factors can contribute towards improving the advice provided by clinicians to their patients post-operation. Some of these modifiable risk factors have been identified and summarised in the first chapter of this thesis, for example smoking habits [131, 132]. However, it is less clear how work and non-work related physical activity may influence the survival of the replaced joint. After lower limb arthroplasty, it appears that in general surgeons recommend avoidance of physical activities that put high strain on the joint, such as high impact sports (e.g. running or basketball), but encourage engagement with activities considered as low impact sports (e.g. swimming), but most of this advice appears to be eminence-based rather than evidence-based [158, 159].

We found no previous systematic review which had examined the association between physical activity (either occupational, or from recreational activities) and risk of revision either of the hip or knee joint. Thus the main objective of this review was: 1) to identify evidence on whether returning to work post-arthroplasty in occupations involving heavy physical activities increases the risk of revision of the joint, and 2) to identify whether post-operative exposure to any form of high-impact or intensity leisure time physical activity (LTPA) contributes to the risk of revision of the joint.

2.2 Methods

A protocol of the systematic review was registered in PROSPERO under the registration number CRD42017067728 in May 2017.

2.2.1 Search strategy

A search strategy was developed based on key terms from the review questions and from the Prospero protocol (e.g. heavy occupation and total knee replacement). Using these terms, an initial search was performed in Pubmed to identify keywords used in the title and/or abstracts of the relevant literature that came out from this initial search. For example farming, work, job or occupation, and total knee arthroplasty. This list with free-text terms and keywords was then combined with a set of medical subject headings (MeSH) terms to run a search in MEDLINE and Embase using the Ovid search engine and in Scopus. The search was limited to studies published in peer review journals, from January 1985 to February 2018 and in the English or Spanish language. Since each database has specific MeSH terms, a detailed search was set up using the terms shown in Appendix A.

All the titles and abstracts obtained from each database were transferred to EndNote X7 software to manage bibliographical references, and duplicates were removed. Letters, notes, editorials and editorial commentaries were also excluded, but if a conference abstract was found we checked whether a full paper was subsequently published. In addition, reference lists from all full papers retrieved, as well as the systematic reviews found during the search, were checked to find any additional relevant studies not covered by the MeSH terms or key words used in the search.

2.2.2 Inclusion and exclusion criteria

All the studies that met our inclusion criteria, were included in the systematic review. Our inclusion criteria were:

i) revision of total hip or total knee replacement on patients aged above 18 years,
ii) the cause of the revision surgery was a reason other than infection
iii) physical activity or daily activities were recorded, and the study included
iv) a minimum of one year follow-up post-arthroplasty
Examples of exclusion criteria used in the process of identifying studies eligible for the review are presented in Table 10.

Table 10. Exclusion criteria for the title, abstract and full text retrieved from the search

Exclusion criteria		Example
• Focus on patients with inflammatory arthritis	→	Ankylosing spondylitis, rheumatoid arthritis or juvenile chronic arthritis
• Focus on patients with other specific pathologies	→	Dysplasia of the hip, haemophilia, sickle cell haemoglobinopathy
• Focus on other surgical hip or knee procedures	→	Hip resurfacing, hemiarthroplasty, osteotomy, UKA
• Focus on other anatomical parts	→	Ankle replacement
• Focus on risk factors related to surgical factors	→	Type of implant, fixation technique, surgical approach
• Focus on wear of the prosthesis	→	Volume of polyethylene wear
• Focus on non-elective procedures	→	THA following a femoral fracture
• Focus on peri or short-term post-operative complications	→	30-90 days readmission after surgery
• Focus on other outcomes	→	Mortality
• The study defines joint failure based exclusively on X-ray	→	Osteolysis
• The study does not report a control group	→	Case series

2.2.3 Data extraction

Two data abstraction sheets were created to extract relevant and consistent data for the studies retrieved; one for case-control studies and another for longitudinal studies (see Appendix A). A draft version was tested on a number of studies to ensure that all relevant information was collected and this led to the final version. One reviewer, Elena Zaballa

(EZ), screened all titles and abstracts, and a second reviewer; Clare Harris (ECH) screened a sample of 10% of the titles and all those that were in doubt. A second screening of the full papers retrieved was performed independently by EZ and ECH. In case of discrepancies, a third reviewer, Karen Walker-Bone (KWB), took part in the discussion.

Data extracted were: i) Author and year, ii) study design, iii) country, iv) duration of follow-up, v) diagnosis to undergo arthroplasty, vi) sample size, vii) age at the time of operation, viii) numbers lost to follow-up, ix) definition of revision, x) potential biases xi) covariates considered, and xii) risk estimates.

2.2.4 Quality assessment

Different structured instruments have been established to assess the quality of a research paper and proved to be effective, for example in assessing randomised control trials. There are also different tools that have been established to assess observational studies, but they do not tend to look at the validity of the studies assessed [160]. Therefore for this study a risk of bias form based upon that developed by the Scottish Intercollegiate Guidelines Network (SIGN) [161] and the Assessment of Quality in Lower Limb Arthroplasty (AQUILA) checklist [162], was developed to assess the risk of bias in the non-randomised studies that were retrieved (see Appendix B). Two reviewers (KWB and EZ) independently assessed each study, reached agreement where there were areas of disagreement, and discussed potential bias and the direction of its effect.

2.3 Results

A total of 18,011 citations were identified in the searches carried out in the MEDLINE, Embase and Scopus databases (see flow chart) using the combination of terms specified in Appendix C.1. Three additional citations, which were published prior to 1985, were identified by hand searching through all references retrieved of relevant papers and systematic reviews. After removing duplicates, 10,361 titles and abstracts were screened to obtain 45 studies that were potentially relevant papers for which full texts were obtained.

Detailed assessment of the full texts resulted in the exclusion of another 33 studies, leaving 12 papers that met our specified inclusion criteria. The title and the specific reason or reasons to exclude each of the full-text papers are summarised in Appendix C.

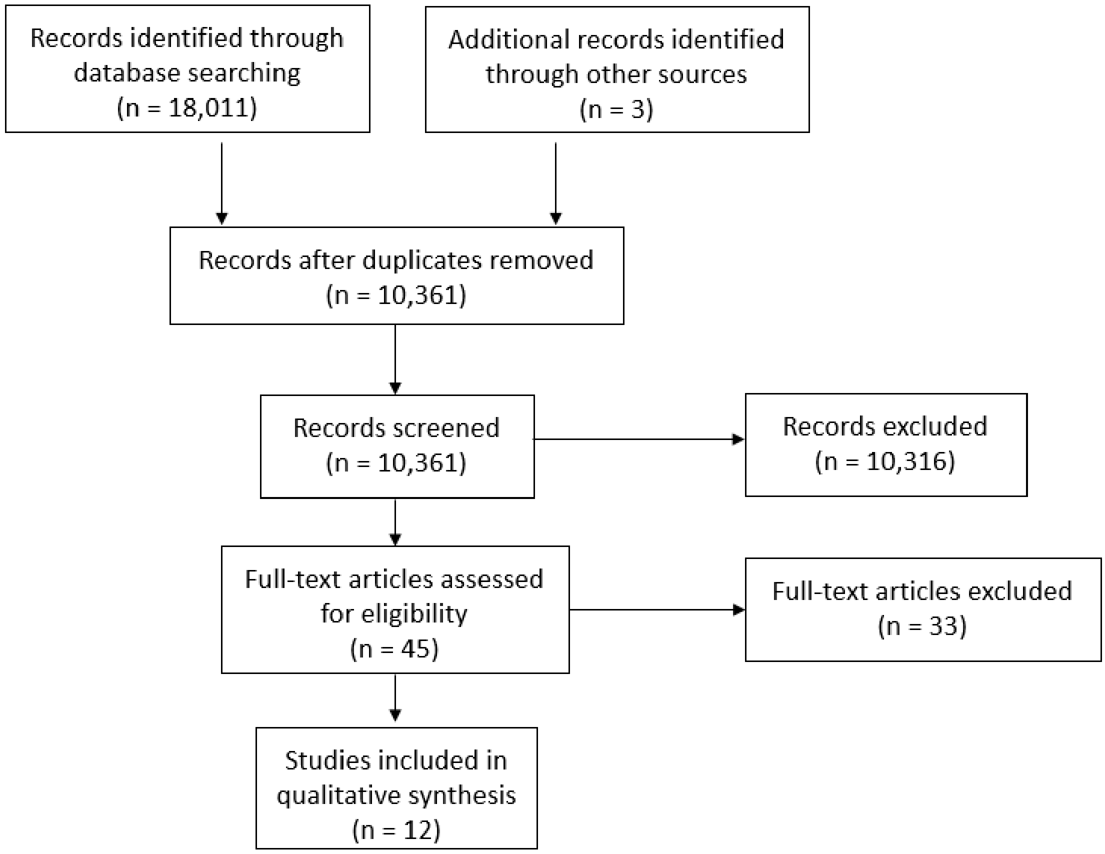

Figure 4. Flow chart for the identification of the studies included

The main characteristics of the epidemiological evidence included in this review are described in Table 11. All the studies were published between 1983 and 2017 in European countries, the USA, Korea and Japan. From the twelve papers identified, nine focused on hip arthroplasty [143, 163-170], and three on knee arthroplasty [171-173]. We found no randomised control trials that met our eligibility criteria for inclusion. Dividing the 12 studies by study design, there were eight longitudinal studies, of which three were prospective [166, 167, 173] and five retrospective [143, 163, 164, 168, 169], and four case-control studies [165, 170-172]. The duration of the follow-up period varied across the studies with a minimum period of 4.9 years [164] and a maximum of 11 years [169]. Overall, we rated the quality of the included studies to answer our research question as high in 3 studies and acceptable in 5 studies; poor in one study, and very poor in 3 studies. Along with the quality of the studies Table 11 summarises the risk of bias in three categories: low, moderate and high. Out of the 12 studies, four were rated as having a low risk of bias; 3 case-control and 1 retrospective study [143, 165, 170, 172]. In contrast, four studies were considered as having a moderate risk of bias [167-169, 173] and four as having a high risk of bias [163, 164, 166, 171].

The main reasons for scoring poorly were: a lack of detail on how the exposure was measured; insufficient information about how the participants were classified into groups exposed to more or less demanding joint load post-operatively; lack of information about selection criteria; and failure to adjust for potential confounders in the analyses.

In the following sub-section we summarise, for the hip and for the knee, the main characteristics and findings from the 12 included papers which complied with our eligibility criteria and were described in Table 11. We report the results from the papers using a narrative synthesis including the results sorted by the nature of physical activity, i.e. work activities, leisure time physical activities (LTPA), and work and LTPA combined, taking into account the hierarchy of the study design.

Table 11. Summary of the studies included in this review listed in date order and by whether the focus was on hip or knee arthroplasty

Author	Year	Country	Study design	Duration of follow-up	Quality assessment	Risk of bias
HIP						
Dubs [163]	1983	Switzerland	Retrospective	5.8 years (range 1-14)	(-)	High
Kilgus [164]	1991	USA	Retrospective	Mean FU period: OA patients More active: 9.2 years Less active: 4.9 years Non-OA patients More active: 10.7 years Less active: 5.2 years	(-)	High
Espehaug [165]	1997	Norway	CC	N/A	(++)	Low
Inoue [166]	1999	Japan	Prospective	Mean length of FU: 7.5 years SD (0.2-15.3)	0	High
Maurer [167]	2001	Switzerland	Prospective	Median FU: 10.2, 7.7 and 5.2 years according to the stem type	(+)	Moderate
Flugsrud [168]	2007	Norway	Retrospective	Registry data available between 1987 and 1st January 2001 Maximum duration of FU (1987-2004)	(+)	Moderate

Author	Year	Country	Study design	Duration of follow-up	Quality assessment	Risk of bias
Lübbeke [143]	2011	Switzerland	Retrospective	FU at 5 and 10 years post-THA	(+)	Low
Ollivier [169]	2012	France	Retrospective	Mean 11 years (range 10-15)	(+)	Moderate
Delfin [170]	2017	Sweden	CC	N/A	(++)	Low
KNEE						
Heck [171]	1992	USA	CC	N/A	(-)	High
Jones [172]	2004	USA	CC	N/A	(++)	Low
Han [173]	2013	Korea	Prospective	Mean FU: 5.1 years, range (0.9-8.6) in group HF and 6.3 years (0.9-8.6) in group U	(+)	Moderate

*CC; case-control. Quality score: high (++), acceptable (+), poor (0), very poor (-). Group HF: high flexion activities, group U: no high flexion activities

2.3.1 Hip arthroplasty

There were nine studies which explored the association between physical activity and the risk of revision surgery after hip arthroplasty. Seven out of the nine papers described longitudinal studies, of either prospective or retrospective design and two papers described case-control studies published with a gap of 20 years between them [165, 170]. In Table 12 and Table 13 the main characteristics of the studies that met the eligibility criteria are described.

Amongst the longitudinal studies, all seven included THA procedures that had been performed no later than 2003. Three of the seven studies only included participants who were physically active at the time of the hip operation [164, 167], or who the author described as "younger" men with an average age of 55 years at THA [163]. The number of included participants ranged from 210 in the study of Olliver et al [169] up to a maximum of 1,535 participants in the study by Flugsrud et al [168]. Overall, more women than men were recruited in all studies, except for the study by Dubs [163] in which all participants were men. The average age at which THA had been performed in each study group varied between 55 and 69 years old. Among those studies that reported age at the time of hip revision surgery, two reported that hip revisions had been performed in younger patients than the mean or average age of the group studied [163, 168]. Across all the hip studies, primary OA was the main diagnosis leading to arthroplasty with a prevalence of over 60%. However, patients were recruited with other underlying diagnoses, including: rheumatoid arthritis; juvenile rheumatoid arthritis; avascular necrosis; developmental dysplasia of the hip; and hip fracture. No study restricted their sample to patients who underwent hip surgery due to primary OA alone.

The studies reported some diversity in the nature and characteristics of the surgical procedures performed. These included the number of different surgeons who performed the hip arthroplasties, laterality of the procedure and fixation technique used. For example, in the studies carried out by Kilgus et al and Ollivier and colleagues [164, 169], the operations were carried out by just two surgeons, whereas in the other five studies, several surgeons performed the operations. In addition to unilateral THA, which was the most frequent procedure, some of the studies included patients who had received bilateral THAs. The hip implants in the included studies were predominantly cemented [163, 164, 166, 167], but some studies also included uncemented [169] or hybrid [143] fixation. All types of fixation were included in the sample of participants studied by Flugsrud et al [168].

In this current review, the outcome of interest, revision of the lower limb arthroplasty, was defined differently by the researchers in the studies we included. Some authors defined revision simply as hip revision [163] or failure of the femoral or acetabular component [166]. However, in the remaining five studies, the case definition specified revision procedures that were performed for aseptic loosening [143, 164, 167-169]. Even amongst these latter studies however, authors used slightly different definitions: Maurer et al focused on failure of the femoral component alone [167] whereas Lübbeke et al defined the event as revision of either femoral, acetabular, or both components [143].

In the longitudinal studies, there was also variation on how exposure to physical activity that loads the hip joint was measured and reported and in the period of time over which the exposure was measured. In some studies measurement of exposure was confined to data abstraction from patient's medical notes or records [164, 166]. Others used patient-completed validated tools for their assessment, including the UCLA scale [143, 169] or the Saltin-Grimby scale [168]. Measurement of the timing of these exposures was reported as having occurred at any of the three possible time points: pre-operatively, peri-operatively and post-operatively. Because of these differences in both the way in which physical activity was examined and the time frame when the exposure was measured, the findings from the studies were grouped according to the type of physical activity to which the population studied were exposed: work activities alone, leisure-time physical activities alone, and work and leisure-time physical activities combined.

2.3.1.1 Findings for work activities

Three studies assessed the effect of work pre-hip arthroplasty on subsequent joint failure. From these, two prospective studies found a greater than three times elevated risk of hip revision in agriculture or in farming workers. Specifically, Maurer et al, in a study of moderate quality, found that the more physical the workload at the time of hip replacement the more risk there was of undergoing hip revision [167]. Men were categorised as being exposed to either little physical stress or physical stress (or farming work), and compared with women. Nevertheless, the criteria upon which the categorisation as little physical stress or physical stress (or farming work) was made were not described in the paper. After adjusting for individual characteristics (height, weight), offset of stem, side of implant, surgeon's experience and subsequent contralateral replacement, men exposed to “little physical stress” (as defined by the authors) were three times more likely to have their hip revised (RR: 3.15 95%CI 1.70-5.80) compared with women. Men exposed to higher levels of physical stress or farming jobs were five times more likely to have their hip revised (RR: 5.24 95%CI 2.80-9.80) compared with women. Similarly Inoue et al found a higher risk of hip failure in people working in agriculture compared with those not working in agriculture (RR: 2.85, p=0.03). Specifically among women working in agriculture at the time of undergoing THA, the risk of hip revision was three times that of women who were not working in agriculture (RR:3.09, p=0.04). However, among men, although the risk of revision was raised, no significant association was observed (RR: 2.37, p=0.40). Confounding variables included in the final model were age, sex, diagnosis and cementing technique. This study was rated of low quality according to our criteria [166]. In contrast to these findings a third study (rated of moderate quality) found no association between revision for aseptic loosening of the cup or stem and work-related activities in either men or women. In fact, in the sample studied the estimated effects suggested that physically-demanding activities pre-arthroplasty had a protective effect over the hip joint [168], but it is unknown whether participants went back to work after replacement.

One case-control study also found heavy occupation as recorded before THR or where relevant post-arthroplasty to be associated with hip joint failure. Espehaug et al (rated high quality according to our criteria) examined cases and matched controls selected from the Norwegian Arthroplasty Register. OA was the most frequent indication for primary THA but this study also included participants for whom the indication was rheumatoid arthritis or developmental dysplasia. Exposure to physical activity at work and in leisure was measured using a bespoke questionnaire tool. Revision, no matter for what reason, was defined as a case and 538 case-control pairs were identified in the Register using this definition. Using a patient-completed survey the type of occupation was recorded before and after hip arthroplasty. Additionally the participants provided information on whether their work related physical activity involved “doing heavy physical work” (yes/no). Among women, “heavy work” was found to be a factor associated with higher rates of revision arthroplasty, with the odds of revision almost doubled compared with women not doing heavy work (OR: 1.9 95%CI 1.2,3.2). Specifically, women in health service jobs and performing domestic work were found to be at higher risk of revision surgery than women doing domestic work alone (OR: 2.5 95%CI 1.2,5.1). Other ORs estimated in this study did not reach statistical significance, but estimated ORs double the risk of hip reoperation across different types of occupations when compared with people who performed domestic work e.g.; health service (OR: 2.1 95%CI 1.0,4.8), and industry/engineering/ construction and domestic work, (OR: 2.0 95%CI 0.7,5.7) [165].

2.3.1.2 Findings for leisure-time physical activities (LTPA)

In the study by Flugsrud et al, rated as acceptable quality, before the arthroplasty was performed participants were asked to complete the Saltin and Grimby scale by picking the option that better described their leisure activities in the twelve months prior to the time of completing the questionnaire. According to this scale spare-time physical activity can entail : i) almost complete inactivity, ii) some physical activity during at least 4 hours a week, iii) regular activity or iv) regular hard physical training for competition. The four groups of this scale correspond to the categories of sedentary, moderate, intermediate and intensive physical activity during leisure as defined by Flugsrud et al. The results of this study showed that men who participated in intermediate/intensive physical activity during leisure before their primary THA had a twofold increased risk of cup revision for aseptic loosening as compared with sedentary men. However, after controlling for the type of implant, physical activity and demographic covariates (age at screening, height, BMI, marital status, smoking habits) the risk of cup revision was found to be fourfold higher in men who engaged in intermediate/intensive leisure activities as compared with sedentary men (RR:4.8 95%CI 1.3,18.2) [168]. In contrast to these findings however, another study, rated as poor quality, found no association between recreational activities before primary THA and the risk of THA failure (RR:0.89 95%CI 0.40,1.98) [166].

Another study rated as of acceptable quality, used the UCLA assessment tool and reported that people taking part in high impact activity (which included sport and heavy labour) after primary THA were more likely to have a hip prosthesis failure than those who reported that they undertook only low impact activities post-operatively (OR:3.64 95CI% 1.49,8.9) [169]. The researchers grouped participants into categories based upon the UCLA scores: high impact was defined as a score on the UCLA scale of 9 or 10, and low impact was defined by a score between 1 and 4. Unfortunately, due to inclusion of occupational activity within the UCLA, it is impossible to know to what extent the post-operative exposures that resulted in high impact activities were at work, in leisure time, or in both. However the study was focused on sport activities practised post-arthroplasty, hence it has been included in this section.

Espehaug et al collected information on sports and recreational activities performed both before the hip symptoms started and after hip arthroplasty. The frequency and the intensity of the sports performed relied on two items from a self-reported survey questioning; whether people took part in competitive sports (yes/no), and also if this was performed on a weekly basis (yes/no). Interestingly, regular exercise post-THA showed a protective effect among the sample studied [165]. Men who reported doing exercise on a regular basis (weekly) before THA were at increased risk of needing a THA revision (OR: 2.6 95%CI 1.4,4.7) as compared with those who were not engaged on a regular basis. However, in contrast, performing regular exercise post-THA was associated with a decreased risk of hip revision in men (OR: 0.7 95%CI 0.4,1.2) and also in women (OR: 0.8 95%CI 0.5,1.2), compared with those who did not engage in regular exercise, but the difference was not statistically significant.

Similarly, another study found more hip revisions in individuals who did not engage in any sport post-THA compared with those who regularly participated in sport after THA (14.3%

vs 1.6%). However the authors did not define what was considered as practising sport regularly [163]. This study was found to be of very low quality according to our assessment criteria.

2.3.1.3 Findings for work & LTPA combined

Kilgus and colleagues divided recipients of total hip arthroplasty into post-operatively active and less active groups. The active group included people who reported a heavy occupation or regularly did sports for several years post-arthroplasty, and the less active group comprised the rest of the THA recipients. Their findings suggested that people more active following THA were at over twice the risk of aseptic loosening as compared with less active patients [164]. However, this study was also found to be of poor quality according to the applied criteria.

Only one study examined physical activity based on the UCLA scale. The authors used this scale to divide patients according to the level of physical activity measured post-arthroplasty in: low activity (UCLA 1 to 4), moderate activity (UCLA 5 to 7) and high activity (UCLA scale 8 to 10) groups. A univariate regression analysis showed that among the patients who developed femoral osteolysis after THA, revision for aseptic loosening was more likely with increasing levels of activity post-operatively [143]. This study was rated as of acceptable quality according to our assessment criteria.

A second case-control study, by Delfin and colleagues. The cases were defined as people undergoing revision arthroplasty due to either dislocation or aseptic loosening of the implant. Using this definition, they were able to find 27 pairs of cases and controls. The physical activity exposures were measured using the self-completed UCLA measurement tool. The results suggested that neither the level of global physical activity reported by the individuals nor the frequency of the physical activity were associated with the risk of revision arthroplasty (OR: 0.46 95%CI 0.12,1.84) [170]. The quality assessment for this study was high.

Table 12. Description of the longitudinal studies retrieved by type of joint replaced

Author, year	Study sample	Diagnosis	FU and events	Case definition	Exposure	Adjusted for	Risk estimate 95% CI
HIP							
Dubs 1983[163]	110 men (152 THAs) identified retrospectively among 150 younger male patients who were invited to take part in survey. All participants operated between 1970 and 1980 in the Wilhelm Schulthess Clinic Average age at arthroplasty: 55.4 years (29-68)	Coxitis (hip OA) Polyarthritis and Bechterew's arthritis patients excluded	5.8 years (1-14) 9 prostheses failed (8 patients)	Revision surgery of the replaced hip joint	Occupation and sports activity both pre and post-THA recorded retrospectively using a self-administered questionnaire	RR calculated from available figures	14.3% of participants who did not engaged in sport after THA needed revision, 1.6% of the participants who practised sports underwent revision. Participants doing sports pre and post-THA vs participants less active or not doing sports: RR; 0.11 (CI 0.01-0.90)
Kilgus 1991[164]	444 women and 244 men from the UCLA hip replacement database operated by two surgeons. Mean age at THA: 48 years in 25 patients who were more physically active, and 60 years in 663 patients who were less physically active	OA (246), avascular necrosis (95), RA* and juvenile RA* (66) and congenital dysplasia of the hip (44)	OA patients More active: 9.2 years Less active: 4.9 years Non-OA patients More active: 10.7 years Less active: 5.2 years	Hip revision procedure for aseptic loosening	Physical activity assessed using medical notes, examining or contacting patients to evaluate their participation in either heavy work or sports after THA. Participants were classified into: a) active group if they participated regularly in heavy labour for several years and/or sports post-THA or b) less active if they did not participate regularly in heavy labour or sports	Age, length of FU period, diagnosis and surgical technique	42/ 663 THAs were revised in the less active group and 7/25 in the more active group. Estimated failure rates at FU: 5 years: 4% in active group and 1% in less active group 10 years: 14% in the active group and 4% in less active group 15 years: 43% in active group and 15% in less active group Patients engaged in sports post-THA had over twice the risk of revision for aseptic loosening compared with less active patients

*RA; rheumatoid arthritis, FU; follow-up, BMI; body mass index

Author, year	Study sample	Diagnosis	FU and events	Case definition	Exposure	Adjusted for	Risk estimate 95% CI
HIP							
Inoue 1999 [166]	111 women and 19 men with 151 THAs performed between October 1978 and August 1988 in a Japanese Hospital. 31 patients were lost to FU; 16 deceased and 15 for other reasons Mean age (range) at THA: 61.5 years (32-84)	OA (103), RA* (35) and others (13)	7.5 years SD (0.2-15.3) 28 radiographic failures, of which 19 had undergone revision procedure	Failure of the femoral component defined as subsidence of the stem or a radiolucent line at the cement prosthesis interface. Failure of the acetabular component defined as component migration or fracture in the cement mantle.	Sociodemographic factors, recreational activities and occupation were recorded from medical records on admission	Age, sex, diagnosis, cementing technique	Working in agriculture, YES vs NO: Overall RR; 2.85 (CI 1.10-7.36) Men: RR; 2.37, p=0.40 Women: RR; 3.09 p=0.04 Recreational activity: Some activity vs none: RR; 0.89 (CI 0.40-1.98)
Maurer 2001 [167]	589 primary THAs performed from 1984 to 1993 in patients who were physically active at the time. Subjects were categorised into 3 groups according to the type of stem received. 6.8% were lost to follow-up and 184 (31%) died before failure could occur Mean age (± SD) at THA: group 1; 68.7 years ± 9.80, group 2; 69.3 years ± 9.50, and group 3; 69.5 years ± 9.70	OA in 66% of the patients from group 1, in 72% from group 2 and in 68% from group 3	Median FU: 10.2 years in group 1, 7.7 years in group 2, 5.2 years in group 3	Revision of the femoral component for aseptic loosening following THA (secondary outcome of the study)	Demographic and prosthetic characteristics and exposure to physical stress measured at the time of the THA as potential risk factors for failure	Covariates of offset of stem, weight, height, OA, side of implant, surgeon's experience and subsequent replacement of the opposite side	Men with little physical stress at work vs women: RR; 3.15 (CI 1.70-5.80) Men with physical stress or in farming work vs women: RR; 5.24 (CI 2.80-9.80)

*RA; rheumatoid arthritis, FU; follow-up, BMI; body mass index

Author, year	Study sample	Diagnosis	FU and events	Case definition	Exposure	Adjusted for	Risk estimate 95% CI
HIP							
Lübbeke 2011 [143]	941 patients with 1,048 primary THAs performed between March 1996 - December 1998, and January 2001 - May 2003. Analysis restricted to those 433 patients with complete clinical and radiological data (503 THA), 58% were women Mean age at THA: 67.7 years (30-91)	All excluding non-elective surgery or metastatic disease	Mean 94.5 months (50-146) Four patients underwent revision at a mean of 74.8 months (57-119)	Osteolysis around the femoral component and revision for aseptic loosening (secondary outcome) in the acetabular or femoral component at 5 and 10 years post-primary THA	Level of physical activity assessed by the UCLA scale.	Not applicable	Osteolysis developed in 5.4% (9/166) of the low activity patients, 7.5% (21/279) of the moderate activity patients and 24.1% (14/58) of the high activity patients. Out of 44 patients who presented with femoral osteolysis, 3 men and 1 woman were revised; 2 in high activity group, 2 in moderate activity group and none in low activity group. The risk of revision for the femoral component increased significantly with increasing levels of physical activity post-THA (p=0.023).

*RA; rheumatoid arthritis, FU; follow-up, BMI; body mass index

Author, year	Study sample	Diagnosis	FU and events	Case definition	Exposure	Adjusted for	Risk estimate 95% CI
HIP							
Flugsrud 2007 [168]	969 women and 566 men who underwent THA before January 2001 as recorded on the Norwegian Arthroplasty Register (NAR). Hip replacements performed pre-NAR were identified if the hips were revised after NAR was initiated. Mean age (± SD) at primary THA: 63 ± 5.4 years in men and 63 ± 5.8 years in women. 121 subjects deceased at FU	Primary OA (1,025), dysplasia of the hip (159), hip fracture (147), RA* (48) and not recorded (113)	165 revision procedures due to aseptic loosening: 59 for stems, 49 for cups and 57 for both.	THA revision for aseptic loosening defined as removal of part of the components or exchange of the prosthesis	Occupation and leisure activities were recorded in a cardiovascular screening carried out during 1977-1983 (pre-THA) using the Saltin-Grimby scale. The average age of patients at screening was 49 years old.	Age at screening, height, BMI, physical activity at work, leisure activities, marital status, smoking and implant category.	Physical activity at work; *Intensive vs sedentary*: Men: RR; 0.6 (CI 0.2-1.6) for the cup and RR; 0.6 (CI 0.3-1.5) for the stem Women: RR; 0.9 (CI 0.3-3.0) for the cup and RR; 0.6 (CI 0.1-2.5) for the stem *Intermediate vs sedentary*: Men: RR; 0.6 (CI 0.2-2.0) for the cup and RR; 0.7 (CI 0.3-1.9) for the stem Women: RR; 1.0 (CI 0.4-2.4) for the cup and RR; 0.9 (CI 0.3-2.7) for the stem Moderate vs sedentary: Men: RR; 0.6 (CI 0.2-1.8) for the cup and RR; 0.8 (CI 0.3-2.0) for the stem Women: RR; 0.7 (CI 0.3-1.5) for cup and RR: 1.3 (CI 0.5-3.0) for the stem Leisure activities: *Intensive + intermediate vs sedentary*: Men: RR; 4.8 (CI 1.3-18.2) for the cup and RR; 1.1 (CI 0.5-2.8) for the stem Women: RR; 1.6 (CI 0.6-4.1) for the cup and RR; 1.3 (CI 0.5-3.4) for the stem *Moderate vs sedentary*: Men: RR; 3.1 (CI 0.8-11.8) for the cup and RR; 0.9 (CI 0.4-2.2) for the stem Women: RR; 0.7 (CI 0.4-1.5) for the cup and RR; 0.6 (CI 0.3-1.2) for the stem

*RA; rheumatoid arthritis, FU; follow-up, BMI; body mass index

Author, year	Study sample	Diagnosis	FU and events	Case definition	Exposure	Adjusted for	Risk estimate 95% CI
HIP							
Ollivier 2012 [169]	Participants identified retrospectively among 843 hip replacements performed by two surgeons between 1995 and 2000. 70 participants who practised high impact sports were matched for age at THA (± 5 years), sex, BMI, ASA score, follow-up (± 2 years) to 140 subjects engaged in low impact sports. Age at THA: 58.76 years ± 9.4 in high impact sports group and 58.57 years ± 9.2 in low impact group	OA, osteonecrosis and developmental dysplasia stage 1	Mean 11 (10-15) years	Revision due to mechanical failure, fracture during athletic activities or radiographic sign of aseptic loosening. Septic loosening cases excluded	Level of physical activity post-op assessed by self-administered questionnaire and the UCLA scale. High impact (UCLA 9-10) and low impact (UCLA 1-4)	Not specified	At final follow-up, 7 patients revised for aseptic loosening; 6 in the high impact activities group (2 for the acetabular component and 4 for the femoral component) and 1 in the low impact activities group due to loosening of the acetabular component. High impact sport vs low impact activities: OR; 3.64 (CI, 1.49-8.9)
KNEE							
Han** 2013 [173]	44 women and 3 men with a total of 72 TKAs operated by a single surgeon between March 2003 and September 2004. Participants were classified as: A) being able to squat, kneel or sit cross-legged (HF), or B) not being able to perform high-flexion activities (U). Mean age at TKA: 68.3 years (45-79)	Primary OA	Mean 7.7 (range, 5.0-8.6) years	Revision for aseptic loosening	Kneeling, squatting or sitting cross-legged post-arthroplasty	Not given	Overall 33/72 TKAs were revised: 26/39 in group HF and 7/33 in group U. Survival rates of knees in subjects able to do high flexion activities vs not able to do high flexion activities: 54% in HF patients and 82% in U patients, at 5 years FU. 31% in HF patients and 78% in U patients, at 8 years FU.

*RA; rheumatoid arthritis, FU; follow-up, BMI; body mass index (-); **Group HF; high flexion activities, group U; no high flexion activities

Table 13. Description of the case-control studies retrieved by type of joint replaced

Author, year	**Study sample**	**Diagnosis**	**Respons e rate**	**Time to event**	**Case definition**	**Exposure**	**Adjusted for**	**Risk estimate 95% CI**
HIP								
Delfin 2017 [174]	27 cases identified from the Orthopaedic department at Blekinge hospital. Controls identified from the same hospital individually matched for sex, age and time since THA (± 2 years) Mean ± SD age at THA: 58.7 ± 7.6 years in cases and 59.9 ±7.3 years in controls	Primary OA in 23 cases and 19 controls Secondary OA in 2 cases and 7 controls Unknown in 2 cases and 1 control	90% in cases 73% in controls	11.9 ± 5.2 years for cases and 12.6 ± 5.3 years for controls	Subjects with stem and/or cup revised July 2012- July 2014 due to loosening or dislocation	Physical activity after THA assessed by UCLA activity scale	None	81.5% of the revisions were due to aseptic loosening and 18.5% due to dislocation. UCLA score ≥ 5 in 56% of the cases and 67% of the controls. Risk for revision: UCLA score: OR; 0.96 (CI 0.73-1.3) / p=0.78 Frequency of physical activity: OR; 0.46 (CI 0.12-1.84) Neither level of frequency of physical activity nor BMI, sex or age increased the risk of revision
Espehaug * 1997 [165]	536 cases and 1,092 controls from the Norwegian Arthroplasty Register (NAR). Controls were matched for gender, age at THA (± 5 years), date of operation (± 30 days) Median age at primary THA: 67 (16-88) years	Primary OA (67%), RA (3.8%), femoral neck fracture (9.3%), congenital dysplasia (12%)	81% overall (cases and controls)	Not given	Patients with a partial or total revision of the hip prosthesis	Self-reported occupation, occupational status and function, heavy physical work (pre and post-arthroplasty) and competitive sports (pre- hip symptoms and post-arthroplasty)	Extra analyses performed to avoid confounding using type of cement, type of prosthesis and use of antibiotic prophylaxis	Heavy work pre/post-THA vs not exposed to heavy work pre/post-THA: OR; 1.1 (CI 0.7-2.0) in men OR; 1.9 (CI 1.2-3.2) in women Occupation ± domestic work vs domestic work (ref) among women: Industry/engineering/construction and domestic work vs ref: OR; 2.0 (CI 0.7-5.7) Health service vs ref: OR; 2.1 (CI 1.0-4.8) Health-service and domestic work vs ref: OR; 2.5 (CI 1.2-5.1) Agriculture/ forestry /at sea and domestic work vs ref: OR; 1.7 (CI 0.9-3.3) Regular vs no regular exercise: Pre-THA OR; 2.6 (CI 1.4-4.7) and post-THA OR;0.7 (CI 0.4-1.2), in men Pre-THA OR; 1.2 (CI 0.8-1.8) and post-THA OR; 0.8 (CI 0.5-1.2) in women

*Only highest OR included in the results

Author, year	Study sample	Diagnosis	Response rate	Time to event	Case definition	Exposure	Adjusted for	Risk estimate 95% CI
KNEE								
Heck 1992 [171]	9 patients (12 TKAs) were matched to patients who underwent the same procedure within 3 months of the date of the arthroplasty. All operations carried out by a single surgeon Mean age at TKA: Cases: 67.4 years (60 - 85) Controls: 73.5 years (48 - 84)	OA, RA, post-traumatic arthritis and systemic lupus erythematosis		Mean time from TKA to revision: 6 years (0.75-9.63)	TKA revision surgery due to gross polyethylene failure defined as "*polyethylene fracture or complete wear-through resulting in unintended prosthetic articulation with metal or bone*"	Level of physical activity at the time of knee arthroplasty was measured using the modified OASDI activity level scoring system		Physical activity level in revised patients was higher compared with the patients free from revision, p=0.023
Jones 2004 [172]	26 cases (17 women and 9 men) with TKA performed between October 1999 and September 2000 and 26 controls individually matched for sex, age (± 5 years), unilateral or bilateral procedure and date of TKA (± 3 years). Cases and controls identified from the medical records of 12 orthopaedic surgeons across 4 hospitals Median age at primary TKA: 70.5 years (47-85)	Bi or tricompartmental knee OA	64 cases and 125 controls that met the eligibility criteria, of which 38 cases and 52 controls enrolled. Reasons for losses were not replying, moving address, declining participation or deceased. Finally 26 case-controls pairs were matched	5 years (2 - 11) from index surgery to revision	Patients aged ≥ 25 years with a TKA within the past 2 to 15 years who had also undergone revision arthroplasty	Occupational and leisure activities measured from the second year post-TKA using the Modifiable Activity Questionnaire (MAQ)	Sex, age, unilateral or bilateral procedure and date of TKA (± 3 years) used to match cases and controls	<u>Leisure activities</u>: OR; 0.99 (CI 0.99-1.02) <u>High intensity leisure activities</u>: OR; 0.96 (CI 0.88-1.05) Physical activity at work: OR; 0.99 (CI 0.99-1.01) <u>High intensity physical activity at work</u>: OR; 1.0 (CI 0.99-1.01) <u>Leisure activities and work:</u> OR; 0.99 (CI 0.99-1.01)

2.3.2 Knee arthroplasty

We found three studies that examined the association between physical activity related to work or LTPA and the risk of TKA revision. A summary of the main features of these studies are presented in Table 12 and Table 13. One was a prospective study [173] and the other two were case-control studies [171, 172]. All the arthroplasty procedures were performed before 2005, either by a single [171] or several orthopaedic surgeons [172]. In the studies performed by Han et al and Jones and colleagues more women than men had arthroplasty procedures, and primary OA was the diagnosis underlying the need for knee arthroplasty. All the studies reported the mean time to knee joint failure after TKA, which ranged between 5 and 7.7 years from the index surgery. As with the hip literature, we found differences in the timeframe when the physical activity exposure was measured: pre-TKA in one study [171], and post-TKA in the other two studies [172, 173].

2.3.2.1 Findings for LTPA (including daily activities)

We found one prospective study that followed up a group of Asian patients who received a specific high-flexion knee prosthesis during their primary surgery. For this particular population, high flexion knee activities are part of their daily routine, hence being able to perform them is an important outcome of the operation. Patients were divided into two groups of participants: those able to squat, kneel or sit cross-legged, and those unable to carry out these activities after knee replacement, and knee prosthesis survival was assessed. The study found poorer prosthesis survival in individuals who performed high flexion activities. Specifically, at follow-up after 8 years, the prosthesis survival rate for patients that could kneel, squat or sit cross-legged was lower than in patients that did not perform these activities (31% vs 78% free from revision) [173]. The quality of the study from Han et al was rated as acceptable according to our pre-defined criteria.

2.3.2.2 Findings for work & LTPA combined

One case-control study rated as high quality, found no association between TKA revision and physical activity from either work or leisure activities, nor a combination of work and leisure activities, despite cases being exposed to work-related and leisure activities considered to be of high intensity. Physical activity, based on the Modifiable Activity Questionnaire (MAQ), was calculated as the energy consumed while performing physical activity in metabolic equivalent per task (MET) / hours per week. Occupational and LTPA measurements were assessed separately post-TKA and categorised as high intensity if the leisure activities were 6 MET or over, or occupation rate was 7 MET or over. No further covariates were used for the adjusted models other than those used to match cases and controls (sex, age, laterality and date of TKA). We did however find a second case-control study which identified a small sample of cases in whom revision of the TKA was required, and a group of controls, which found that the cases had a higher activity level than those who did not require revision. Patient's activity level was classified as sedentary (level 0 to 3) or as performing a higher activity level (level 4 to 7) using a modification of the old age, survivors, and disability insurance (OASDI) regulations and also taking into account whether the participant was working or retired at the time of the TKA. This study was however rated as of very poor quality to answer our research question [171].

2.4 Discussion

In this systematic review we aimed to explore the evidence as to whether exposure to high-intensity or heavy physical activity at work or in leisure-time after a primary hip or knee arthroplasty increased the risk of subsequent joint failure and revision surgery. From amongst 10,361 studies identified as of interest, we were able to include only 12 which fulfilled our inclusion/exclusion criteria. Despite a high volume of studies, it was very clear that few investigators have collected the information required to address our research question. From the 12 included studies, two reported a positive significant association between work activities (specifically farming work) performed before arthroplasty [166, 167] and subsequent revision procedure, and a third study also reported a significant association between work activities performed pre and post-THA (specifically heavy work) and hip revision surgery [165]. In the only available study of occupational factors, no association was found between post-operative work activities and the risk of knee revision surgery [172]. Two studies reported a positive association between the risk of hip revision and: a) practising intermediate-intensive physical activity during leisure, for example heavy gardening or running prior to hip arthroplasty [168], or b) participating in sports such as jogging or skiing post hip arthroplasty [169]. In the two included studies of knee arthroplasty, the evidence was conflicting: the one high-quality study reported no association between non-work related physical activity and knee revision [172], whereas the other (poor quality) study showed a bigger risk of failure of the TKA among people reporting higher levels of daily activities or work related physical activity. For this study people were assigned to a category depending on the level of activity the participants picked in the OARSI scale at the time of the TKA [171].

In order to address our specific research question the exposure to physical activity would ideally be measured following lower limb arthroplasty since accounting only for physical activity due to work or leisure activities prior to surgery may lead to an underestimation of the effect assessed. In particular, those who were very active pre-operatively may not necessarily be able to achieve the same activities post-operatively and vice versa. For example, Flugsrud et al used the physical activity recorded for patients who attended a cardiovascular screening at an average age of 49 years old, with the primary hip arthroplasty being performed later at an average age of 63 years old [168]. As a plausible explanation for their findings, the authors proposed that the protective effect of physically-demanding jobs on hip revision was because people stopped working after hip replacement, but data about post-operative work participation were not available in this study. Changes in work participation after THA and TKA have been systematically reported by Hoorntje et al and Tilbury et al respectively. Their findings show that in studies performed after 2000, a total of 14% of the participants did not resume work post total hip arthroplasty, whilst between 17 to 23% did not return to work in the first six months post TKA [175, 176]. Moreover those who returned to work post-THA may have moved to a different type of occupation [177], implying a different level of workload. A similar pattern has been observed for returning to sports following arthroplasty. Less people tend to resume sport activities after THA and TKA, and the intensity or impact of the sports that could affect the joint tends to decrease [178, 179].

A second feature to take into consideration when interpreting the results are the different instruments used to measure physical activity. The one most frequently used was the UCLA activity scale, [180] which rates the level of physical activity on a scale from 0 (wholly inactive) to 10 (very active or high impact sports). In this scale, which also includes heavy labour in level 9, people are required to choose the level that best represents them. Choosing a lower level indicates less physical activity and a higher level score relates to a greater level of activity. Another study used the Saltin and Grimby scale [181] in which participants complete two questions, selecting the most appropriate option that describes their occupational activity and LTPA in the past year. According to this scale an occupational activity can be described as: i) predominantly sedentary (e.g, desk worker) ii) sitting or standing (e.g. cashier), iii) walking and performing some handling of material (e.g. post-man), or iv) heavy manual work (e.g. dock worker). This scale also describes the spare-time physical activity as: i) almost completely inactive, ii) some physical activity during at least 4 hours a week, iii) regular activity or iv) regular hard physical training for competition. A third scale identified in the studies retrieved was the Modifiable Activity Questionnaire (MAQ) that measures physical activity at work, and at leisure time, as well as physical inactivity, on a scale of 10 categories and refers to the physical activity performed in the last 12 months [182]. A final tool, the modified OASDI activity level scoring system, was used in the study performed by Heck [171]. In this scale the participant chooses an option that ranges between 0 and 7. A score below 3 indicates a range of activity from being in a nursing home to lifting less than 10 pounds, and a score of 4 or above covers light to very heavy labour, mainly based on the weight lifted. Clearly, the use of these different instruments precludes comparison across studies, and from the descriptions above it is clear that each tool measures somewhat different levels of exposure; some tools combine occupational and leisure time activities whilst others separate them. For the remaining studies the physical activity information was collected through self-reported questionnaires which varied considerably and were non-standardised. To allow clinicians to have the information necessary to provide evidence based recommendations to patients in the future, it is clear that studies need to agree to use the same approach in classifying post-operative exposure, separating occupational from leisure time-exposures.

The findings from this review are sparse, particularly if limited to good quality studies that included post-arthroplasty physical activity measurements. On this basis only one study reported a significant positive association between work and hip revision [165], and one study reported no association between work and knee revision [172]. For the LTPA the results were contradictory: two studies found a positive significant association [143], as opposed to two studies in which hip revision was not associated with LTPA. In addition, one study reported no association between leisure activities and knee revision [172].

To our knowledge no prior publications on this topic are available with which to compare our findings. Because of this we decided to compare our findings with those reported in studies focused on the relationship between radiographic failure and physical activity. These studies were identified during the full-text article assessment and were excluded because the outcome was radiographic failure not revision. This was considered to be appropriate since it is believed that bone loss precedes revision surgery for aseptic loosening, which is the most common indication for revision surgery, and also because for some of the papers included in this review, failure was defined as revision due to aseptic loosening. From these papers it was clear that the findings from radiographic failure for hip arthroplasty recipients were equally controversial to those observed in our systematic review. Some studies suggested that patients with a more active style, including people who had engaged in skiing post-THA, had an early radiographic failure due to the wear of the implant [183, 184]. In contrast, Ritter et al found no correlation between sport post hip arthroplasty and signs of prosthetic loosening [141]. However, the authors of this last study discouraged high intensity activities in their patients. In relation to LTPA post TKA, only one study included in our review found no deleterious effect on the knee joint, results similar to those in a study performed by Hofstaedter et al in which no sign of osteolysis was found in people engaging in alpine skiing after TKA [146].

This review has some limitations that have to be acknowledged. Our search did not include grey literature, so did not include working papers or reports that could potentially be relevant to the research question. We only included studies published following a peer-reviewed process. Additionally the search was limited to English or Spanish due to lack of resources for translation. Some relevant literature might have been published in other languages, although key papers are more likely to be published in English. We chose to perform a narrative synthesis of the evidence rather than a quantitative analysis due to the heterogeneity of the time frame of exposure measurements and the variation in the methods of assessment of activity. Also, the number of studies addressing occupation and LTPA separately were too few to be able to pool the results. Finally, revision was a secondary outcome to the original study for two of the included studies [143, 167] .

Conclusion

In summary, the findings from this review evidenced the paucity of relevant studies on this research question, especially for revision surgery after TKA. We also found that many studies only assessed relevant exposure before the operation, which may be of limited relevance to post-operative activities. This limited our ability to compare findings from the studies. Given the lack of evidence and the inconsistencies found, more research is clearly needed to assess the risk of mechanically loading the replaced hip or knee following hip or knee arthroplasty.

To shed light onto this important question, in this thesis we focused on one of the two research questions raised in this systematic review; whether working post-arthroplasty in physically-demanding jobs increases the risk of revision of the replaced joint. From the findings of the review it was clear that to examine whether work might be a potential risk factor for joint failure, defined as revision, it was necessary to consider separately exposure to work and non-work related activities carried out post-arthroplasty. To do this we set up a retrospective cohort study which involved two different cohorts of arthroplasty recipients as described in Chapter 3 to Chapter 7. Our study aimed to assess the mid or long term outcomes of individuals who had a hip or knee replacement to explore to what extent being exposed to heavy occupations may be a potential risk post-arthroplasty, taking also into consideration leisure activities or other physical activity performed after lower limb replacement. The ultimate goal was to generate evidence which will allow clinicians to advise their patients on carrying out work activities post-arthroplasty, based on evidence based information.

Chapter 3 : Data and Methods

3.1 Study design

This study is a multicentre, retrospective follow-up study based on existing cohorts of hip and knee arthroplasty recipients.

3.1.1 Study sample

To answer our research question, we searched for existing prospective cohort studies of lower limb arthroplasty patients which had carefully characterised the population at baseline and were still under active follow-up. Cohorts needed to have at least five years of follow-up and contain as many people as possible who had been aged < 65 years at the time of their primary operation. Two cohorts of lower limb arthroplasty recipients were identified as suitable: in the UK (COASt) and Switzerland (GAR).

For both cohorts, we were able to extract data from hospital registers where the primary surgery had been performed, primary and secondary care records, and also follow-up questionnaires that had been completed by patients at intervals since the primary joint replacement. The cohorts were as follows:

A. For the hip:

- Clinical Outcomes in Arthroplasty Study (COASt),
- Geneva Hip Arthroplasty Registry (GAR) and

B. For the knee:

- Clinical Outcomes in Arthroplasty study (COASt),

3.1.2 Eligibility for inclusion

Patients were eligible for inclusion if they were aged between 18 and 65 years of age at the time of undergoing unilateral total hip arthroplasty (THA), total knee arthroplasty (TKA) or unicompartmental knee arthroplasty (UKA), and the primary surgery had been performed at least 5 years before the current study.

Where patients had undergone more than one joint replacement and these were recorded, we took the first procedure performed as the index surgery for the current study.

Patients were excluded if they had been diagnosed with a major post-operative surgical complication, e.g. infection during the first six months after the index surgery, because this made them unsuitable for assessment of the impact of post-operative work or other physical exposures on the primary operation.

3.2 Power and sample size

We undertook sample size and power calculations for each cohort based upon PROMs at follow-up aiming to maximise the sample size to detect differences with a 5% significance level and 80% power using the main outcomes of this study .

3.2.1 Function

Data from the Geneva Arthroplasty Registry (GAR) were used to explore the effect of occupation on patient reported outcome measures (PROMS) at five years post hip arthroplasty surgery. To calculate the number of people needed to detect differences between the mean values shown in Table 14, we used ANOVA power simulations performed in Stata with the command –simpower.

Table 14. Sample size calculation based on functional outcome measures in GAR

	Unemployed	Office workers	Light work	Heavy work	Sample size
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	
HARRIS HIP SCORE function	88.5 (12.6)	93.8 (11.6)	91.2 (11.6)	89.9 (12.6)	440
HARRIS HIP SCORE pain	39.6 (7.4)	40.9 (7.4)	40.2 (7.3)	37.8 (9.1)	528
WOMAC pain	69.6 (25.6)	77.9 (24.7)	70.2 (22.8)	67.5 (27.2)	480
WOMAC function	69.5 (26.4)	78.2 (23.3)	69.2 (23.1)	65.0 (26.9)	448

*Unpublished data from the Geneva Joint Arthroplasty Registry [185]

Assuming that the four groups (unemployed, office workers, light, and heavy workers) were of equal size, a sample size of 528 subjects would be sufficient to detect differences between the groups in the mean scores of the outcomes presented in Table 14, with a 5% significance level and 80% power.

As far as we are aware, no previous study has described PROMS in either heavy or light occupations after knee arthroplasty. Following the findings reported by Wylde et al [186] as mentioned above, and in the absence of published studies, we expect that the sample size needed to detect differences in function after knee replacement will be lower than after hip replacement.

3.3 Cohorts

3.3.1 The Clinical Outcomes in Arthroplasty Study (COASt)

This observational study was set up as part of a research programme funded by the National Institute for Health Research (NIHR). The aim of the research was to develop models for predicting outcomes after lower limb arthroplasty and to give advice on the cost-effectiveness of implementation of tools that predict poor outcomes after arthroplasty. In order to achieve the research goals four packages were developed to:

- Describe current and future projections of primary and revision lower limb arthroplasty procedures
- Describe possible variation in the rates of hip and knee replacement across the UK
- Provide an instrument to predict poor outcomes after arthroplasty
- Carry out a health economic assessment of the instrument developed
- Test the developed tool amongst a group of patients who were going to have a knee or hip arthroplasty.

For the purpose of this last objective it was necessary to set up an observational study to collect data longitudinally; the Clinical Outcomes in Arthroplasty Study (COASt) [187]. The recruitment took place across two hospitals located in the South of England: Southampton University Hospital NHS Foundation Trust (UHS), in Southampton, and Nuffield Orthopaedic Centre (NOC), in Oxford.

Recruitment began in 2010 with a target of 3,200 patients across both centres. All patients who were on a waiting list for hip or knee arthroplasty within the two centres were invited to take part in the study, providing that they were over 18 years-old at the time of the surgery and were willing to give consent. Only those patients with Charcot's arthropathy or other severe neurological disorders (e.g. Parkinson's disease) that could degenerate or influence the outcome were excluded from the study. By 2016 the number of participants enrolled in the study was 3,794.

Within the COASt study there are three sub-cohorts of patients who provided written informed consent under two different ethical approval processes (Figure 5);

1) South COASt (SCOASt) recruited at UHS,
2) North COASt (NCOASt) recruited at NOC and,
3) Oxford Musculoskeletal Biobank (OMB) recruited at NOC

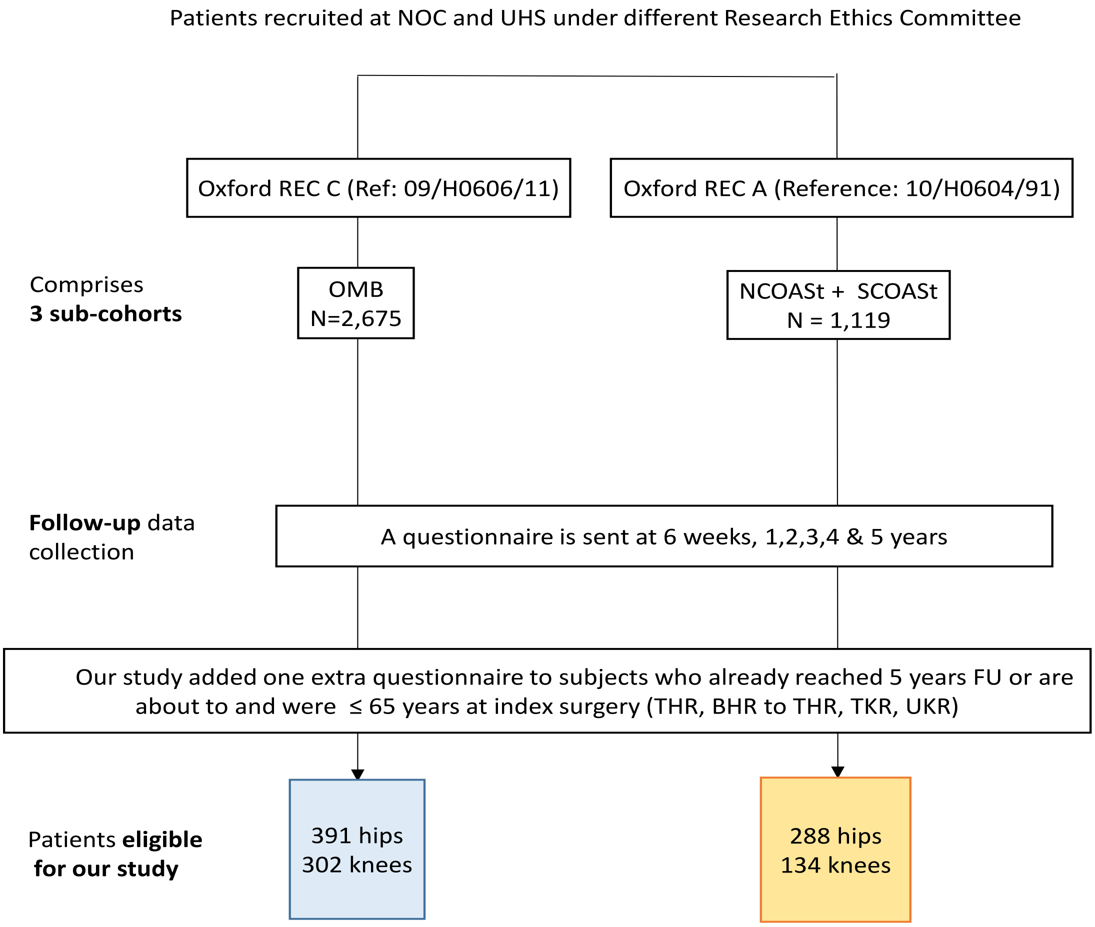

Figure 5. COASt cohorts, recruitment process, follow-up data collection and eligibility for follow-up

NCOASt and SCOASt participants were recruited under Oxford REC A ethics application procedures whereas OMB patients were recruited under Oxford REC C ethics application procedures. For patients listed for arthroplasty in different joints and at different points in time, it was possible to collect information for both operations, but a consent for each arthroplasty was required. Once patients consented to be part of the study, the following information was gathered:

a) pre-operation (baseline). The patients completed a self-assessment inpatient surgery questionnaire along with PROMs. In addition a procedure specific physical assessment was performed.
b) In-patient data: all relevant clinical, intra-operative and peri-operative information was extracted from medical notes.
c) Post-operation. Participants were followed at 6 weeks and then annually until 5 years after arthroplasty. This follow-up included:
   - Socio-demographic factors: age, sex
   - Co-morbidities, medication dose and ASA grade
   - Work status pre-operatively
   - Physical assessment: Hand grip strength, get up and go test, mobility and use of walking aids
   - Patient reported outcomes (PROMs):
     - ✓ Measure of Intermittent and Constant Osteoarthritis Pain (ICOAP)
     - ✓ Hospital Anxiety Depression Score (HADS)
     - ✓ Oxford Hip Score (OHS) and Oxford Knee Score (OKS)
     - ✓ Patients expectations and lifestyle factors
     - ✓ University of California at Los Angeles (UCLA) activity score
     - ✓ Aberdeen Impairment Measurement
     - ✓ European Quality of Life 5-Dimensions (EQ5D-5L)

Additionally, other tests were performed (e.g. X-rays, DXA scan) and patients could give consent to donate biological samples. Between March 2010 and April 2016 a total of 3,794 patients undergoing any of the surgical procedures displayed in Table 15 were recruited at Southampton (n=824) and Oxford (n=2,970).

Table 15. Description of surgical procedures performed in the COASt cohort

Knee procedures	Hip procedures
• Patello Femoral Resurfacing	• Hip Resurfacing Arthroplasty
• Primary Total Knee Arthroplasty	• Primary Total Hip Arthroplasty
• Revision Total Knee Arthroplasty	• Revision Total Hip Arthroplasty
• Unicompartmental Knee Arthroplasty	• Hip – Other
• Knee Arthroscopy / Knee – Other	

*Table reproduced from NIHR report [187]

Despite the large number of participants recruited in the COASt study (see Figure 5) many of them were not eligible for this study because people awaiting hip or knee replacement tend to be over 65 years of age. Additionally, some of the COASt participants who complied with the age criteria underwent replacement from 2014 onwards, thus the time lagged between the arthroplasty and questionnaire completion was less than 5 years.

The response rate at one year follow up was 87%. This cohort offered a clear opportunity to contact patients and to obtain data in order to address the main question of the study reported in this thesis.

3.3.2 Geneva Arthroplasty Register (GAR)

The Geneva University Hospital (HUG) [185] is the largest teaching hospital in Switzerland with 1,908 beds. Being the only public hospital in the area, it has a large Division of Orthopaedics and Trauma Surgery with 40 to 45 orthopaedic surgeons. Since March 1996 all patients who underwent urgent or primary elective hip replacement, or hip revision procedures, at the hospital were enrolled in a hospital based registry and followed prospectively. Two years after this initiative started (April 1998), it was decided to include also all the knee arthroplasty procedures performed at the hospital.

This registry was set up following the example of joint registries established in the Nordic countries. GAR is considered a unique registry because of the richness and detailed information that it gathers. This includes some self-reported measures, unlike other regional or national registries where no self-reported measures are gathered as part of the routine follow-up. The main goals of GAR were to monitor surgical techniques used, to detect any poor performance of the different types of implants used, and lastly to improve patient safety and quality of life after replacement. All patients are contacted at intervals of 5 years after surgery to attend clinical and radiological examinations, as well as to complete PROMs. However, some patients are monitored more strictly (every two years). This is the case for patients who received a new type of implant, patients with a metal on metal bearing prosthesis, or patients who had previously shown signs of osteolysis. During the first few years of the registry, Charnley disability grade and Merle d'Aubigne and Postel score were also recorded, and as the study has developed, new validated tools have been incorporated.

Attrition rate has tended to increase over time. Younger patients have been more likely to be lost to follow-up, whereas mortality rates are higher in patients over 80 years of age. According to data up to 2014 available from GAR, at 5 years follow-up 63.9% of the patients completed the follow-up questionnaire, at 10 years 54.4% and at 15 years 55.8%. GAR participants are comparable with those found in the Danish and Swedish registries regarding sex, age ratio and diagnosis. Between 1996 and 2014 a total of 6,106 patients underwent elective primary THA at a mean age of 68.2 (SD ± 12.6) years and 778 patients underwent revision procedures. Approximately 55% of the primary hip arthroplasties were performed in women and primary OA was the main indication (70.2%). Approximately 20% of GAR patients are eligible for the current study because they were under 65 years of age at the time of the index surgery, which was performed five or more years ago.

The GAR provides good quality data collected at the time of the surgery and at follow-up on:

a) Demographic factors: sex, age, BMI and socio-economic factors
b) Co-morbidities: ASA score and medication
c) Clinical examination: muscle strength and mobility
d) X-rays at follow-up
e) Factors related to surgery: implants, type of fixation, surgical approach, length of stay
f) Complications after THA: mortality and, if revision surgery is required, the cause of the revision
g) Patient-reported outcome measures (PROMs) pre and post-operatively.

Uniquely, also information on occupation prior to the arthroplasty is collected and occupations were classified as heavy manual, light manual or office job according to the judgement of the surgeon. This registry study was approved by the Institutional Ethics Review Board.

3.3.3 Similarities and differences between COASt and GAR

As described in section 3.3.1 and 3.3.2, COASt and GAR were set up for different purposes and the information collected in each cohort is somewhat different. Table 16 shows the similarities and differences in variables collected across COASt and GAR at baseline and at follow-up. Both cohorts included information pre-surgery on certain variables, but the way the information was collected was different as explained below:

- Comorbidities; at the time of the surgery GAR recorded whether patients had diabetes and hypertension, whereas in COASt more detailed information was collected at baseline and also at follow-up. In addition to these two conditions COASt patients reported whether they were treated or diagnosed with a list of conditions (e.g. renal or bowel problems, lung problems, stroke, anxiety or depression)
- Patient's occupation pre-surgery; in COASt, information was collected about pre-operative employment status and the name of their occupation. In GAR, the orthopaedic surgeon classified the occupations of their patients as heavy manual, light manual or office worker after interviewing the patient.

Table 16. Similarities and differences in variables collected in the COASt and GAR at baseline and at follow-up

COMPARABLE VARIABLES BETWEEN COHORTS	
• Sex , age BMI • Age • Diagnosis for primary arthroplasty • Type of intervention and side • Activity level: UCLA	• Smoking status • Occupation pre-surgery • Charnley score • American Society of Anesthesiologists (ASA) grade
DIFFERENCES BETWEEN VARIABLES COMPARING COHORTS	
a) *PROMS at baseline and follow-up*	
COASt	**GAR**
• Mental health: HADs • Function and pain: OHS, OKS, ICOAP	• Mental health and general health: SF-12 • Function and pain: Merle d'Aubigne and Postel score, Harris Hip score (HHS), WOMAC 3.0
• Satisfaction: EQ-5D and lifestyle, patients expectation and outcome • Health economics • Index of multiple deprivation (IMD)	• Satisfaction: Visual analogue scale
b) *other variables*	
• Technique details (approach)	• Technique details • Type of implant • Main complications • Re-operation • Type of previous surgery

The difference between the cohorts lies mainly in: i) the variables related to the implant used and the surgical variables collected at the primary elective arthroplasty (e.g. the type of implant or main complications), and ii) the validated tools used in each cohort to assess mental health status, function and pain in the lower extremity pre and post-operation, and patient satisfaction with the outcome of the arthroplasty.

3.3.4 Other cohorts to include in the study

In addition to COASt and GAR, other potential cohorts were also identified as possibly suitable to be included in this study. However after contacting the investigators it became clear it would not be feasible to include them for different reasons. Participants from the Exeter Primary Outcomes study cohort were no longer in active follow up and contact details were out of date and not accessible to us. In the case of the Phase 3 Oxford unicompartmental knee cohort we were unable to secure the permission of the investigators for a follow-up. Participants enrolled in the Knee Arthroplasty Trial (KAT) study (set up in the UK) were still under follow-up but we were not given permission to contact them to avoid overburdening participants.

3.4 Work questionnaire design

To address the main question for the current study, we used relevant information already available from the case notes, registers and questionnaires, but it was also necessary to collect new information. Therefore we created a questionnaire and modified the items depending on the joint to which the arthroplasty was performed: hip or knee (see Appendix D). The questionnaire included:

a) items from validated instruments (e.g. OHS and SF-12) where available,
b) questions previously used and validated in other studies, for example in the HEAF study [188], and
c) original questions specifically written for this study.

We aimed to collect information as homogeneously as possible across the different cohorts. However:

1) Some of the information routinely collected over the years by COASt and GAR was recorded using different validated instruments. To allow us to analyse data from

our questionnaire along with data from previous years we used the same instruments that had been previously used in each cohort; e.g. mental health status was assessed using HADS in the COASt cohort and using the SF-12 questionnaire in GAR.

2) The order of the items also varied slightly in the GAR questionnaire, in response to the feedback obtained from participants in Geneva.

Finally, some patients also had their contralateral joint replaced, or another lower limb arthroplasty between the date of the index surgery and the date of completing the questionnaire. To prevent any misunderstanding about the surgery we were interested in, we included the date of the surgery we were interested in at the beginning of each section of the questionnaire. The different sections of the questionnaire are summarised in following sub-sections.

3.4.1 Demographic factors

We asked about socio-demographic factors (date of birth and sex) and BMI. Weight and height was obtained at index surgery to calculate the BMI at baseline. Since all patients were completing our questionnaire at a minimum of five years after having their arthroplasty, we asked them to complete details of their current weight and height, as their BMI may have changed in that period.

Smoking status is another important variable but to avoid overburdening the participants with a lengthy questionnaire, we decided to use smoking status as recorded at the time of the surgery, despite the fact that this status might have changed during the follow-up. Information on date of birth and sex were collected again in order to verify that the data collected through the questionnaire are linked correctly to the existing data from the same patient.

3.4.2 Surgical factors

For the patients recruited to the COASt study, no information was available about any previous surgery to the hip or knee joint. Hence for these participants we decided to add a table to the questionnaire in order to obtain a lifetime history of surgery to each hip and knee. We asked whether any surgery was performed and if yes, in which year the operation was carried out. We included different types of operations that the patients could have had prior to the joint replacement: i) surgery to cartilage or ligaments, ii) resurfacing, iii) osteotomy, iv) joint replacement and v) other surgery. We also asked whether the index joint had been revised, and if so when this had occurred.

3.4.3 Work factors

3.4.3.1 Paid work prior to arthroplasty

We asked questions about paid work prior to the hip or knee replacement. These items covered: the last paid job held prior to arthroplasty (e.g. teacher or carpenter); the type of job (dichotomised to self-employed or employee); starting date of the job and, if they had left the job, the ending date of that job and whether the reason for leaving that job was related to the joint to be replaced.

3.4.3.2 Physical activity in work since surgery

To answer the main study questions it was important to capture as much information as possible about whether participants returned to work, what type of work they returned to and how long for and specifically to what physical demands they were exposed.

In epidemiological research occupational titles are often used to estimate the physical demands associated with a job, but participants within the same type of job are not necessarily exposed to the same level and type of physically-demanding tasks. To avoid misclassification of our participants regarding work exposure, we included specific questions asking participants to self-assess their exposure to activities that put mechanical stress on the hip and knee joints.

To create a full occupational history, our questions related to all jobs that each participant held for more than one month after the index surgery. Specifically we asked about: what the type of job was and the time the job was held. Since the participant had their joint replaced at least five years earlier it was possible that the subject had since left the job. If this was the case, we asked whether the reason for stopping the job was partly related to having had the joint replaced. Finally, we listed a set of physically-demanding activities and asked whether in an average day their job involved any of the activities. The activities included were based upon the literature about those physical activities that are known to be connected with primary OA, such as kneeling, lifting weight or squatting. The questions we used were adapted from those previously used in epidemiological research [189]. Specifically our questionnaire covered the following activities:

- standing or walking for more than 4 hours in total per day,
- walking more than 2 miles in total per day,
- lifting or carrying 25lbs (10 kg) or more, and 56 lbs (25 kg) or more by hand,
- digging or shovelling,
- kneeling or squatting,
- climbing ladders,
- climbing more than 30 flights of stairs per day (up or down).

3.4.4 Non work physical activities

Aside from physical activities in the workplace many patients also undertake physical activities that have nothing to do with work e.g. hobbies. Therefore we needed to capture additional information about these non-work exposures (leisure and daily activities).

After replacement surgery, patients may return to sport or leisure activities to some degree. Currently there are no evidence-based guidelines regarding the type of sports that can be safely undertaken after arthroplasty. Therefore recommendations depend on experts' opinion. In 2001 Healy and colleagues asked 54 surgeons from the Hip Society to classify 42 athletic activities into four categories (recommended/allowed, allowed with experience, not recommended and no conclusion) based upon the individual advice the surgeon would give to their patients after hip arthroplasty [190]. A few years later another study was carried out, but on this occasion more surgeons from the American Association of Hip and Knee Surgeons and Hip Society participated. Similar to Healy's earlier study, the experts were asked to group 37 activities into the same four categories. Overall, 12 activities out of 37 had changed from one category to another when compared with the earlier study [191]. What was however agreed in both studies was that sports that put a high strain on the hip or knee such as contact sports were not recommended after replacement surgery.

With our intention to develop some evidence, all questions in this section were about possible relevant non-occupational activities that patients might have engaged in since their replacement up until the time of completing the questionnaire. Physical activities were grouped into three categories according to the joint strain that they entailed and in the following order:

- high mechanical impact joint-loading (e.g. running, or singles tennis);
- medium mechanical impact joint-loading (e.g. heavy gardening, cycling, dancing), and
- low mechanical impact joint-loading (e.g. housework, light gardening, ballroom dancing, swimming).

For each of these sport categories (high, medium and low impact activities) we used the same wording to make it easier and faster to complete the questionnaire. We also included examples of activities relevant to each category, to try and avoid misclassification.

Additionally we enquired about the time that elapsed between the arthroplasty and return to the sports or leisure activity, and the period of time (in months or years) that the subject continued doing these activities. Finally we asked about the frequency the activity was performed (number of times per year) and the average time spent per week doing these activities in order to estimate the “dose” of exposures.

3.4.5 Outcomes after arthroplasty

3.4.5.1 Revision rate

Details of any hip and knee revision procedure were available from the hospital records in GAR. For COASt participants we included a question concerning whether a revision procedure was performed, and if so on what date it was carried out.

3.4.5.2 Function and Pain

In addition to the need for revision, function and pain were other important outcomes that needed to be taken into account when assessing the success of the joint replacement. We included questions to evaluate both function and pain, over and above the existing data collected routinely in COASt and GAR. Specifically we were interested in how the participants function had been at two different points in time: when they felt they reached their optimal function after replacement, and at the time of completing the questionnaire.

Firstly, when participants felt they reached their optimal function following replacement. Although both COASt and GAR cohorts routinely collect data on physical function and pain at follow-up, we included a set of questions to examine the same outcomes because we were interested in a specific point in time which may not necessarily coincide with the time of follow-up. A set of items was included to record the time after which they achieved their best function since the replacement (grouped in <6 months, more than 6 months but less than a year, between 1 and 2 years and longer than 2 years since replacement); the necessity of using a stick when walking when at their best (options from not at all to all the time); whether they were having hip or knee pain at night when at their best (from pain on no nights to pain every night); and how often the pain from the joint interfered with function during the day when at their best (options from never to all the time). In addition a list including several daily activities was provided to enable comparison between individuals

- walking for a mile on the flat
- walking on rough ground
- walking uphill and downhill
- walking (up / down) a flight of stairs
- kneeling down and getting up again
- Getting out of bed
- getting in and out of a car
- doing household shopping
- personal hygiene
- standing up from a chair
- Putting on socks or stockings
- Sitting

Secondly, at the time of follow-up, we used the same validated tool (i.e. OHS for the hips and OKS for the knees) in both cohorts to assess pain, stiffness and function.

Additionally we asked all participants whether they had pain or stiffness in any other hip or knee joints than the joint to which they had the arthroplasty, and whether they had any other problems that limited their activities.

3.4.5.3 Validated outcome measures

Patient’s perceptions of the outcome of the arthroplasty were explored using specific PROMs (OHS, OKS and WOMAC-12) with a focus on hip and knee function. A brief description of each of the instruments is given below:

a) Oxford Hip Score (OHS)

OHS is a brief questionnaire (12 items) specific for patients undergoing THA with a recall period of the last 4 weeks. It includes items to assess pain and function dimensions, specifically: pain severity in the hip, sleep, experiencing sudden severe pain, limping, walking, climbing stairs, and daily activities (putting on a pair of socks or tights, standing, using transport, personal hygiene and shopping). Each item offers 5 options that score from 0, representing significant disability due to the hip, to 4 indicating the best outcome possible. The final score is obtained as a sum of all items and ranges from 0, which indicates the poorest outcome, to 48, being the best possible result [192-194].

Additionally, using the OHS questionnaire two subscales can be calculated using specific items that relate to function (questions 2, 3, 4, 5 , 6, 7) and pain (questions 1, 8 ,9, 10, 11, 12) respectively. These are the Oxford Hip Score Functional Component Subscale (OHS-FCS) and the Oxford Hip Score Pain Component Subscale (OHS-PCS). Each of these subscales provide a score ranging between 0 and 24. The final score is calculated by summing the corresponding items for each scale, and rescaling the values obtained from 0 to 100. A higher score indicates a better outcome.

Scoring system. Following the criteria defined by the authors of the score, the total OHS is regarded as missing if more than two items were unanswered. To avoid missingness the mean average can be imputed when two or less of the items are found incomplete [193]. For the subscales, OHS-FCS and OHS-PCS, no threshold was available to define the number of unanswered items needed to use the subscale when data are missing. The total OHS score was grouped in the four categories following the Kalairajah et al approach [195] based on the Harris Hip score. The cut off points translated into a scale from 0 to 48 was: poor (OHS <27), fair, (OHS between 27 and 33), good (OHS between 34 and 41), and excellent (OHS > 41).

b) Oxford Knee Score (OKS)

The Oxford Knee Score is a tool which was developed for patients undergoing or who have undergone knee arthroplasty. The length of the questionnaire, the recall period, and the way to calculate the final score is similar to the OHS, but OKS includes questions and activities that are specific for the knee. The items included in this score cover: pain severity in the knee, mobility of the joint, the possibility of limping when walking and the ability to perform different daily activities: walk down a flight of stairs, stand from a chair after sitting, kneeling, whether the knee gives way, sleeping, personal hygiene, doing household shopping, and using transport [196, 197].

Similarly to the OHS, two subscales can be generated from the OKS; the Oxford Knee Score Function subscale (OKS-FCS) and the Oxford Knee Pain (OKS-PCS) subscale. The OKS-FCS consists of five items that are function-related (items 2, 3, 7, 11, 12), and the OKS-PCS is based upon seven items related to pain (items 1, 4, 5, 6, 8, 9, 10). The final value of each sub-scale, calculated as in the OHS subscales, can take a value from 0 to 100. The lower score indicates worse outcome.

Scoring system. The score is considered to be missing if more than two items are not completed. For two or less missing responses the mean value of the score can be imputed to the unanswered questions. Following the same criteria we applied in the OHS, the total OKS score was grouped in 4 categories as follows:

- Poor, OKS <27
- Fair, OKS between 27 and 33
- Good , OKS between 34 and 41
- Excellent OKS > 41

c) **Western Ontario & McMaster Universities Arthritis Index (WOMAC-12**)

This instrument was designed to be used in patients with hip and knee OA, but it has also been used to detect changes in patients after lower limb arthroplasty. For the GAR cohort we used the short version of WOMAC, which has 12 items [198]. The rationale to use this PROM with these participants was that this tool is already routinely collected during the follow-up of this cohort.

WOMAC-12 enquires about pain experienced when performing 5 different activities, and any difficulty experienced whilst doing 7 different activities. The participants choose the option that best describes their situation among the five possible options provided. The responses from items 1 to 5 are used to generate the WOMAC-12 pain score, and the responses from items 6 to 12 to calculate the WOMAC-12 physical function score.

Scoring system. Each item is followed by a 5-point Likert scale which is scored between 0 and 4. The final score is calculated as the sum of the corresponding items and rescaled from 0 to 100, where a higher score indicates a better result. To handle the missing values we used the approach previously described by Whitehouse and colleagues in their validation of the WOMAC-12 function scale, where a patient’s response was invalid if 3 or more values were missing. The WOMAC-12 function score can however be generated if two or less items were missing by imputation of the average value for the subscale [199].

d) Short-Form 12 Health Survey (SF-12)

The SF-12 health survey is a widely used tool developed to measure functional health and general well-being. It comprises 12 categorical questions (yes/no) from which two components are calculated. The Physical Health Component (PCS) covers health domains; role-physical, body pain and general health. And the Mental Health Component comprises questions about vitality, social functioning role-emotional and mental health [200]. SF-12 score ranges from 0 to 48, with higher values indicating a better mental and physical health status.

Scoring system. Both, physical and mental SF-12 component summary scales were calculated according to the SF-12 standard scoring system [200]. According to this, all items must have been completed in order to generate the score, otherwise it is regarded as missing. To our understanding there are no cut off points to group people in different categories according to the PCS or MCS score obtained, we therefore used quintiles to define those people with the poorest scores (Q1 worse outcome, Q5 better outcome).

3.4.6 Piloting of the questionnaire

The draft questionnaire was piloted in an independent sample of arthroplasty patients in Southampton and surrounding areas (n=10) to check if it was understandable, straightforward to answer and not too time-consuming to complete.

For the Swiss component the questionnaire was translated into French by a French native speaker and afterwards translated back into English by an English native speaker to check the accuracy of the translation. The French version was also tested in patients attending Orthopaedic clinics, and their feedback resulted in further minor changes to the Swiss questionnaire.

Some of the Swiss patients expressed difficulty in following some of the items related to function because this group of questions referred to two different points in time (present and at their best) and the questions were relatively similar. In response, we modified the order of the items in the Swiss version of the questionnaire. Items related to function were divided into two different and non-consecutive sections; questions about current function were included in section 1 and questions about function at their best time after surgery were in section 4 of the questionnaire.

It was also thought that the section on physical activities was slightly complicated because at first sight it appeared we were asking the same questions more than once. To clarify, we included three coloured boxes, one for each type of activity (high, medium or low joint load impact) and a brief paragraph was added at the beginning of this section explaining that each of the three coloured boxes corresponded to different types of sports although the questions had the same wording.

Finally, and despite some questions (e.g. smoking habits) being excluded in the early stages of designing the questionnaire, some patients from Southampton and Geneva felt the length of the questionnaire was too long. However, it was considered that all the items included were necessary to address the questions of the study, hence no further questions were removed.

3.4.7 Ethics approval

In March 2017 ethics approval from the NHS Research Ethics Committee, Oxford REC A (ref. 10/H0604/91/AM11 IRAS 65920) was obtained to send our questionnaire to eligible patients from the COASt study. This was thought to be sufficient to contact all COASt participants but a second ethics approval was later required to contact other potential participants who had originally been recruited through the Oxford Musculoskeletal Biobank. This was obtained in March 2018 from the NHS Research Ethics Oxford Committee REC C (ref. 09/H0606/11).

For the study population in Switzerland, the Commission Cantonale d'éthique de la Recherche (CCER) gave ethics permission in October 2017 for us to send a questionnaire out to all eligible patients from the Geneva Arthroplasty Registry. To prevent upset, the mortality register in Geneva and where possible, the patients' addresses were checked before posting out the questionnaires.

A final approval to carry out the study was obtained from the Ethics and Research Governance Committee of the University of Southampton for both COASt and Geneva cohorts (submission ID 48599).

3.5 Description of existing baseline characteristics

During the pre-arthroplasty assessment (the time-point of recruitment to the original study; COASt and GAR) both cohorts collected the same information for each of the arthroplasty recipients, which were subsequently used in our analyses. In this sub-section we describe these variables and indicate which cohorts include this information (Table 17).

Table 17 Variables recorded at pre-arthroplasty assessment

	GAR	COASt – hips	COASt – knee
Index of multiple deprivation		✓	✓
Charnley score	✓	✓	
ASA score	✓	✓	✓
Indication for primary arthroplasty	✓	✓	✓

The Index of multiple deprivation (IMD) is a measurement that uses seven domains to quantify relative deprivation in small areas across England. Using a combination of: income deprivation, employment deprivation, education, skills and training deprivation, health deprivation and disability, crime, barriers to Housing and Services and Living environment deprivation, the IMD ranks every small area in England from 1 (most deprived area) to 32,844 (least deprived area).

The Charnley score, widely used in the orthopaedic literature, categorises hip arthroplasty patients into three groups according to co-morbid conditions and their ability to walk, as summarised in Table 18 [201].

Table 18. Description of the Charnley categories collected at the time of the surgery

Charnley categories
• Class A. People with one hip affected by OA and no other health condition that affects their walking ability. • Class B. People with both hip joints affected by OA and no other health condition that affects their walking ability. • Class C. People with multiple joints affected by OA, and a health condition that limits their walking ability, e.g. polyarthritis, cardiovascular or respiratory problems

The indication for primary surgery was collected at the time of the arthroplasty; in the GAR registry the information was recorded by the Hospital, and in the COASt study the information was gathered from two difference sources: i) the National Joint Registry (NJR) form completed by the surgeon, and ii) additionally self-reported through a questionnaire completed by the participants prior to the arthroplasty. For the latter self-reported data people were asked about all possible indications for having a joint arthroplasty, e.g. Do you suffer from Osteoarthritis? (Yes/ Not to my knowledge). For the analysis we opted for using the data collected from the NJR form because we considered this information to be more reliable and it was found to be more fully completed with less missing data than the self-reported information. However, if the indication for primary surgery was missing from the NJR form, we used the self-reported indication instead.

The American Society of Anesthesiologists (ASA) physical status [202] is a classification with six categories that describes the preoperative health status of patients undergoing surgery, see Table 19.

Table 19. Categories defining for the physical state of patients before having a surgical procedure

American Society of Anesthesiologists classification
ASA 1: Normal healthy patients
ASA 2: Patients with a mild systemic disease
ASA 3: Patients with a severe systemic disease
ASA 4: Patients with severe systemic disease that is a constant threat to life
ASA 5: Moribund patients who are not expected to survive without the operation
ASA 6: A declared brain-dead patient

3.6 Definition of the outcome measures

3.6.1 Implant failure

Implant failure was defined as the necessity for a revision procedure of the primary arthroplasty for any reason other than infection (information only available for GAR cohort). Both prosthesis removal and replacement, and removal and replacement of any of the components of the prosthesis such as cups or stems, were considered as a revision procedure. In the COASt cohort, information about which component of the prosthesis had failed was not available.

3.6.2 Poor function at follow-up

Given that revision is a rare event, we secondly investigated whether being exposed to heavy occupational activities affected function at a minimum of five years post-arthroplasty. This outcome was measured using different PROMS at the time of the follow-up;

- WOMAC-12 and SF-12, measured in the GAR cohort
- OHS, measured in both hip arthroplasty cohorts (GAR and COASt) and,
- OKS, measured in the knee cohort (COASt)

For function measured using the OHS and OKS scores, poor function was defined based upon the categories proposed by Kalairajah for the Harris Hip Score [195] and, when translated into the OHS scale ranges between 0 and 48. For the WOMAC-12 and the SF-12 no thresholds are available; we therefore used quintiles to group the participants and defined poor function as shown in Table 20.

Table 20. Definition of poor function at follow-up according to the PROMS measured

Oxford Hip Score	**Oxford Knee Score**
• Excellent (OHS > 41) • Good (OHS 34 to 41) • Fair (OHS 27 to 33) • Poor (OHS < 27)	• Excellent (OKS > 41) • Good (OKS 34 to 41) • Fair (OKS 27 to 33) • Poor (OKS < 27)
WOMAC-12 (physical function and pain)	**SF-12 physical component score**
Highest quintiles (Q5)- poor function	Lowest quintile (Q1) - poor function

3.6.3 Leaving a job for problems related to the replaced joint

This information was obtained by asking the participants to tick a box if “they left the job at least partly because of problems with the hip or knee replaced”. This same question was asked for each post-arthroplasty job reported by the participants (up to a maximum of three). For this secondary outcome we imposed no restriction to the length of time since returning to work and stopping the work because of having problems with the replaced joint.

3.7 Data management

3.7.1 Demographic variables

Level of education was collected differently in each cohort. In GAR, education was based upon completion of primary studies (up to 14 years of age), secondary studies (up to 18 years of age) or any further studies (over 18 years of age). In COASt the educational attainment was originally gathered in five categories (No qualifications, GCSE, A levels, further education and higher education as degree, diploma or PhD) and was grouped for the current analyses as no qualifications, ≤ 18 years and higher education.

3.7.2 Clinical characteristics

a) Type of bearing surfaces

Metal on metal implants (MoM), as stated in the first chapter of the thesis, showed abnormally high rates of failure which caused this type of implants to be withdrawn from the market at the beginning of the second decade of 2000s. The period of time over which MoM implants were still being used overlaps with the follow-up period of this study, especially in the case of the GAR cohort for which the duration of follow-up could be as long as 22 years. Therefore, where the data were available, we considered the type of bearing surfaces in two main categories; MoM and non-MoM implants. In the non-MoM group the coating materials of the implant included ceramic-polyethylene HXL, ceramic-polyethylene, metal-polyethylene, and ceramic-ceramic.

b) Cup, stems and size of the femur head

This information was only available for the GAR cohort. Combinations of the cups and stems used in the hip arthroplasty procedure were categorised, taking also into account the type of bearing surface.

The size of the replacement femoral head was grouped using the same categories previously used in the GAR annual reports. These were 22, 28, 32, 36 and > 36 mm. This latter category included femoral heads of 38, 40, 42, 44, 46, 48, 50, 52, 54 and 56 mm.

3.7.3 Optimal function post-arthroplasty

We asked participants to recall and report the level of pain and function at the point when they had achieved their optimal function post-arthroplasty. In order to maximise statistical power, the responses were grouped into two categories:

a) For time elapsed since arthroplasty to optimal function the categories were; less than one year (< than 6 months, 6 months to 1 year) and ≥ one year (one to two years and over two years)
b) For the need to use a stick when walking: No (Not at all, occasionally) and Yes (most of the time, all of the time)
c) For pain during daytime: No (never, occasionally), and Yes (often, all the time)
d) For pain at night: No (No nights, only 1 or 2 nights), and Yes (Some nights, most nights or every night)

3.7.4 Leisure time and daily activities post-arthroplasty

The questions about leisure activities and housework were divided into three sub-sections; high, medium, and low impact activities. In each of these sub-sections we enquired about the type of exercise practised along with totals of its frequency (number of times per year) and duration (number of months and weekly hours exposed post-arthroplasty). For example, a person who had been engaged in different activities that implied different weight bearing to a joint such as cycling (medium impact) and swimming (low impact), an entry should have been made in both the medium impact and the low impact activity sections.

a) Type of impact activities

In order for us to use the data in a reliable way, we first classified all the activities reported by the participants into high, medium or low impact activities according to the load on the joint based upon literature available [145, 158]. For activities not reported in the literature we sought agreement on the stress the activity may cause on the joint. In Table 21 are summarised all of the non-work related physical activities which were mentioned by at least three participants.

Secondly, we checked how the three sub-sections about leisure time and daily physical activities had been completed by our participants. We assessed whether the activities that had been written down in each of the sub-sections posed a similar type of strain on the joint, following the groups shown in Table 21. For example, we examined whether a person who reported using weight machines and who also hiked reported this information within the section dedicated to medium impact activities, or alternatively the use of weight machine was given in the section of high impact activities and hiking in the medium impact activities section.

The rationale to do this was to explore whether the activities reported by the participants had been correctly assigned. As a person can be engaged in several different types of sport, we decided to categorise people according to the highest joint load they were exposed to post-arthroplasty.

Table 21. Classification of the leisure time and daily physical activities self-reported by joint load

High impact	Medium impact	Low impact
Badminton Climbing Cricket Cross-trainer Football Tennis Ice-Hockey Jogging Running Squash Skiing Tap dancing Water skiing	Bowling Cross-country skiing Cycling Mountain biking Dancing, basic ballet, LBT (exercise class) Golf Heavy gardening Horse riding Nordic walking Petanque Rowing, sailing Weight training/ weight machines	Aqua aerobics Ballroom dancing Darts Errands, grocery shopping Gardening Housework Pilates Shooting Swimming Tai-Chi, mindfulness Yoga Walking, brisk walking

We found that 22 people reported what we considered to be a medium impact activity in the high impact section, with a further 48 people reporting a high impact activity in the medium impact section.

We therefore finally classified participants as being exposed to high, medium or low impact activities depending on the maximum joint weight bearing they had been exposed to post-arthroplasty as a result of doing leisure and household activities.

b) *Duration and frequency of the LTPA and housework activities performed*

To avoid under or over-reporting time exposed to an activity in those cases in which the survey was not completed as expected, we assigned the maximum amount of years and maximum number of weekly hours reported depending on the type of impact the person was exposed to. When two similar activities were given in 2 different sub-sections of the questionnaire (for example where two high impact activities were reported separately in each of the high and medium sub-sections), the frequency of the physical activity that was done most often was used in the analysis.

The frequency of the physical activity was collapsed into: never, < weekly (including the responses for less than 3 times a year, 3 to 10 times a year and 11 to 50 times a year) and ≥ weekly.

c) Combination of type of impact and frequency of the activity

In an attempt to take into account both joint load and frequency of the activity performed together, we categorised participants into groups to distinguish between those who were extremely active post-surgery and those who were completely inactive, to examine whether being highly active would have any effect on the replaced joint. The groups created were:

- Inactive; including people who did not report any type of leisure or daily physical activity (neither high, medium nor low) and therefore no frequency
- Medium active; comprising those engaged in low or intermediate activities post-arthroplasty regardless of how often the activities were performed, and also participants who engaged in high impact activities less than once a week
- Highly active; comprising people carrying out high impact activities more than once a week.

3.7.5 Occupational characteristics

All data were double entered and subsequently checked for possible inconsistencies during the data entry process by the IT team at the MRC Lifecourse Epidemiology Unit. Occupational codes from the Standard Occupational Classification [203] were assigned to job titles both pre- and post-arthroplasty using the CASCOT software. For each job title this software assigns a SOC code along with a score ranging from 0 to 100. This last score is an indication of the reliability of the occupational code that has been linked to each job title. The higher the score the more accurate the match performed by the software. Scores above 60 were accepted as correct and codes with a score below 60 were manually checked and revised where required. Additionally, the National Statistics Socio Economic Classification was obtained based on the standard occupational classification.

Amongst the information collected on jobs held post-arthroplasty, we asked for the start and end dates of each working period. In many cases the starting date provided was prior to the replacement surgery date, hence the post-arthroplasty starting date needed to be imputed. The most recent reviews published on the time taken to return to work post-arthroplasty conclude that there is wide variation observed among the studies, ranging from 1 to 17 weeks for the hip [175] and three to six months for the knee [176]. Therefore, we imputed three months after the surgery date as the job starting date post replacement.

For the survival analyses, when the event assessed was leaving a job post-arthroplasty partly because of the replaced hip, it was necessary to take into account jobs that overlapped. In these cases, time at risk was split into several periods of time to create a chronological timeline using each of the dates of starting and ending a job. For each of the periods of time resulting from the overlapped jobs we assigned the physically-demanding activities performed from the information reported. For example, an individual who reported two different jobs post-surgery; 1st) performed from April 2010 to June 2012 which entailed walking more than 2 miles a day and climbing ladders and, 2nd) from January 2011 to February 2017 which also involved standing for more than four hours a day. The periods of time at risk and occupational activities for this person were assigned as: i) Apr 2010-Jan 2011 walking and climbing ladders, ii) Jan 2011-Jun 2012 walking, standing > 4 hours and climbing ladders, and iii) Jun 2012 - Feb 2017 standing > 4 hours.

3.8 Statistical analyses

We performed the same analyses for each of the hip and knee cohorts that were part of this study, as long as the number of events of interest allowed us to fit the models. For some of the outcomes assessed, we were unable to fit models because the number of events in the cohorts were too small.

For descriptive purposes, in each of the cohorts assessed, we tested whether there were significant differences between men and women using the following tests: i) the Spearman test for ordinal variables, ii) χ^2 for categorical but non ordinal variables, iii) t test for continuous variables normally distributed, and iv) Wilcoxon rank-sum test for continuous variables not normally distributed.

3.8.1 Hip or knee implant failure (revision surgery)

For each of the covariates examined, we calculated the prevalence rates and the mean time contributed per person (in years) to either revision or follow-up, for participants who had a revision procedure and for those free from revision. Time to event was calculated from three months of the date of the arthroplasty to either: i) the date the revision surgery was performed (if one had been performed) or ii) the date the survey was returned, whichever came first. Hazard ratios with their corresponding 95% confidence intervals (CI) were calculated using Cox proportional hazards regression model to estimate the association between the risk of revision of the replaced joint and the following variables:

- Baseline characteristics (BMI, level of education, smoking, Charnley score, ASA score)
- Clinical and surgical factors (indication for arthroplasty, fixation method, side operated, type of bearing surfacing and size of the femur head)
- Function related characteristics at optimal function post-arthroplasty (walking with a stick, pain during the day, pain at night)
- Leisure time and daily physical activities post-arthroplasty (type of impact activity, frequency and duration of the activity; years exposed).

These models were adjusted for sex and age at the time of the operation since these were considered as the minimum set of covariates to include in the models. From these minimally adjusted models, covariates that were significant ($p<0.1$) to be included in further analysis.

To our knowledge, factors related to the optimal function reached post-arthroplasty have not been previously used in other studies as covariates. In a second step in our analysis, when optimal function post-arthroplasty factors (the use of a stick, pain during the day, pain at night, and time to reach best function) were significant (p<0.1), we explored whether the associations with revision (if any) remained after controlling for other covariates than sex and age at the time of operation. These regression models were adjusted for the minimal set of covariates, and those baseline, clinical and surgical factors that were significant in the minimally adjusted models. Those that were significant at a 10% significance level were taken forward to the next stage of analysis.

Leisure time and daily physical activity is an important covariate to take into account when assessing whether occupational activities post-arthroplasty are a risk factor for hip or knee revision. We explored the interaction effect between the type of impact activity and frequency of exercise, with revision surgery, but we were limited by the sample size and number of events (revision surgery) and could not explore this further. In a third stage of the analyses, we examined whether LTPA and household activities carried out post-arthroplasty were associated with revision after adjusting for the minimal set of covariates of baseline, clinical, and surgical factors identified from the minimally adjusted models, in addition to the optimal function post-arthroplasty factors taken forward in the second stage. Leisure activity covariates that were significantly associated with revision (p<0.1) were used in the final regression models looking at associations between occupational activities and risk of revision (adjusted for all relevant covariates).

For the regression models looking at physically-demanding occupational activities, the sample studied was limited to participants who worked post-arthroplasty for at least one month post-operation. In this stage, we first compared people who carried out a demanding occupational activity against those who returned to work and did not, adjusting for sex and age at the time of operation. Second, we fitted regression models adjusting for different sets of covariates identified in the previous steps. Given that a job may entail more than one physically-demanding occupational activity, we combined occupational activities significantly associated with revision, or in the absence of them, those activities with an estimated effect over 1.7, and compared them with participants with a sedentary occupation (i.e. their job did not entail any of physically-demanding activities examined). The rationale for doing this was to explore whether the associations for the occupational activities may be driven by a small group of participants. For example; 50 people reported kneeling/squatting and climbing ladders, and another 32 people reported kneeling/squatting and lifting/ carrying more than 25 kg, however 24 out the 32 and 50 people reported that they were exposed to all three occupational activities.

As explained in sub-sections 3.4.3 and 3.4.4 and, the exposure of participants to work and non-work related activities was collected through a survey. The study was therefore subject to only those people who were able to return the questionnaire. We were not able to use competing risks methods.

In the GAR cohort we identified a few participants (n=38) for whom the primary hip arthroplasty had been a non-elective procedure. To avoid bias in the association observed between demographic, clinical, leisure or occupational physical activities and hip revision, we performed sensitivity analyses in the minimally adjusted models for those associations with a p-value < 0.2. No difference was observed in analysis with or without this group of people, thus they remained as part of both the GAR analysis and the combined data analysis.

3.8.2 Poor function at follow-up as measured by different PROMS

These analyses were limited to participants who had completed the corresponding PROM and who were free from revision surgery at follow-up (at a minimum of 5 years post-arthroplasty). Poor function was defined by:

i) a cut-off point where available (OHS and OKS), or

ii) quintiles in the absence of defined categories. For WOMAC-12 physical function or WOMAC-12 pain those in Q5 had poor function, for SF-12 those participants included in the first quintile had poor function.

We calculated the prevalence rates for participants with and without poor function at follow-up, and estimated RRs with corresponding 95%CIs using Poisson regression models with robust error variance. Separate analyses for each component of WOMAC-12 (physical function and pain) and SF-12 (physical component score) were performed following the same stages described above in the revision surgery section. The findings for WOMAC-12 physical function and WOMAC-12 pain were very similar, thus we opted not to show WOMAC-12 pain in the results.

Firstly, we identified, at a 10% level of significance, factors associated with poor function at follow-up, adjusting for a minimal set of covariates (age at follow-up, sex and duration of the follow-up). Secondly, we examined associations between variables related to optimal function post-operation and poor function at follow-up, adjusting for baseline, clinical and surgical factors identified as significant in the previous steps ($p < 0.1$). Thirdly, the associations between poor function at follow-up and leisure time and daily physical activities were further adjusted for the covariates identified in the first and second steps. Those significant at ($p < 0.1$) were used in the final regression models looking at occupational activities and poor function at follow-up.

All the models fitted for occupational activities were limited to those participants who worked post-arthroplasty for a minimum period of one month. Several sets of regression models were fitted (as above) using the different groups of covariates identified in the previous steps.

3.8.3 Leaving a job in part because of problems with the joint replaced

To investigate this outcome, the analysis was restricted to those participants who worked post-arthroplasty and reported a beginning and ending date for each job, or where relevant, that they were still working at the time of the follow-up questionnaire. A subject could report up to three jobs post-operation, hence they also could report the event of interest more than once if they held more than one job following the surgery. We took into account only the first event that occurred.

For the covariates gathered, we calculated the prevalence rates and the mean time contributed per person (in years). Time to event was censored: a) on the date the participant reported leaving a job because of the replaced joint, b) at follow-up if the participants were still working at survey completion, or c) when the job finished for other reasons than the outcome examined. We followed the same steps as those followed in section 3.8.1, but in this analysis the minimum set of covariates adjusted for was age at operation, sex, and age at the time of questionnaires completion. Hazard ratios with their corresponding 95 %CI were calculated using Cox proportional hazard regression models to estimate the association between the risk of revision of the replaced joint and the following variables:

- Baseline characteristics
- Clinical and surgical factors
- Function related characteristics at optimal function post-arthroplasty
- Leisure time and daily physical activity post-arthroplasty

Finally, occupational activities that doubled hazard ratio were combined in pairs and compared for the risk of stopping their job against workers with only sedentary work. Finally, mutually adjusted models were fitted with all the relevant covariates and the statistically significant occupational activities.

All statistical analyses were performed using STATA® version 15.1.

Chapter 4 : Results from the Geneva Arthroplasty Registry

4.1 Response to the postal survey

In total, the Geneva Arthroplasty Register (GAR) contained the records of 1,721 patients who had received primary hip arthroplasties between March 1996 and December 2012 and were aged < 65 years at the time of the surgery. Some of the GAR participants had both hips replaced at different times between 1996 and 2012, however, according to our eligibility criteria, the first hip arthroplasty performed became the index joint for our study. Figure 6 summarises the eligible GAR sample according to our pre-defined criteria and the response rate obtained by January 2019.

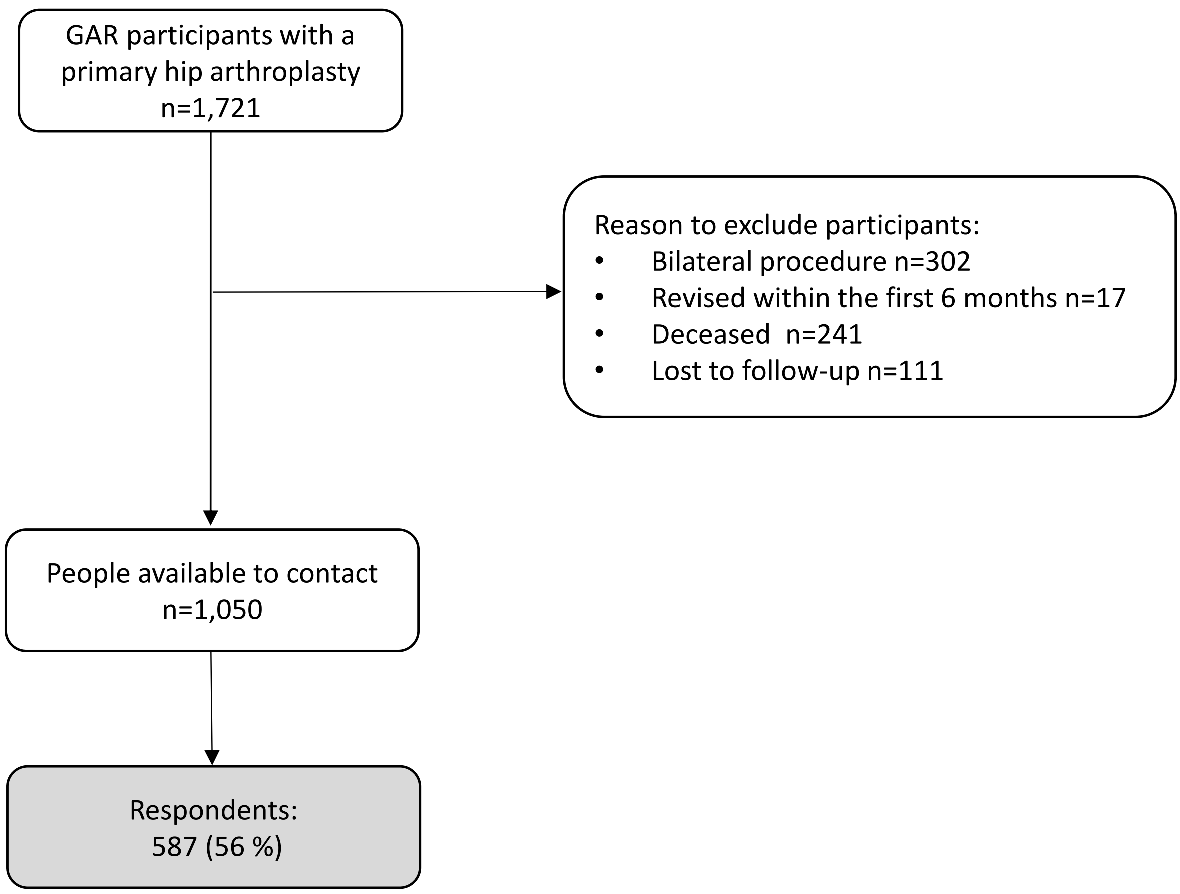

Figure 6. Flow chart summarising the eligibility and responses of the GAR participants

From this initial sample, we excluded people: i) who had a bilateral procedure during the same operation (302), ii) were revised within the first six months post-operation (17), were deceased (241), or iii) were lost to follow-up at the time of sending out the survey

(111). This resulted in 1,050 participants who were eligible to participate in this study. Questionnaires and letters were posted to all between October 2017 and December 2018. Non-respondents were sent a reminder questionnaire. By January 2019 a total of 587 people (response rate 56%) had returned the questionnaire at a median age of 69.5 years (IQR: 62.3, 74.6) and with a mean follow-up time of 12.4 (SD ± 4.9) years post-arthroplasty.

4.2 Description of the sample

Table 22 summarises the demographic and clinical characteristics of these younger hip arthroplasty recipients at the time of the primary operation. A total of 587 respondents, 54% of whom were men, underwent primary hip arthroplasty at a median age of 58.0 (IQR: 51.0, 61.0) years. Their BMI was slightly overweight at 26.8 (SD ± 4.9) and 29% of them were smokers (not shown in table). The main indication for hip arthroplasty was primary OA (61%) and secondary OA (39%). Secondary OA included the following indications: dysplasia of the hip (61), inflammatory arthritis (10), fracture (64), and aseptic necrosis or other (91). In addition to the index hip joint included in the study, 26% of the participants had also their contralateral hip affected OA and other health condition that affected their ability to walk, and a further 20% had several arthritic joints at the time of the primary operation and other health condition that limited their ability to walk (as described by the Charnley score). Amongst the participants, 56 people had undergone a surgical procedure to the same hip prior to their THA procedure, for example an osteotomy procedure or osteosynthesis.

The most common prosthetic bearing surface used in this younger sample of THA recipients was Metal-on-Metal (MoM) (41%), followed by Ceramic-on-Polyethylene (CoP) (30%) and Ceramic-on-Polyethylene HXL (CoP HXL) (28%), Metal on Polyethylene (MoP) (1%) and Ceramic-on-Ceramic (CoC) (<1%). Considering the type of fixation used, hybrid implants were the most prevalent (54%), followed by uncemented (43%) and cemented implants (3%). Different brands of cups, stems and combinations of them were used.

Table 22. Baseline demographic and clinical characteristics of the 587 respondents from the GAR

	All (n=587)	**Men (n=319)**	**Women (n=268)**
Age at operation Median (IQR)	58.0 (51.0, 61.0)	57.0 (50.0, 61.0)	58.0 (52.0, 62.0)
BMI, Mean (SD)	26.8 (4.9)	27.5 (4.1)	25.9 (5.5)
Charnley n (%)			
Class A	301 (51)	154 (48)	147 (55)
Class B	154 (26)	93 (29)	61 (23)
Class C	118 (20)	67 (21)	51 (19)
Missing	14 (2)	5 (2)	9 (3)
Indication for THA n (%)			
Primary OA	361 (61)	202 (63)	159 (59)
Secondary OA	226 (39)	117 (37)	109 (41)
Type of fixation n (%)			
Uncemented	252 (43)	150 (47)	102 (38)
Cemented	20 (3)	8 (3)	12 (4)
Hybrid	315 (54)	161 (50)	154 (57)
Bearing surfacing n (%)			
MoM	238 (41)	137 (43)	101 (38)
Other	349 (59)	182 (57)	167 (62)
Side n (%)			
Right	293(50)	151 (47)	142 (53)
Left	294 (50)	168 (53)	126 (47)
Previous operations to the same joint n (%)			
Yes	56 (10)	29 (9)	27 (10)
No	531 (90)	290 (91)	241 (90)
ASA score n (%)			
Healthy	157 (27)	73 (23)	84 (31)
Mild systemic disease	396 (67)	225 (70)	171 (64)
Severe systemic disease	34 (6)	21 (7)	13 (5)

In the GAR cohort, we were unable to test differences between respondents and non-respondents for baseline characteristics at the time of the arthroplasty. Amongst respondents, we found differences in sex distribution in relation to the BMI and ASA score gathered at the time of the arthroplasty. Men were slightly heavier than women ($p<0.01$) and the trend in the ASA score was different between men and women.

Time to achieve best improvement post-arthroplasty

Respondents were asked to recall the time post-operatively at which they reached their best function. Half of participants (n=289) reported that they reached their best function within 6 months following arthroplasty. Another quarter of the participants (n=139), reached their best outcome between six to 12 months, 13% (n=74) between one year and 18 months and 5% of individuals reported that their best function was obtained two years post-operation. A small number (n=49) of the participants did not complete this questionnaire item.

Occupation pre and post hip arthroplasty

A total of 91 people (15%) reported that they never held a paid job before their hip operation, 469 (80%) confirmed that they had worked at some point before undergoing THA, and this information was not given by 27 participants (5%). At the time of the operation, 127 of the 469 people were not working. 42 out of the 127 who had stopped working pre-operatively reported that their hip was partly or the main reason for stopping working. Another 332 of the 469 participants who had a paid job before the THA were still in the same job at the time the THA was performed Figure 7.

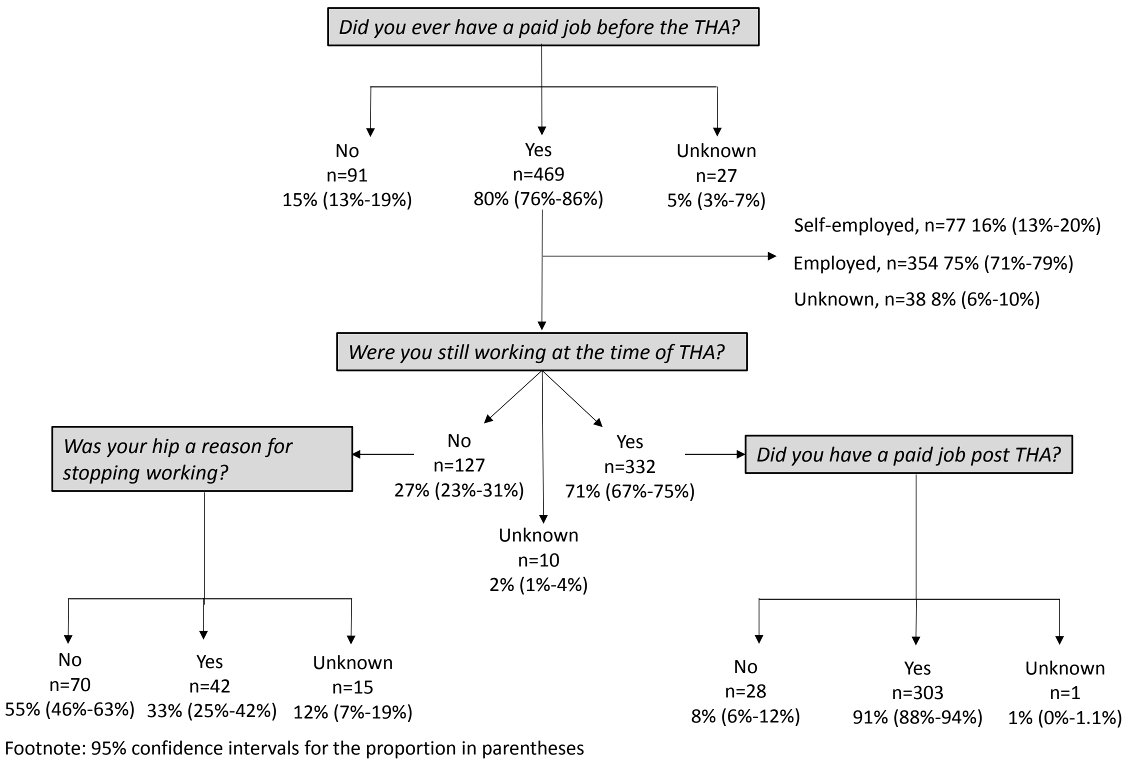

Figure 7. Flow chart showing occupational status pre and post-arthroplasty

Following arthroplasty, most of the participants (91%) who were working at the time of the arthroplasty returned to work. A further 28 of those not working at the time of the surgery also returned to work after THA. Those individuals who held a job following the primary operation were younger than those who did not resume work, with a median age of 56.0 (IQR: 49.0, 60.0) vs 60.0 (IQR: 56.0, 63.0) (p<0.01).

The median time worked post-operation was 5.5 years (IQR: 1.7, 9.0). Out of the 343 participants who continued in work post-arthroplasty, 295 reported information on the number of jobs held before stop working regardless of the reason. 266 of these 295 individuals reported holding one job (90%), another 22 (8%) had 2 jobs, and 7 (2%) three jobs after THA.

To address the main aims of this thesis, we investigated the role of post-operative occupational activities and leisure-time physical activities on a number of different outcomes between the time of the index joint arthroplasty and our follow-up:

- Revision surgery necessitated through failure of the arthroplasty (and not through infection)
- Poor function at the time of our follow-up (as measured by OHS, WOMAC physical function and SF-12 physical function)
- Reporting that the participant had returned to a job post-operatively for at least 1 month but that they had given up this job subsequently because of difficulties related to their index hip joint

4.3 Revision as an outcome of total hip arthroplasty

For the purposes of the current analyses, a revision arthroplasty was only included if it had been performed for any reason other than infection. From the 587 respondents, 5 were excluded from this analysis because the reason for their hip revision was infection-related. The person-time at risk was calculated as the time between the primary THA of the index joint and revision hip surgery, death or completion of the questionnaire. At a median follow-up of 12.4 years, with a minimum of 5 and a maximum of 22 years, the survival rate of the primary hip implant was 92%. The main reason for revision was aseptic loosening (47%) followed by granuloma/ALVAL (24%) and recurrent dislocation (9%) Table 23. Other indications for hip revision were recorded as: impingement (n=3), peri-prosthetic fracture (n=3), persistent pain (n=1), and malposition of the implant (n=1). For one person the indication for revision was unknown since the revision surgery was performed in another hospital than the Geneva University Hospital.

Table 23. Characteristics of the revision procedure

	All n (%)
Age at THA, n (%)	
<50 years	125 (21%)
50 - 54years	75 (13%)
55 - 59 years	161 (28%)
>60 years	221 (38%)
Revision	
No	537 (92%)
Yes	45 (8%)
Cause of revision	
Aseptic loosening	21
Granuloma/ALVAL[1]	11
Recurrent dislocation	4
Others	9

[1]ALVAL aseptic lymphocyte-dominant vasculitis-associated lesion

The mean time from the index surgery to revision was 9.2 years (SD ± 4.7), with the first hip implant failure recorded 6 months post-arthroplasty and the longest duration 20 years post-arthroplasty. Revisions were performed on a range of different prosthetic brands; 8 different types of cups and 8 different types of stems, and also different combinations of them as summarised in Appendix F (Table 97).

All the analyses were carried out for all participants and then by sex separately, but in the interests of space the tables hereafter only include the results for all participants.

Initially, we explored the relationships between the risk of revision and possible confounding factors: baseline characteristics (Table 24); clinical and surgical factors at baseline (Table 25); optimal function achieved post-operatively (Table 26). These were explored separately with age at time of the primary operation and sex as potential confounders. Subsequently, we investigated the role of LTPA post-arthroplasty (Table 28) on the risk of revision surgery. Finally, we explored the risks associated with occupational physical activities (Table 30). Based upon the results of these analyses, factors which were significantly associated at the $p<0.1$ level were taken forward as adjustments factors for the final models looking at the effect of occupational activities on revision.

Assessment of the associations between baseline characteristics at THA and risk of revision

In Table 24, the relationship between baseline characteristics and the risk of hip revision were explored. We found that the older age at which the THA was performed the less likely the participant was to have the hip revised. For every year increase in age, the risk of revision was reduced by 3% (HR: 0.97 95%CI 0.94,1.00*)*. However, no significant associations were found for: sex, BMI, level of education, smoking status at baseline, Charnley score, nor the ASA score recorded at the time of the surgery and the risk of hip revision. Although neither sex nor BMI were found to be risk factors for revision arthroplasty in this dataset, it was decided to include them as covariates for subsequent models of the risk of revision surgery given their relevance in other datasets.

Table 24. Association between baseline characteristics and the risk of hip revision

	Revision		**Mean time to (years)**		
	No n (%)	**Yes n (%)**	**Follow-up**	**Revision**	**HR[1] (95%CIs)**
Sex					
Males	293 (93)	23 (7)	12.5	8.4	1
Females	244 (92)	22 (8)	11.8	8.0	1.23 (0.69,2.21)
Age at THA Median, (IQR)	58.0 (52.0 , 61.0)	56.0 (47.0, 59.0)	-	-	*0.97 (0.94,1.00)*
BMI					
Normal	186 (89)	22 (11)	12.6	8.8	1
Underweight	14 (93)	1 (7)	11.1	6.6	0.73 (0.10,5.48)
Overweight	208 (95)	11 (5)	12.0	11.6	0.53 (0.25,1.12)
Obese	129 (92)	11 (8)	12.0	7.7	0.88 (0.42,1.86)
Missing	1 (100)	0	7.2		-
Education					
Compulsory	164 (94)	11 (6)	12.8	8.3	1
Secondary	113 (90)	13 (10)	12.1	8.2	1.63 (0.73,3.66)
Further	160 (95)	10 (5)	10.0	6.5	1.08 (0.46,2.57)
Missing	100 (90)	11 (10)	12.7	11.5	-
Smoking					
Never	260 (92%)	23 (8)	11.7	8.3	1
Former	86 (91%)	8 (9)	9.7	9.2	1.29 (0.56,2.96)
Current	157 (92)	13 (8)	12.6	6.6	0.79 (0.39,1.60)
Missing	34 (97)	1 (3)	16.9	20.3	-
Charnley					
Class A	276 (93)	23 (7)	13.1	9.8	1
Class B	139 (91)	14 (8)	12.1	10.0	1.13 (0.58,2.21)
Class C	108 (93)	8 (7)	9.7	6.1	1.12 (0.50,2.51)

	Revision		Mean time to (years)		
	No n (%)	**Yes n (%)**	**Follow-up**	**Revision**	**HR[1] (95%CIs)**
Missing	14 (100)	0			-
ASA score					
Healthy	143 (93)	12 (7)	12.4	8.6	1
Mild systemic disorder	361 (92)	32 (8)	12.1	8.2	1.24 (0.63,2.42)
Severe systemic disorder	33 (97)	1 (3)	12.0	9.2	0.43 (0.06,3.36)

[1] Age at operation and sex–adjusted estimates. HR in italics p<0.1

Clinical and surgical characteristics in relation to revision

The effect of clinical and surgical factors on the risk of hip revision was assessed in Table 25. People with fracture as the indication for THA were at double the risk of hip revision (HR: 2.36 95%CI 1.07,5.23) compared with those with primary OA as the indication. This was especially the case amongst men where those with a fracture as the indication for THA were at 3 times greater risk of hip revision than those with primary OA (HR: 3.08 95%CI 1.02,9.27) (Appendix F; Table 98).

Amongst those with fracture (n=64) as the indication for THA, some were performed electively and others as an emergency. In total, 37 THAs were performed as an emergency. It was possible that the risk of revision might be affected by emergency as compared with elective THA. We therefore carried out additional sensitivity analyses for those variables assessed in the minimally adjusted models that were significant at a 20% level of significance (p<0.2). The results showed (data not shown) that the inclusion of these 37 participants in the sample had no effect on the HRs estimated in the minimally adjusted models (Table 24 to Table 26, Table 28 and Table 30).

Compared with uncemented implants, the risk of hip revision was twice as high in those people with cemented implants (HR: 2.53 95%CI 0.96,6.67). Similarly, we found a strong association between both the type of bearing surface and the size of the femur head, and the need for hip revision. People with MoM implants were almost three times more likely to have their hip revised than those with a bearing surface other than MoM (HR: 2.82 95%CI 1.47,5.43). This risk of hip revision was even greater among women with MoM implants, with a four-times higher risk of hip revision compared with women with any other type of bearing surface (HR: 4.42 95%CI 1.60,12.19). Likewise, people with a replacement femur head size > 36mm were at a nine-fold greater risk of hip revision as compared with those with a 28mm femur head size, albeit with wide confidence intervals (HR: 9.86 95%CI 4.35,22.32).

Table 25. Association between clinical and surgical characteristics and hip revision

	Revision		**Mean time to (years)**		
	No n (%)	**Yes n (%)**	**Follow-up**	**Revision**	**HR[1] (95% CIs)**
Indication for THA					
OA	335 (93)	24 (7)	12.5	8.2	1
Dysplasia	55 (95)	4 (5)	12.0	13.7	0.67 (0.21,2.13)
Inflammatory arthritis	10 (100)	-	15.1	-	-
Fracture	55 (86)	9 (14)	9.9	7.8	**2.36 (1.07,5.23)**
Aseptic necrosis	82 (91)	8 (9)	11.9	7.9	1.17 (0.50,2.75)
Fixation					
Uncemented	233 (93)	17 (7)	8.0	7.7	1
Cemented	13 (72)	6 (18)	16.9	7.2	*2.53 (0.96,6.67)*
Hybrid	291 (93)	22 (7)	15.0	10.2	0.56 (0.28,1.12)
Contralateral hip[2]					
No	337 (94)	23 (6)	10.1	7.7	1
Yes	200 (90)	22 (10)	13.8	9.9	1.19 (0.66,2.14)
Side					
Right	265 (91)	25 (8)	12.5	7.8	1
Left	272 (93)	20 (7)	11.6	8.7	0.88 (0.49,1.60)
Bearing surface					
Other	329 (95)	16 (5)	9.2	11.4	1
MoM	208 (88)	29 (12)	12.9	7.8	**2.82 (1.47,5.43)**
Head size (mm)					
22	3 (75)	1 (25)	13.3	2.1	3.87 (0.50,29.88)
28	413 (93)	30 (66)	13.8	11.3	1
32	59 (98)	1 (2)	6.2	5.4	0.93 (0.12,7.15)
36	41 (93)	2 (5)	7.1	2.9	2.66 (0.60,11.84)
>36	21 (66)	11 (34)	11.0	7.7	**9.86 (4.35,22.32)**

[1] Age at operation and sex–adjusted estimates [2]Contralateral hip replaced after index THA performed. HR in italics p<0.1

Neither having the contralateral hip replaced following the index THA nor the side on which the operation was performed were associated with the risk of hip revision.

<u>Relationship between optimal function post-operatively, time to attain optimal function and risk of revision</u>

In order to understand the relationships between post-operative activities and revision, we explored the relationship between optimal function post-surgery and time taken to achieve optimal outcomes in relation to the risk of revision (Table 26). We investigated the risk associated with night pain from hip at best function; pain during the day at best function and using a stick to walk at time of best function.

Table 26. Associations between optimal function, time taken to reach optimal function post-THA and hip revision

	Revision		Mean time to (years)		
	No n (%)	**Yes n (%)**	**Follow-up**	**Revision**	**HR[1] (95% CIs)**
Time to best function					
< 1 year	405 (95)	23 (5)	12.3	9.2	1
≥ 1 year	90 (86)	15 (14)	9.9	7.7	**2.95 (1.50,5.80)**
Missing	42 (86)	7 (14)	15.1	8.2	-
Stick to walk					
No	475 (93)	33 (7)	12.1	8.3	1
Yes	33 (80)	8 (20)	11.0	7.1	**3.07 (1.41,6.69)**
Missing	29 (88)	4 (12)	13.8	9.6	-
Pain during day					
No	472 (93)	34 (6)	12.0	8.7	1
Yes	31 (93)	8 (7)	9.9	5.2	**3.73 (1.71,8.13)**
Missing	34 (92)	3 (8)	14.9	8.2	-
Pain at night					
No	402 (92)	33 (8)	12.5	8.4	1
Yes	101 (92)	9 (8)	9.9	6.4	1.18 (0.56,2.49)
Missing	34 (92)	3 (8)	13.8	8.2	-

[1] Age at operation and sex–adjusted estimates

These results showed that experiencing pain at night at their best post-arthroplasty was not associated with the risk of hip revision surgery in our patient group. However, we found an over 3-fold increased risk of revision amongst those who reported pain during the day, or that they needed a stick to walk when at their best post-operative function.

People who achieved their best possible function more than one year after arthroplasty were at almost three times higher risk of hip revision than those who reached their best function within the first year post-operation (HR: 2.95 95%CI 1.50,5.80).

We then examined whether the associations for time taken to achieve best function and for function at their best remained when we controlled for the important covariates identified from the analyses shown in Table 24 and Table 25. The HRs estimated for the relationship between function related variables and hip revision adjusted for baseline factors, and clinical and surgical characteristics are shown in Table 27.

Table 27. Associations between function and time taken to reach optimal function post-THA and hip revision adjusted for important baseline characteristics and clinical and surgical factors

	Revision		
	No n (%)	**Yes n (%)**	**HR[1] (95% CIs)**
Time to best function			
< 1 year	405 (95)	23 (5)	1
≥ 1 year	90 (86)	15 (14)	**3.38 (1.61,7.08)**
Missing	42 (86)	7 (14)	-
Stick to walk			
No	475 (93)	33 (7)	1
Yes	33 (80)	8 (20)	**3.44 (1.49,7.94)**
Missing	29 (88)	4 (12)	-
Pain during day			
No	472 (93)	34 (6)	1
Yes	31 (93)	8 (7)	**4.02 (1.75,9.26)**
Missing	34 (92)	3 (8)	
Pain at night			
No	402 (92)	33 (8)	1
Yes	101 (92)	9 (8)	0.95 (0.43,2.12)
Missing	34 (92)	3 (8)	-

[1] Age at operation, sex, BMI, indication for THA, fixation, bearing surface, femoral head size adjusted estimates

The results showed that after these further adjustments using a stick to walk at their best and needing over a year to reach their best function remained strongly associated with an increased risk of hip revision. However, the estimated HR for pain during the day and hip revision increased from 3.73 to 4.02 after further adjustments. The explanatory variable that contributed to this increase was the bearing surface of the implant.

<u>Leisure time and daily physical activities post-THA in relation to risk of revision</u>

In Table 28 we assessed the association between reported levels of LTPA (including sports activities and unpaid housework) and the risk of hip revision. Neither the type of impact activity nor the frequency with which this was performed, was statistically significantly associated with the risk of hip revision although there was a non-significant trend for a higher risk associated with both impact and frequency. Combining the type of LTPA and the frequency, 3 categories were created: inactive; “highly active” engaged in high impact activities ≥ once/week and “medium active” people who engaged in low/medium impact activities only or who engaged in high impact activities but < once/week.

Table 28. Associations between leisure time and daily physical activities post-THA and risk of hip revision

	Revision		Mean time to (years)		
	No n (%)	**Yes n (%)**	**Follow-up**	**Revision**	**HR[1] (95% CIs)**
Type of impact activities					
None	63 (94)	4 (6)	14.7	5.1	1
Low	179 (93)	13 (7)	12.0	10.7	1.21 (0.39,3.76)
Medium	145 (93)	11 (7)	10.5	6.5	1.40 (0.45,4.41)
High	94 (92)	8 (8)	11.8	7.7	1.52 (0.45,5.05)
Not known	56 (86)	9 (14)	14.4	8.4	-
Frequency					
No activity	63 (94)	4 (6)	14.7	5.1	1
< Weekly	168 (94)	11 (6)	11.8	9.8	1.12 (0.35,3.52)
≥ Weekly	197 (92)	17 (8)	10.9	7.7	1.58 (0.53,4.75)
Missing	109 (89)	13 (7)	13.5	11.3	-
Impact activities & frequency					
Inactive	63 (94)	4 (6)	14.7	5.1	1
Highly active	45(87)	7 (15)	9.7	7.7	2.97 (0.87,10.19)
Medium active	364 (94)	25 (6)	11.8	9.2	1.18 (0.41,3.41)
Missing	65 (88)	9 (12)	14.4	8.4	-
Years exposed Median (IQR)	9.5 (6.3-14.1)	11.5 (9.0-13.8)	-	-	*0.91 (0.82,1.01)*
Hours/week Median (IQR)	4.0 (2.0-10.0)	3.0 (1.5-10.0)	-	-	1.00 (0.96,1.05)

[1] Age at operation and sex adjusted estimates. HR in italics p<0.1

Comparing the results for people categorised as highly active, as compared with those who were sedentary or inactive yielded an estimated effect size of 2.97 in increasing the risk of hip revision surgery, although this estimate was surrounded by wide confidence limits (0.87-10.19) and straddled the “no effect” level.

We were unable to investigate whether there was an interaction between the types of impact sport engaged in post-THA and how often this was carried out, in relation to the risk of hip revision, because the number of people who underwent revision in our sample was too small to perform this analysis.

Then, we assessed whether covariates that related to LTPA and household activities were to be taken forward to the final occupational regression models. To do this we calculated associations between LTPA variables and the risk of hip revision, adjusting for the relevant baseline characteristics, clinical factors and function markers (see Table 29).

Table 29. Associations between leisure time and daily physical activities post-THA and hip revision adjusted for baseline characteristics, clinical and surgical factors and function markers

	Revision		Mean time to (years)		
	No n (%)	**Yes n (%)**	**Follow-up**	**Revision**	**HR[1] (95% CIs)**
Type of impact activity					
None	63 (94)	4 (6)	14.7	5.1	1
Low activity	179 (93)	13 (7)	12.0	10.7	0.89 (0.25,3.13)
Medium activity	145 (93)	11 (7)	10.5	6.5	1.87 (0.50,6.95)
High activity	94 (92)	8 (8)	11.8	7.7	2.03 (0.51,8.07)
Not known	56 (86)	9 (14)	14.4	8.4	-
Frequency					
None	63 (94)	4 (6)	14.7	5.1	1
<weekly	168 (94)	11 (6)	11.8	9.8	1.19 (0.34,4.15)
≥weekly	197 (92)	17 (8)	10.9	7.7	1.65 (0.47,5.81)
Missing	109 (89)	13 (11)	13.5	11.3	-
Type of impact activity & frequency					
Inactive	63 (94)	4 (6)	14.7	5.1	1
Highly active	45 (87)	7 (15)	9.7	7.7	*4.22 (0.95,18.76)*
Medium active	364 (94)	25 (6)	11.8	9.2	1.40 (0.40,4.90)
Missing	65 (88)	9 (12)	14.4	8.4	-
Years exposed Median (IQR)	9.5 (6.3-14.1)	11.5 (9.0-13.8)	-	-	0.94 (0.80,1.11)
Hours/week Median (IQR)	4.0 (2.0-10.0)	3.0 (1.5-10.0)	-	-	1.00 (0.96,1.04)

[1] Age, sex, BMI indication for THA, bearing surface, fixation method, femur head size, time to reach their best, the use of a stick, pain during the day adjusted estimates. HR in italics p<0.1

The results showed that people who were grouped as being highly active post-THA, i.e. doing high impact sport once a week or more, were at increased risk of revision (HR: 4.22 95%CI 0.95,18.76) when compared with those who were inactive, albeit with wide confidence intervals. The rest of the associations assessed between LTPA variables and the risk of hip revision remained non-significant. Therefore a combination of the type of impact activity and frequency was taken forward to the final models for occupational activities (Table 31).

Physically-demanding occupational activities post-THA and risk of revision

Amongst our sample, following primary hip replacement 343 people (61% men, n=209) returned to work or started a new paid job. When we compared people who worked post-THA versus those who did not work post-surgery, the results showed no significant association between doing any paid work post-THA and risk of hip revision (data not shown). Interestingly, men who went back to work were 59% less likely to have their hip revised than those who did not return to work post-operation (HR: 0.41 95%CI 0.17,0.97).

In the analysis to explore exposure to occupational activities and the risk of hip revision (shown in Table 30 and Table 31) only people who held a paid job for at least one month post-THA were taken into account. The minimally adjusted models (Table 30), using sex and age at arthroplasty as covariates, compared the risk of hip revision for participants who reported performing a physically-demanding occupational activity versus those who did not perform the occupational activity examined.

Table 30. Association between physically-demanding occupational activities post-THA and hip revision

	Revision		**Mean time to (years)**		
	No n (%)	**Yes n (%)**	**Follow-up**	**Revision**	**HR[1] (95% CIs)**
Standing > 4h /day					
No	142(95)	8 (5)	10.1	7.9	1
Yes	96 (95)	5 (5)	10.8	9.8	1.14 (0.36,3.54)
Missing	82 (89)	10 (11)	14.1	8.3	-
Walking > 2 miles /day					
No	154 (95)	9 (5)	10.8	8.2	1
Yes	83 (95)	4 (5)	10.1	8.2	1.11 (0.34,3.69)
Missing	83 (89)	10 (11)	13.5	8.3	-
Lifting / carrying ≥ 10kg					
No	161 (95)	8 (5)	10.0	7.9	1
Yes	76 (94)	5 (6)	11.7	10.7	1.67 (0.53,5.28)
Missing	83 (89)	10 (11)	13.8	8.3	
Lifting/ carrying ≥ 25kg					
No	205 (95)	11 (5)	10.6	9.8	1
Yes	32 (94)	2 (6)	9.4	5.5	2.03 (0.42,9.71)
Missing	83 (89)	10 (11)	14.0	8.3	
Kneeling/squatting					
No	158 (96)	6(4)	10.0	9.8	1
Yes	79 (92)	7 (8)	11.7	7.5	**3.20 (1.03,9.93)**
Missing	83 (89)	10 (11)	14.1	8.3	-
Climbing >30 flights stairs/day					
No	147 (92)	12 (8)	10.7	9.0	1
Yes	90 (99)	1 (1)	9.7	7.3	0.20 (0.03,1.54)
Missing	83 (89)	10 (11)	14.1	8.3	-

	Revision		Mean time to (years)		
	No n (%)	**Yes n (%)**	**Follow-up**	**Revision**	**HR[1] (95% CIs)**
Climbing ladders (up/down)					
No	185 (95)	9 (5)	9.8	7.9	1
Yes	522 (93)	4 (7)	12.1	9.8	2.01 (0.59,6.91)
Missing	83 (89)	10 (11)	14.0	8.3	-

[1] Age at operation and sex adjusted estimates

None of the participants who reported digging/shovelling post-THA underwent hip revision, thus this activity is not shown in Table 30. Those people who knelt/squatted were three times more likely to undergo hip revision as compared with those who did not (HR: 3.20 95% CI 1.03,9.93). We found that climbing ladders was associated with an estimated doubling of the risk of hip revision when compared with workers that did not report this occupational activity (HR: 2.01 95%CI 0.59,6.91) but once again, this estimate had wide confidence intervals. Conversely climbing more than 30 flights of stairs each day appeared to convey some level of protection against the risk of hip revision (HR: 0.20 (0.03,1.54), when compared with workers that did not carry out this activity, but the confidence intervals around this estimate included 1.0.

In the final stages of our analysis we assessed the relationship between physically-demanding occupational activities performed post-THA (i.e. standing, kneeling/squatting, walking, lifting or carrying weights, and climbing ladders or stairs) and the risk of hip revision adjusted for a different set of covariates as defined in Table 24, Table 25, Table 27 and Table 29 in four separate models. We found no significant association between any of the occupational activities performed post-arthroplasty and the risk of hip revision. The estimated HRs were consistent across all the models fitted (Model 1 to 4) with adjustments as indicated in Table 31. The results showed that those who knelt/squatted were four times more likely to undergo hip revision when compared with people who did not perform this occupational activity; Model 2 (HR: 4.46, 95%CI 1.20,16.60) and Model 4 (HR: 4.52 95%CI 1.16,17.58). The associations in Models 1 and 3, although they did not reach significance, yielded estimates of 2.96 and 2.84 respectively.

None of the exposures: walking more than 2 miles/day, lifting weights or climbing ladders were associated with the risk of hip revision. However, reported climbing >30 flights of stairs a day was consistently associated with a lower risk of hip revision across Models 1 to 4 with estimated HRs ranging between 0.19 and 0.21, but all with wide confidence intervals embracing 1.0.

In a further step, we combined those workers who reported any of two of the three occupational activities that showed higher risk of hip revision (kneeling/squatting, climbing ladders or lifting/carrying ≥25 kg), and compared them with workers who did not perform any of the seven occupational activities assessed (stand, walk, lift/carry weights, dig/shovel, kneel/squat, climb ladder, climb stairs). The estimated HRs are presented in Table 31. We found a non-significant association between the activities combined and the risk of hip revision, but the estimates were consistent across Models 1 to 4 with an increased risk of revision that ranged between 1.72 to 2.54 for kneeling/squatting & lifting/ carrying ≥ 25kg, and 2.06 to 3.05 for and for climbing ladders & lifting/ carrying ≥ 25kg

Not all the participants who returned the questionnaire worked after THA. Amongst the participants not exposed to work after THA (40%) there were 20 hips revised, which considerably reduced the power to detect associations between work factors and the risk of hip revision.

Table 31. Associations between physically-demanding occupational activities performed post-THA and hip revision

	MODEL 1	MODEL 2	MODEL 3	MODEL 4
Occupational activities (No vs Yes)	**HR (95% CIs)**	**HR (95% CIs)**	**HR (95% CIs)**	**HR (95% CIs)**
Standing > 4h / day	1.04 (0.30,3.57)	1.47 (0.41,5.28)	1.10 (0.31,3.91)	1.52 (0.41,5.56)
Walking >2 miles / day	1.64 (0.45,5.93)	2.10 (0.54,8.13)	2.05 (0.54,7.83)	2.55 (0.62,10.53)
Lifting or carrying ≥ 10kg	1.39 (0.38,5.03)	1.69 (0.44,6.41)	1.39 (0.38,5.14)	1.87 (0.48,7.21)
Lifting or carrying ≥ 25kg	3.36 (0.60,18.83)	3.20 (0.54,19.14)	3.31 (0.58,18.92)	3.24 (0.54,19.61)
Kneeling/squatting	2.96 (0.86,10.19)	**4.46 (1.20,16.60)**	2.84 (0.79,10.17)	**4.52 (1.16,17.58)**
Climbing>30 flights / day	0.19 (0.02,1.58)	0.21 (0.02,1.73)	0.20 (0.02,1.66)	0.19 (0.02,1.66)
Climbing ladders	1.44 (0.38,5.41)	1.68 (0.41,6.81)	1.63 (0.42,6.33)	1.94 (0.45,8.28)
Sedentary occupation vs 2 occupational activities combined				
Kneeling/squatting & lifting/ carrying ≥ 25kg	1.98 (0.34,11.60)	1.72 (0.24,12.16)	2.54 (0.39,16.34)	2.01 (0.26,15.41)
Kneeling/squatting & climbing ladders	1.23 (0.37,4.09)	1.88 (0.50,7.12)	1.33 (0.39,4.61)	2.27 (0.55,9.34)
Climbing ladders & lifting/ carrying ≥ 25kg	2.06 (0.36,11.89)	2.35 (0.31,17.84)	2.84 (0.44,18.48)	3.05 (0.35,26.85)

Risk estimates shown come from separate regression models after adjustment for:

Model 1: Age at arthroplasty, sex, BMI at baseline, indication for hip replacement, bearing surface, fixation, femur head size adjusted estimates.

Model 2: Age at arthroplasty, sex, BMI at baseline, indication for hip replacement, bearing surface, fixation, femur head size, time to best function, stick to walk, pain during day adjusted estimates.

Model 3: Age at arthroplasty, sex, BMI at baseline, indication for hip replacement, bearing surface, fixation, femur head size, leisure time and daily activities adjusted estimates.

Model 4: Age at arthroplasty, sex, BMI at baseline, indication for hip replacement, bearing surface, fixation, femur head size, time to best function, stick to walk, pain during day, leisure time and daily activities adjusted estimates.

4.4 Factors associated with poor function after total hip arthroplasty surgery

We also investigated whether returning to work involving physically-demanding occupational activities was associated with poorer physical function scores at follow-up. Current function was measured using four different Patient Reported Outcome Measures (PROMs) in our follow-up questionnaire (completed at a mean follow-up of 12.4 years post-arthroplasty). The PROMs were OHS, WOMAC-12 physical function (WOMAC-12 p.f.), WOMAC-12 pain and SF-12 physical component summary (PCS). For these analyses, we excluded those who had their hip arthroplasty revised for any reason (n=50). Participants were also excluded from analyses if they did not complete every question required to score that functional outcome on the validated tools. For this reason, the sample sizes for analysis varied slightly between each functional outcome: 19 people did not complete OHS; 12 people gave incomplete information for WOMAC-12 p.f.; 57 were incomplete for SF-12 and 8 people did not complete the WOMAC pain scale. Resultant sample sizes are described in detail in the sub-sections (4.4.1, 4.4.2 and 4.4.3).

In the absence of established cut-off points we defined poor function at follow-up as the worst quintile of the sample for both scores; the PCS and WOMAC-12 physical function. For the OHS we followed the categorisation proposed by Kalairajah et al [195], which defines poor OHS as having a score < 27. For the minimally adjusted models with function as the outcome, sex, age at questionnaire completion and duration of follow-up since date of the index operation were considered covariates. Therefore, all analyses were adjusted for these three factors (Table 33 to Table 37):

- Table 33. Associations between baseline characteristics and poor function at follow-up measured as OHS, PCS and WOMAC-12 p.f. adjusted for sex, age, and duration of follow-up.
- Table 34. Association between clinical and surgical factors and poor function at follow-up measured as OHS, PCS and WOMAC-12 p.f. adjusted for sex, age, and duration of follow-up. In this table, data were only presented for primary versus secondary OA in the interests of space. However, we were also able to explore the relationship between the underlying cause of secondary OA and poor OHS, and

where relevant, detailed results are provided in the subsections 4.4.1, 4.4.2 and 4.4.3.

- Table 35. Association between time to reach best function post-operatively and optimal function and poor function at follow-up measured as OHS, PCS and WOMAC-12 p.f. adjusted for age, sex and duration of follow-up.Table 36. Association between leisure and daily activities post-arthroplasty and poor function at follow-up measured as OHS, PCS and WOMAC-12 p.f. adjusted for sex, age and duration of follow-up.
- Table 37. Association between exposure to physically-demanding occupational activities post-arthroplasty and poor function at follow-up measured as OHS, PCS and WOMAC-12 p.f. adjusted for sex, age and duration of follow-up. Further adjusted models using covariates identified in the minimally adjusted models are presented and described in the corresponding sub-sections that follow (4.4.1, 4.4.2, 4.4.3 3).

At a mean follow-up of 12.2 years post hip arthroplasty, the median OHS function subscale was 95.8 (IQR 78.8, 100.0) and OHS pain subscale 95.8 (IQR:75.0, 100.0). More than 80% of the participants reported that their function in the past four weeks before completing the survey was excellent or good, 10% were fair and 9% were grouped as having a poor OHS (24 men, 23 women) as described in Table 32.

Table 32. Distribution of Oxford Hip Score across categories

OHS, n (%)	All	Men	Women
Excellent	335 (65)	187 (66)	148 (63)
Good	85 (16)	44 (16)	41 (17)
Fair	51 (10)	28 (10)	23 (10)
Poor	47 (9)	24 (8)	23 (10)

The PCS scores were grouped into quintiles of the distribution, with a higher PCS quintile indicating better physical function. We defined current poor PCS as the group of people who were categorised in the lowest PCS quintile (Q1) and compared them with those who were categorised in quintiles Q2, Q3, Q4 and Q5. Similarly, we defined those with a WOMAC-12 p.f. in the fifth quintile as those having the poorest current outcome and compared predictors for being in this group as compared with the other four quintiles.

Table 33. Associations between baseline characteristics and poor OHS, PCS and WOMAC-12 physical function at follow-up

	Poor OHS			Poor PCS			Poor WOMAC-12 p.f.		
	No n (%)	**Yes n (%)**	**RR[1] (95% CIs)**	**No n (%)**	**Yes n (%)**	**RR[1] (95% CIs)**	**No n (%)**	**Yes n (%)**	**RR[1] (95% CIs)**
Sex									
Males	259 (92)	24 (8)	1	222 (88)	43 (16)	1	235 (82)	52 (18)	1
Females	212 (90)	23 (10)	1.17 (0.68,2.01)	162 (75)	53 (25)	**1.53 (1.07,2.20)**	192 (81)	46 (19)	1.08 (0.76,1.55)
Age at follow-up Median (IQR)	69.5 (63.3,74.6)	66.3 (56.7,75.4)	**0.96 (0.93,0.99)**	69.0 62.5 69.0	71.1 60.3 71.1)	1.00 (0.97,1.02)	69.2 62.5 74.2	69.9 60.5 75.7)	0.99 (0.97,1.02)
BMI									
Normal	173 (96)	7 (4)	1	146 (85)	26 (15)	1	161 (88)	22 (12)	1
Underweight	13 (93)	1 (7)	1.31 (0.17,10.31)	9 (75)	3 (25)	1.46 (0.51,4.12)	13 (93)	1 (7)	0.56 (0.08,3.81)
Overweight	179 (89)	23 (11)	**4.06 (1.76,9.36)**	153 (82)	35 (19)	1.43 (0.89,2.30)	166 (82)	36 (18)	*1.64 (0.98,2.76)*
Obese	106 (87)	16 (13)	**4.59 (1.92,10.97)**	76 (70)	32 (30)	**2.18 (1.38,3.45)**	87 (69)	39 (31)	**2.85 (1.73,4.67)**
Education									
Compulsory	135 (85)	23 (15)	1	109 (76)	35 (24)	1	116 (73)	43 (27)	1
Secondary	99 (93)	8 (7)	**0.45 (0.21,0.95)**	84 (84)	16 (16)	*0.62 (0.37,1.06)*	86 (80)	22 (20)	0.73 (0.46,1.15)
Further	153 (97)	5 (3)	**0.19 (0.08,0.49)**	133 (87)	19 (13)	**0.51 (0.31,0.86)**	146 (91)	14 (9)	**0.33 (0.19,0.57)**
Missing	84 (88)	11 (12)	-	58 (69)	26 (31)		79 (81)	19 (19)	-
Smoking									
Never	230 (91)	22 (9)	1	189 (82)	41 (18)	1	208 (82)	45 (18)	1
Former	77 (93)	6 (7)	0.94 (0.39,2.26)	64 (81)	15 (19)	1.25 (0.73,2.13)	71 (84)	14 (16)	0.98 (0.56,1.70)
Current	137 (91)	14 (9)	0.91 (0.48,1.72)	103 (73)	38 (27)	**1.63 (1.09,2.45)**	122 (79)	33 (21)	1.18 (0.78,1.79)
Missing	27 (84)	5 (16)	-	28 (93)	2 (7)	-	26 (81)	6 (19)	-

[1] Risk estimates shown come from separate regression models after adjustment for: age, sex and duration of follow-up adjusted estimates. RR in italics p<0.1

	Poor OHS			Poor PCS			Poor WOMAC-12 p.f.		
	No n (%)	Yes n (%)	RR[1] (95% CIs)	No n (%)	Yes n (%)	RR[1] (95% CIs)	No n (%)	Yes n (%)	RR[1] (95% CIs)
Charnley									
Class A	249 (94)	17 (6)	1	209 (85)	36 (15)	1	233 (87)	35 (13)	1
Class B	124 (92)	11 (8)	1.27 (0.62,2.63)	103 (80)	26 (20)	1.43 (0.91,2.26)	107 (79)	29 (21)	**1.65 (1.05,2.58)**
Class C	86 (83)	17 (17)	**2.99 (1.58,5.66)**	61 (66)	32 (34)	**2.52 (1.67,3.79)**	76 (71)	76 (31)	**2.41 (1.56,3.73)**
Missing	12 (86)	2 (14)	-	11 (85)	2 (15)	-	11 (79)	3 (21)	-
ASA score									
Healthy	134 (95)	7 (5)	1	119 (89)	14 (11)	1	127 (89)	15 (11)	1
Mild systemic disorder	307 (89)	37 (11)	**2.51 (1.15,5.48)**	246 (76)	76 (24)	**2.45 (1.47,4.08)**	272 (77)	79 (22)	**2.27 (1.36,3.77)**
Severe systemic disorder	30 (91)	3 (9)	2.28 (0.64,8.19)	19 (76)	6 (24)	**2.61 (1.09,6.26)**	28 (87)	4 (13)	1.27 (0.46,3.50)

[1] Risk estimates shown come from separate regression models after adjustment for: age, sex and duration of follow-up adjusted estimates. RR in italics p<0.1

Table 34. Associations between clinical and surgical variables and poor OHS, SF-12 physical component (PCS) and WOMAC-12 physical function at follow-up

	Poor OHS			**Poor PCS**			**Poor WOMAC-12 p.f.**		
	No n (%)	**Yes n (%)**	**RR[1] (95% CIs)**	**No n (%)**	**Yes n (%)**	**RR[1] (95% CIs)**	**No n (%)**	**Yes n (%)**	**RR[1] (95% CIs)**
Indication for THA									
Primary OA	300 (93)	22 (7)	1	240(81)	57 (20)	1	270 (83)	57 (17)	1
Secondary OA	48 (87)	7 (13)	1.55 (0.85,2.81)	38 (76)	12 (24)	1.11 (0.76,1.63)	44 (81)	10 (18)	1.20 (0.81,1.77)
Contralateral									
No	302 (93)	21 (7)	1	251 (84)	48 (16)	1	277 (84)	53 (16)	1
Yes	169 (87)	26 (13)	**1.94 (1.09,3.44)**	133 (74)	48 (26)	**1.67 (1.16,2.41)**	150 (77)	45 (23)	1.36 (0.94,1.96)
Fixation									
Uncemented	211 (93)	16 (7)	1	182 (84)	34 (16)	1	197 (86)	33 (14)	1
Cemented	251 (90)	27 (10)	**3.98 (1.60,9.89)**	4 (44)	5 (56)	**3.29 (1.56,6.92)**	222 (79)	60 (21)	**2.52 (1.14,5.60)**
Hybrid	9 (69)	4 (31)	1.62 (0.85,3.10)	198 (78)	57 (22)	*1.46 (0.93,2.29)*	8 (62)	5 (38)	1.47 (0.91,2.39)
Side									
Right	234 (90)	25 (10)	1	186 (78)	53 (22)	1	210 (81)	48 (18)	1
Left	237 (92)	22 (8)	0.94 (0.55,1.62)	198 (82)	43 (18)	0.84 (0.59,1.21)	217 (81)	50 (19)	1.03 (0.72,1.47)
Head size (mm)									
28	361(91)	37 (9)	1	288 (79)	77 (21)	1	322(80)	81 (20)	1
32	55 (96)	2 (4)	0.38(0.09,1.72)	49 (94)	3 (6)	**0.30 (0.09,0.96)**	52 (90)	6 (10)	0.56 (0.23,1.33)
36	37 (95)	2 (4)	0.58 (0.13,2.57)	31 (79)	5 (21)	1.07 (0.53,2.18)	36 (90)	4 (10)	0.54 (0.20,1.50)
>36	17 (81)	4 (19)	1.66 (0.58,4.74)	15 (71)	6 (29)	1.59 (0.76,3.32)	15 (71)	6 (29)	1.45 (0.66,3.17)
22 mm	1 (33)	2 (67)	**4.94 (2.05,11.93)**	1 (33)	2 (67)	**2.69 (1.10,6.55)**	2 (67)	1 (33)	1.55 (0.30,8.09)

	Poor OHS			Poor PCS			Poor WOMAC-12 p.f.		
	No n (%)	Yes n (%)	RR[1] (95% CIs)	No n (%)	Yes n (%)	RR[1] (95% CIs)	No n (%)	Yes n (%)	RR[1] (95% CIs)
Bearing surface									
Other	289 (91)	28 (9)	1	238 (81)	55 (19)	1	259 (80)	65 (20)	1
MoM	182 (91)	19 (9)	1.10 (0.64,1.87)	146 (78)	41 (22)	1.22 (0.85,1.75)	168 (84)	33 (16)	0.81 (0.55,1.17)

[1] Risk estimates shown come from separate regression models after adjustment for: age, sex and duration of follow-up–adjusted estimates

Table 35. Associations between time to best post-operative function, optimal function, function in the contralateral hip and poor OHS, SF-12 physical component (PCS) and WOMAC-12 physical function at follow-up

	Poor OHS			**Poor PCS**			**Poor WOMAC-12 p.f.**		
	No n (%)	**Yes n (%)**	**RR[1] (95% CIs)**	**No n (%)**	**Yes n (%)**	**RR[1] (95% CIs)**	**No n (%)**	**Yes n (%)**	**RR[1] (95% CIs)**
Time to best function									
< 1 year	376 (95)	21 (5)	1	306 (83)	63 (17)	1	346 (87)	53 (13)	1
≥ 1 year	68 (78)	19 (22)	**3.90 (2.12,7.16)**	61 (73)	22 (27)	**1.56 (1.02,2.39)**	55 (62)	34 (38)	**3.08 (2.13,4.47)**
Missing	27 (79)	7 (21)	-	17 (61)	11 (39)	-	26 (70)	11 (30)	-
Stick to walk									
No	432 (94)	30 (6)	1	356 (82)	78 (18)	1	392 (83)	78 (17)	1
Yes	20 (62)	12 (38)	**5.52 (3.03,10.04)**	16 (53)	14 (47)	**2.60 (1.69,3.99)**	14 (45)	17 (55)	**3.32 (2.28,4.85)**
Missing	19 (79)	5 (21)	-	12 (75)	4 (25)	-	21 (88)	3 (12)	-
Pain									
No	370 (96)	14 (4)	1	308 (86)	52 (14)	1	348 (89)	41 (11)	1
Yes	75 (73)	28 (27)	**7.44 (4.02,13.76)**	59 (63)	35 (37)	**2.65 (1.84,3.81)**	53 (51)	50 (49)	**4.93 (3.48,6.99)**
Missing	26 (84)	5 (16)	-	17 (65)	9 (35)	-	26 (79)	7 (21)	-
Current pain/ stiffness contralateral hip									
No	379 (95)	20 (5)	1	316 (85)	57 (15)	1	351 (87)	52 (13)	1
Yes	36 (67)	18 (33)	**6.38 (3.51,11.59)**	25 (48)	27 (52)	**3.36 (2.32,4.87)**	26 (47)	29 (53)	**4.17 (2.91,5.95)**
Missing	56 (86)	9 (14)	-	43 (78)	12 (22)	-	50 (75)	17 (25)	-

[1] Risk estimates shown come from separate regression models after adjustment for: age, sex and duration of follow-up adjusted estimates

Table 36. Associations between leisure time and daily activities post-THA and poor OHS, SF-12 physical component (PCS) and WOMAC-12 physical function at follow-up

	Poor OHS			Poor PCS			Poor WOMAC-12 p.f.		
	No n (%)	**Yes n (%)**	**RR[1] (95% CIs)**	**No n (%)**	**Yes n (%)**	**RR[1] (95% CIs)**	**No n (%)**	**Yes n (%)**	**RR[1] (95% CIs)**
Type of impact activity									
None	49 (80)	19 (18)	1	39 (71)	16 (29)	1	42 (69)	19 (31)	1
Low	153 (87)	22 (13)	0.69 (0.37,1.28)	122 (76)	38 (24)	0.74 (0.45,1.24)	133 (76)	42 (24)	0.80 (0.50,1.28)
Medium	136 (96)	6 (4)	**0.22 (0.09,0.55)**	114 (85)	20 (15)	**0.50 (0.28,0.89)**	129 (89)	16 (11)	0.37 (0.20,0.67)
High	93 (100)	0	-	84 (92)	7 (8)	**0.26 (0.11,0.60)**	87 (94)	6 (6)	**0.21 (0.09,0.51)**
Not known	40 (85)	7 (15)	-	25 (62)	15 (37)	-	36 (71)	15 (29)	-
Frequency									
No activity	49 (80)	12 (20)	1	39 (71)	16 (29)	1	42 (69)	19 (31)	1
< weekly	149 (91)	15 (9)	**0.43 (0.21,0.88)**	134 (83)	27 (17)	**0.56 (0.32,0.96)**	138 (84)	27 (16)	**0.53 (0.32,0.88)**
≥ weekly	187 (95)	9 (5)	**0.24 (0.11,0.50)**	155 (87)	24 (13)	**0.43 (0.25,0.74)**	174 (89)	21 (11)	**0.36 (0.20,0.62)**
Missing	86 (88)	11 (11)	-	56 (66)	29 (34)	-	73 (70)	31 (30)	-
Type of impact activity & frequency									
Inactive	49 (80)	12 (20)	1	39 (71)	16 (29)	1	42 (69)	19 (31)	1
Highly active	45 (100)	0	-	40 (95)	2 (5)	**0.16 (0.04,0.69)**	45 (100)	0	-
Medium	328 (92)	28 (8)	**0.41 (0.22,0.75)**	273 (82)	61 (18)	**0.59 (0.36,0.95)**	297 (83)	62 (17)	**0.56 (0.36,0.88)**
Missing	49 (87)	7 (13)	-	32 (65)	17 (35)	-	43 (72)	17 (28)	-
Years exposed Median (IQR)	9.5 (6.3-14.0)	8.8 (6.8,15.3)	0.90 (0.80,1.02)	9.4 (6.3,14.3)	10.0 (6.6-13.4)	*0.92 (0.84,1.01)*	9.5 (6.3, 14.2)	10.7 (6.8 ,16.6)	0.94 (0.86,1.04)
Hours/week Median (IQR)	4.0 (2.0-10.0)	2.0 (1.0-7.0)	0.95 (0.88,1.03)	4.0 (2.0,10.0)	3.0 (1.5-7.0)	0.97 (0.93,1.01)	4.0 (2.0,10.0)	4.0 (2.0 ,10.0)	**0.94 (0.89,0.99)**

[1] Risk estimates shown come from separate regression models after adjustment for: age, sex and duration of follow-up adjusted estimates. RR in italics p<0.1

Table 37. Associations between physically-demanding occupational activities post-THA and poor OHS, SF-12 physical component (PCS) and WOMAC-12 physical function at follow-up

	Poor OHS			**Poor PCS**			**Poor WOMAC-12 p.f.**		
	No n (%)	**Yes n (%)**	**RR[1] (95% CIs)**	**No n (%)**	**Yes n (%)**	**RR[1] (95% CIs)**	**No n (%)**	**Yes n (%)**	**RR[1] (95% CIs)**
Standing > 4h /day									
No	136 (97)	3 (3)	1	119 (91)	12 (9)	1	129 (92)	11 (7)	1
Yes	94 (98)	2 (2)	1.12 (0.17,7.51)	76 (84)	14 (16)	*1.88 (0.91,3.88)*	86 (90)	10 (10)	1.28 (0.56,2.89)
Missing	71 (90)	8 (10)	-	63 (83)	13 (17)	-	66 (82)	14 (17)	-
Walking > 2 miles /day									
No	147 (97)	4 (3)	1	129 (90)	14 (10)	1	142 (93)	11(7)	1
Yes	82 (98)	1 (2)	0.50 (0.05,4.91)	65 (84)	12 (16)	1.79 (0.88,3.67)	72 (88)	10 (12)	1.62 (0.71,3.69)
Missing	63 (90)	7 (10)	-	64 (83)	13 (17)	-	67 (83)	14 (17)	-
Lifting / carrying ≥ 10kg /day									
No	156 (98)	3 (2)	1	138 (91)	13 (9)	1	148 (93)	11 (7)	1
Yes	73 (97)	2 (3)	1.54 (0.25,9.54)	56 (81)	13 (19)	**2.54 (1.29,5.01)**	66 (85)	10 (13)	1.70 (0.78,3.69)
Missing	72 (90)	8 (10)	-	64 (83)	13 (17)	-	67 (83)	14 (17)	-
Lifting / carrying ≥ 25kg /day									
No	200 (99)	3 (1)	1	170 (89)	21 (11)	1	190 (94)	13 (7)	1
Yes	29 (94)	2 (6)	*4.78 (0.73,31.24)*	24 (83)	5 (17)	1.89 (0.76,4.70)	24 (75)	8 (25)	**3.40 (1.51,7.63)**
Missing	64 (90)	7 (10)		64 (83)	13 (17)		67 (83)	14 (17)	-

	Poor OHS			Poor PCS			Poor WOMAC-12 p.f.		
	No n (%)	**Yes n (%)**	**RR[1] (95% CIs)**	**No n (%)**	**Yes n (%)**	**RR[1] (95% CIs)**	**No n (%)**	**Yes n (%)**	**RR[1] (95% CIs)**
Digging /shovelling									
No	209 (98)	5 (2)	-	176 (80)	24 (12)	1	198 (92)	17 (8)	1
Yes	19 (100)	0 (0)	-	17 (89)	2 (11)	1.11 (0.27,4.55)	15 (79)	4 (21)	*2.37 (0.87,6.50)*
Missing	73 (90)	8 (10)	-	65 (83)	13 (17)	-	68 (83)	14 (17)	-
Kneeling / squatting									
No	153 (98)	3 (2)	1	134 (90)	15 (10)	1	149 (95)	8 (5%)	1
Yes	76 (96)	2 (4)	1.61 (0.27,9.48)	60 (85)	11 (15)	1.74 (0.86,3.50)	65 (83)	13 (17%)	*3.27 (1.40,7.62)*
Missing	72 (90)	8 (10)	-	64 (83)	13 (16)	-	67 (83)	14 (17%)	
Climbing >30 flights stairs /day									
No	145 (97)	4 (3)	1	117 (86)	19 (14)	1	135 (92)	11 (9%)	1
Yes	93 (98)	2 (2)	1.27 (0.20,7.93)	77 (92)	7 (8)	0.67 (0.30,1.52)	79 (89)	10 (11%)	1.41 (0.62,3.17)
Missing	63 (90)	7 (10)		64 (83)	13 (17)		67 (83)	14 (17%)	
Climbing ladders (up/down)									
No	177 (97)	5 (3)	-	154 (89)	20 (11)	1	169 (92)	14 (8)	1
Yes	52 (100)	0	-	40 (87)	6 (13)	1.34 (0.57,3.12)	45 (87)	7 (13)	1.61 (0.70,3.67)
Missing	72 (90)	8 (10)	-	64 (83)	13 (17)	-	67 (83)	14 (17)	

[1] Age, sex and duration of follow-up adjusted estimate. RR in italics p<0.1

4.4.1 Poor Oxford Hip Score (OHS) at follow-up

In this section, 518 participants who completed the OHS and free from hip revision, were included in the analyses to examine predictor factors of poor OHS at follow-up. The minimally adjusted models are presented in Table 33 to Table 37.

Baseline characteristics at THA and risk of poor OHS at follow-up

Age, BMI, Charnley score and ASA score measured at the time of the primary arthroplasty were predictors of poor OHS at follow-up (Table 33). For every year the patient was younger at the time of the arthroplasty, the risk of poor OHS increased by 4%. Raised BMI ≥ 25 kg/cm^2 quadrupled the risk of poor OHS as compared with normal weight, and people with more than two osteoarthritic joints and other health conditions that affected their ability to walk at the time of surgery, were at greater risk of current poor OHS than those with only the index joint affected (RR: 2.99 95%CI 1.58, 5.66). Participants with a higher educational level at baseline were at reduced risk of poor OHS at follow-up by 55% (for those who completed secondary education) and by 81% (for those who had completed further education) as compared with those who only completed compulsory education.

Clinical and surgical characteristics in relation to poor OHS at follow-up

In Table 34 we explored the relationship between clinical and surgical clinical factors and current poor OHS, in minimally adjusted analyses. Data were only presented for primary versus secondary osteoarthritis in the interests of space. No clear association was found between the clinical indication for THA and the risk of current poor OHS. However, we did find that aseptic necrosis as the primary indication for THA was associated with poorer current OHS as compared with those people whose indication for index THA was primary OA (RR: 2.19, 95%CI 1.15, 4.16). For this reason, indication for THA was taken forward as a covariate in the next set of models fitted.

Other results pertaining to clinical and surgical factors suggested that the type of fixation, and having had the contralateral hip replaced since the time of the index surgery, were both risk factors for current poor OHS. Participants with a cemented prosthesis were at an almost four-fold higher risk of poor current OHS as compared with people who had received uncemented prostheses (RR: 3.98 95%CI 1.60,9.89). Having the contralateral hip replaced increased the risk of a poor OHS by 94% as compared with those without the contralateral hip replaced. Only 3 participants had a 22mm femur head implanted, hence despite this being significantly associated with the risk of poorer current OHS, this variable was not taken forward in further analysis. No other implant related variable (side or joint bearing surfaces) was found to have an effect on the risk of current poor OHS.

Time to reach optimal function post-operatively, function at best and current function in the contralateral hip and risk of poor OHS at follow-up

In Table 35, we explored the effects of time to reach optimal function and best function achieved post operatively on current risk of poor OHS. All function-related variables considered were found to be associated with the risk of current poor OHS. People who reported reaching their best function one year or more post-operation were four times more likely to have poor OHS at the present time (RR: 3.90 95% CI 2.12,7.16) as compared with those who reached best function within the first year. People who reported that they still experienced pain from their hip (during day or night) when they attained their best outcome from the surgery were considerably more likely to have a current poor OHS (RR: 7.44, 95%CI 4.02, 13.76). Likewise, people who reported that they needed to use a stick to walk when at their best, were found to have a five-fold greater risk of poor OHS at follow-up (RR: 5.52 95%CI 3.03,10.04).

Additionally those who reported current pain or stiffness in the contralateral hip were at greater risk of having current poor OHS (RR: 6.38, 95%CI 3.51,11.59).

In the next analysis, therefore, we explored the effects of these functional variables on current OHS taking into account all the baseline characteristics (BMI, education, ASA score) and clinical and surgical factors (contralateral hip replaced post-THA, indication for THA and fixation) shown to be associated with the current risk of poor OHS Table 38.

After the additional adjustment, we found that the effect of each of these measures of function (taking ≥ 12 months to reach best function; walking with a stick at best function; pain at best function) were attenuated but remained associated with current poor OHS.

Table 38. Association between time to reach best function, optimum function achieved, current function in the contralateral hip, and poor OHS at follow-up after further adjustment

	Poor OHS		RR[1] (95% CIs)
	No n (%)	Yes n (%)	
Time to best function			
< 1 year	376 (95)	21 (5)	1
≥ 1 year	68 (78)	19 (22)	**3.44 (1.59,7.43)**
Missing	27 (79)	7 (21)	-
Stick to walk			
No	432 (94)	30 (6)	1
Yes	20 (62)	12 (38)	**2.68 (1.14,6.33)**
Missing	19 (79)	5 (21)	-
Pain			
No	370 (96)	14 (4)	1
Yes	75 (73)	28 (27)	**4.70 (2.25,9.80)**
Missing	26 (84)	5 (16)	-
Current pain/stiffness other hip			
No	379 (95)	20 (5)	1
Yes	36 (67)	18 (33)	**4.41 (2.06,9.43)**
Missing	56 (86)	9 (14)	-

[1]Adjusted for Age, sex, duration of follow-up, BMI at baseline, level of education, ASA score, contralateral hip replaced post-THA, indication for THA, fixation adjusted estimates

Leisure time and daily physical activities post-THA in relation to risk of poor OHS at follow-up

Table 36 explored the associations between leisure-time physical activities performed post-operation and current poor OHS. None of the participants who engaged in high impact activities following arthroplasty were found to have poor OHS at follow-up. Higher impact activity at greater frequency reduced the risk of current poor OHS. Compared with inactive people, the results suggested a reduced risk of poor OHS by 78% for those who engaged in medium impact weight bearing activities. Participation in medium active leisure activity at any frequency was protective against having a poor current OHS when compared with being inactive (RR: 0.41 95%CI 0.22,0.75) (Table 36).

Therefore, in the next step, LTPA was taken forward as were baseline characteristics, clinical and surgical factors and time to reach best function and measures of function which were associated with poor OHS at follow-up (Table 39). The type of impact activity, frequency and the combination of these two factors were no longer significantly associated with a reduction in the risk of current poor OHS in these adjusted models post-

THA. Consequently, no LTPA variables were taken forward to the analyses of effects of physically-demanding occupational activities on the risk of current poor OHS.

Table 39. Associations between post-operative leisure and daily activities and the risk of poor OHS at follow-up

	Poor OHS		
	No n (%)	**Yes n (%)**	**RR[1] (95% CIs)**
Type of impact activities			
None done	49 (80)	19 (18)	1
Low activity	153 (87)	22 (13)	1.00 (0.41,2.48)
Medium activity	136 (96)	6 (4)	0.48 (0.17,1.38)
High activity	93 (100)	0	-
Not known	40 (85)	7 (15)	-
Frequency			
None	49 (80)	12 (20)	1
Less than once/week	149 (91)	15 (9)	0.84 (0.30,2.32)
Once/week or more	187 (95)	9 (5)	0.64 (0.22,1.87)
Missing	86 (89)	11 (11)	-
Type of impact activities & frequency			
Inactive	49 (80)	12 (20)	1
Highly active	45 (100)	0	-
Medium active	328 (92)	28 (8)	0.76 (0.33,1.78)
Missing	49 (87)	7 (13)	-
Years exposed Median (IQR)	9.5 (6.3-14.1)	11.5 (9.0-13.8)	0.72 (0.46,1.13)
Hours/week Median (IQR)	4.0 (2.0-10.0)	3.0 (1.5-10.0)	0.92 (0.83,1.02)

[1] Adjusted for age, sex, duration of follow-up, BMI at baseline, level of education, ASA score, contralateral hip replaced post-THA, indication for THA, fixation, time to best function, stick at best time, pain (day or night), current pain/stiffness contralateral hip adjusted estimates.

Physically-demanding occupational activities post-THA and the risk of poor OHS at follow-up

Amongst the 518 participants who underwent hip arthroplasty, 314 continued working post operation of whom just 13 scored poorly on the OHS at the time of follow-up. This small number of people with current poor function made it difficult to detect a difference between those who performed any one physically-demanding occupational activity and those who did not. However, compared with those people who did not work post-THA, working post-arthroplasty was found to have a protective effect against the risk of current poor OHS at follow-up (RR: 0.20 95%CI 0.11,0.37).

We present the association between occupational activities carried out post-THA and current poor OHS adjusted for age at follow-up and duration of follow-up in Table 37. This analysis was performed limited to those people who reported an occupation following replacement (n=314). The results showed that the amount of years worked following THA was not associated with poor function at follow-up (data not shown).

None of the participants amongst those who reported either digging/shovelling or climbing ladders up and down had poor OHS at follow-up. The results showed no significant association between the risk of poor OHS at follow-up and the 6 remaining occupational activities (standing more than 4 hours, walking more than 2 miles, lifting/carrying ≥10 or ≥25 kg, kneeling/squatting and climbing more than 30 flights of stairs). Because only 13 people out of the 314 who worked post hip arthroplasty had poor OHS at follow-up, the number of events in the sample analysed was too small to detect differences between the groups compared.

In the final models fitted for occupational activities using different set of adjustments, shown in Table 40, we assessed the relationship between exposure to physically-demanding occupational activities post-operatively and current poor OHS using two different sets of covariates (Model 1 and Model 2) that were identified in the previous steps. As explained above, the small number of people who worked post-THA and with poor OHS at follow-up limited our ability to calculate the risk ratios for some of the models fitted. No significant association was observed between the occupational activities examined and the risk of current poor function, in Model 1 nor Model 2. However, the estimated RR for lifting/carrying≥ 25 kg compared with people who did not report these activities was 2.77 in Model 1 (95%CI 0.82,9.35) and 2.00 in Model 2 (95%CI 0.22,17.87).

We compared workers who lifted or carried ≥25 kg and knelt/squatted with those who reported a sedentary job (no physically-demanding activity performed) and there was no significantly increased risk of having a high current OHS.

Table 40. Associations between physically-demanding occupational activities performed post-THA and the risk of poor OHS at follow-up

	MODEL 1	**MODEL 2**
Occupational activities (No vs Yes)	**RR (95% CIs)**	**RR (95% CIs)**
Standing > 4 hours / day	0.94 (0.05,18.66)	1.80 (0.06,57.89)
Walking > 2 miles / day	**0.30 (0.10,0.91)**	-*
Lifting/carrying ≥ 10kg	1.06 (0.32,3.54)	1.36 (0.20,9.18)
Lifting/carrying ≥ 25kg	*2.77 (0.82,9.35)*	*2.00 (0.22,17.87)*
Kneeling/squatting	*2.47 (0.26,23.23)*	*1.95 (0.01,274.44)*
Climbing >30 flights of stairs / day	2.71 (0.26,28.01)	1.70 (0.03,109.05)
Sedentary occupation vs 2 occupational activities combined		
Kneeling/squatting & lifting/carrying ≥ 25 kg /day	0.25 (0.02,2.79)	-*

Risk estimates shown come from separate regression models after adjustment for:

Model 1. Age, sex, duration of follow-up, BMI at baseline, education, ASA score at baseline, contralateral operated post-THA, diagnosis for THA, fixation method

Model 2. Age, sex, duration of follow-up, BMI at baseline, education, ASA score at baseline, contralateral operated post-THA, diagnosis for THA, fixation method, time to best function, using a stick at best function achieved, pain day/night, current pain/stiffness in contralateral hip adjusted estimates

*The small number of people who worked post-arthroplasty and with poor OHS at follow-up did not allow fitting of some of the models. HR in italics p<0.1

4.4.2 Poor SF-12 physical component summary (PCS) at follow-up

A total of 480 people who had not undergone hip revision surgery at follow-up completed the SF-12 physical function component (PCS). The mean PCS at 12.4 years follow-up was 43.9 (SD ± 10.9), with no differences between men and women (p=0.43).

In this section we explored predictors of being in the lowest quintile for PCS at follow-up (worst function). For the minimally adjusted models described below the risk ratios estimated were adjusted for sex, age and duration of follow-up as covariates (Table 33 to Table 37).

Baseline characteristics at THA and risk of poor PCS at follow-up

Results from Table 33 showed that patients' characteristics at the time of the surgery were associated with the risk of current poor PCS at follow-up. Women were 53% more likely to experience current poor PCS than men, and smokers at baseline had a 63% increased risk of poor PCS at follow-up when compared with non-smokers. People who reported having a higher level of education were 49% less likely to have current poor PCS than those who reported that they completed no more than compulsory education. We also found more than double the risk of current poor PCS in obese participants (BMI ≥30kg/m^2) when compared with those in a healthy weight range (RR: 2.18 95%CI 1.38,3.45), in people with multiple arthritic joints and other condition that affects their ability to walk as compared with people without (RR: 2.52 95%CI 1.67,3.79), and in those with lower ASA scores (less anaesthetic risk).

Clinical and surgical characteristics in relation to poor PCS at follow-up

We examined the relationship between clinical and surgical factors and the risk of poor PCS at follow-up in Table 34**.** The results showed that neither the indication for THA, the side where the arthroplasty was performed, nor the type of bearing surfacing were associated with having current poor PCS, whereas the type of fixation and head size were predictors of current poor PCS. Cemented fixation tripled the risk of poor PCS at follow-up when compared with uncemented fixation (RR: 3.29 95%CI 1.56,6.92), whilst a 32mm head size of the femur reduced the risk of current poor PCS by 70% compared with those who had a 28mm head size implanted.

Time to reach optimal function, function at best post-operatively and current function in the contralateral hip and risk of poor PCS at follow-up

Function related characteristics of the study, participants at their best time post-operation and the period of time to reach their best were significantly associated with poor PCS at 12 years follow-up (Table 35). Participants who achieved their best improvement ≥12 months following hip arthroplasty were 56% more likely to have poor current PCS than those who took < 12 months to reach their best.

We also found that both the need to use a stick to walk and reporting pain at their best were associated with current poor PCS. The risk of poor PCS at follow-up was more than doubled for those who used a stick at their best (RR: 2.60 95%CI 1.69,3.99) and for those who reported pain at their best (RR: 2.65 95%CI 1.84,3.81).

In a next step, we determined whether the associations observed in Table 35 remained after controlling for further adjustments identified in the minimally adjusted models (age, sex, and duration of the follow-up). For this next analysis, illustrated in Table 41, RRs were adjusted for baseline characteristics and clinical and surgical factors. Another factor associated with poor PCS was current stiffness or pain in the contralateral hip at follow-up (HR: 3.30 95%CI 2.11,5.16).

Table 41. Association between time to reach best function, and optimal function post-THA, current function in contralateral hip and poor PCS at follow-up adjusted for baseline characteristics, clinical and surgical factors

	Poor PCS		
	No n (%)	**Yes n (%)**	**RR[1] (95% CI)**
Time to best function			
< 1 year	306 (83)	63 (17)	1
≥ 1 year	61 (73)	22 (27)	**1.74 (1.02,2.97)**
Missing	17 (61)	11 (39)	-
Stick to walk			
No	356 (82)	78 (18)	1
Yes	16 (53)	14 (47)	1.71 (0.92,3.16)
Missing	12 (75)	4 (25)	-
Pain			
Yes	308 (86)	52 (14)	1
No	59 (63)	35 (37)	**2.23 (1.38,3.63)**
Missing	17 (65)	9 (35)	-
Current pain stiffness/contralateral hip			
No	316 (85)	57 (15)	1
Yes	25 (48)	27 (52)	**3.30 (2.11,5.16)**
Missing	43 (78)	12 (22)	-

[1] Age, sex, duration of follow-up, education, smoking, BMI at baseline, ASA score, contralateral hip replaced, fixation method, size of femur head adjusted estimates

All the variables that related to time to best function and function at their best post-THA were associated with the risk of poor PCS at follow-up, although needing to use a stick to walk at time of optimal function became non-significant. Current pain or stiffness in the contralateral hip remained associated with the risk of current poor PCS at a significance level of 10%. Therefore all these variables were taken forward to the final models exploring the effect of post-operative exposure to physically-demanding occupational activities and risk of poor PCS at follow-up.

Leisure time physical activity and daily activities post-THA and risk of poor PCS at follow-up

In Table 36 leisure time and daily physical activities performed after THA were evaluated as potential predictor factors for the risk of current poor PCS. In these minimally adjusted models, the results showed that the risk of poor PCS at follow-up was reduced by 74% in people who engaged in high impact activities and by 50% in those undertaking medium impact activities as compared with those who were inactive. Similarly a higher frequency of activity also reduced the risk of a current poor PCS.

An analysis looking at a combination of the type of impact activities and their frequency suggested that there was a protective effect against current poor PCS amongst those who engaged in medium or low impact activities with a frequency between 3 and 50 times per year, as compared with inactive people (RR: 0.59 95%CI 0.36,0.95). Despite the small number of participants who were considered to be highly active post-arthroplasty, a reduced risk of poor PCS was observed (RR: 0.16 95%CI 0.04, 0.69). However, neither the number of years (duration) nor total estimated number of hours per week engaging in LTPA and daily activities were significantly associated with the risk of poor PCS at follow-up.

In the next set of analyses we evaluated whether these markers of LTPA were covariates to take forward to the final regression models. Thus we examined associations between LTPA variables (type of impact activity, frequency, load impact & frequency and years exposed post-THA) and current poor PCS, controlling for the following covariates: baseline characteristics, clinical and surgical factors and time to reach best function and function measured at best (Table 42).

Table 42. Association between leisure time and daily activities and the risk of current poor PCS adjusted for baseline, clinical, surgical and functional characteristics

	Poor PCS		
	No n (%)	**Yes n (%)**	**RR[1] (95% CIs)**
Type of impact activities			
None done	39 (71)	16 (29)	1
Low activity	122 (76)	38 (24)	0.65 (0.32,1.32)
Medium activity	114 (85)	20 (15)	0.65 (0.31,1.39)
High activity	84 (92)	7 (8)	0.44 (0.16,1.27)
Not known	25 (62)	15 (37)	-
Frequency			
No activity	39 (71)	16 (29)	1
<weekly	134 (83)	27 (17)	0.58 (0.27,1.26)
≥ weekly	155 (87)	24 (13)	**0.40 (0.17,0.90)**
Missing	56(66)	29 (34)	-
Type of impact activities & frequency			
Inactive	39 (71)	16 (29)	1
Highly active	40 (95)	2 (5)	*0.20 (0.03,1.37)*
Medium active	273 (82)	61 (18)	0.62 (0.32,1.22)
Missing	32 (65)	17 (35)	-
Years exposed Median (IQR)	9.4 (6.3-14.3)	10.0 (6.6,13.4)	1.04 (0.95,1.14)
Hours/week Median (IQR)	4.0 (2.0,10.0)	3.0 (1.5,7.0)	0.97 (0.90,1.03)

[1] Age, sex, duration of follow-up, education, smoking, BMI, ASA score, contralateral hip replaced, fixation method, size of femur head, time to best function, use of a stick, pain and current pain/stiffness in the other hip adjusted estimates. HR in italics p<0.1

The associations between LTPA and current poor PCS described in the minimally adjusted models (Table 36) no longer attained statistical significance after further adjustments, apart from the frequency with which the activity was performed. People who reported engaging in LTPA or daily activities ≥ than once a week reduced their risk of poor PCS by 60% compared with those people who were inactive (RR: 0.40 95%CI 0.17,0.90). Thus frequency of LTPA was taken forward.

Physically-demanding occupational activities post-THA and the risk of current poor PCS

Following THA, 297 out of the 480 people who completed the follow-up PCS had held a paid job for at least one month. The mean time worked post-THA was 3.8 years (IQR: 0.9-8.5) for those who had current poor PCS, and 5.6 years (IQR: 1.8-8.4) for those without poor PCS. A comparison between those who worked and those who did not work post-

THA suggested that returning to work had a protective effect against poor PCS at 12 years post-operation (RR: 0.42 95%CI 0.28,0.62).

For all the analyses involving occupational activities, only those people who worked after arthroplasty were included (n=297), amongst whom 39 were found to report poor PCS at follow-up.

First we assessed the association between physically-demanding occupational activities post-operation and the risk of poor PCS at follow-up (Table 37). We found that lifting/carrying ≥10 kg was associated with current poor PCS (RR: 2.54 95%CI 1.29,5.01) as compared with workers who did not lift or carry weights at work. None of the remaining occupational activities showed any statistically significant relationships with the risk of poor PCS at follow-up.

In the final models we examined the relationship between physically-demanding occupational activities post-THA and current poor PCS, adjusting for different sets of covariates as identified in previous analyses. The results, presented in Table 43, showed no significant association between the occupational activities post-THA, with poor current PCS, in any of the models fitted (Models 1 to 4). Despite the level of uncertainty, the point estimates for those who kneeled or squatted against those who did not kneel or squat showed a doubling of the risk of having current poor OHS across Models 1 to 4, with estimated HRs ranging between 1.90 and 2.40. Likewise, the estimated risk for climbing ladders up or down was doubled in Models 2 and 4. A further three occupational activities (standing, digging/shovelling and climbing >30 flights of stairs/day) did not show a consistent pattern across the four models fitted, possibly due to the small number of individuals with poor PCS who undertook each of these occupational activities.

We compared each occupational activity against not carrying out that same activity to assess associations between the activity and risk of hip revision. However, a job may involve more than one physically-demanding activity, and since no occupational activity alone was significantly associated with poor PCS, we considered whether exposure to two physically-demanding activities with an estimate effect over 2 (a combination of carrying/lifting ≥10 kg, kneeling/squatting or climbing ladders) increased the risk of a current poor PCS when compared with people who did not perform any physically-demanding occupational activity (sedentary occupation). The results of this analysis, also shown in Table 43 yielded estimated RRs with more than double the risk of poor PCS for those who knelt/squatted & lifted/carried ≥ 10 kg in Model 2 (RR: 2.27 95%CI 0.71,7.20), Model 3 (RR: 2.18 95%CI 0.80,5.96) and Model 4 (RR: 2.90 95%CI 0.81,10.46).

Table 43. Associations between physically-demanding occupational activities performed post-THA and poor PCS at follow-up

	MODEL 1	MODEL 2	MODEL 3	MODEL 4
Occupational activities (NO vs YES)	**RR (95% CIs)**	**RR (95% CIs)**	**RR (95% CIs)**	**RR (95% CIs)**
Standing >4h / day	1.27 (0.45,3.55)	1.06 (0.37,3.08)	1.31 (0.46,3.69)	0.94 (0.30,2.94)
Walking>2 miles/ day	1.81 (0.68,4.82)	1.71 (0.63,4.64)	1.78 (0.66,4.80)	1.44 (0.50,4.17)
Lifting/carrying ≥10 kg	1.63 (0.64,4.16)	1.96 (0.69,5.58)	1.68 (0.68,4.16)	2.26 (0.74,6.91)
Lifting/carrying ≥25 kg	2.09 (0.60,7.22)	1.77 (0.33,9.40)	1.92 (0.53,6.96)	1.69 (0.31,9.17)
Digging/shovelling	0.56 (0.07,4.65)	0.86 (0.09,8.15)	0.63 (0.08,5.22)	1.11 (0.12,10.39)
Kneeling/squatting	2.15 (0.87,5.35)	1.90 (0.67,5.44)	2.40 (0.98,5.87)	2.21 (0.78,6.24)
Climbing >30 flight stairs/ day	1.01 (0.40,2.53)	0.91 (0.34,2.44)	1.23 (0.51,2.95)	1.12 (0.43,2.88)
Climbing ladders (up/down)	1.66 (0.63,4.40)	2.21 (0.74,6.57)	1.93 (0.72,5.13)	2.50 (0.80,7.77)
Sedentary jobs vs a combination of two occupational activities				
Kneeling/squatting & Lifting-carrying ≥10 kg	1.67 (0.63,4.43)	2.27 (0.71,7.20)	2.18 (0.80,5.96)	2.90 (0.81,10.46)
Climbing ladders & kneeling/squatting	1.04 (0.35,3.05)	1.71 (0.45,6.50)	1.47 (0.42,5.19)	2.32 (0.58,9.34)
Climbing ladders & Lifting/carrying ≥ 10 kg	0.99 (0.34,2.85)	1.21 (0.29,5.11)	1.30 (0.44,3.81)	1.73 (0.36,8.43)

Risk estimates shown come from separate regression models after adjustment for:
Model 1. Adjusted for: Sex, age, duration of follow-up, education, smoking, BMI, ASA score, contralateral hip replaced, fixation method, size of femur head
Model 2. Adjusted for: Sex, age, duration of follow-up, education, smoking, BMI, ASA score, contralateral hip replaced, fixation method, size of femur head time to reach best function, use of a stick, pain, stiffness/pain contralateral hip
Model 3. Adjusted for: Sex, age, duration of follow-up, education, smoking, BMI, ASA score, contralateral hip replaced, fixation method, size of femur head, activities frequency
Model 4. Adjusted for: Sex, age, duration of follow-up, education, smoking, BMI, ASA score, contralateral hip replaced, fixation method, size of femur head, time to reach best function, use of a stick, pain, stiffness/pain contralateral hip, activities frequency

4.4.3 Poor WOMAC-12 physical function component score at follow-up

In this section we examine the factors which predicted a poor WOMAC-12 physical function (p.f.) component score at follow-up. To do this we analysed the sample of 525 people who had not undergone hip revision surgery at the time of follow-up, and who had completed the WOMAC-12 p.f. questions.

In the minimally adjusted models shown in Table 33 to Table 37 the covariates that had an effect on current poor WOMAC-12 p.f. were identified and taken forward to the final models which explored the relationship of physically-demanding occupational activities and risk of poor WOMAC-12 p.f.

<u>Baseline characteristics at THA and risk of poor WOMAC-12 p.f. at follow-up</u>

We evaluated the association between baseline characteristics and a poor WOMAC-12 p.f. score at follow-up (Table 33). Neither sex nor smoking were associated with poor WOMAC-12 p.f. at follow-up. People with a BMI at baseline over 25kg/m^2 were at higher risk of poor WOMAC-12 p.f. at follow-up compared with those of normal body weight: RR 1.64 95%CI 0.98,2.76 for overweight, and RR 2.85 95%CI 1.73,4.67 for obese participants. The more joints affected by OA at baseline and presence of other health conditions that affected their ability to walk (as measured by Charnley score) the higher the risk of poor WOMAC-12 p.f. at follow up; RR: 1.65 95%CI 1.05,2.58 when another joint was affected, and RR:2.41 95%CI 1.56,3.73 if more than two joints were affected. Likewise, those with higher ASA scores at baseline were at double the risk of poor current WOMAC-12 p.f. (RR: 2.27 95%CI 1.36-3.77).

Conversely, having attained a higher level of education (after 18 years of age) was associated with a lower risk of poor WOMAC-12 p.f. at follow-up as compared with those who reported having only compulsory education (RR: 0.33 95%CI 0.19,0.57).

<u>Clinical and surgical characteristics in relation to WOMAC-12 p.f. at follow-up</u>

In Table 34 we explored the effect of clinical and surgical factors on current poor WOMAC-12 p.f. After adjusting for sex, age and duration of follow-up, neither the head size of the femur, the type of bearing surface, nor the indication for THA (primary versus secondary OA) were significantly associated with the risk of current poor WOMAC-12 p.f. However, when we examined the association amongst those whose indication for the primary THA had been secondary osteoarthritis, the risk of current poor WOMAC-12 p.f. amongst participants with aseptic necrosis was elevated relative to those with primary OA (RR: 1.65 95%CI 1.07,2.56). Thus, indication for THA was taken forward in further analyses. The type of fixation was also found to be a risk factor for current poor WOMAC-12 p.f. such that cemented arthroplasty procedures were twice as likely to report current poor WOMAC-12 p.f. (RR: 2.52 95%CI 1.14,5.60) when compared with the scores amongst those with uncemented THA.

<u>Time to reach optimal function post-operatively, function at best and current function in the contralateral hip and risk of poor WOMAC p.f. at follow-up</u>

In Table 35 we showed that there was a clear relationship between function related variables at the best time reached post-THA, and the risk of current poor WOMAC-12 p.f. For those who took more than one year to achieve their best improvement following arthroplasty, the risk of poor WOMAC-12 p.f. at follow-up was 3 times higher than for those who achieved their best in less than a year post-arthroplasty (RR:3.08 95%CI 2.13,4.47). A threefold increased risk of poor WOMAC-12 p.f. was seen amongst those who reported using a stick to walk at the time they reached their best function (RR: 3.32 95%CI 2.28,4.85), and almost fivefold increased risk for those who experienced pain at the time when they reached their best function post operation (RR: 4.93 95%CI 3.48,6.99).

Additionally, those who had pain or stiffness at the time of follow-up in the contralateral hip were four-times more likely to have current poor WOMAC-12 p.f. (RR: 4.17 95%CI 2.91,5.95).

In the next step, we assessed whether the associations observed between time to best function and function related variables post-operatively and poor WOMAC-12 p.f. remained after adjusting for further factors identified Table 33 and Table 34 (minimally adjusted models).

Table 44. Association between time to reach best function, and optimal function post-THA, current function in contralateral hip and poor WOMAC-12 p.f. at follow-up adjusted for baseline, clinical and surgical factors.

	Poor WOMAC-12 pf		**RR[1] (95% CIs)**
	No n (%)	**Yes n (%)**	
Time to best function			
< 1 year	346 (87)	53 (13)	1
≥1 year	55 (62)	34 (38)	**2.78 (1.82,4.25)**
Missing	26 (70)	11 (30)	
Stick to walk			
No	392 (83)	78 (17)	1
Yes	14 (45)	17 (55)	**2.07 (1.27,3.36)**
Missing	21 (88)	3 (12)	
Pain			
No	348 (89)	41 (11)	1
Yes	53 (51)	50 (49)	**3.44 (2.31,5.11)**
Missing	26 (79)	7 (21)	
Current pain/stiffness other hip			
No	351 (87)	52 (13)	1
Yes	26 (47)	29 (53)	**2.58 (1.65,4.03)**
Missing	50 (75)	17 (25)	

[1]Sex, age, duration of follow-up, BMI at baseline, level of education, ASA score, Charnley score, indication for THA, contralateral hip replaced, fixation method adjusted estimates

The results, presented in Table 44, showed that after further adjustments, the four variables examined remained associated with the risk of poor WOMAC-12 p.f. at follow-up. Thus these variables were used as covariates in the final regression models for occupational activities.

<u>Leisure time and daily physical activities post-THA in relation to risk of poor WOMAC-12 p.f. at follow-up</u>

Table 36 summarised the associations between LTPA and household activities performed post-THA and the risk of current poor WOMAC-12 p.f. adjusted for sex, age and duration of follow-up. Compared with people who were inactive, those who engaged in high impact activities post-THA reduced their risk of poor WOMAC-12 p.f. at follow-up by 79% (RR:0.21 95%CI 0.09,0.51), and those who performed activities once a week or more were also less likely to have current poor WOMAC-12 p.f. (RR: 0.36 95%CI:0.20,0.62).

In the next step, we examined whether LTPA were covariates to take forward to the final models. We looked at associations between LTPA variables and poor WOMAC-12 p.f.

controlling for baseline characteristics, clinical and surgical factors and time to reach best function and functional factors at their best (Table 45).

Table 45. Associations between leisure time and daily activities and poor WOMAC-12 p.f. adjusted for baseline, clinical and surgical factors, time to reach best function and function at best post operatively and function in contralateral hip

	Poor WOMAC -12 p.f.		
	No n (%)	**Yes n (%)**	**RR[1] (95% CIs)**
Type of impact activities			
None	42 (69)	19 (31)	1
Low	133 (76)	42 (24)	0.91 (0.51,1.63)
Medium	129 (89)	16 (11)	0.75 (0.39,1.42)
High activity	87 (94)	6 (6)	0.65 (0.26,1.62)
Not known	36 (71)	15 (29)	-
Frequency			
No activity	42 (69)	19 (31)	1
<weekly	138 (84)	27 (16)	0.89 (0.50,1.57)
≥ weekly	174 (89)	21 (11)	0.56 (0.29,1.08)
Missing	73 (70)	31 (30)	-
Type of impact activities & frequency			
Inactive	42 (69)	19 (31)	1
Highly active	45 (100)	0 (0)	-
Medium	297 (83)	62 (17)	0.85 (0.50,1.45)
Missing	43 (72)	17 (28)	-
Years exposed Mean, IQR	9.5 (6.3, 14.2)	10.7 (6.8 ,16.6)	1.00 (0.88,1.13)
Hours/week Mean, IQR	4.0 (2.0,10.0)	4.0 (2.0 ,10.0)	**0.94 (0.88,0.99)**

[1]Sex, age, duration of follow-up, BMI at baseline, education, ASA score, Charnley score, indication for THA, contralateral hip replaced, time to best function, use a stick at their best, pain day/night, current pain/stiffness in contralateral hip adjusted estimates

The results showed that the associations observed in the minimally adjusted models, between the type of impact activities performed, their frequency and the combination of both factors was no longer significant after including these further adjustments. Therefore, none of the variables assessed in relation to LTPA were taken forward.

Physically-demanding occupational activities post-THA and the risk of poor WOMAC-12 p.f. at follow-up

People who held a job post-arthroplasty were less likely to have a poor WOMAC-12 p.f. at follow-up than those who did not work post-operation (RR: 0.36 95%CI 0.24, 0.53). Participants in this sample worked a mean of 5.5 years (IQR: 1.7, 8.6) post-THA.

To assess the effect of occupational activities performed post-THA on current poor WOMAC-12 p.f. we included those 316 participants who reported having at least one job post-arthroplasty for a minimum of a month. The minimally adjusted models looking at the relationship between exposure to physically-demanding occupational activities post-THA and current poor WOMAC-12 p.f. are shown in Table 37. We found a three-fold increased risk of poor WOMAC-12 p.f. at follow-up among workers who reported lifting/carrying ≥25kg (RR: 3.40 95%CI 1.51,7.63), and kneeling/squatting (RR: 3.27 95%CI 1.40,7.62) post-operatively, as compared with those who did not carry out these activities. No significant association was observed among the remaining occupational activities. However the estimated HR for poor WOMAC-12 p.f. at follow-up in workers who dug/shovelled was 2.37 when compared with those who did not report this activity, but with a risk difference ranging between a 13% decrease and a six-fold increase; 95%CI 0.87,6.50.

In the final models, shown in Table 46, we assessed the relationship between occupational activities performed post THA and current poor WOMAC-12 p.f. adjusted for the covariates identified in previous steps. In Model 1, the results showed that after adjusting for baseline, clinical and surgical factors, lifting/carrying weights and kneeling/squatting were significantly associated with the risk of poor WOMAC-12 p.f. at follow-up. Those workers who lifted/carried ≥ 25 kg were at 5-fold increased risk of current poor WOMAC-12 p.f. (RR: 5.20 95%CI 2.02,13.42), and those who knelt/squatted were over twice as likely to have current poor WOMAC-12 p.f. (RR: 2.62 95%CI 1.05,6.54). None of the remaining occupational activities were found to be associated with the risk of poor WOMAC-12 p.f. After further adjustments used in Model 2 (baseline characteristics, clinical and surgical factors, and time to best function and function-related factors) the association observed for lifting/carrying ≥25 kg remained, although attenuated (RR:3.14 95%CI 1.00,9.83), whereas kneeling/squatting was no longer significantly associated with the risk of current poor WOMAC-12 p.f.

We finally examined people who carried out any two of the activities that were significant in Model 1 or Model 2 (kneeling/squatting and lifting/carrying ≥25 kg), or activities for which the estimated effect was higher than two (digging/shovelling) and compared them with those who did not perform any demanding occupational activities (sedentary occupation) (see Table 46). Overall, digging/shovelling combined with lifting/carrying ≥25 kg increased the risk of poor WOMAC-12 p.f. at follow-up in both Model 1 and Model 2, although with wide confidence intervals.

Table 46. Association between physically-demanding occupational activities performed post-THA and risk of current poor WOMAC-12 p.f.

	MODEL 1	MODEL 2
Occupational activities (NO vs YES)	**RR (95% CI)**	**RR (95% CI)**
Standing > 4h /day	1.62 (0.65,4.09)	1.24 (0.44,3.50)
Walking > 2 miles /day	1.81 (0.79,4.11)	1.60 (0.70,3.67)
Lifting/ carrying ≥ 10kg /day	1.79 (0.75,4.27)	1.70 (0.73,3.97)
Lifting / carrying ≥ 25kg /day	**5.20 (2.02,13.42)**	**3.14 (1.00,9.83)**
Digging/shovelling /day	2.83 (0.81,9.85)	3.60 (0.94,13.80)
Kneeling/squatting /day	**2.62 (1.05,6.54)**	2.00 (0.85,4.70)
Climbing >30 flights stairs/ day	1.27 (0.53,3.04)	1.68 (0.69,4.09)
Climbing ladders (up/down) / day	1.34 (0.51,3.50)	1.76 (0.65,4.78)
Sedentary jobs vs a combination of two occupational activities		
Digging/shovelling & lifting ≥ 25kg	**5.56 (1.52,20.42)**	**7.74 (1.70,35.18)**
Kneeling/squatting & digging/shovelling	2.02 (0.60,6.81)	2.87 (0.72,11.37)
Kneeling/squatting & carrying/lifting ≥ 25kg	2.48 (0.85,7.25)	2.36 (0.78,7.17)

Risk estimates shown come from separate regression models after adjustment for:

Model 1. Adjusted for: Sex, age, duration of follow-up, BMI at baseline, level of education, ASA score, Charnley score, indication for THA, contralateral replacement, fixation method

Model 2. Adjusted for: Sex, age, duration of follow-up, BMI at baseline, level of education, ASA score, Charnley score, indication for THA, contralateral replacement, fixation method, time to best function, use of a use at their best, pain at their best, pain/stiffness contralateral hip

4.5 Returning to work post-arthroplasty and reporting having to give up work because of difficulties with the index hip

In this sub-section we examined whether exposure to physically-demanding occupational activities was associated with the risk of leaving a job post-arthroplasty because of the hip that had been replaced. The duration of follow-up was censored when the participants reported that they had stopped working for whatever reason after arthroplasty, or up to follow-up in the case where the participants were still working at that time. In this latter case, time at risk (person-years) was calculated from the date they started working post-arthroplasty to the date the follow-up questionnaire was completed.

For this analysis we could include participants who worked post-arthroplasty (n=298) and provided beginning and ending dates for each of their jobs, or reported that they were still working at the time survey completion. A total of 27 people, 15 men and 12 women, stopped their job post-operatively partly because of the replaced hip.

Age at the time of the operation, sex and current age were used as the minimum set of covariates in the models presented in Table 33 to Table 37.

Baseline characteristics and the risk of stopping paid work because of the replaced hip

Table 47 summarises the association between baseline characteristics and the risk of leaving a job post-THA because of the hip. We found no association between either age, sex, BMI at baseline, or Charnley score and the risk of leaving a job because of the replaced hip.

Compared with workers with a compulsory level of education, those with secondary and further education were 79% and 68% less likely to stop working after having gone back post-arthroplasty. However, the results showed an increased risk of stopping work post-operation due to the hip for those with poorer physical status at the time of the arthroplasty (as measured by the ASA score) as compared with those classed as healthy (HR: 4.80, 95%CI 1.23,18.6).

Table 47. Association between baseline characteristics and the risk of having to stop work post-arthroplasty because of the replaced hip

	Stopping work		Mean time to (years)		
	No n (%)	**Yes n (%)**	**follow-up**	**Stopping work**	**HR[1] (95% CIs)**
Sex					
Males	165 (92)	15 (9)	6.2	4.7	1
Females	106 (90)	12 (10)	5.8	1.2	1.15 (0.54,2.46)
Age at surgery Median (IQR)	56 (49,60)	56 (43,60)	-	-	1.00 (0.91,1.10)
Body mass index					
Normal	99 (87)	15 (13)	6.0	2.5	1
Underweight	8 (100)	0	6.9	-	-
Overweight	115 (92)	9 (8)	6.2	2.3	0.65 (0.27,1.56)
Obese	49 (94)	3 (6)	5.2	3.3	0.73 (0.23,2.32)
Education					
Compulsory	54 (82)	12 (18)	5.1	4.4	1
Secondary	59 (95)	3 (5)	6.6	1.2	**0.21 (0.06,0.75)**
Further	109 (93)	8 (7)	6.0	2.0	**0.32 (0.13,0.79)**
Missing	49 (92)	4 (8)	7.3	3.1	-

	Stopping work		Mean time to (years)		
	No n (%)	**Yes n (%)**	**follow-up**	**Stopping work**	**HR[1] (95% CIs)**
Smoking					
Never	131 (91)	13 (10)	5.4	1.3	1
Former	43 (90)	4 (10)	5.8	5.3	0.88 (0.28,2.70)
Current	80 (89)	10 (11)	7.0	2.7	1.01 (0.43,2.36)
Missing	17 (100)	0	10.6	-	-
Charnley					
Class A	137 (88)	18 (12)	6.1	2.5	1
Class B	83 (93)	6 (7)	6.0	3.2	0.52 (0.21,1.31)
Class C	45 (94)	3 (6)	5.8	1.8	0.53 (0.15,1.80)
Missing	6 (100)	0	6.8	-	-
ASA score					
Healthy	94 (90)	10 (10)	7.3	1.8	1
Mild systemic disorder	168 (91)	14 (9)	5.3	2.9	1.14 (0.50,2.59)
Severe systemic disorder	9 (75)	3 (25)	3.8	1.8	**4.80 (1.23,18.6)**

[1]Age at operation, age at follow-up and sex adjusted models

<u>Clinical and surgical factors and the risk of having to stop work because of the replaced hip</u>

Considering the clinical or surgical factors (Table 48), the minimally adjusted models showed that the indication for having THA was strongly associated with the risk of having to stop work post-operation. People who underwent THA due to secondary OA were at three times increased risk of leaving work post-arthroplasty because of the hip as compared with those who underwent THA because of primary OA (HR: 3.00 95%CI 1.26,7.15). When we assessed the separate indications for THA (grouped together in the Table 48 as secondary OA) against primary OA, aseptic necrosis (HR: 3.62 95% CI 1.24,10.63) and fracture (HR: 2.90 95% CI 1.03,8.21) were both positively associated with having to leave work due to the replaced hip.

Table 48. Association between clinical and surgical factors and the risk of having to stop working post-THA because of the replaced hip

	Stopping work		Mean time to (years)		
	No n (%)	**Yes n (%)**	**follow-up**	**Stopping work**	**HR[1] (95%CIs)**
Indication for THA					
Primary OA	178 (95%)	10 (5%)	5.8	2.3	1
Secondary OA	93 (85%)	17 (15%)	6.5	2.5	**3.00 (1.26,7.15)**
Fixation					
Uncemented	141 (91%)	13 (9%)	5.8	2.1	1
Cemented	7 (87%)	1 (12%)	10.6	0.2	0.94 (0.12,7.63)
Hybrid	123 (91%)	13 (9%)	6.2	2.5	1.10 (0.44,2.71)
Contralateral hip replaced[2]					
No	172 (92%)	14 (8%)	5.8	1.3	1
Yes	99 (%88)	13 (12%)	7.2	5.1	1.31 (0.61,2.82)
Side					
Right	142 (90%)	15 (10%)	5.8	2.4	1
Left	129 (91%)	12 (9%)	6.2	2.8	0.90 (0.42,1.93)
Bearing surface					
Other	154 (91)	15 (8)	5.5	2.5	1
MoM	117 (91)	12 (9)	7.3	1.3	1.12 (0.52,2.40)
Head size (mm)					
22	1 (100)	0	10.6	-	-
28	187 (87)	24 (11)	6.6	2.9	1
32	41 (95)	2 (5)	5.6	1.4	0.29 (0.06,1.39)
36	28 (100)	0	5.3	-	-
>36	14 (93)	1 (7)	8.8	1.3	0.34 (0.04,2.66)

[1]Age at operation, age at follow-up and sex adjusted models [2] Contralateral hip replaced after index THA

Neither the fixation method used, the type of bearing surface nor the diameter of the femur head were predictors of leaving work following arthroplasty.

<u>Time to reach best function and best function reached post-operatively in relation to the risk of having to stop work because of the replaced hip</u>

In Table 49 we examined the relationship between the time to achieving the best possible function post-THA, and function related factors at their best, with the risk of stopping work post-operatively because of the hip. The results showed that the need to use a stick to walk when at their best and feeling pain at their best (night or day) were both significantly associated with the risk of stopping work because of the replaced hip.

We also found that those workers who took a year or more to reach their best function following arthroplasty were at increased risk of having to stop working because of their replaced hip compared with those who recovered their function within the first year (HR: 4.42 95%CI 1.97,9.92).

Table 49. Association between time to reach optimal function and best function reached post-THA and the risk of having to stop working because of the replaced hip

	Stopping work		Mean time to (years)		
	No n (%)	**Yes n (%)**	**Follow-up**	**Stopping work**	**HR[1] (95%CIs)**
Time to best function					
< 1 year	219 (94)	13 (6)	6.0	3.7	1
≥ 1 year	37 (76)	12 (25)	6.1	1.2	**4.42 (1.97,9.92)**
Missing	15 (88)	2 (12)	6.6	4.2	
Stick to walk					
No	255 (93)	20 (7)	6.1	1.8	1
Yes	6 (50)	6 (50)	2.3	4.7	**12.24 (4.53,33.06)**
Missing	10 (91)	1 (9)	5.8	2.3	
Pain					
No	223 (94)	14 (6)	6.0	1.3	1
Yes	34 (74)	12 (26)	6.1	4.0	**4.72 (2.13,10.47)**
Missing	13 (93)	1 (7)	6.6	2.3	-

[1]Age at operation, age at follow-up and sex adjusted models

In subsequent analyses, shown in Table 50, we examined whether the function related variables presented in Table 49 remained associated with the risk of stopping working when controlling for the baseline characteristics and clinical and surgical variables identified in the previous steps.

Table 50. Association between time to best function and optimal function post-THA and risk of stopping work because of the replaced hip adjusted for baseline characteristics and clinical and surgical factors

	Stopping work		Mean time to (years)		
	No n (%)	**Yes n (%)**	**Follow-up**	**Stopping work**	**HR[1] (95% CIs)**
Time to best function					
< 1 year	219 (94)	13 (6)	6.0	3.7	1
≥ 1 year	37 (76)	12 (25)	6.1	1.2	**5.15 (2.14,12.38)**
Missing	15 (88)	2(12)	6.6	4.2	
Stick to walk					
No	255 (93)	20 (7)	6.1	1.8	1
Yes	6 (50)	6 (50)	2.3	4.7	**8.55 (2.80,26.14)**
Missing	10 (91)	1 (9)	5.8	2.3	
Pain					
No	223 (94)	14 (6)	6.0	1.3	1
Yes	34 (74)	12 (26)	6.1	4.0	**4.33 (1.86,10.06)**
Missing	13 (93)	1 (7)	6.6	2.3	-

[1] Age at operation, age at follow-up, sex, BMI at baseline, education, ASA score, indication for THA

The results showed that time to reach best function and the other function at best variables (the need to use a stick to walk or having hip pain when at their best) were associated with the risk of having to stop paid work because of the hip. Thus, these three covariates were taken forwards to the final models (Table 54).

Leisure time and daily physical activities post-THA and the risk of having to stop paid work because of the replaced hip

The associations between LTPA performed post-THA and the risk of leaving the job because of the replaced hip are shown in Table 51. We found that the type of impact activity, how often this was performed and a combination of both factors were significantly associated with the risk of having to leave a job due to the hip. The risk of stopping work decreased by 67% for those who engaged in medium sport and by 82% for those who engaged in high impact sports post-THA.

Table 51. Association between leisure time and daily physical activities post-THA and the risk of having to stop work because of the replaced hip

	Stopping work		Mean time to (years)		
	No n (%)	**Yes n (%)**	**Follow-up**	**Stopping work**	**HR[1] (95%CIs)**
Type of impact activities					
None	15 (79)	4 (21)	7.6	5.1	1
Low	70 (89)	9 (11)	6.2	1.3	0.39 (0.13,1.20)
Medium	99 (91)	10 (9)	5.8	2.1	**0.33 (0.11,0.99)**
High	66 (94)	4 (6)	6.4	7.5	**0.18 (0.05,0.67)**
Unknown	21 (95)	0	4.7	-	-
Frequency					
No activity	15 (79)	4 (21)	7.6	5.1	1
<weekly	98 (89)	12 (11)	6.6	3.7	**0.34 (0.12,0.98)**
≥ weekly	118 (94)	8 (6)	5.9	1.1	**0.23 (0.08,0.73)**
Missing	40 (93)	3 (7)	4.4	5.2	-
Type of impact activities & frequency					
Inactive	15 (79)	4 (21)	7.6	5.1	1
Highly active	35 (100)	0	6.2	-	-
Medium active	193 (89)	23 (11)	6.1	2.3	**0.37 (0.14,0.97)**
Missing	28 (100)	0	4.7	-	--
Years exposed Median (IQR)	9.5 (6.3,13.8)	12.3 (7.5,16.2)	-	-	0.92 (0.70,1.20)
Hours/week Median (IQR)	4.0 (2.0,10.0)	3.5 (1.8-7.0)	-	-	0.98 (0.91,1.05)

[1]Age at operation, age at follow-up and sex adjusted models

Similarly, leaving work because of the replaced hip was less likely to occur the more often the leisure and daily activities were performed; less than once a week (HR: 0.34 95%CI 0.12,0.98) and once or more per week (HR: 0.23 95%CI0.08,0.73), as compared with those who were sedentary i.e. people who did not report any type of LTPA.

Neither the number of years exposed to LTPA nor the weekly hours spent per week on these activities were found to be associated with the risk of stopping working because of the hip.

We then assessed whether the associations observed between LTPA and the risk of having to leave the job remained when further adjustments were added to the model. These results presented in Table 52, showed that the frequency of activity, and a combination of type of impact and frequency of activity were no longer associated with the risk of having to leave the job post-operation. However, high impact activities performed post-arthroplasty remained protective against the risk of leaving work, at a 10% level of significance. Type of impact was therefore taken forward to the final regression models to examine the effect of physically-demanding occupational activities on the risk of needing to leave the job because of the replaced hip (next sub-section Tables 54 and 55).

Table 52. Association between leisure time and daily physical activities and the risk of having to stop working post-THA adjusted for baseline characteristics, clinical and surgical factors, LTPA

	Stopping work		Mean time to (years)		
	No n (%)	**Yes n (%)**	**Follow-up**	**Stopping work**	**HR[1] (95% CIs)**
Type of impact activity					
None	15 (79)	4 (21)	7.6	5.1	1
Low	70 (89)	9 (11)	6.2	1.3	0.36 (0.09,1.41)
Medium	99 (91)	10 (9)	5.8	2.1	0.61 (0.14,2.72)
High	66 (94)	4 (6)	6.4	7.5	*0.23 (0.04,1.32*)
Unknown	21 (100)	0	4.7	-	-
Frequency					
No activity	15 (79)	4 (21)	7.6	5.1	1
< weekly	98 (89)	12 (11)	6.6	3.7	0.39 (0.10,1.55)
≥ weekly	118 (94)	8 (6)	5.9	1.1	0.45 (0.10,2.02)
Missing	40 (93)	3 (7)	4.4	5.2	-
Type of impact activity & frequency					
Inactive	15 (79)	4 (21)	7.6	5.1	1
Highly active	35 (10)	0	6.2	-	-
Medium active	193 (89)	23 (11)	6.1	2.3	0.40 (0.11,1.47)
Missing	28 (100)	0	4.7	-	-
Years exposed Median (IQR)	9.5 (6.3,13.8)	12.3 (7.5,16.2)	-	-	1.06 (0.66,1.70)
Hours/week Median (IQR)	4.0 (2.0,10.0)	3.5 (1.8-7.0)	-	-	0.98 (0.90,1.08)

[1]Age at operation, age at follow-up, sex, BMI at baseline, level education, ASA score, indication for THA, time to their best, pain at their best, use of stick to walk adjusted estimates. HR in italics p<0.1

Exposure to physically-demanding occupational activities post-THA in relation to the risk of having to stop paid work because of the replaced hip

In this sub-section we looked at the association between exposure to occupational activities post-THA and the risk of stopping working because of the replaced hip. We found that those who stopped working post-THA because of having problems with their replaced hip remained in their main occupations for fewer years compared with those who did not (HR: 0.58 95%CI 0.48,0.71).

Table 53 presents the minimally adjusted regression models using age at operation, current age and sex as covariates. In these regression models, we compared workers who reported doing an occupational activity against those who did not carry out that occupational activity.

We found that people who had to stand for more than 4 hours a day were at a three-fold increased risk of reporting that they had to leave their job because of their replaced hip (HR: 3.05 95%CI 1.12,8.34) when compared with people not performing this activity.

None of the remaining occupational activities examined were significantly associated with leaving work because of the replaced hip. However, the estimated risk of having to leave the job was doubled for those who knelt/squatted (HR: 2.65 95%CI 0.96,7.37) and for those who lifted/carried weights ≥ 10kg (HR: 1.95 95%CI 0.72,5.28), when compared with those not performing these activities.

Table 53. Association between physically-demanding occupational activities post-THA and the risk of having to stop working because of the replaced hip

	Stop working		Mean time to (years)		
	No n (%)	**Yes n (%)**	**Follow-up**	**Stop working**	**HR[1] (95%CIs)**
Standing>4h /day					
No	145 (96)	6 (4)	6.5	5.2	1
Yes	92 (90)	10 (10)	5.9	2.9	**3.05 (1.12,8.34)**
Missing	34 (76)	11 (24)	4.3	1.8	
Walking>2miles / day					
No	153 (93)	11 (7)	6.4	5.2	1
Yes	83 (94)	5 (6)	6.1	1.3	1.09 (0.40,3.01)
Missing	36 (77)	11 (23)	4.2	1.8	
Lifting carrying ≥10kg					
No	162 (95)	8 (5)	6.2	3.2	1
Yes	74 (90)	8 (10)	6.6	9.5	1.95 (0.72,5.28)
Missing	36 (77)	11 (23)	4.0	1.5	-
Lifting carrying ≥25kg					
No	203 (93)	14 (7)	6.4	5.2	1
Yes	33 (94)	2 (6)	5.9	5.2	0.95 (0.21,4.36)
Missing	35 (74)	11 (26)	4.2	1.5	-
Digging/shovelling					
No	217 (94)	15 (6)	6.3	5.2	1
Yes	18 (95)	1 (5)	6.8	1.3	1.04 (0.13,8.11)
Missing	36 (76)	11 (23)	4.0	1.5	-
Kneeling/squatting					
No	158 (96)	7 (4)	6.1	5.3	1
Yes	78 (90)	9 (10)	6.8	1.3	2.65 (0.96,7.37)
Missing	35 (76)	11 (24)	4.2	1.5	-
Climbing >30 flight stairs/ day					
No	149 (93)	12 (7)	6.2	5.2	1
Yes	87 (95)	5 (5)	6.4	1.3	0.79 (0.26,2.36)
Missing	35 (76)	11 (24)	4.2	1.5	-
Climbing ladders (up & down)					
No	183 (93)	13 (7)	6.2	5.2	1
Yes	53 (93)	4 (7)	7.1	5.0	1.08 (0.34,3.51)
Missing	35 (74)	12 (7)	4.2	1.5	-

[1]Age at operation, age at follow-up and sex adjusted models [2] Age at operation, current age adjusted models

In a final step, we examined the association between the occupational activities performed post-arthroplasty and the risk of leaving work adjusting for the covariates identified in previous models. We compared workers who performed an occupational activity against those who reported not doing the activity analysed. The results, summarised in Table 54, showed a significant association between kneeling/squatting and the risk of having to stop working because of the hip post-arthroplasty. Those workers who knelt/squatted were at four-fold greater risk of having to stop work than those who did not kneel/squat; in Model 2 (HR: 3.99 95%CI 1.26,12.68) and in Model 4 (HR: 4.33 95% CI 1.29,14.54). In Models 1 and 3 the HRs were non-significantly associated with at least double the risk of having to stop work because of the hip.

In the minimally adjusted models standing for more than 4 hours/day was significantly associated with leaving the job because of the replaced hip. In the final models, after further adjustments, the estimated effect, although not significant, was consistent across Models 1 to 4, suggesting that those workers who were standing for more than 4 hours/day had twice the risk of stopping working because of the hip (HR 2.64 to 2.94). Similarly, although non-significant, the effect of lifting/carrying ≥10kg doubled the risk of having to stop working in Models 2, 3 and 4.

Overall in our sample Models 1 to 4 suggested that the estimated HRs for standing for more than 4 hours, kneeling/squatting and lifting ≥ 10 kg were at least twice as likely to stop working. We therefore, compared people who performed any two of the three occupational activities against the risk amongst workers with a sedentary occupation. The estimated effects for a combination of standing ≥4 hours/day and kneeling/squatting at work (see Table 55) yielded an increased risk of leaving a job because of the replaced hip when compared with workers in a sedentary job in both Model 2 (HR 2.87 95%CI 0.78,10.58) and Model 3 (HR 3.49 95%CI 0.82,14.82), but once again with a large level of uncertainty.

Table 54. Associations between physically-demanding occupational activities performed post-THA and the risk of having to stop working because of the replaced hip

	MODEL 1	MODEL 2	MODEL 3	MODEL 4
Occupational activities (No vs Yes)	**HR (95% CIs)**	**HR (95% CIs)**	**HR (95% CIs)**	**HR (95% CIs)**
Standing >4h /day	2.97 (0.99,8.97)	2.94 (0.92,9.45)	2.64 (0.87,8.07)	2.91 (0.88,9.66)
Walking >2 miles /day	1.00 (0.34,2.92)	1.11 (0.34,3.68)	0.82 (0.27,2.47)	0.95 (0.28,3.28)
Lifting/carrying >= 10kg	1.82 (0.59,5.64)	2.15 (0.66,7.03)	2.00 (0.63,6.39)	2.29 (0.66,7.97)
Lifting/ carrying >= 25kg	0.96 (0.20,4.74)	0.67 (0.12,3.63)	0.89 (0.18,4.33)	0.61 (0.11,3.34)
Digging/shovelling	0.93 (0.11,7.60)	1.05 (0.12,9.42)	0.86 (0.11,6.95)	1.01 (0.11,9.24)
Kneeling/squatting	2.75 (0.94,8.03)	**3.99 (1.26,12.68)**	2.75 (0.92,8.22)	**4.33 (1.29,14.54)**
Climbing >30 flights stairs/ day	0.93 (0.29,2.95)	0.97 (0.28,3.30)	0.92 (0.28,2.98)	1.11 (0.31,3.93)
Climbing ladders	0.91 (0.26,3.13)	1.27 (0.34,4.68)	0.87 (0.25,3.09)	1.27 (0.33,4.94)

Risk estimates shown come from separate regression models after adjustment for:

Model 1. Adjusted for: Age at operation, age at follow-up, sex, BMI baseline, education, ASA score, indication for THA

Model 2. Adjusted for: Age at operation, age at follow-up, sex, BMI baseline, education, ASA score, indication for THA, time to best function, pain (night/day) and use of a stick at their best

Model 3. Adjusted for: Age at operation, age at follow-up, sex, BMI baseline, education, ASA score, indication for THA, type of impact activity

Model 4. Adjusted for: Age at operation, age at follow-up, sex, BMI baseline, education, ASA score, indication for THA time to best function, pain (night/day) and use of a stick at their best, type of impact activity

Table 55. Association between combined occupational activities post-THA and the risk of having to stop working because of the replaced hip

	MODEL 1	MODEL 2	MODEL 3	MODEL 4
Sedentary job vs occupational activities combined	**HR (95% CIs)**	**HR (95% CIs)**	**HR (95% CIs)**	**HR (95% CIs)**
Standing > 4 hours & kneeling/squatting	1.12 (0.40,3.14)	2.87 (0.78,10.58)	1.17 (0.40,3.44)	3.49 (0.82,14.82)
Standing > 4 hours & lifting/carrying ≥ 10kg	0.71 (0.22,2.22)	1.06 (0.23,4.78)	0.61 (0.19,1.99)	0.92 (0.20,4.19)
Kneeling/squatting & lifting/carrying ≥ 10kg	0.71 (0.21,2.40)	1.46 (0.29,7.38)	0.62 (0.17,2.20)	1.28 (0.24,6.79)

Risk estimates shown come from separate regression models after adjustment for:

Model 1. Adjusted for: Age at operation, age at follow-up, sex, BMI at baseline, education ASA score, indication for THA.

Model 2. Adjusted for: Age at operation, age at follow-up, sex, BMI at baseline, education ASA score, indication for THA, time to reach best function, the use of a stick and pain (day and/or night) at their best post-THA.

Model 3. Adjusted for: Age at operation, age at follow-up, sex, BMI at baseline education ASA score, indication for THA, sport post-THA

Model 4. Adjusted for: Age at operation, age at follow-up, sex, BMI at baseline, education, ASA score, indication for THA, time to reach best function, the use of a stick and pain (day and/or night) at their best post-THA, type of impact sport.

Chapter 5 : Results from the Clinical Outcomes in Arthroplasty Study (COASt) – Hip arthroplasty

5.1 Response to the postal survey

Participants in this section of the thesis were drawn from the COASt study. To be eligible for inclusion, they needed to have received a unilateral primary THA performed between the start of COASt April 2010 and December 2013 and be aged ≤ 65 years at the time. Participants were not contacted if they were known to have had prior arthroplasty to another joint (described as “not index surgery” in Figure 8), were deceased or lost to follow-up.

Figure 8 summarises the response rates and reasons for exclusion.

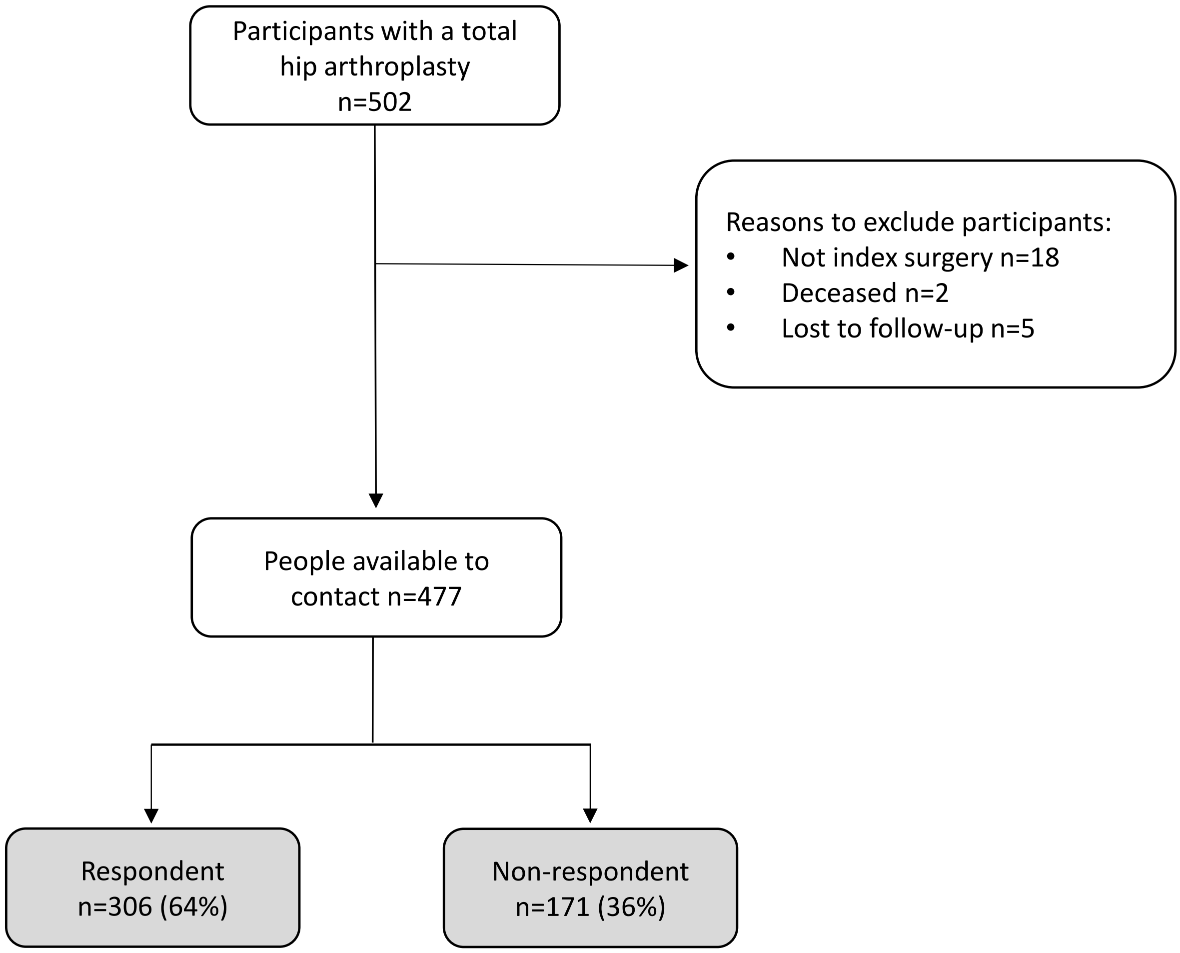

Figure 8. Flow chart summarising the eligibility and responses of the COASt participants - hip

After the exclusions, 477 people were posted a questionnaire between July 2017 and September 2018. After sending a reminder to those who did not reply, we received a total of 306 replies (response rate 63.5%) at a mean follow-up time since primary surgery of 6.5 years (SD ± 1).

5.2 Description of hip patients in COASt

To explore the possibility of a response bias, we tested differences between respondents and non-respondents for baseline characteristics gathered at the time of the arthroplasty. Those people who did not return the questionnaire after being sent a reminder were considered to be non-respondents. We found that neither sex, ASA score, IMD score nor BMI at baseline differed between respondents and non-respondents. However non-respondents tended to be younger.

Table 56. Differences in baseline characteristics between COASt-hip respondents and non-respondents

	Non-respondent n=171	**Respondent n=306**	**p-value**
Sex, n (%)			
Men	66 (40%)	101 (33%)	0.17
Women	101 (60%)	205 (67%)	
Age at THR, median IQR	55 (48,61)	59 (55,63)	< 0.01
ASA grade, n (%)			
I	39 (23)	77 (25)	0.374
II	89 (53)	162 (53)	
III	16 (10)	17 (6)	
Missing	23 (18)	50 (16)	
IMD score, n (%)			
1 (least deprived)	28 (17)	69 (24)	0.07
2	31 (19)	61 (21)	
3	34 (20)	63 (22)	
4	33 (20)	57 (19)	
5 (most deprived)	41 (24)	42 (14)	
BMI, n (%)			
Underweight	2 (1)	32(1)	0.30
Normal	43 (26)	81(26)	
Overweight	51 (31)	116(38)	
Obese	70 (42)	107 (34)	

Footnote: Baseline data not available in 4 participants in the category non-respondents

The baseline characteristics of the 306 respondents are summarised in Table 57. They underwent hip arthroplasty at a median age of 59 years (IQR: 55, 63). Participants were mainly women (67%), and were, on average, slightly overweight with a BMI of 28.4 (SD ± 5.3).

The indication for THA in four out of five participants (79%) was primary OA. The secondary OA group included: rheumatoid arthritis (n=6), avascular necrosis (n=5), congenital dislocation (n=24), and chronic trauma (n=2). More than half of the implants were hybrid prostheses (58%) with the rest made up of uncemented (22%) and cemented (7%) implants (13% of the implant details were missing).

According to the ASA score which was measured at the time of the operation, 25% of the participants were healthy (ASA score =1), approximately half of our sample had mild systemic disease (ASA score =2), whilst 6% had severe systemic disease (ASA score =3).

We found no significant differences between men and women in relation to the baseline, clinical or implant related characteristics assessed.

Table 57. Baseline demographic and clinical characteristics of the respondents from the COASt - hip

	All (n=306)	**Men (n=101)**	**Women (n=205)**
Age at THA Median (IQR)	59 (55, 63)	60 (54, 64)	59 (55,63)
BMI Mean (SD)	28.4 (5.3)	29.0 (4.2)	28.1 (5.7)
Charnley score, n (%)			
Class A	94 (31)	32 (32)	62 (30)
Class B	60 (20)	18 (18)	42 (20)
Class C	32 (10)	11 (11)	21 (10)
Missing	120 (39)	40 (40)	80 (39)
Indication for THA, n (%)			
Primary OA	242 (79)	80 (79)	162 (79)
Secondary OA	37 (12)	8 (8)	29 (14)
Missing	27 (9)	13 (13)	14 (7)
Type of fixation, n (%)			
Cemented	22 (7)	3 (3)	19 (9)
Uncemented	67 (22)	20 (20)	47 (23)
Hybrid	177 (58)	61 (60)	116 (57)
Missing	40 (13)	17 (17)	23 (11)

	All (n=306)	Men (n=101)	Women (n=205)
Side, n (%)			
Right	147 (48)	50 (50)	97 (47)
Left	146 (48)	47 (47)	99 (48)
Missing	13 (4)	4 (4)	9 (4)
ASA score, n (%)			
Healthy	77 (25)	28 (28)	49 (24)
Mild systemic disorder	162 (53)	49 (49)	113 (55)
Severe systemic disorder	17 (6)	4 (4)	13 (6)
Missing	50 (16)	20 (20)	30 (15)

Time to reach optimal function post-operatively

Following an arthroplasty procedure, pain and physical function generally improve rapidly. We therefore asked respondents about their function when at their best post-operatively and the time taken to reach their best. We found that almost half of the respondents (48%) achieved their best function within the first six months post-operation, 29% between 6 months and one year, 14% between one and two years, but in 9% of respondents, the best function was reached more than two years after the surgery.

Occupational status pre and post hip arthroplasty

Figure 9 describes the employment status of respondents pre and post operation. In total, 276 (90%) participants reported that they had a job prior to undergoing hip arthroplasty, with 83% of them employed, 16% self-employed and 1% unknown. At the time of the THA 32% of the people who reported having a paid job (n=276) at any time before the operation were not working, with 18% of them citing the hip symptoms as their main reason for having had to stop work.

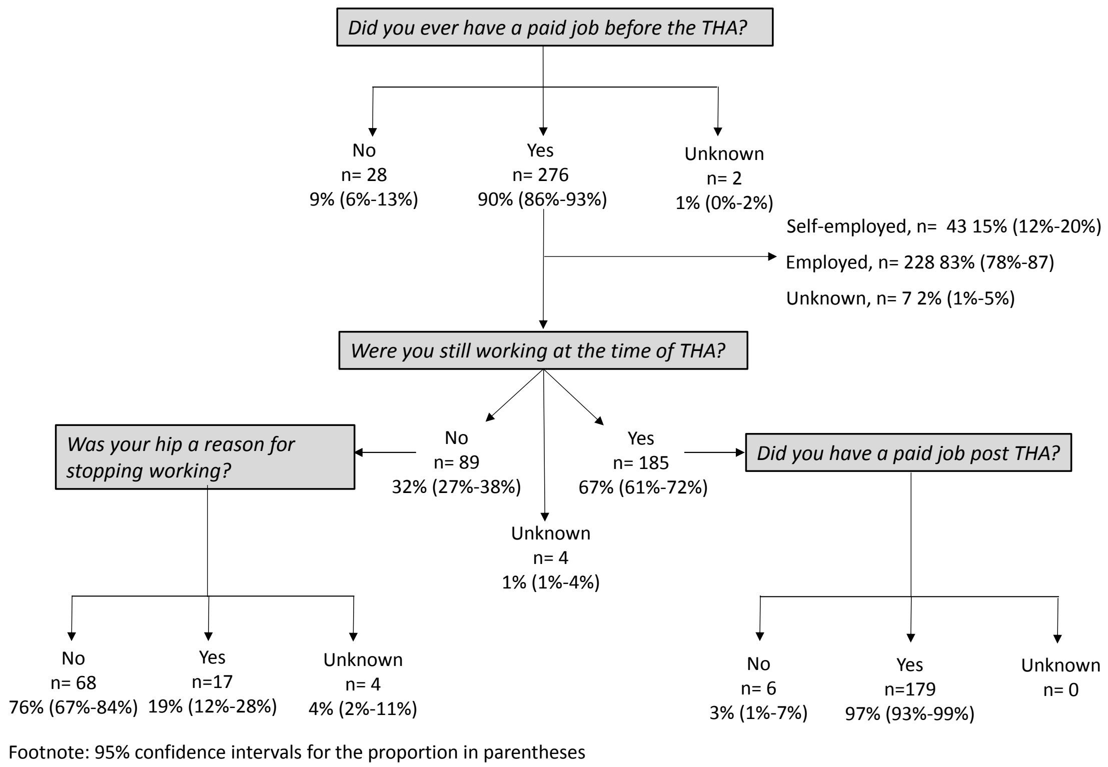

Figure 9. Flow chart showing occupational status pre and post hip arthroplasty

Most of the individuals who were working at the time of the THA returned to work (97%). Additionally, 20 people who were not working or did not provide information pre-arthroplasty reported that they had a paid job post-THA.

COASt participants worked 5.3 years (SD ± 2.2) post-THA, with approximately three quarters of the people who resumed work having one job, 13% having two jobs, and 6% having three jobs. No information was reported by 4% of the participants.

Using the same criteria as in Chapter 4 (Results from the GAR cohort) the main outcomes assessed were: (1) THA failure defined as a prosthesis failure leading to a revision procedure, (2) high levels of pain or poor function because of the hip at the time of our follow-up or (3) report of stopping work, having initially started work post-operatively, because of the operated hip.

At a mean of 6.5 years follow-up post THA, with a minimum of 5 and a maximum of 8 years follow-up, 3% of the participants (n=8) in our sample reported that they had had their hip revised (5 women, 3 men). The age at which THA was performed varied from 19 to 63 years-old. The indication for THA was primary OA (n=5), congenital dislocation (n=2) and unknown for one participant. After THA, the participants worked in a variety of occupations.

5.3 Revision as an outcome of total hip arthroplasty

Just 3% (n=8) of our participants reported that they had undergone a hip revision procedure post-arthroplasty and of these, three did not provide the date when the hip revision surgery was performed. In an attempt to complete this information, we checked hospital records where the primary operation was performed (Southampton General Hospital or Nuffield Hospital Oxford), but found no record of hip revision. In the absence of such records, it was not possible to confirm (a) if a revision had been performed or (b) where and when it had been undertaken (it is feasible that revision surgery had taken place in the private sector or another NHS provider).

Because of the small number of hip revisions and the uncertainty about the revision dates in three of the 8 participants, we were unable to examine whether baseline characteristics, clinical and implant related factors, function related factors, leisure time and daily activities post-THA and occupational activities performed post hip arthroplasty were associated with the risk of hip revision.

5.4 Factors associated with functional outcomes (as defined by the Oxford Hip Score (OHS)) at follow-up after total hip arthroplasty surgery

We also investigated the functional outcomes at follow-up amongst our respondents. In COASt, the functional outcome tool measured was the Oxford Hip Score (OHS) PROM (see section 3.4.5.3 Validated outcome measures for more details). The OHS allows assessment of pain and physical function in two sub-scales. From the initial 306 people who returned our questionnaire, we excluded 14 people because: i) they underwent revision surgery to their index hip (n=8), or ii) they did not complete the OHS score (n=6). The final sample therefore comprised 292 individuals.

In general, the COASt cohort participants had high scores for both OHS subscales; the OHS function and the OHS pain subscale (Table 58), indicating a good level of physical function and low level of pain at follow-up.

Table 58. Descriptive statistics of the outcomes measured post-THA

	All	Men	Women
OHS, Median IQR	46.0 (41.0, 48.0)	46.0 (42.0, 48.0)	46.0 (40.0, 48.0)
OHS Function, Median IQR	95.8 (83.3, 100.0)	95.8 (87.5, 100.0)	95.8 (83.3, 100.0)
OHS Pain, Median IQR	95.8 (87.5, 100.0)	100.0 (87.5, 100.0)	95.8 (87.5, 100.0)

Taking the approach described by Kalairajah [195] participants with poor OHS at follow-up were those in the "poor" category (OHS < 27) (See Table 59). There were no sex differences in the OHS at follow-up. In the four weeks prior to completing the follow-up questionnaire, 73% of participants reported that they had excellent function, 16% good, 5% fair and 6% poor.

Table 59. Distribution of Oxford Hip Score across categories and by sex

OHS, n (%)	All	Men	Women
Excellent	215 (73)	75 (79)	140 (71)
Good	46 (16)	12 (13)	34 (17)
Fair	14 (5)	4 (4)	10 (5)
Poor	17 (6)	4 (4)	13 (7)

In the subsequent analyses, we explored whether baseline characteristics, clinical and surgical factors, function related factors, LTPA post-arthroplasty and work activities post-arthroplasty were predictor factors for poor OHS at follow-up (when the survey was completed). Sex, age and duration of the follow-up were used as the minimum set of covariates taken into account in the minimally adjusted models shown below in Table 60 and Table 61.

<u>Baseline characteristics at THA and risk of poor OHS at follow-up</u>

Table 60 summarises the associations between participant characteristics at the time of THA, and poor OHS at follow-up. The results show that smokers at baseline and participants within Charnley class C were more likely to have poor hip function at follow-up. Moreover, a BMI above normal weight, and poorer health at the time of surgery (measured by the ASA score) appeared to increase the risk of poor function at follow-up. In contrast, having higher levels of educational attainment protected against poorer function at follow-up in the sample analysed.

Table 60. Association between baseline characteristics and risk of poor OHS at follow-up

	Poor OHS		
	No n (%)	**Yes n (%)**	**RR[1] (95% CIs)**
Sex			
Males	91 (96)	4 (4)	1
Females	184 (93)	13 (7)	1.58 (0.53,4.71)
Age at THA, Median (IQR)	66.2 (60.7,66.2)	67.2 (61.7,67.2)	0.99 (0.93,1.05)
BMI			
Underweight	3 (100)	0 (0)	-
Normal	90 (97)	3 (3)	1
Overweight	96 (94)	6 (6)	2.04 (0.47,8.89)
Obese	86 (91)	8 (9)	3.01 (0.77,11.86)
Education			
None	48 (89)	6 (11)	1
≤18 years	57 (92)	5 (8)	0.69 (0.22,2.13)
Higher education	91 (97)	3 (3)	*0.28 (0.07,1.15)*
Missing	79 (96)	3 (4)	-
Smoking			
No	188 (95)	9 (5)	1
Yes	13 (72)	5 (28)	**6.04 (2.18,16.72)**
Missing	74 (96)	3 (4)	-
Charnley			
Class A	85 (98)	2 (2)	1
Class B	52 (93)	4 (7)	3.04 (0.58,15.87)
Class C	27 (84)	5 (17)	*7.20 (1.40,37.11)*
Missing	111 (95)	6 (5)	-
ASA score			
Healthy	70 (95)	4 (5)	1
Mild systemic disorder	147 (95)	8 (5)	0.98 (0.30,3.26)
Severe systemic disorder	11 (79)	3 (21)	*3.99 (0.96,16.58)*
Missing	47 (96)	2 (4)	-

[1]Sex, age and duration of follow-up adjusted estimates. RR in italics p<.01

<u>Clinical and surgical characteristics in relation to poor OHS at follow-up</u>

We examined associations between clinical and surgical factors and the risk of current OHS function (data not shown). Neither the type of implant fixation (cemented, uncemented or hybrid), the side on which the surgery was performed nor the indication for THA were significantly associated with poor OHS at follow-up.

Time to reach optimal function post-operatively, function at best and current function in the contralateral hip in relation to the risk of poor OHS at follow-up

Considering factors related to function, either at their best post-THA or related to the contralateral hip at the time of follow-up, we found that neither the time taken to reach their best function post-THA nor having to use a stick at their best post-THA were significantly associated with the risk of current poor OHS (data not shown).

However, we did find a four-fold increased risk of current poor OHS in those participants who reported pain, either during the day or at night, at the time of their best functional outcome post-operation (RR: 4.29 95%CI 1.41,13.10). Reporting pain/stiffness in the contralateral hip at the time of the survey completion was also strongly associated with poor OHS with a 6-fold increased risk of having poor OHS at follow-up as compared with those who were free from pain or stiffness at their best (RR:6.59 95%CI 2.65,16.43).

Leisure time and daily physical activities post-THA and the risk of poor OHS at follow-up

LTPA and housework performed post-arthroplasty did not increase the risk of having poor OHS at follow-up. On the contrary, we found that non-work related physical activity had a protective effect against poor OHS at follow-up (RR: 0.18 95%CI 0.05,0.60) compared with physically inactive participants. Similar results were observed for those who did medium impact activities, but amongst this group only one person had current poor function (RR: 0.03 95%CI 0.00,0.29). None of the 60 people who engaged in high impact activities after hip arthroplasty had poor OHS at the time of completing the questionnaire. We found no significant association between how often the LTPA was performed (frequency) and poor OHS at 6 years follow-up. Similarly, neither the number of years doing LTPA nor the average amount of hours spent per week on LTPA were found to be associated with having current poor OHS.

Physically-demanding occupational activities post-THA and the risk of poor OHS at follow-up

We also assessed the effect of working after arthroplasty on poor OHS at follow-up amongst those who worked post-arthroplasty (see Table 61). After controlling for age, sex and duration of follow-up, the results showed that those who worked post-operation were at 80% lower risk of having poor OHS at 6 years post-operation (RR:0.20 95%CI 0.05,0.80) as compared with those who did not work post-operatively.

Table 61. Association between working post-THA and current poor OHS

	Poor OHS		
	No n (%)	**Yes n (%)**	**RR[1] (95% CIs)**
Returned to work			
No	93 (89)	11 (11)	1
Yes	182 (97)	6 (3)	**0.20 (0.05,0.80)**
Years worked post-THA Mean (IQR)	5.3 (4.5, 6.6)	5.2 (4.1, 5.8)	0.96 (0.80,1.15)

[1]Sex, age and duration of follow-up adjusted estimates

No significant association was observed between the years worked post-THA and poor OHS at follow-up.

A total of 188 (64%) out of the 292 participants reported holding a paid job post-arthroplasty. We aimed to explore the associations between occupational activities performed post-operation and poor OHS at follow-up, in a similar manner to that utilised in the GAR cohort (Chapter 1). However, in the COASt cohort, only 3% (n=6) of the participants who held a job post-arthroplasty reported poor OHS at follow-up. Therefore, we were unable to assess the relationship between occupational activities post-THA and poor OHS at follow-up due to the small numbers. None of the 6 individuals with current poor OHS carried out any lifting, digging/shovelling nor climbing ladders as part of their occupational activities.

5.5 Returning to work post-arthroplasty and reporting having to give up work because of difficulties with the replaced hip

In the following sub-section, we assessed associations between occupational activities carried out after arthroplasty and the risk of leaving a job mainly or partly due to problems with the replaced hip.

For this analysis we included only those individuals who worked a minimum of a month post-operation, as long as they provided the start and end dates for the job performed, or stated they were still working at follow-up. This left 190 people in these analyses, of whom 13 (7%); 3 men and 10 women, reported that they had stopped working due to problems with their replaced hip.

The duration of follow-up was censored when the participants reported that they had stopped working for any reason after arthroplasty, or at the time of completing the questionnaire if the participants were still working.

We explored the effect of baseline characteristics, clinical and surgical factors, function related factors and LTPA and daily activity post-operation on the risk of stopping work due to the replaced hip. In all these regression models sex, age at the operation, and current age were considered as covariates.

<u>Baseline characteristics at THA and the risk of stopping work because of the replaced hip</u>

Table 62 presents the associations between baseline characteristics and the risk of stopping work. For the regression models fitted for BMI, we combined people who were underweight with those with a normal BMI, because only two participants were underweight.

None of the baseline factors showed a significant association with the risk of stopping work post-THA because of the replaced hip.

Table 62. Associations between baseline characteristics and the risk of having to stop working post-THA

	Stopping work		Mean time to (years)		
	No n (%)	**Yes n (%)**	**Follow -up**	**Stopping work**	**HR[1] (95% CIs)**
Sex					
Males	68 (96)	3 (4)	4.8	3.2	1
Females	109 (92)	10 (8)	5.0	4.1	3.23 (0.71,14.7)
Age at THA Median (IQR)	57.0 (51.0, 60.0)	57.5 (46.0, 62.0)	-	-	1.10 (0.73,1.66)
BMI					
Normal / Underweight	47 (92)	4 (8)	5.3	4.1	1
Overweight	74 (94)	5 (6)	4.8	4.0	1.28 (0.34,4.91)
Obese	56 (94)	3 (5)	4.9	4.4	0.99 (0.24,4.03)
Missing	1 (50)	1 (50)	6.7	3.2	-
Education					
None	27 (93)	4 (13)	5.5	0.8	1
≤18 years	42 (91)	4 (9)	4.7	3.0	0.73 (0.17,3.02)
Higher education	61 (100)	0	4.8	-	-
Missing	47 (90)	5 (10)	6.0	6.2	-

	Stopping work		Mean time to (years)		
	No n (%)	Yes n (%)	Follow -up	Stopping work	HR[1] (95% CIs)
Smoking					
No	123 (95)	7 (5)	4.8	1.2	1
Yes	12 (92)	1 (8)	4.7	3.0	0.96 (0.12,7.93)
Missing	42 (89)	5 (11)	6.3	6.2	-
Charnley					
Class A	61 (91)	6 (9)	4.6	3.0	1
Class B	37 (95)	2 (5)	4.9	2.1	0.23 (0.03,1.90)
Class C	13 (100)	0	4.9	-	-
Missing	66 (93)	5 (7)	5.6	6.2	-
ASA score					
Healthy	49 (92)	4 (8)	5.2	2.2	1
Mild systemic disorder	85 (91)	8 (9)	5.1	4.4	1.29 (0.39,4.25)
Severe systemic disorder	10 (100)	0	4.8	-	-
Missing	33 (97)	1 (3)	4.8	3.2	-

[1]Sex, age at operation and current age adjusted estimates

<u>Clinical and surgical factors and the risk of having to stop work because of the replaced hip</u>

Likewise, exploring the risk associated with surgical factors, neither the indication for primary THA, the side operated, nor the type of implant fixation (cemented, uncemented and hybrid) were significantly associated with having to stop work because of hip problems post-operation (data not shown).

<u>Time to reach optimal function and best function reached post-operatively in relation to the risk of having to stop work because of the replaced hip</u>

Considering the variables related to function at their best post-operation and the time needed to reach it, the results showed that the risk of stopping work post-THA was significantly increased in workers who reported pain, at night or during the day, when at their best, as compared with those workers who reported no pain when at their best (HR: 4.46 95%CI 1.30,15.37). Conversely, the amount of months needed to reach their best possible function post-arthroplasty, and the need to use a stick to walk at their best post-arthroplasty were not found to be predictors of stopping work due to their replaced hip.

Leisure time and daily physical activity post-THA and the risk of having to stop paid work because of the replaced hip

None of the type of impact activity (high, medium, low or none), the frequency of activity participation, the number of years exposed to LTPA post-arthroplasty, nor the hours per week spent in LTPA were found to be associated with the risk of stopping work following arthroplasty (data not shown).

Physically-demanding occupational activities post-THA in relation to the risk of having to stop paid work because of the replaced hip

To examine the relationship between carrying out occupational activities post-THA and stopping work because of the replaced hip, we compared workers who carried out an occupational activity with those who did not perform that specific activity. In Table 63 are summarised the associations between occupational activities post-THA and the risk of stopping work because of the replaced hip. The potential confounders considered were sex, age at arthroplasty and age at the time of completing the questionnaire.

The results showed that there was an increased risk of stopping work mainly or partly because of the replaced hip following hip arthroplasty for those workers who lifted/carried weight ≥ 10 kg (HR: 6.15 95%CI 1.84,20.57), knelt/squatted (HR: 7.10 95%CI 1.92,26.23), and climbed ladders (HR: 10.02 95%CI 2.36,42.57), albeit with wide confidence intervals. The remaining occupational activities: standing for more than 4 hours/day; walking more than 2 miles/day; lifting/carrying ≥ 25 kg were non-significantly associated with stopping work, with risk estimates all above 2.
No additional analyses were performed because of the size of the sample and the small number of outcome events.

Table 63. Associations between physically-demanding occupational activities post-THA and the risk of having to stop paid work because of the replaced hip

	Stopping work		**Mean time to (years)**		
	No n (%)	**Yes n (%)**	**Follow -up**	**Stopping work**	**HR[1] (95%CIs)**
Standing > 4h /day					
No	81 (96)	4 (5)	4.9	6.7	1
Yes	87 (91)	9 (9)	5.1	3.1	2.99 (0.89,10.04)
Missing	9 (100)	0	3.5	-	-
Walking >2miles /day					
No	110 (94)	7 (6)	5.1	5.1	1
Yes	58 (90)	6 (9)	4.8	1.2	2.08 (0.67,6.43)
Missing	9 (100)	0	3.5	-	-
Lifting/carrying ≥ 10 kg					
No	110 (96)	4 (4)	5.1	3.8	1
Yes	58 (87)	9 (13)	4.9	3.7	**6.15 (1.84,20.57**)
Missing	9 (100)	0	3.5	-	-
Lifting/carrying ≥ 25 kg					
No	142 (93)	11 (7)	4.9	4.1	1
Yes	26 (93)	2 (7)	5.1	0.2	4.25 (0.59,30.39)
Missing	9 (100)	0	3.5	-	-
Digging/shovelling					
No	155 (95)	9 (5)	5.1	4.1	1
Yes	13 (76)	4 (24)	3.9	3.1	**24.95 (4.31,144.57)**
Missing	9 (100)	0	3.5	-	-
Kneeling/squatting					
No	107 (97)	3 (3)	5.1	6.2	1
Yes	61 (86)	10 (14)	4.8	3.2	**7.10 (1.92,26.23)**
Missing	9 (100)	0	3.5	-	-
Climbing >30 flights of stairs/day					
No	143 (94)	13 (8)	4.9	3.7	-
Yes	25 (100)	0	5.0	-	-
Missing	9 (100)	0	3.5	-	-
Climbing ladders					
No	141 (94)	9 (6)	5.1	4.1	1
Yes	27 (87)	4 (13)	4.8	3.2	**10.02 (2.36,42.57)**
Missing	9 (100)	0	3.5	-	-

[1]Sex, age at operation, current age adjusted estimates

Chapter 6 : Amalgamation of the GAR and COASt cohorts – Hip arthroplasty

6.1 Description of the sample

We pooled data from the cohorts described in Chapter 4 (GAR) and Chapter 5 (COASt - hip) to increase the power to detect differences between performing and not performing physically-demanding occupational activities in relation to; i) the need for hip revision, ii) poor function at follow-up measured by the OHS, and iii) leaving a job post-arthroplasty because of problems with the replaced hip. For consistency, before pooling the data, we excluded participants from COASt who were 65 years of age at the time of the primary arthroplasty because all participants from GAR were under 65 years when the primary operation was performed.

Table 64. Baseline demographic characteristics of the respondents from the GAR and COASt cohorts

	GAR	**COASt**
Sex, n (%)		
Men	316 (54%)	88 (33%)
Women	266 (46%)	181 (67%)
Age at THA, Median (IQR)	58.0 (51.0, 61.0)	58.0 (53.0, 62.0)
Age at follow-up Median (IQR)	69.5 (62.3, 74.6)	64.6 (59.6, 68.3)
ASA score, n (%)		
Healthy	155 (27)	71 (26)
Mild systemic disease	393 (67)	136 (51)
Severe systemic disease	34 (6)	15 (6)
Missing	-	47 (17)
BMI at THA, n (%)		
Underweight	15 (2)	2 (1)
Normal	208 (36)	75 (28)
Overweight	219 (38)	105 (39)
Obese	139 (23)	84 (31)
Missing	1 (1)	3 (1)

The main demographic and clinical characteristics of the sample studied, by cohort, are summarised in Table 64. The sample included a total of 851 participants of whom the majority (69%) were from the GAR cohort.

We found differences in the distribution of sex, age at THA, and BMI at baseline between the cohorts. In GAR there were more men (54%) than women, whereas in COASt the percentage of male participants was 33%. Likewise, there were differences in the BMI of the participants at baseline ($p<0.01$), showing that BMI at the time of surgery was higher in COASt participants than in GAR participants.

There were no differences between cohorts in relation to health status (as measured by ASA score) or Charnley score at the time of undergoing hip arthroplasty.

Given the differences observed between the participants from the two cohorts, we decided to include the cohort from which the participant was recruited as a covariate in the regression models fitted hereafter.

6.2 Revision as an outcome of total hip arthroplasty

Out of the 851 participants, 844 contributed a total of 8,663.222 person-years to the analyses of risk factors for revision. Amongst participants, 53 (6.2%) reported hip revision of the index joint at a median follow-up of 8.2 years (IQR: 6.6-14.2).

In the regression models we examined separately the relationship between hip revision and the following characteristics; baseline characteristics (Table 65), clinical and surgical factors at baseline (data not shown), optimal function achieved post-operatively and time to achieve it (Table 66), leisure time and daily activities performed post-THA (Table 67) and physically-demanding occupational activities post-THA (Table 69). Sex, age at the time of THA and location of the arthroplasty cohort (UK or Geneva) were considered to be the minimum set of covariates to adjust for in these minimally adjusted models.

<u>Associations between baseline characteristics at THA and risk of revision</u>

Table 65 summarises the associations between participant characteristics at the time of the operation and the risk of hip revision. None of the variables examined were significantly associated with the risk of hip revision, except for the age at which the primary operation was performed. The results showed that the risk of a revision was reduced when the primary hip arthroplasty was performed at an older age (HR: 0.96 95%CI 0.93,0.99).

Table 65. Association between baseline characteristics and risk of hip revision

	Revision		Mean time to (years)		
	No n (%)	**Yes n (%)**	**Follow-up**	**Revision**	**HR[1] (95%CIs)**
Sex					
Males	378 (94)	26 (6)	9.6	8.2	1
Females	420 (94)	27 (6)	7.7	7.7	1.17 (0.67,2.06)
Age at THA	58.0	56.0			
Median (IQR)	(52.0,62.0)	(47.0,60.0)	-	-	**0.96 (0.93,0.99)**
BMI					
Normal	258 (91)	25 (9)	8.8	8.4	1
Underweight	16 (94)	1 (6)	8.8	6.6	0.72 (0.10,5.36)
Overweight	311 (96)	13 (4)	8.0	11.3	0.61 (0.30,1.24)
Obese	209 (94)	14 (6)	7.8	7.4	0.98 (0.48,1.97)
Missing	4 (100)	0	6.6	-	-
Education					
≤18 years	381 (93)	29 (7)	9.3	7.7	1
>18 years	246 (96)	11 (4)	7.4	6.4	0.78 (0.39,1.59)
Missing	171 (93)	13 (7)	7.9	10.7	-
Smoking					
No	524 (94)	36 (6)	7.5	8.0	1
Yes	174 (93)	14 (7)	12.1	6.5	0.77 (0.40,1.48)
Missing	100 (97)	3 (3)	7.8	10.2	-
Charnley score					
Class A	356 (93)	28 (7)	9.9	7.7	1
Class B	191 (93)	15 (7)	9.8	1.0	0.93 (0.48,1.78)
Class C	136 (94)	8 (6)	7.7	6.1	0.94 (0.43,2.09)
Missing	115 (98)	2 (2)	7.6	0	-
ASA score					
Healthy	212 (94)	14 (6)	8.9	7.4	1
Mild systemic disorder	493 (93)	36 (7)	8.3	7.8	1.27 (0.67,2.42)
Severe systemic disorder	47 (96)	2 (4)	9.5	9.2	0.42 (0.05,3.24)
Missing	46 (98)	1 (2)	5.6	2.3	-
Cohort					
COASt study	257 (32)	8 (15)	6.5	1.0	1
Geneva	537 (68)	45 (85)	12.1	8.2	1.27 (0,47,3.47)
Missing	-	4 (100)	-	-	-

[1]Sex, age at operation and cohort adjusted estimates

<u>Clinical and surgical characteristics in relation to revision</u>

No significant association was found between any of the clinical and surgical factors, including: indication for THA (primary OA vs secondary OA); the method of fixation used (uncemented, cemented, hybrid); nor the side where the operation was performed, and the risk of hip revision (data not shown).

Relationship between optimal function post-operatively, time to attain optimal function and risk of revision

The minimally adjusted models for function characteristics at their best after hip arthroplasty and the time taken to achieve best function are presented in Table 66. Compared with those achieving optimal function from the surgery within the first 12 months after the operation, those who needed ≥ 12 months were at more than double the risk of requiring a hip revision procedure (HR:2.71 95%CI 1.44,5.12).

We also found a positive association between the risk of hip revision and: i) the need to use a stick to walk at their optimal function (HR: 2.99 95%CI 1.44,6.23), and ii) feeling pain during the day at their best function (HR: 4.27 95%CI 2.10,8.66) as compared with those who did not. Pain at night when at their best was not significantly associated with the risk of hip revision.

Table 66. Association between optimal function and time taken to reach optimal function post-THA and hip revision

	Revision		**Mean time to (years)**		
	No n(%)	**Yes n (%)**	**Follow-up**	**Revision**	**HR[1] (95%CIs)**
Time to best function					
< 1 year	606 (96)	27 (4)	7.9	8.3	1
≥ 1 year	149 (89)	19 (11)	7.5	6.4	**2.71 (1.44,5.12)**
Missing	43 (86)	7 (14)	15.0	8.2	-
Stick to walk					
No	714 (95)	39 (5)	7.9	8.2	1
Yes	54 (84)	10 (16)	7.9	6.4	**2.99 (1.44,6.23)**
Missing	30 (88)	4 (12)	13.1	9.6	-
Pain during day					
No	719 (95)	39 (5)	7.8	8.2	1
Yes	44 (80)	11 (20)	8.1	3.9	**4.27 (2.10,8.66)**
Missing	18 (100)	-	14.7	8.2	-
Pain at night					
No	616 (94)	38 (6)	7.9	8.2	1
Yes	148 (92)	12 (8)	7.7	5.4	1.28 (0.64,2.54)
Missing	34 (92)	3 (8)	13.8	8.2	-

[1]Sex, age at operation and cohort adjusted estimates

Leisure time and daily physical activities post-THA in relation to risk of revision

The associations between LTPA and household activities and the risk of hip revision are presented in Table 67. None of the leisure time and daily activities variables were associated with the risk of hip revision.

Table 67. Associations between leisure time and daily physical activities post-THA and risk of hip revision

	Revision		Mean time to (years)		
	No n (%)	**Yes n (%)**	**Follow-up**	**Revision**	**HR[1] (95%CIs)**
Type of impact activity					
None	68 (93)	5 (7)	13.3	5.1	1
Low	303 (94)	18 (6)	7.7	9.2	1.44 (0.47,4.35)
Medium	216 (94)	13 (6)	7.7	6.1	1.41 (0.45,4.38)
High	151 (95)	8 (5)	7.5	7.7	1.33 (0.40,4.44)
Unknown	60 (87)	9 (13)	13.8	8.4	-
Frequency					
No activity	63 (94)	4 (6)	14.7	5.1	1
<weekly	264 (95)	13 (5)	7.8	8.3	1.14 (0.37,3.54)
≥ weekly	343 94()	22 (6)	7.4	7.6	1.60 (0.54,4.78)
Missing	128 (90)	14 (10)	12.7	11.3	-
Type of impact activity & frequency					
Inactive	63 (94)	4 (6)	14.7	5.1	1
Highly active	71 (91)	7 (9)	7.3	7.7	2.55 (0.74,8.82)
Medium active	587 (95)	32 (5)	7.7	8.2	1.25 (0.43,3.60)
Missing	77 (89)	10 (11)	13.2	8.4	-
Years exposed Median (IQR)	6.8 (5.4, 10.8)	9.4 (6.3, 13.1)	-	-	*0.91 (0.82,1.01)*
Weekly/hours Median (IQR)	4.0 (2.0 10.0)	4.0 (2.0 10.0)	-	-	1.01 (0.98,1.04)

[1]Sex, age at operation and cohort adjusted estimates. HR in italics p<0.1

Similarly, when we looked at the combination of the type of activity and the frequency with which this was performed no association was found. However, the estimated risk for highly active participants (i.e. high impact activities at least once a week) was not statistically significantly associated but doubled the risk of hip revision when compared with those who were sedentary (no LTPA reported) (HR: 2.55 95% CI 0.74,8.82).

We then looked at whether the association between the years exposed to leisure and daily activities identified in Table 67, remained after adjusting for covariates identified in previous steps; time to reach optimal function, the use of a stick and pain during the day at their best (see Table 68).

Table 68. Associations between leisure time and daily physical activities post-THA and risk of hip revision adjusted for baseline characteristics and function markers

	Revision		Mean time to (years)		
	No n (%)	**Yes n (%)**	**Follow-up**	**Revision**	**HR[1] (95%CIs)**
Type of impact activity					
None	68 (93)	5 (7)	13.3	5.1	1
Low	303 (94)	18 (6)	7.7	9.2	1.64 (0.52,5.20)
Medium	216 (94)	13 (6)	7.7	6.1	2.07 (0.62,6.87)
High	151 (95)	8 (5)	7.5	7.7	2.15 (0.60,7.76)
Unknown	60 (87)	9 (13)	13.8	8.4	
Frequency					
No activity	63 (94)	4 (6)	14.7	5.1	1
<weekly	264 (95)	13 (5)	7.8	8.3	1.54 (0.48,4.95)
≥ weekly	343 94()	22 (6)	7.4	7.6	2.24 (0.70,7.19)
Missing	128 (90)	14 (10)	12.7	11.3	
Type of impact activity & frequency					
Inactive	63 (94)	4 (6)	14.7	5.1	1
Highly active	71 (91)	7 (9)	7.3	7.7	**4.23 (1.13,15.81)**
Medium active	587 (95)	32 (5)	7.7	8.2	1.69 (0.56,5.15)
Missing	77 (89)	10 (11)	13.2	8.4	
Years exposed Median (IQR)	6.8 (5.4, 10.8)	9.4 (6.3, 13.1)	-	**-**	0.93 (0.84,1.04)
Weekly/hours Median (IQR)	4.0 (2.0 10.0)	4.0 (2.0 10.0)	-	-	1.00 (0.96,1.04)

[1]Sex, age at operation, BMI baseline, to time best function, pain during the day, use of a stick at their best, cohort adjusted estimates

The amount of years engaged in leisure time and daily physical activities post-THA lost significance after adjustments, and highly active participants quadrupled the risk of hip revision compared with physically inactive people, i.e. those who did not report any type of leisure or daily activity.

<u>Physically-demanding occupational activities post-THA and risk of hip revision</u>

A total of 529 (62%) participants, reported that they held a job post-arthroplasty, 295 (35%) did not work post-THA, and for 27 (3%) participants this information was unknown. We found no significant association between the risk of hip revision and working post-arthroplasty (HR: 0.77 95%CI 0.42,1.41), nor the number of years in work post-operation (HR: 1.02 95%CI 0.94,1.11) although, if anything, those who returned to work appeared to have a lesser risk of revision surgery.

The minimally adjusted models exploring the association between physically-demanding occupational activities performed post-THA and the risk of hip revision are shown in Table 69.

Table 69. Associations between physically-demanding occupational activities post-THA and the risk of hip revision

	Revision		Mean time to (years)		
	No n (%)	Yes n (%)	Follow-up	Revision	HR[1] (95%CIs)
Standing > 4h /day					
No	216 (95)	11 (5)	7.6	7.0	1
Yes	184 (95)	9 (5)	7.3	6.6	1.24 (0.48,3.23)
Missing	99 (91)	10 (9)	12.1	8.3	
Walking > 2 miles/day					
No	259 (95)	13 (5)	7.6	7.7	1
Yes	140 (95)	7 (5)	7.3	5.5	1.16 (0.43,3.16)
Missing	100 (91)	10 (9)	12.3	8.3	
Lifting carrying ≥ 10kg					
No	264 (96)	12 (4)	7.5	7.7	1
Yes	135 (94)	8 (6)	7.4	5.7	1.53 (0.57,4.07)
Missing	100 (91)	10 (9)	12.3	8.3	
Lifting carrying ≥ 25 kg					
No	345 (96)	16 (4)	7.5	7.7	1
Yes	54 (93)	4 (7)	7.0	5.4	2.07 (0.56,7.68)
Missing	100 (91)	10 (9)	12.3	8.3	
Digging/shovelling					
No	368 (95)	18 (5)	7.5	7.7	1
Yes	30 (94)	2 (6)	9.0	1.7	2.08 (0.44,9.85)
Missing	101 (91)	10 (9)	12.5	8.3	
Kneeling/squatting					
No	257 (96)	11 (4)	7.5	7.0	1
Yes	142 (84)	9 (6)	7.3	6.7	1.93 (0.74,5.02)
Missing	100 (91)	10 (9)	12.3	8.3	
Climbing 30 flights of stairs/day					
No	288 (94)	17 (6)	7.3	7.7	1
Yes	111 (97)	3 (3)	9.1	3.9	0.37 (0.08,1.66)
Missing	100 (91)	10 (9)	12.3	8.3	
Climbing ladders					
No	323 (96)	15 (4)	7.4	7.7	1
Yes	76 (94)	5 (6)	9.1	5.7	1.90 (0.64,5.69)
Missing	100 (91)	10 (9)	12.3	8.3	

[1]Sex, age at operation and cohort adjusted estimates

Our results showed no significant associations between carrying out any of the occupational activities post-arthroplasty and having a hip implant failure. Nevertheless, the estimated effect among workers who knelt/squatted, carried/lifted ≥ 25kg, climbed ladders, dug/shovelled was a doubled or almost doubled risk of having hip revision surgery, compared with those who did not carry out the occupational activity assessed.

Similarly, those who climbed 30 flights of stairs/day at work were at lower risk of hip revision as compared with those who did not, but the confidence intervals around this estimate included 1.0 (HR: 0.37 95%CI 0.08,1.66).

The final models looking at the association between each occupational activity and risk of hip revision are shown in Table 70. The estimated risks were consistent across Models 1 to 3, although none of the associations reached significance. Once again climbing 30 flights of stairs/day at work was associated with a lower risk of hip revision in Models 1 to 3, with confidence intervals including 1.0. In contrast, the estimate effect for lifting or carrying ≥25 kg doubled the risk of hip revision (HR: 2.01 95%CI 0.54,7.50) in Model 2 with a large level of uncertainty.

Table 70. Associations between physically-demanding occupational activities performed post-THA and risk of hip revision adjusted for different covariates

	MODEL 1	**MODEL 2**	**MODEL 3**
No vs Yes	**HR[1] (95%CIs)**	**HR[1] (95%CIs)**	**HR[1] (95%CIs)**
Standing > 4h / day	1.21 (0.45,3.25)	1.22 (0.47,3.18)	1.22 (0.46,3.29)
Walking >2 miles/ day	1.13 (0.41,3.12)	1.14 (0.42,3.11)	1.15 (0.42,3.19)
Lifting carrying ≥ 10kg	1.50 (0.54,4.12)	1.51 (0.56,4.03)	1.48 (0.54,4.08)
Lifting carrying ≥ 25 kg	1.70 (0.42,6.81)	2.01 (0.54,7.50)	1.71 (0.43,6.80)
Digging/shovelling	1.57 (0.33,7.39)	1.98 (0.41,9.45)	1.53 (0.32,7.39)
Kneeling/squatting	1.72 (0.63,4.68)	1.87 (0.72,4.88)	1.67 (0.61,4.57)
Climbing 30 flights of stairs / day	0.39 (0.09,1.77)	0.34 (0.08,1.56)	0.36 (0.08,1.68)
Climbing ladders	1.79 (0.60,5.33)	1.87 (0.62,5.64)	1.74 (0.58,5.26)

Risk estimates shown come from separate regression models after adjustment for:

Model 1. Adjusted for: age at operation, sex, time to best function, the use of a stick at their best, pain during the day at their best, cohort

Model 2. Adjusted for: Age at operation, sex, type of impact activity & frequency, cohort

Model 3. Adjusted for: Age at operation, sex, time to best function, the use of a stick at their best, pain during the day at their best type of impact activity & frequency, cohort

6.3 Factors associated with poor function, as defined by a poor Oxford Hip Score (OHS), at follow-up after total hip arthroplasty surgery

In participants from both cohorts the OHS at follow-up was assessed by questionnaire response. We evaluated factors associated with current poor OHS following hip replacement, and whether occupational activities performed post-arthroplasty may affect the risk of poor OHS at follow-up.

According to the criteria as described and followed in Chapter 4.4 and Chapter 5.4, participants were excluded from this analysis if: i) their hip arthroplasty had been revised for any reason (n=53), or ii) it was not possible to calculate OHS score from the responses provided by the participants. The pooled sample comprised 773 people, 518 from GAR and 255 from COASt.

The OHS was scored as a categorical variable with four groups (excellent, good, fair, and poor) using the categories proposed by Kalairajah et al as previously described in Chapter 3 (Data and Methods).

Table 71 summarises the OHS at the time of follow-up in people who worked and also those who did not work post-arthroplasty. The prevalence rates showed that only a small number of participants (n=17) who were in work following THA were categorised as having poor OHS at follow-up. Additionally, 12 out of these 17 participants returned to a sedentary occupation whilst the rest reported doing some level of occupational activity. Because of sparse data it was not possible to perform any further analysis.

Table 71. Oxford Hip Score categories by occupational status post-THA

		Job post-arthroplasty n (%)		
		No	**Yes**	**Unknown**
OHS	Excellent	149 (57)	364 (74)	8 (36)
	Good	47 (18)	77 (16)	4 (18)
	Fair	28 (11)	31 (6)	5 (23)
	Poor	38 (15)	17 (3)	5 (23)

6.4 Returning to work post-arthroplasty and reporting having to give up work because of difficulties with the replaced hip

A total of 485 participants from both the GAR and COASt cohorts, contributed to these analyses with a total of 2,962.053 person-years. The sample included 295 respondents from Geneva and 190 from COASt, who reported having a paid job following their primary hip arthroplasty for at least one month. Approximately 8% of the people from the pooled dataset reported having left their job following arthroplasty as a consequence of problems from the replaced hip.

<u>Baseline characteristics and the risk of stopping paid work because of the replaced hip</u>

The relationship between baseline characteristics and the risk of leaving a job are presented in Table 72. The results showed that none of: sex; age at operation; BMI; smoking; or the Charnley score (all measured at THA), were significantly associated with the risk of stopping work because of the replaced hip. However, those with a higher level of educational attainment beyond 18 years of age, were at lower risk of needing to leave their job post-operatively by 65% when compared with participants who were educated only until aged 18 years (HR: 0.35 95%CI 0.16,0.79).

Table 72. Associations between baseline characteristics and stopping work post-THA because of the replaced hip

	Stopping work		Mean time to (years)		
	No n (%)	**Yes n (%)**	**Follow-up**	**Stopping work**	**HR[1] (95%CIs)**
Sex					
Males	225 (93)	16 (7)	5.5	3.2	1
Females	209 (90)	22 (10)	5.3	1.4	1.54 (0.81,2.94)
Age at THA	56.0	56.5	-	-	
Median (IQR)	(50, 60)	(4 4, 60)			1.03 (0.93,1.13)
BMI					
Normal	143 (89)	18 (11)	5.5	2.1	1
Underweight	9 (100)	0	6.9	-	-
Overweight	184 (93)	13 (7)	5.3	2.6	0.77 (0.36,1.63)
Obese	97 (94)	6 (6)	5.1	4.2	0.96 (0.40,2.30)
Missing	1(50)	1(50)	6.7	3.2	-
Education					
≤ 18 years	175 (89)	22 (11)	5.1	2.2	1
> 18 years	165 (95)	8 (5)	5.1	2.0	**0.35 (0.16,0.79)**
Missing	94 (92)	8 (8)	6.5	4.8	
Smoking					
No	287 (93)	23 (7)	5.1	1.3	1
Yes	90 (89)	11(11)	6.6	2.9	1.23 (0.58,2.62)
Missing	57 (93)	4 (7)	6.4	5.3	-
Charnley					
Class A	193 (89)	23 (11)	5.1	2.5	1
Class B	116 (94)	8 (6)	5.4	2.2	0.54 (0.24,1.19)
Class C	57 (95)	3 (5)	5.2	1.8	0.44 (0.13,1.45)
Missing	68 (94)	4 (6)	5.6	5.3	-

	Stopping work		Mean time to (years)		
	No n (%)	Yes n (%)	Follow-up	Stopping work	HR[1] (95%CIs)
ASA score					
Healthy	140 (92)	13 (8)	6.3	1.4	1
Mild systemic disorder	245 (92)	21 (8)	5.2	4.1	1.31 (0.66,2.63)
Severe systemic disorder	17 (85)	3 (15)	4.2	1.8	*3.09 (0.85,11.22)*
Missing	32 (97)	1 (3)	4.8	3.2	-

[1]Age at operation, sex, age at follow-up and cohort adjusted estimates. HR in italics p<0.1

At 10% significance level, our results suggested that participants with a severe systemic disease (as defined by ASA score) at the time of the primary operation were three times more likely to stop working because of their hip post-operation compared with those classified as healthy individuals (HR: 3.09 95%CI 0.85,11.22).

<u>Clinical and surgical factors, and the risk of stopping paid work because of the replaced hip</u>

As shown in Table 73, neither the fixation method used nor the side where the operation was performed were significantly associated with stopping work due to the replaced hip. However, at a 10% significance level, the indication for THA was significantly associated with the risk of stopping paid work. Participants whose indication for THA was secondary OA had almost double the risk of stopping work when compared with those whose indication for surgery was primary OA (HR: 1.90 95%CI 0.91,3.95).

Table 73. Association between clinical and surgical factors and the risk of stopping a paid job post-THA because of the replaced hip

	Stopping work		Mean time to (years)		
	No n (%)	Yes n (%)	follow-up	Stopping work	HR[1] (95%CIs)
Indication for THA					
Primary OA	300 (94)	19 (6)	5.2	2.9	1
Secondary OA	117 (87)	18 (13)	6.1	2.1	*1.90 (0.91,3.95)*
Missing	17 (94)	1 (6)	4.8	3.2	-
Fixation					
Uncemented	179 (90)	19 (7)	5.7	3.5	1
Cemented	19 (95)	1 (5)	6.3	0.2	0.38 (0.05,2.96)
Hybrid	212 (93)	16 (7)	5.2	2.5	0.72 (0.35,1.47)
Missing	24 (92)	2 (8)	4.8	2.3	-
Side					
Left	218 (91)	21 (9)	5.4	2.9	1
Right	207 (91)	16 (7)	5.5	1.2	0.83 (0.43,1.58)
Missing	9 (90)	1 (10)	4.8	3.2	-

[1]Age at operation, sex, age at follow-up and cohort adjusted estimates. HR in italics indicates p<0.1

<u>Time to reach optimal function and function at best post-operatively in relation to the risk of having to stop paid work because of the replaced hip</u>

Table 74 summarises the relationship between function variables that related to best outcome reached post-arthroplasty and the necessary time to achieve the optimal function post-arthroplasty, and the risk of stopping work because of the replaced hip.

Table 74. Association between time to achieve optimal function and best function post-THA, and the risk of stopping work because of the replaced hip

	Stopping work		**Mean time to (years)**		
	No n (%)	**Yes n (%)**	**Follow-up**	**Stopping work**	**HR[1] (95%CIs)**
Time to best function					
< 1 year	345 (95)	19 (5)	5.4	3.0	1
≥ 1 year	74 (81)	17 (19)	5.2	1.3	**3.44 (1.77,6.69)**
Missing	15 (88)	2 (12)	6.6	4.2	-
Stick to walk					
No	410 (93)	31 (7)	5.4	2.9	1
Yes	14 (70)	6 (30)	4.9	3.1	**5.46 (2.21,13.45)**
Missing	10 (91)	1 (9)	5.8	2.3	-
Pain					
No	359 (95)	19 (5)	5.3	1.4	1
Yes	61 (77)	18 (23)	5.3	3.1	**4.52 (2.36,8.66)**
Missing	14 (93)	1 (7)	6.6	2.3	-

[1]Age at operation, sex, age at follow-up and cohort adjusted estimates

We found a clear positive association between both the need to use a stick when at their best, and of feeling pain (during the day or night) at their best and the risk of leaving a paid job because of their replaced hip. Individuals who used a stick were five times more likely to quit their job because of their hip when compared with those who did not (HR: 5.46 95%CI 2.21,13.45), and those who experienced pain were at over four-fold increased risk of stopping work when compared with those who were free from pain at their optimal function (HR: 4.52 95%CI 2.36,8.66). In separate analyses, we did however find that pain and using a stick to walk were correlated so that some of these findings are explained by collinearity.

In the next step, we assessed whether these associations remained significant after adjusting for baseline (level of education) and clinical (indication for THA) covariates that were previously identified at a 10% level of significance. The results, presented in Table 75, showed that after further adjustment, all three factors examined (time to optimal function, the use of a stick to walk, and pain during the day at their best) remained strongly associated with the risk of stopping a paid job due to the replaced hip. We therefore took forward these three covariates to the final models of the effects of occupational activities.

Table 75. Association between time to optimal function and best function characteristics post-THA, and the risk of stopping work because of the replaced hip, adjusted for baseline and clinical factors

	Stopping work		
	No n (%)	**Yes n (%)**	**HR[1] (95 CIs)**
Time to best function			
< 1 year	345 (95)	19 (5)	1
≥ 1 year	74 (81)	17 (19)	**3.43 (1.73,6.82)**
Missing	15 (88)	2 (12)	-
Stick to walk			
No	410 (93)	31 (7)	1
Yes	14 (70)	6 (30)	**5.01 (2.01,12.5)**
Missing	10 (91)	1 (9)	-
Pain during day			
No	359 (95)	19 (5)	1
Yes	61 (77)	18 (23)	**3.86 (2.01,7.43)**
Missing	14 (93)	1 (7)	-

[1]Age at operation, sex, age at follow-up, cohort, level of education and indication for THA adjusted estimates

<u>Leisure time and daily physical activities post-THA and the risk of having to stop work because of the replaced hip</u>

The results from examining the association between non-work related physical activity performed post-THA and the risk of stopping work because of the replaced hip, are shown in Table 76. Neither the number of years exposed to activity or the weekly hours engaged in LTPA and household activities were associated with the risk of leaving a paid job. We found that using physically inactive people as a referent group, those who engaged in high impact activities post-operation were at reduced risk of leaving work because of their hip by 79% (HR: 0.21 95%CI 0.06,0.69). Additionally, at a 10% significance level, medium impact activities reduced the risk of stopping work by 63% (HR: 0.37 95%CI 0.13,1.05) when compared with those who were inactive.

Table 76. Association between leisure time and daily activities post-THA and risk of stopping work because of the replaced hip

	Stopping work		Mean time to (years)		
	No n (%)	**Yes n (%)**	**Follow-up**	**Stopping work**	**HR[1] (95%CIs)**
Type of impact activity					
None	18 (82)	4 (18)	5.8	5.1	1
Low	140 (90)	16 (10)	5.5	2.2	0.47 (0.16,1.32)
Medium	144 (92)	13 (8)	5.3	1.8	*0.37 (0.13,1.05)*
High	110 (96)	5 (4)	5.3	5.2	**0.21 (0.06,0.69)**
Unknown	22 (100)	0	4.7	-	-
Frequency					
No activity	15 (79)	4 (21)	7.6	5.1	1
<weekly	162 (92)	14 (8)	5.9	3.2	**0.28 (0.10,0.80)**
≥ weekly	208 (93)	16(7)	5.3	1.3	**0.27 (0.09,0.77)**
Missing	49 (92)	4 (8)	4.7	3.2	-
Type of impact activity & frequency					
Inactive	15 (79)	4 (21)	7.6	5.1	1
Highly active	53 (98)	1 (2)	5.7	4.1	**0.06 (0.01,0.54)**
Medium active	332 (91)	33 (9)	5.4	2.4	**0.34 (0.13,0.91)**
Missing	34 (100)	0	4.8	-	-
Years exposed Median (IQR)	6.7 (5.3, 9.8)	7.4 (5.1, 12.9)	-	-	0.91 (0.77,1.08)
Hours/week Median (IQR)	4.0 (2.0, 10.0)	3.0 (1.5, 7.0)	-	-	0.97 (0.91,1.04)

[1]Age at operation, sex, age at follow-up and cohort adjusted estimates. HR italics indicates p<0.1

We also found that more frequent participation in LTPA reduced the risk of having to stop work because of the hip by about 73% when compared with those who were physically inactive.

An assessment of the combination of the type of impact activities and the frequency of participation, showed that those categorised as medium active participants were 56% less likely to leave their job because of the replaced hip (HR: 0.34 95%CI 0.13,0.91). An even greater reduction in the risk of leaving a paid job was observed in the group who engaged in high impact activities once a week or more, but these analyses were only based on one person who reported that they had left their job because of the replaced hip and were highly active.

Subsequently, we examined whether the associations observed between the leisure time and daily activities with the risk of stopping work remained after further adjustments. In this next analysis, presented in Table 77, we additionally adjusted for the baseline characteristics, clinical and surgical factors, and function factors at their best identified in the minimally adjusted models at a significance level of 10%.

Table 77. Associations between leisure time and daily physical activities post-THA and stopping work because of the replaced hip, adjusted for baseline, clinical and function factors

	Stopping work		
	No n (%)	**Yes n (%)**	**HR[1] (95 CIs)**
Type of impact activity			
None	18 (82)	4 (18)	1
Low	140 (90)	16 (10)	0.69 (0.23,2.06)
Medium	144 (92)	13 (8)	0.83 (0.26,2.67)
High	110 (96)	5 (4)	0.44 (0.12,1.62)
Unknown	22 (100)	0	-
Frequency			
None	15 (79)	4 (21)	1
< weekly	162 (92)	14 (8)	0.51 (0.16,1.57)
≥ weekly	208 (93)	16(7)	0.52 (0.16,1.65)
Missing	49 (92)	4 (8)	-
Type of impact activity & frequency			
Inactive	15 (79)	4 (21)	1
Highly active	53 (98)	1 (2)	*0.11 (0.01,1.10)*
Medium active	332 (91)	33 (9)	0.59 (0.20,1.72)
Missing	34 (100)	0	-
Years exposed Median (IQR)	-	-	0.93 (0.78,1.11)
Hours/week Median (IQR)	-	-	0.96 (0.89,1.03)

[1]Age at operation, sex, age at follow-up, cohort, level of education, indication for THA, time to best function, stick to walk at best post-THA, pain at best post-THA adjusted estimates. HR in italics indicates p<0.1

We found that, after these adjustments, most of the associations found in the minimally adjusted model for leisure time and daily activities (Table 76) no longer attained significance. However, the protective effect observed for the combination of high impact activities performed more than once a week remained. Given that amongst the highly active group of people, only one person had left their job due to the hip, we decided that this covariate could not be taken forward (Table 79).

<u>Physically-demanding occupational activities post-THA in relation to the risk of having to leave work because of the replaced hip</u>

The minimally adjusted models exploring the relationship between occupational activities performed post-arthroplasty and the risk of leaving the job because of a hip problem are shown in Table 78*.* After adjusting for sex, current age, age at operation and the cohort of origin, we found that standing for more than four hours a day, lifting or carrying ≥ 10kg, and kneeling or squatting at work were strongly associated with leaving a job post-arthroplasty because of the replaced hip.

Table 78. Association between physically-demanding occupational activities performed post-THA and stopping work because of the replaced hip

	Stopping work		**Mean time to (years)**		
	No n (%)	**Yes n (%)**	**Follow -up**	**Stopping work**	**HR[1] (95%CIs)**
Standing > 4h / day					
No	222 (96)	9 (4)	5.5	5.2	1
Yes	166 (90)	19 (10)	5.7	3.0	**3.50 (1.58,7.76)**
Missing	46 (82)	10 (18)	3.6	1.5	-
Walking > 2miles /day					
No	260 (94)	17 (6)	5.5	5.2	1
Yes	128 (92)	11 (8)	5.7	1.3	1.50 (0.71,3.17)
Missing	46 (82)	10 (18)	3.6	1.5	-
Lifting/carrying ≥ 10kg					
No	267 (96)	12 (4)	5.5	3.2	1
Yes	121 (88)	16 (12)	5.8	4.1	**3.38 (1.57,7.26)**
Missing	46 (82)	10 (18)	3.6	1.3	-
Lifting/carrying ≥ 25 kg					
No	337 (93)	24 (7)	5.5	4.1	1
Yes	51 (93)	4 (7)	5.5	0.3	1.42 (0.46,4.39)
Missing	46 (82)	10 (18)	3.6	1.3	-
Digging/shovelling					
No	364 (94)	25 (6)	5.5	4.2	1
Yes	24 (89)	3 (11)	3.6	1.3	2.46 (0.71,8.58)
Missing	46 (82)	10 (18)			-
Kneeling/squatting					
No	262 (96)	10 (4)	5.3	5.8	1
Yes	126 (88)	18 (12)	6.0	2.9	**4.21 (1.91,9.28)**
Missing	46 (82)	10 (18)	3.6	1.3	-
Climbing 30 flights of stairs / day					
No	283 (92)	23 (8)	5.3	4.1	1
Yes	105(95)	5 (5)	6.0	1.3	0.57 (0.21,1.58)
Missing	46 (82)	10 (18)	3.8	1.3	-
Climbing ladders					
No	319 (94)	22 (6)	5.4	4.1	1
Yes	69 (92)	6 (8)	5.9	3.2	1.58 (0.63,3.93)
Missing	46 (82)	10 (18)	3.6	1.3	-

[1]Age at operation, sex, age at follow-up, cohort adjusted estimates

Compared with not performing the occupational activity assessed, the risk of leaving a paid job post-operation because of the replaced joint was more than tripled in workers who stood for more than 4 hours a day (HR: 3.50 95%CI 1.58,7.76) and in those who lifted/carried ≥10 kg (HR: 3.38 95%CI 1.57,7.26). Additionally, participants kneeling/squatting were at over four-fold increased risk of quitting their job because of problems with the replaced joint (HR: 4.21 95%CI 1.91,9.28).

All the covariates identified in previous steps were taken forward to the final regression models, presented in Table 79, to examine the association between the occupational activities performed post-operation and the risk of leaving a job because of the replaced hip. The results across Model 1 (adjusted for baseline and clinical factors) and Model 2 (adjusted for baseline, clinical and optimal function related factors) were consistent. There was a strong association between leaving a job post-THA because of the replaced hip and standing for more than 4 hours a day (HR: 2.92 95%CI 1.26,6.75); lifting/carrying ≥ 10 kg (HR: 3.18 95%CI 1.39,7.28); and kneeling/squatting (HR: 4.50 95%CI 1.94,10.46) when compared with workers not performing these activities.

Table 79. Association between physically-demanding occupational activities performed post-THA and the risk of stopping work because of the replaced hip

	MODEL 1	**MODEL 2**
No vs Yes	**HR (95% CIs)**	**HR (95% CIs)**
Standing > 4h/ day	**3.10 (1.38,6.97)**	**2.92 (1.26,6.75)**
Walking > 2 miles/ day	1.38 (0.65,2.93)	1.27 (0.57,2.82)
Lifting / carrying ≥ 10kg	**2.87 (1.30,6.34)**	**3.18 (1.39,7.28)**
Lifting / carrying ≥ 25kg	1.23 (0.40,3.84)	1.03 (0.32,3.26)
Digging/shovelling	2.62 (0.73,9.39)	2.47 (0.69,8.88)
Kneeling/squatting	**3.98 (1.79,8.84)**	**4.50 (1.94,10.46)**
Climbing > 30 flights of stairs / day	0.64 (0.23,1.79)	0.65 (0.22,1.87)
Climbing ladders	1.65 (0.65,4.20)	1.79 (0.70,4.57)

Risk estimates shown come from separate regression models after adjustment for:
Model 1. Adjusted for: Age at operation, age at follow-up, sex, level of education, indication for THA, cohort.
Model 2. Adjusted for: Age at operation, age at follow-up, sex, level of education, indication for THA, time to best function, the use of stick at best function, pain at best function, cohort

In the subsequent analysis, we looked at different combinations of the 3 occupational activities that were significantly associated in Table 79 with the risk of leaving work post-arthroplasty (see Table 80). In this analysis, the referent group for comparison were those in sedentary occupations (no physically-demanding occupational activity reported) post-operatively. We found that people standing > 4 hours a day and also kneeling/squatting doubled their risk of quitting their job post-arthroplasty, regardless of the adjustments performed in Model 1 (HR: 2.19 95%CI 1.03,4.65) and Model 2 (HR: 2.81 95%CI 1.20,6.57). A combination of kneeling/squatting and lifting/carrying ≥ 10kg was also significantly associated with the risk of stopping work in Model 2, but not in Model 1.

When workers who reported standing > 4 hours/day & lifting/carrying ≥ 10kg were compared with people in a sedentary job, the estimated HRs yielded an increased risk of leaving a job post-operation because of the hip, however these results did not reach significance; Model 1 (HR:2.03 95%CI 0.92,4.46) and Model 2 (HR:2.31 95%CI 0.97,5.50).

Further regression analysis, in which the three physically-demanding occupational activities were mutually adjusted, showed reduction of the effects of standing for > 4 hours/day and lifting or carrying ≥ 10kg. However, the effect of kneeling/squatting remained statistically significant (p=0.037), indicating that this was having the strongest effect driving the associations between standing more than 4 hours, lifting/carrying ≥ 10 kg and needing to leave work because of the hip.

Table 80. Association between performing combined occupational activities post-THA and the risk of having to stop working because of the replaced hip

	MODEL 1	**MODEL 2**
Sedentary job vs occupational activities combined	**HR (95% CIs)**	**HR (95% CIs)**
Standing > 4 hours/day & lifting/carrying ≥ 10kg	2.03 (0.92,4.46)	2.31 (0.97,5.50)
Kneeling/squatting & lifting/carrying ≥ 10kg	1.98 (0.88,4.47)	**2.70 (1.10,6.66)**
Standing> 4 hours/day & kneeling/squatting	**2.19 (1.03,4.65)**	**2.81 (1.20,6.57)**

Risk estimates shown come from separate regression models after adjustment for:
Model 1. Adjusted for: Age at operation, age at follow-up, sex, level of education, indication for THA, cohort.
Model 2. Adjusted for Age at operation, age at follow-up, sex, level of education, indication for THA, time to best function, the use of stick at best function, pain at best function, cohort

Chapter 7 : Results from the Clinical Outcomes in Arthroplasty Study (COASt) – Knee arthroplasty

7.1 Response to the postal survey

The sample studied in this chapter comprised participants from the COASt study. These were eligible if they underwent a unilateral unicompartmental (UKA) or total knee arthroplasty (TKA) procedure at an age of ≤ 65 years, and the operation had been performed no later than December 2013. A total of 437 COASt participants that complied with our eligibility criteria were identified as shown in Figure 10.

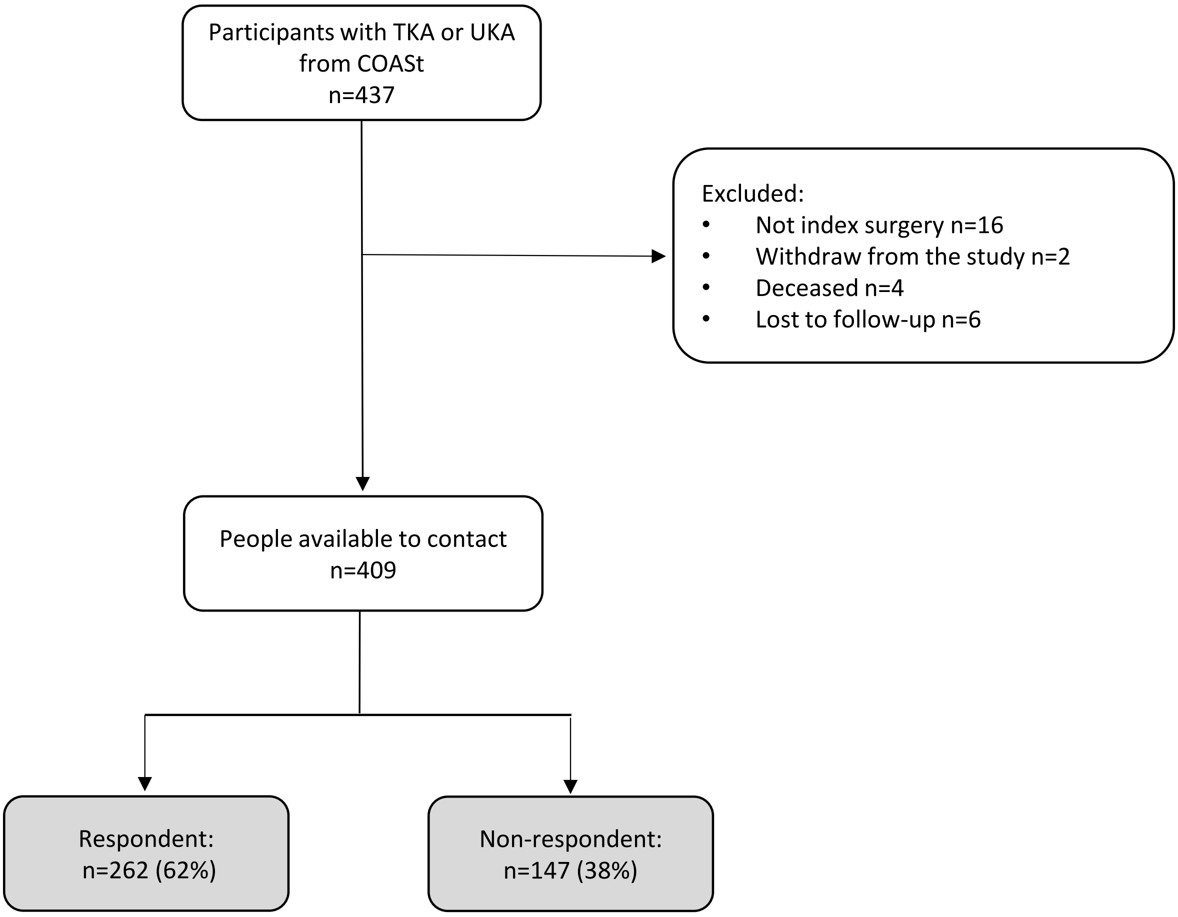

Figure 10. Flow chart summarising the eligibility and responses of the COASt participants-knee

In total, 28 people were excluded from the sample for the following reasons: i) a prior arthroplasty had been performed to another joint of the lower limb (described as "not index surgery" in Figure 10) ii) the address was not available or they had moved out of the country, iii) between the arthroplasty and the time at which the survey was sent the participant had died, and iv) the participant had withdrawn from the study. This resulted in 409 people to whom we posted the follow-up questionnaire, amongst whom 262 replied (response rate 62%) at a mean follow-up of 6.3 years (SD ± 1).

Sixteen of the non-respondents no longer lived at the address provided at the time of the surgery and letters were returned to us as unknown.

7.2 Description of the baseline characteristics of the knee arthroplasty patients in COASt

First, we evaluated whether there were significant differences across baseline characteristics between respondent and non-respondents. There were no differences in relation to health status at the time of the arthroplasty (as measured by ASA score) nor IMD score. However non-respondents tended to be women, younger at the time of knee arthroplasty and have a higher BMI > 30 kg/m^2.

Table 81. Differences in baseline characteristics between COASt-knee respondents and non-respondents

	Non-respondent n=147	**Respondent n=262**	**p-value**
Sex, n (%)			
Men	54 (38)	114 (44)	0.027
Women	88 (62)	148 (56)	
Age at TKA/UKA, median (IQR)	58 (52,62)	60 (55,64)	0.0002
ASA grade, n (%)			
I	16 (20)	58 (27)	0.0624
II	52 (64)	137 (64)	
III	13 (16)	19 (9)	
IMD* score, n (%)			
1 (least deprived)	33 (23)	48 (18)	0.085
2	34 (24)	46 (18)	
3	29 (20)	51 (20)	
4	16 (11)	64 (25)	
5 (most deprived)	30 (21)	50 (19)	
BMI, n (%)			
Normal	8 (6)	33 (13)	0.014
Overweight	41 (29)	92 (36)	
Obese	92 (65)	134 (52)	

The baseline characteristics of the respondents by sex are summarised in Table 82. Overall the sample comprised 251 respondents, 57% of whom were women. The arthroplasty was performed at a median age of 60 years (IQR: 55, 64), with primary OA being the main indication for the surgery (78%). Other indications for arthroplasty grouped as secondary OA were: rheumatoid arthritis (n=10), other inflammatory arthropathies (n=6) and other conditions (n=6). At the time of the primary operation approximately half were graded with a mild systemic disease (ASA score) and 8% of them reported that they were smokers (data not shown).

Table 82. Baseline demographic and clinical characteristics of the respondents from COASt – Knee, by sex

	All (n=251)	**Men (n=109)**	**Women (n=142)**
Age at TKA/UKA Median (IQR)	60 (55,54)	62 (56,64)	59 (54,64)
BMI mean (SD)	31.0 (5.7)	30.4 (5.1)	31.6 (6.0)
Indication for TKA/UKA, n (%)			
Primary OA	195 (78)	83 (76)	112 (79)
Secondary OA	22 (9)	10 (9)	12 (8)
Missing	34 (13)	16 (15)	18 (13)
ASA score, n (%)			
Healthy	56 (22)	34 (31)	22 (15)
Mild systemic disorder	130 (52)	46 (42)	84 (59)
Severe systemic disorder	18 (7)	7 (6)	11 (8)
Missing	47 (19)	22 (20)	25 (18)
Type of procedure, n (%)			
TKA	108 (43)	46 (42)	62 (44)
UKA	143 (57)	63 (58)	80 (56)

*Index of multiple deprivation

Two different types of surgical procedure had been carried out on cohort members; total and partial knee replacement, with the latter procedure type being the most prevalent (57%). Unfortunately, given the relatively small sample sizes involved, we could not analyse outcomes separately and therefore undertook analyses of the whole sample but adding the type of procedure as a covariate into each model.

We found significant differences between men and women in the median age at which the operation was performed, with women undergoing arthroplasty at a younger age (p=0.02), and having worse health than men measured by the ASA score (p<0.01). None of the remaining characteristics (indication for arthroplasty, BMI at baseline and IMD score) differed by sex.

Time to reach optimal function post-operatively

The time to obtain the best outcome in terms of pain reduction and physical function improvement post-arthroplasty varied across the COASt participants. Approximately one third of the participants (29%) achieved their best outcome from the operation in the first 6 months, 38% between 6 months and one year, 23% between one year and two years post-operation and 7% only after two years (figures not shown in tables).

Occupational status pre and post knee arthroplasty

The employment status of the respondents, both pre and post-arthroplasty, is described in Figure 11. A total of 91% of the study participants reported that they had had a job at some point in time before undergoing the partial or total knee replacement surgery. A further 9% had never held a paid job, and 1% did not answer this question. Amongst those people who had worked pre-arthroplasty, almost four out of five (78%) were employed rather than self-employed.

At the time of surgery 28% (64) of the 228 people who had worked had left their job, and in 26% cases (18/64) the knee was part of, or the main reason for having left their job.

For those 162 participants who held a job at the time of the UKA or TKA, 90% (146) continued working post-arthroplasty for at least one month. A further 11 people who were not working at the time of the operation, or who left this information unanswered, started a job at some point after the arthroplasty. Of the people who reported a job post-arthroplasty, a total of 130 (82%) held one job, 18 participants (11%) had two different jobs, and 6 people (4%) reported three different jobs following knee arthroplasty. At the time of completing the survey 84 participants were still working.

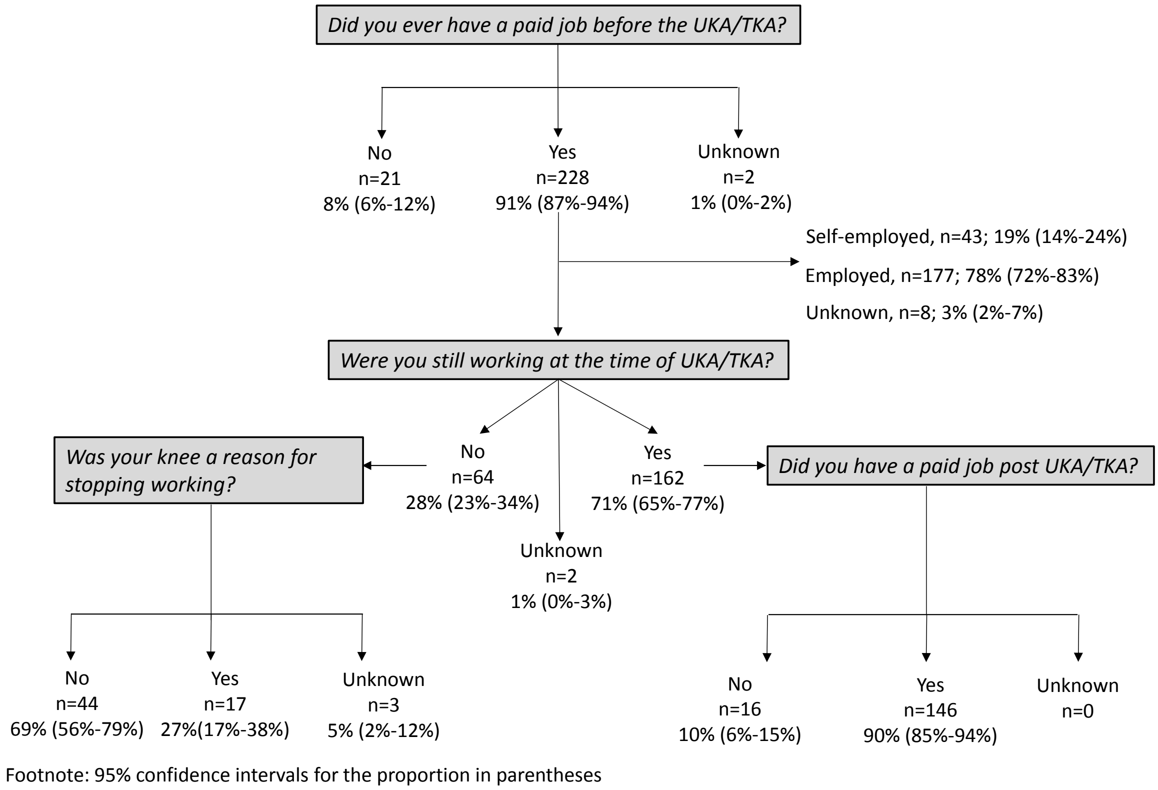

Figure 11. Flow chart showing occupational status pre and post knee arthroplasty

In order to examine whether being exposed to physically-demanding occupational activities post-knee arthroplasty has an effect on the replaced joint, we examined three different outcomes at a minimum of 5 years following the knee operation; i) the need for revision surgery due to implant failure, ii) poor function at follow-up measured by the Oxford Knee Score (OKS) and iii) the need to stop working because of having difficulties with their replaced knee.

7.3 Revision as an outcome of knee replacement

For this analysis knee arthroplasty failure was defined as either the need for a surgical procedure to convert UKA to TKA or an exchange of the knee implant. At a mean follow-up of 6.3 years (SD ± 0.96), 15 individuals (6%) out of the 251 reported having their knee implant revised.

In 5 out of the 15 people with a knee implant failure revision date was unknown. These 5 participants were 4 women and 1 men, who underwent TKA/UKA between 57 and 65 years of age. Most of them worked pre-arthroplasty (n=4) but only two returned to work post-operation. Two of these participants with an unknown revision date, had their knee revised within the first six months following the index operation, therefore in line with our exclusion criteria (such an early failure is more likely to be a complication of the operation or due to infection rather than result from post-operative physical exposures) these participants were excluded from the survival analyses. We checked hospital records for the other participants with an unknown revision date but we were unable to find records of revision procedures. This may mean that the revision procedure had been performed in a hospital other than the one in which the primary arthroplasty was performed but unfortunately meant that these participants could not be included in the survival analyses. Therefore, in total we could investigate risk factors for revision in 10 cases.

In this section we examined the association between different factors (baseline and clinical characteristics, time to reach best post-operative function and function related factors, LTPA post-TKA and occupational activities post-TKA) and the risk of knee revision. Since the number of revision procedures in our sample was small, we carried out a limited number of regression analyses using sex, age at operation, and type of procedure (UKA, TKA) as the minimal set of covariates adjusted for.

The prevalence rates presented in Table 83 and Table 84 are based on the people who reported having their knee revised at any time post-arthroplasty (n=15), whilst the estimates of risks were calculated based on the 10 people with a revision surgery date available.

Assessment of the associations between baseline characteristics at UKA/TKA and the risk of revision

Table 83 summarises the association between baseline characteristics and the risk of knee revision. None of the factors assessed (sex, age at the operation, level of education, BMI, smoking status, and ASA score) were significantly associated with the risk of knee revision.

Table 83. Association between baseline characteristics and risk of knee revision

	Revision		Mean time to (years)		
	No n (%)	Yes[1] n (%)	Follow-up	Revision	HR[1,2] (95% CIs)
Sex					
Males	103 (95)	6 (5)	6.3	4.1	1
Females	133 (94)	9 (6)	6.5	4.4	0.76 (0.22,2.66)
Age at UKA/TKA Median (IQR)	60.0 (55.0,64.0)	60.0 (57.0,65.0)	-	-	1.01 (0.90,1.13)
BMI					
Normal	30 (94)	2 (6)	6.9	4.4	1
Overweight	84 (94)	5 (6)	6.5	5.2	1.04 (0.11,10.08)
Obese	120 (94)	8 (6)	6.2	3.9	1.53 (0.18,12.76)
Missing	2 (100)	0	5.6	-	-
Education					
None	64 (94)	4 (6)	5.9	3.5	1
≤18 years	60 (94)	4 (6)	6.5	4.4	0.76 (0.17,3.39)
Higher education	56 (93)	4 (7)	6.2	5.2	0.91 (0.20,4.21)
Missing	56 (95)	3 (5)	7.1	-	-
Smoking					
No	175 (94)	11 (6)	6.4	4.4	1
Yes	20 (95)	1 (5)	6.2	4.4	1.08 (0.13,8.79)
Missing	41 (95)	3 (5)	6.6	-	-
ASA score					
Healthy	52 (93)	4 (7)	6.4	3.4	1
Mild systemic disorder	123 (95)	7 (5)	6.5	4.4	0.70 (0.15,3.31)
Severe systemic disorder	15 (83)	3 (17)	6.4	4.0	2.15 (0.32,14.21)
Missing	46 (98)	1 (2)	6.2	-	-

[1] To get estimated risks five people with uncertain dates of revision were excluded. [2]Adjusted for age at operation, sex and type of procedure

<u>Clinical and surgical characteristics in relation to risk of knee revision</u>

Similarly, neither the indication for the UKA/TKA (primary OA or secondary OA) nor the side where the operation was performed were significantly associated with knee revision (data not shown).

<u>Relationship between optimal function post-operatively, time to optimal function and risk of revision</u>

We then looked at reported function variables at their best post knee arthroplasty and the time taken to reach their best function in relation to the need for knee revision surgery. We found no significant associations between the risk of knee revision and: i) the time taken to reach the best possible function (<1 year vs ≥1 year) (HR: 1.43 95%CI 0.34,5.99), ii) the need to use a stick to walk (no vs yes) at their best post-arthroplasty (HR: 0.73 95%CI 0.08, 6.41) or iii) pain at night (no vs yes) at their best (HR: 3.41 95%CI 0.92, 12.56).

However, compared with those not feeling joint pain during the day at their best, participants who reported experiencing pain during the day despite being at their best post-operatively were significantly more likely to undergo knee revision (HR: 10.69 95%CI 2.93,39.00).

Leisure time and daily physical activities post-TKA/UKA in relation to risk of revision

Following partial or total knee replacement, 12% of the participants reported engaging in at least one high impact activity during the six year follow-up. No case of knee revision was self-reported amongst those who either: did not do physical activities post-operatively; nor amongst those who engaged in high impact activities post UKA or TKA. Therefore, to evaluate whether type of impact activity was a risk factor for revision, we compared participants who reported that they had engaged in medium impact activities against those who reported that they had performed only low impact physical activities post-operatively.

Similarly, the frequency at which the activities were performed (none, < once a week or ≥once a week), the number of years exposed to these activities post-operation and the number of hours per week doing the activities were not found to be associated with the subsequent risk of knee revision.

Exposure to physically-demanding occupational activities post UKA/TKA and risk of revision

A total of 158 out of the 251 participants (63%) worked post-arthroplasty for a mean time of 4.5 years (SD ± 2.1), with a minimum of 3 months at work and a maximum of 8.3 years. As described in Figure 11, 90% of those who were in paid work at the time of the primary operation returned to work after their arthroplasty.

The results for the association between working post-arthroplasty and risk of revision surgery did not reach significance. However the estimated hazard ratio yielded a 6-fold increased risk of knee revision for those who worked post-arthroplasty as compared with those who did not work with confidence intervals were very wide (HR: 6.68 95%CI 0.81,54.90).

To assess the effect of exposure to occupational activities post-arthroplasty on knee revision, the analyses only included people who worked post-arthroplasty (n=158). Amongst this group, 11 participants self-reported undergoing knee revision surgery. In Table 84 we compared workers that performed a specific occupational activity with those who did not carry out the activity in their post-operative employment. The results showed that those walking for more than 2 hours a day on an average working day were at five times higher risk of knee revision than those who did not (HR: 5.06 95%CI 1.01,25.30). None of the remaining occupational activities (lifting/carrying weights, digging/shovelling, kneeling/squatting, climbing > 30 flights of stairs/day) were significantly associated with the risk of knee revision.

No further analyses could be performed to evaluate the relationship between occupational activities post-arthroplasty and knee revision because of the small number of knee revisions available in the sample studied.

Table 84. Association between physically-demanding occupational activities performed post UKA/TKA and risk of knee revision

	Revision		**Mean time to (years)**		
	No n (%)	**Yes[1] n (%)**	**Follow-up**	**Revision**	**HR[1,2] (95% CIs)**
Standing > 4h /day					
No	67 (97)	2 (3)	6.3		
Yes	73 (89)	9 (11)	6.6	4.4	-
Missing	7 (100)	0	5.1	-	-
Walking > 2 miles /day					
No	82 (96)	3 (4)	6.4	3.6	1
Yes	56 (87)	8 (13)	6.6	4.4	**5.06 (1.01,25.30)**
Missing	9 (100)	0	5.1	-	-
Lifting/carrying ≥ 10 kg					
No	81 (93)	6 (7)	6.6	4.8	1
Yes	58 (92)	5 (8)	6.4	4.1	1.60 (0.39,6.54)
Missing	8 (100)	0	5.1	-	-
Lifting/carrying ≥ 25 kg					
No	107 (92)	10 (9)	6.5	4.4	-
Yes	30 (100)	0	6.5	-	-
Missing	10 (91)	1 (9)	5.2	5.1	-

	Revision		Mean time to (years)		
	No n (%)	Yes[1] n (%)	Follow-up	Revision	HR[1,2] (95% CIs)
Digging/shovelling					
No	118 (93)	9 (7)	6.4	4.4	1
Yes	19 (95)	1 (5)	6.8	3.4	0.58 (0.06,5.32)
Missing	10 (91)	1 (9)	5.2	5.1	-
Kneeling/squatting					
No	91 (92)	8 (8)	6.4	4.3	1
Yes	48 (94)	3 (6)	6.5	4.4	0.84 (0.21,3.42)
Missing	8 (100)	0	5.1	-	-
Climbing >30 flights of stairs /day					
No	109 (93)	8 (7)	6.6	4.4	1
Yes	30 (91)	3 (9)	6.4	4.6	1.01 (0.21,4.94)
Missing	8 (100)	0	5.1	-	-
Climbing ladders					
No	112 (94)	7 (6)	6.5	4.8	1
Yes	27 (90)	3 (10)	6.4	4.1	2.07 (0.40,10.74*)*
Missing	8 (89)	1 (11)	5.2	5.1	-

[1] To get estimated risks one people with uncertain dates of revision were excluded. [2] Age at operation, sex and type of procedure adjusted estimates

7.4 Factors associated with functional outcomes (as defined by the Oxford Knee Score (OKS)) at follow-up after partial or total knee arthroplasty surgery

In this section we explored factors associated with poor function at the time of questionnaire follow-up, and whether there was an association between return to work involving physically-demanding occupational activities and poor functional outcome score at a minimum of 5 years post UKA/TKA.

The PROM used to address this question was the Oxford Knee Score (OKS) (see section 3.4.5.3). We took the same approach as that used within the COASt hip cohort, in that we defined the group of people with the poorest function at follow-up based upon the categorization proposed by Kalairajah et al [195] in which the scores are: excellent (OKS > 41), good (OKS 34 to 41), fair (OKS 27 to 33), and poor (OKS < 27). In this analysis we excluded a total of 19 respondents from the original sample: i) those who self-reported that they had their knee revised (n=15), and also ii) those who did not complete the OKS score (n=4). This resulted in a sample of 232 individuals (102 men and 130 women) who completed their OKS at a minimum of 5 years and a maximum of 8.1 years post-knee arthroplasty. As shown in Table 85, at follow-up more than half the participants (54%) had an excellent OKS, 24% good, 10% fair but 12% were found to have a poor OKS. This latter group included 11 men and 16 women.

Table 85. Description of the Oxford Knee Score at follow-up

	All	Men	Women
OKS in categories			
Excellent	125 (54)	57 (56)	68 (52)
Good	55 (24)	21 (21)	34 (26)
Fair	25 (10)	13 (13)	12 (10)
Poor	27 (12)	11 (11)	16 (12)
OKS subscales, Median (IQR)			
Function	85 (70-95)	85 (70-95)	83 (70-90)
Pain	93 (77-100)	93 (71-100)	92 (79-100)

We examined the effect of a range of factors (baseline and clinical, optimal function and time to obtain it, leisure time and daily activities post-operation, and occupational activities post-operation) on the risk of having current poor OKS. All the models fitted (see Table 86 to Table 89) were adjusted for sex, age at questionnaire completion, duration of follow-up and type of procedure (UKA or TKA).

<u>Baseline characteristics at UKA/TKA and risk of poor OKS at follow-up</u>

In Table 86 the associations between baseline characteristics and the risk of poor OKS at follow-up are summarised. We found a significant association between being obese, smoking at the time of the arthroplasty and poorer health at the time of the primary surgery (measured by ASA score) with having poor OKS at follow-up.

Compared with participants of normal weight, those who were obese (BMI ≥30 kg/m^2) had a four-fold greater risk of current poor OKS (HR: 4.35 95%CI 1.10,17.15). Those who were smokers at the time of the arthroplasty were at three-fold increased risk of current poor OKS as compared with non-smokers (RR: 3.48 95%CI 1.46,8.29). Also participants who had a severe systemic disorder (ASA score =2) were more likely to have poor OKS at follow-up compared with those who were healthy (ASA score =0) (RR: 4.81 95%CI 1.42,16.27).

Table 86. Associations between baseline characteristics and the risk of poor OKS at follow-up

	Poor OKS		
	No n (%)	**Yes n (%)**	**RR[1] (95%CIs)**
Sex			
Males	91 (89)	11 (11)	1
Females	114 (88)	16 (12)	1.10 (0.54,2.25)
Age at TKA/UKA Median (IQR)	66.7 (61.3,69.8)	67.6 (57.8,69.8)	0.96 (0.91,1.02)
BMI			
Normal	38 (95)	2 (5)	1
Underweight	85 (95)	4 (5)	1
Overweight	74 (80)	19 (20)	0.98 (0.19,4.93)
Obese	8 (80)	2 (20)	**4.35 (1.10,17.15)**
Education			
Compulsory	56 (87)	7 (11)	1
Secondary	50 (83)	10 (17)	1.59 (0.63,4.03)
Further	53 (95)	3 (5)	0.41 (0.12,1.37)
Missing	46 (87)	7 (13)	-
Smoking			
No	158 (91)	15 (9)	1
Yes	14 (70)	6 (30)	**3.48 (1.46,8.29)**
Missing	33 (85)	6 (15)	-
ASA score			
Healthy	48 (92)	4 (8)	1
Mild systemic disorder	110 (92)	10 (8)	1.16 (0.37,3.64)
Severe systemic disorder	10 (67)	5 (33)	**4.81 (1.42,16.27)**
Missing	37 (82)	8 (18)	-

[1]Age at follow-up, sex, duration of follow-up and type of procedure adjusted estimates

None of the remaining factors explored (sex, age at operation or level of education) were significantly associated with the risk of poor OKS at follow-up.

Clinical and surgical characteristics and risk of poor OKS at follow-up

Neither of the clinical characteristics evaluated (indication for TKA/UKA and side of the surgery) were associated with poor OKS at follow-up (data not shown).

Time to reach optimal function and function at best post-operatively, and current pain/stiffness in the contralateral knee, in relation to the risk of poor OKS at follow-up

We found no significant association between the time taken for a participant to reach their optimal function post-arthroplasty and the risk of poor OKS at follow-up (Table 87). In contrast, the need to use a stick to walk, and feeling pain (during the day or at night) when they were at their best post-operation were significantly associated with current poor OKS.

The results also showed that participants who reported pain/stiffness in the contralateral knee at the time of the questionnaire completion, were at five-fold increased risk of having current poor OKS as compared with those free from these symptoms in the contralateral knee (HR: 5.18 95%CI 2.36,11.36).

Table 87. Association between time to best post-operative function, optimal function, function in the contralateral knee and poor OKS at follow-up

	Poor OKS		
	No n (%)	**Yes n (%)**	**RR[1] (95% CIs)**
Time to best function			
< 1 year	141 (90)	16 (10)	1
≥ 1 year	58 (85)	10 (15)	1.41 (0.67,2.96)
Missing	6 (86)	1 (14)	-
Stick to walk			
No	190 (94)	13 (6)	1
Yes	15 (52)	14 (48)	**13.72 (6.92,27.23)**
Pain			
No	156 (97)	5 (3)	1
Yes	49 (69)	22 (31)	**10.79 (4.18,27.86)**
Current pain/stiffness contralateral knee			
No	138 (95)	8 (5)	1
Yes	44 (71)	18 (29)	**5.18 (2.36,11.36)**
Missing	23 (96)	1 (4)	-

[1]Age at follow-up, sex, duration of follow-up and type of procedure adjusted estimates

Leisure time and daily physical activities post-TKA in relation to risk of poor OKS at follow-up

The relationship between leisure time and household activities post-TKA/UKA and poor OKS at follow-up are presented in Table 88. The results showed that the type of impact activities engaged in, and the frequency of participation, were significantly associated with the risk of poor OKS at follow-up.

Compared with people who reported no physical activity, those who engaged in low impact, or medium impact activities had a lower risk of poor OKS at follow-up. Those who participated in high impact activities also had a lower risk of poor OKS, but these results were based on a group of only 30 people amongst whom only one person self-reported poor OKS at follow-up.

Both the number of years exposed to leisure time and daily physical activities and the number of hours spent per week were also significantly associated with a lower risk of poor OKS at follow-up.

Table 88. Association between leisure time and daily physical activities post-arthroplasty and poor OKS at follow-up

	Poor OKS		
	No n (%)	**Yes n (%)**	**RR[1] (95% CIs)**
Type of impact activities			
None	8 (62)	5 (38)	1
Low	101 (86)	17 (14)	**0.38 (0.18,0.83)**
Medium	63 (94)	4 (6)	**0.15 (0.05,0.46)**
High	30 (97)	1 (3)	**0.07 (0.01,0.62)**
Unknown	3 (100)	0	
Frequency			
No activity	-	-	-
< weekly	77 (83)	16 (17)	1
≥ weekly	109 (95)	6 (5)	**0.30 (0.12,0.75)**
Missing	19 (79)	5 (21)	
Type of impact activities & frequency			
Inactive	-	-	-
Highly active	15 (94)	1 (6)	1
Medium active	179 (89)	21 (11)	1.81 (0.24,13.93)
Missing	11 (69)	6 (31)	
Years exposed Median (IQR)	5.4 (4.7, 6.5)	4.9 (4.4, 5.6)	**0.80 (0.64,0.99)**
Hours/week Median (IQR)	5.0 (2.0 ,10.0)	2.0 (1.0,4.0)	**0.88 (0.77,1.00)**

[1]Age at follow-up, sex, duration of follow-up and type of procedure adjusted estimates

Physically-demanding occupational activities post TKA/UKA and the risk of poor OKS at follow-up

In this sub-section we compared participants who worked following partial or total knee replacement versus those who did not. We found that returning to work post-operation was associated with a reduced risk of having current poor OKS by 82% (RR: 0.18 95% CI 0.08,0.37).

For the analyses related to the physically-demanding occupational activities performed post-arthroplasty, the sample was limited to people who self-reported that they worked for at least one month post-operation (n=146). We assessed the associations between the types of occupational activities performed post-arthroplasty and the risk of current poor OKS. The estimated HRs compared workers who performed a physically-demanding occupational activity and those who did not. The covariates considered in these regression models were sex, age at follow-up, duration of follow-up and type of procedure (UKA or TKA).

The results are presented in Table 89. A total of 9 participants (6%) had current poor OKS, only 4 of whom reported doing at least one occupational activity (e.g. standing more than four hours/day). With such small numbers, some of the confidence intervals estimated were wide and did not reach significance. However, people who lifted/carried ≥25 kg were at significantly increased risk of having poor OKS at follow-up when compared with those who did not (RR: 5.44 95%CI 1.02,29.03). None of the remaining activities assessed were significantly associated with the risk of having a poor OKS at follow-up.

Table 89. Association between physically-demanding occupational activities post-arthroplasty and the risk of poor OKS at follow-up

	Poor OKS		
	No n (%)	**Yes n (%)**	**RR[1] (95%CIs)**
Standing > 4h / day			
No	61 (92)	5 (8)	1
Yes	69 (95)	4 (5)	1.47 (0.48,4.46)
Missing	7 (100)	0	-
Walking > 2 miles / day			
No	75 (93)	6 (7)	1
Yes	53 (94)	3 (5)	0.75 (0.20,2.80)
Missing	9 (100)	0	-
Lifting / carrying ≥ 10kg			
No	75 (94)	5 (6)	1
Yes	54 (93)	4 (7)	*2.30 (0.77,6.87)*
Missing	8 (100)	0	-
Lifting/ carrying ≥ 25kg			
No	100 (94)	7 (7)	1
Yes	27 (93)	2 (7)	**5.44 (1.02,29.03)**
Missing	10 (100)	0	-
Digging/shovelling			
No	110(90)	8 (7)	1
Yes	17 (94)	1 (6)	3.88 (0.46,32.83)
Missing	10 (100)	0	-
Kneeling/squatting			
No	85 (93)	6 (7)	1
Yes	45 (96)	2 (4)	1.44 (0.27,7.54)
Missing	9 (90)	1 (10)	-
Climbing >30 flights stairs /day			
No	101 (93)	8 (7)	1
Yes	28 (97)	1 (3)	0.71 (0.09,5.94)
Missing	8 (100)	0	-

	Poor OKS		
	No n (%)	**Yes n (%)**	**RR[1] (95%CIs)**
Climbing ladders			
No	104 (93)	8 (7)	1
Yes	25 (96)	1 (4)	2.77 (0.29,26.60)
Missing	8 (100)	0	-

[1]Age at follow-up, sex, duration of follow-up and type of procedure adjusted estimates. HR in italics p<0.1

7.5 Returning to work post-arthroplasty and reporting having to give up work because of difficulties with the replaced knee

For the analyses described in this section we were able to include 145 individuals, who: i) provided a beginning and ending date for the job performed post knee arthroplasty or ii) confirmed that they were still working when the questionnaire was completed. The mean time in work after arthroplasty was 4.6 years (SD ± 2.1), with a minimum of 3 months and a maximum of 8.3 years. Fifteen (10%) of the 145 individuals reported that they left their job mainly or partly because they had problems with their replaced knee. Nine of the people who stopped working had a TKA procedure and a further 6 a UKA procedure.

One person reported that they had left two jobs post-arthroplasty, in both cases due to the replaced knee. As discussed in the methods section we calculated time at risk for each participant from the date they started to work post-arthroplasty to the date the first event occurred; to the time they completed the follow-up questionnaire if the participant was working at follow-up, or until the date they stopped their work for any reason.

In Table 90, Table 91 and Table 92, we examined the relationship between predictor factors (baseline and clinical factors, optimal function post-operation and time to achieve optimal function, leisure time and daily physical activity post-operation, and occupational activities post-operation) and leaving a paid job post-arthroplasty because of difficulties with the replaced knee.

<u>Baseline characteristics at UKA/TKA and the risk of stopping paid work because of the replaced knee</u>

Associations between baseline characteristics and the risk of leaving a job due to the replaced knee are summarised in Table 90. None of the participants who were smokers at the time of the arthroplasty, or who had a severe systemic disorder, stopped working post-operation because of the replaced knee. We found no significant association between the factors assessed (sex, age at knee replacement, BMI, level of education at baseline) and the risk of quitting a job post-arthroplasty.

Table 90. Association between baseline characteristics and stopping paid work because of the replaced knee

	Stopping work		Mean time to (years)		
	No n (%)	Yes n (%)	Follow-up	Stopping work	HR[1] (95%CIs)
Sex					
Males	61 (91)	6 (9)	4.8	2.4	1
Females	69 (88)	9 (12)	4.8	3.3	1.16 (0.44,3.06)
Age at UKA/TKA Median (IQR)	58 (53,63)	58 (52,64)	-	-	1.18 (0.71,1.97)
BMI					
Normal Underweight	21 (91)	2 (9)	4.8	1.8	1
Overweight	48 (89)	6 (11)	4.8	3.4	1.38 (0.27,7.01)
Obese	60 (90)	7 (10)	5.3	2.9	1.42 (0.30,6.76)
Missing	1 (100)	0	4.7	-	-
Education					
Primary	29 (91)	3 (9)	4.8	3.9	1
Secondary	29 (88)	4 (12)	5.6	4.2	0.84 (0.21,3.41)
Further	37 (90)	4 (10)	4.8	2.9	0.85 (0.22,3.27)
Missing	35 (90)	4 (10)	-	-	-
Smoking					
No	93 (89)	12 (11)	4.8	3.3	-
Yes	12 (100)	0	5.3	-	-
Missing	25 (89)	3 (11)	2.9	1.8	-
ASA score					
Healthy	35 (95)	2 (5)	5.6	3.4	-
Mild systemic disorder	60 (86)	10 (14)	4.4	3.8	-
Severe systemic disorder	7 (100)	0	4.1	-	-
Missing	28 (90)	3 (10)	4.8	2.1	-

[1]Age at follow-up, sex, age at operation, type of procedure adjusted estimates

<u>Clinical characteristics and the risk of having to stop paid work because of the replaced knee</u>

The analysis showed that the side of the operation (right or left) was not associated with leaving the job post-operation. Additionally, none of the participants with secondary OA as an indication for TKA or UKA left their job due to the replaced knee (data not shown).

<u>Relationship between optimal function post-operatively, time to attain optimal function and risk of having to stop paid work because of the replaced knee</u>

The relationship between optimal function related variables, time to achieve this optimal function and stopping work because of the replaced knee are presented in Table 91. We found that the time taken to reach their best function following knee arthroplasty was not significantly associated with the risk of stopping work. However, people who reported pain, either during the day or at night, at the time when they obtained their optimal function post-arthroplasty were four times more likely to leave a job due to the replaced knee as compared with those who reported no pain when at their best function (HR: 4.13 95%CI 1.53,11.16). Likewise, needing to use a stick to walk when at their best post-arthroplasty was significantly associated with stopping work because of the replaced knee but with wide confidence intervals (HR: 5.14 95% CI 1.06,24.86).

Table 91. Association between time to best function and optimal function post-arthroplasty and stopping work because of the replaced knee

	Stopping work		Mean time to (years)		
	No n (%)	**Yes n (%)**	**Follow-up**	**Stopping work**	**HR[1] (95%CIs)**
Time to best function					
< 1 year	91 (92)	8 (8)	4.8	2.1	1
≥ 1 year	33 (83)	7 (17)	4.8	3.9	1.63 (0.61,4.30)
Missing	6 (100)	0	5.0	-	-
Stick to walk					
No	128 (91)	13 (9)	4.8	2.9	1
Yes	2 (20)	2 (50)	6.0	1.2	**5.14 (1.06,24.86)**
Pain					
No	101 (94)	7 (6)	4.8	1.1	1
Yes	29 (78)	8 (22)	4.9	2.8	**4.13 (1.53,11.16)**

[1]Age at follow-up, sex, age at operation, type of procedure adjusted estimates

<u>Leisure time and daily physical activities post UKA/TKA in relation to the risk of having to stop paid work because of the replaced knee</u>

Neither the participants who were inactive (no physical activity reported) nor those who engaged in high impact activities post operation, left their job because of the operated knee. We therefore compared workers who performed low impact activities with those who reported medium impact activities, but found no association between the type of impact activity and leaving the job post-operation (Data not shown).

None of the remaining factors examined: frequency of the physical activities performed; the number of years exposed; or the weekly hours of leisure and daily activities were significantly associated with stopping work due to the replaced knee.

We were unable to combine the type of impact activity with the frequency at which this was performed, as nobody in the remaining sample reported carrying out any type of high impact activity.

<u>Physically-demanding occupational activities post UKA/TKA in relation to the risk of having to stop paid work because of the replaced knee</u>

We next evaluated the associations between occupational activities performed post knee arthroplasty and the risk of stopping work. The results, summarised in Table 92, showed a strong association between lifting or carrying ≥ 10 kg, and climbing 30 flights of stairs per day with the risk of stopping work due to the replaced knee.

Table 92. Association between physically-demanding occupational activities post-arthroplasty and stopping work because of the replaced knee

	Stopping work		Mean time to (years)		
	No n (%)	Yes n (%)	Follow-up	Stopping work	HR[1] (95%CIs)
Standing > 4h / day					
No	64 (93)	5 (7)	4.9	2.4	1
Yes	66 (87)	10 (13)	4.8	3.3	2.65 (0.92,7.59)
Walking > 2 miles / day					
No	77 (91)	8 (9)	4.9	2.4	1
Yes	53 (88)	7 (12)	4.8	3.2	1.62 (0.60,4.38)
Lifting carrying ≥ 10 kg					
No	82 (94)	5 (6)	4.9	2.4	1
Yes	48 (83)	10 (17)	4.8	3.2	**4.57 (1.52,13.79)**
Lifting carrying ≥ 25 kg					
No	104 (89)	13 (11)	4.8	2.4	1
Yes	26 (93)	2 (7)	4.8	4.1	0.48 (0.10,2.24)
Digging/shovelling					
No	114 (90)	13 (10)	4.8	2.7	1
Yes	16 (89)	2 (11)	4.6	3.1	1.01 (0.22,4.68)
Kneeling/squatting					
No	91 (92)	8 (8)	4.8	1.4	1
Yes	39 (85)	7 (15)	4.8	3.8	2.35 (0.90,6.16)
Climbing 30 flights of stairs /day					
No	109 (93)	8 (7)	4.8	2.1	1
Yes	21 (75)	7 (25)	4.8	3.9	**3.52 (1.29,9.59)**
Climbing ladders					
No	107 (90)	12 (10)	4.8	2.5	1
Yes	23 (88)	3 (12)	4.8	3.9	0.82 (0.21,3.21)

[1]Age at follow-up, sex, age at operation, type of procedure adjusted estimates.

After controlling for age at follow-up, sex, age at operation and type of procedure performed, workers lifting or carrying ≥ 10 kg were 4 times more likely to report that they had needed to stop a job as compared with those who did not carry out occupational lifting (HR: 4.57 95%CI 1.52,13.79). Similarly, those who climbed 30 flights of stairs/day were three times more likely to report that they had left a job post-arthroplasty because of their replaced knee (HR: 3.52 95%CI 1.29,9.59). Additionally, although non-significant, the estimated effect for leaving a job post-arthroplasty was more than doubled in those who reported that they stood for more than 4 hours/day (HR:2.65 95%CI 0.92,7.59) or that they knelt or squatted (HR: 2.35 95%CI 0.90,6.16) when compared with workers who did not.

In our sample, only 145 (58%) of the 251 people who underwent knee arthroplasty worked post-arthroplasty, of which 65% had a UKA procedure and 35% a TKA procedure. The size of this sub-sample limited any further analyses and in particular prevented further adjustments using clinical or surgical factors identified in Table 91 to explore whether the associations observed in the minimally adjusted model related to occupational activities (Table 92) persisted.

Chapter 8 : Summary of the associations between post-operative occupational and non-occupational physical activities and the risk of revision, poor function and workability post-arthroplasty

Chapter 1 to Chapter 7 detail the set of analyses performed in the GAR and COASt cohorts to investigate our principal research questions. The aim of this Chapter is to summarise the key findings in relation to post-operative occupational and non-occupational physical activities and the risk of revision, poor function and workability post-arthroplasty.

Overall, our results show that lower limb arthroplasty (total hip, total knee and unicompartmental knee) are very successful procedures. With minimum of 5 and maximum of 22 year follow-up, we found a low rate of revision surgery, and a high prevalence of excellent or good self-reported function. In these cohorts, most of the participants who were working at the time of the operation, regardless of whether they underwent hip or knee replacement, returned to work following a period of recovery, and remained in work for approximately five years post-operation.

However, we identified a group of participants who reported either that it took more than one year post-operatively for them to reach their best function or that, even at their best function, they were experiencing pain in that joint during the day (and during the night for TKA and UKA) or that they used a stick to walk whilst at their “best” function. Amongst these people, there was a higher risk of poor function at follow-up, but there was also a higher risk of revision surgery.

Table 93 to Table 96 summarise the results of the analyses exploring the effects of post-operative occupational activities, leisure and daily physical activities on the risk of revision surgery, poor function at follow-up or ability to work following lower limb arthroplasty for each of the cohorts researched. The estimated risks shown in these tables correspond to the regression models with most adjustments.

The tables highlight statistically significant associations, and also non-significant associations with a HR or RR that yielded an estimated doubling of the risk of the outcome examined. We chose to highlight these estimated risks for two reasons. Firstly, despite our efforts, we were in the end only able to include two cohorts of patients with a fairly limited number of adverse outcomes, making the investigation relatively underpowered and highlighting these might point to potential risks to the replaced joint that should be taken into consideration. Secondly, in the UK, the government administers a non-fault compensation scheme (the Industrial Injuries Disablement Benefit (IIDB)) for people who have sustained harm or disease that it can be reasonably assumed to have been caused by their occupation, on the balance of probabilities. For diseases which are caused only by work, the attribution is very straightforward. However, for other conditions that can be caused by both occupational and non-occupational causes e.g. lung cancer, knee OA, they appear identical whatever the cause. In such cases, the Industrial Injuries Advisory Council looks for consistent epidemiological evidence of at least double the risk of the disease associated with the occupation or occupational exposure [50]. Using these criteria, IIDB is currently paid for people disabled with hip OA associated with farming, and knee OA associated with coal mining and carpet and floor fitting and laying. Therefore, if failure of lower limb arthroplasty were consistently found to be associated with one or more occupational exposures with a risk raised > 2-fold, prescription could potentially be recommended.

8.1 Physical activity performed after hip arthroplasty

Table 93 summarises the main findings from the analyses of the associations between post-operative occupational activities and the risk of revision surgery, poor function and having to stop work because of the replaced hip.

a) Occupational activities

Revision. Self-reported post-operative kneeling or squatting at work was the only occupational exposure which increased the risk of revision of the hip arthroplasty with a HR of 4.35 (95%CI 1.10,17.28) in the GAR cohort. Interestingly when we combined data from both hip cohorts, the estimated association for revision associated with kneeling or squatting became non-significant and the HR was below 2. Self-reported climbing over 30 flights of stairs per day appeared to convey a protective effect (HR: 0.20 95%CI 0.02,1.78) although this finding was not statistically significant at the 95% level of confidence. None of the other occupational activities that were assessed (standing more than 4 hours a day, walking >2 miles a day, lifting or carrying weights >25 kg, digging or shovelling, and climbing ladders) were found to be risk factors for revision surgery.

Table 93. Summary of the estimated effects found between occupational activities performed post THA and the risk of revision, poor function and workability

	REVISION			POOR FUNCTION					STOPPING WORK		
Occupational activities (No vs Yes)	**GAR**	**COASt**	**BOTH**	**GAR, OHS**	**GAR, PCS**	**GAR WOMAC 12 p.f**	**COASt OHS**	**BOTH, OHS**	**GAR**	**COASt**	**BOTH**
Standing > 4h/ day	○		○	○	○	○			++	++	+++
Walking > 2 miles/ day	○		○		○	○			○	++	○
Lifting / carrying ≥ 10kg	○		○	○	++	○			++	+++	+++
Lifting / carrying ≥ 25kg	○		○	++	○	+++			○	++	○
Digging / shovelling			○		○	++			○	+++	++
Kneeling / squatting	+++		○	++	++	++			+++	+++	+++
Climbing > 30 flights of stairs / day	– –		– –	○	○	○			○		○
Climbing ladders	○		○		++	○			○	+++	○
Sedentary job vs combination of two occupational activities											
Standing > 4hours & kneeling/squatting									++		+++
Standing > 4hours & lifting/carrying ≥ 10kg									○		++
Kneeling/squatting & lifting/carrying ≥ 10kg					++				○		+++
Kneeling/squatting & lifting/carrying ≥ 25kg	++			– –		++					

+++	Statistically significant association (α=5%)
○	Non-statistically significant (α=5%)
– –	Non- statistically significant results (α=5%) showing a protective effect for the outcome (≥50% risk reduction)
++	Non-statistically significant results, with estimated HR or RR ≥ 2.0
(grey)	Too few data to perform the analysis

Function. Lifting or carrying ≥25 kg at work was a risk factor for poorer functional outcomes according to two PROMs (WOMAC-12 physical function and OHS), but in the case of the OHS, the effect did not reach significance. Kneeling or squatting at work appeared to be a risk factor for poor function at follow-up for all three of the PROMs used to measure function at follow-up, but did not reach significance. Less consistent evidence was seen for three further occupational exposures: lifting/carrying ≥ 10kg; digging/shovelling at work and climbing ladders, for each of which an elevated risk of poor function was found but only in one of the PROMs used, and the associations did not reach significance.

Stopping work. Interestingly, when the outcome was self-reported having had to stop a job partly because of the replaced hip, all physically-demanding work exposures except for climbing > 30 flights of stairs per day appeared to increase the risk (although not always statistically significantly). In particular, standing for more than 4 hours a day; lifting/carrying ≥10 kg; digging/shovelling, climbing ladders, and kneeling or squatting were significantly associated with an increased risk of this outcome. When we investigated associations between combinations of occupational activities with a HR over two, we found that the combination of standing for more than 4 hours per day and kneeling or squatting, and lifting/carrying ≥10kg and kneeling or squatting were significant risk factors for needing to stop working because of problems with the replaced joint. Moreover, in subsequent mutually adjusted models carried out to determine whether it was one of these three activities in particular that was leading to stopping work, or the combination of several activities, we found that kneeling or squatting was the key risk factor that was, partly or mainly, driving the risk of having to stop a job post arthroplasty because of the replaced hip.

b) Leisure time and daily physical activities

The follow-up questionnaire asked participants to estimate, for each type of leisure time physical activity, how long in duration they were engaged with those activities after the arthroplasty and how much time on average they spent doing that activity each week. In Table 94 and Table 96, the results are presented according to each of those categorisations. The main associations between leisure time and daily physical activities performed post-THA and; i) the risk of hip revision, ii) poor function at follow-up, and iii) self-reported risk of stopping work because of the replaced hip are summarised in Table 94.

Revision. At the time of follow-up (6 years post-arthroplasty in the COASt cohort) there were too few revision hip arthroplasties to analyse the effect of physical activities. However, in GAR, with longer follow-up available, self-reported post-operative engagement in high impact activities (e.g. football or skiing) or being a highly active participant (defined as doing high impact activities more than once a week), both showed a non-significantly increased risk of revision of the hip arthroplasty. When both datasets were combined however, engagement in medium-impact activities, high-impact activities and engagement in sport at least weekly (at any intensity) were associated with an increased (non-significant) risk of revision of the hip. Interestingly, in these combined analyses, highly active participants were at significantly increased risk (HR: 4.05 95%CI 1.09,15.00). Neither the amount of years that people self-reported being engaged in any type of non-work related physical activity, nor the hours per week that the participants undertook sport or daily activities, were found to be associated with the risk of revision.

Poor Function as defined by PROMs at follow-up. None of the categories assessed for leisure time and household activities were associated with an increasing risk of poor function at follow-up measured by any of the included PROMs. However a protective effect against the risk of poor function at follow-up was found. In particular, low-impact physical activities e.g. walking or swimming (RR: 0.18 95%CI 0.05,0.60) and medium impact activities (RR: 0.03 95%CI 0.00,0.29) significantly reduced the risk of poor function in the COASt cohort at follow-up. The reported number of hours doing the activities significantly reduced the risk of a poor WOMAC-12 p.f. (RR: 0.94 95% CI 0.88,0.99), as did reporting doing leisure activities at least once a week, using the physical component of PCS to measure function (RR:0.40 95%CI 0.17,0.90). Based on results from this same PROM (PCS), engagement in high impact activities and a combination of high impact activities at least once a week (highly active people) were associated with a non-significant reduction of poor function in the GAR hip arthroplasty cohort.

Table 94. Summary of the estimated associations found between leisure and daily physical activities performed post THA and the risk of revision, poor function and workability

	REVISION			POOR FUNCTION				STOPPING WORK		
	GAR	COASt	BOTH	GAR OHS	COASt OHS	GAR PCS	GAR WOMAC 12 p.f	GAR	COASt	BOTH
Low impact activities	○		○	○	– – –	○	○	– –	○	○
Medium impact activities	○		++	– –	– – –	○	○	○	– –	○
High activity impact activities	++		++			– –	○	– –		– –
Frequency; < weekly	○		○	○		○	○	– –		– –
Frequency; ≥ weekly	○		++	○	○*	– – –	○	– –	++*	– –
Highly active participants	++		+++			– –				– –
Medium active participants	○		○	○		○	○	– –		○
Years exposed	○		○	○	○	○	○	○	○	○
Hours/week exposed	○		○	○	○	○	– – –	○	○	○

+++	Statistically significant association (α=5%)
++	Non-statistically significant results, with estimated HR or RR ≥ 2.0
○	Non-statistically significant results (α=5%)
– –	Non-statistically significant results showing a protective effect for the outcome studied (≥50% risk reduction)
– – –	Statistically significant results (α=5%) showing a protective effect for the outcome studied
	Limited data to perform the analysis

*≥ Once a week versus < once a week

Stopping work because of a problem with the replaced hip. For this outcome, also summarised in Table 94, no leisure time activity category was associated with a significant increased risk of reporting having had to leave a job because of the replaced hip. However, several categories were non-significantly associated with a protective effect on leaving the job post-operation. For instance, engaging in high impact activities appeared to decrease the risk of stopping a job (not statistically significantly) in GAR and in the combined analyses for GAR and COASt. However, reporting higher frequency participation in sport (at least once weekly) appeared to increase the risk of reporting having stopped work in COASt, although these findings were based on small numbers.

None of the analyses performed found the number of years, or the average weekly hours spent doing leisure activities to be associated with the risk of quitting a job.

8.2 Physical activity performed after knee arthroplasty

The results of the analyses exploring the associations between occupational activities performed post-TKA/UKA and risk of revision surgery, poor function and reporting having had to stop working mainly or partly because of the replaced knee are summarised in Table 95.

a) Occupational activities

Revision. Self-reported walking for more than 2 miles a day at work after knee arthroplasty was found to be a significant risk factor for revision arthroplasty (HR:5.06 95%CI 1.01,25.30). Climbing up and down ladders after knee arthroplasty was also associated with a non-significantly elevated risk of revision of the knee arthroplasty. In two of the six remaining occupational activities, the small numbers did not allow us to fit models, and none of the rest of the occupational activities (lifting/carrying ≥10kg, digging/shovelling, kneeling/squatting, climbing >30 flights of stairs) were found associated with an increasing risk of revision surgery.

Poor function at follow-up. Four occupational activities were associated with an increased risk of a poor OKS at follow-up (lifting/carrying weights of ≥10 kg and ≥25kg; digging/shovelling and climbing up and down ladders). However, only carrying/lifting the heavier weights (≥25kg) was significantly associated.

Stopping work. As with hip arthroplasty, a number of physically-demanding activities were associated with an increased risk of stopping a job in part because of the replaced knee: standing >4 hours/day; lifting/carrying ≥10kg; kneeling/squatting and climbing > 30 flights stairs/day, but only carrying ≥10kg and climbing >30 flights stairs/day were significantly associated with quitting a job after knee surgery. However, it appeared that carrying heavier weights (≥25kg) conveyed some protection against this outcome, although this was not significant.

Table 95. Summary of the estimated effects found between the occupational activities performed post TKA/UKA and the outcomes assessed

Occupational activities (No vs Yes)	REVISION	POOR FUNCTION	STOPPING WORK
Standing > 4h/ day		○	++
Walking > 2 miles/ day	+++	○	○
Lifting / carrying ≥ 10kg	○	++	+++
Lifting / carrying ≥ 25kg		+++	– –
Digging / shovelling	○	++	○
Kneeling / squatting	○	○	++
Climbing > 30 flights of stairs / day	○	○	+++
Climbing ladders	++	++	○

+++	Statistically significant association (α=5%)
++	Non-statistically significant results, with estimated HR or RR ≥ 2.0
○	Non-statistically significant results
– –	Non-statistically significant results showing a protective effect for the outcome studied (≥50% risk reduction)
(grey)	Limited data to perform the analysis

b) Leisure time and daily physical activities

Finally, the results from the analysis that explored the associations between leisure time and daily physical activities post-TKA/UKA and the risk of knee revision, poor function at follow-up and having to stop work because of the replaced knee are presented in Table 96.

None of the variables examined in relation to leisure-time and daily physical activity were associated with an increased risk of any of the adverse outcomes explored (revision, poor function at follow-up or leaving a job post-operation). There was however, convincing and statistically significant evidence of a reduced risk of poor OKS at follow-up associated with engagement in non-work related physical activity following knee arthroplasty.

Table 96. Summary of the estimated effects of leisure and daily physical activities performed post TKA/UKA and the outcomes assessed

	REVISION	POOR FUNCTION	STOPPING WORK
Low impact activities		– – –	
Medium impact activities	– –*	– – –	○*
High activity impact activities		– – –**	
Frequency; ≥ weekly	○	– – –	○
Highly active participants			
Medium active participants		○***	
Years exposed	○	– – –	○
Hours/week exposed	○	– – –	○

*Medium impact activities against low impact activities; ** Results based on 1 event; ***Compared with highly active (highly active group with one event)

+++	Statistically significant results (α=5%)
++	Non-statistically significant results, with estimate HR or RR ≥ 2.0
○	Non-statistically significant results
– –	Non-statistically significant results showing a protective effect for the outcome studied (≥50% risk reduction)
– – –	Statistically significant results (α=5%) showing a protective effect for the outcome studied
	Limited data to perform the analysis

This Chapter presented a summary of the results of the analyses in which the associations between occupational and non-occupational physical exposures performed post-arthroplasty and the risk of revision, poor function at follow-up and workability after both hip and knee arthroplasty were evaluated. There is some evidence to suggest that some post-operative occupational exposures, in particular kneeling/squatting may increase the risk of revision surgery after THA. Moreover, it appeared that jobs requiring any of a range of physical exposures post-THA were challenging and it was more likely that people left that work because of their hip. After THA, there was some evidence that exposure to higher impact leisure at least once a week might increase the risk of revision surgery. However, engaging with leisure time activities was generally protective against poor function at follow-up. After TKA/UKA, there was some suggestion that needing to walk > 2 miles/day on an average working day, increased the risk of revision whilst lifting heavy weights (≥25kg) increased the risk of poor function at follow-up. Once again, it appeared that more physically-demanding work (lifting weights and/or climbing ladders) were occupational activities more challenging after knee arthroplasty with more people reporting that they had needed to stop working because of knee problems. It was clear that post-operative leisure-time physical activities had important benefits for function at follow-up after UKA/TKA arthroplasty.

Chapter 9 : Discussion

9.1 General discussion

In this thesis we sought to address the important and clinically relevant question as to whether being exposed to physically-demanding occupational and non-occupational activities post-arthroplasty has any impact on the survival of the prosthesis or the functional capabilities or workability of the individual in the mid to long-term. To address this question, we first carried out a systematic review to identify what evidence there was already in the literature about the risk of lower limb arthroplasty revision surgery associated with any type of physically-demanding activities, whether from occupational or sport or leisure.

We formulated the research question using a PICO strategy which consisted of: a) people over 18 years of age who underwent lower limb arthroplasty, b) were exposed to any type of physical activity (work and non-work related), and underwent hip or knee revision surgery. After running a search in three different databases that covered studies published between January 1985 and February 2018, we identified 12 studies that met our eligibility criteria; most of which were focused on hip replacement (9 studies).

After critical appraisal of the literature gathered, we performed a narrative review finding very limited evidence to answer as to whether or to what extent, work and non-work related physical activities might affect the replaced joint and contribute to the risk of revision surgery. As described in Chapter 1 (section 1.1) there is a wide body of literature published on risk factors for arthroplasty revision, focused largely on surgical [133-135] and lifestyle factors [119, 131, 132, 204], but our systematic review showed the scarcity of studies which had considered leisure activities and near absence of studies which considered occupation. Importantly, where information was available, the literature does not always differentiate between physical activity related to work, and that related to leisure activities. Methodological differences in the studies made it challenging to compare the findings. In particular, it was difficult to find information about the duration of exposure to any type of physical activity and, in some studies, it was unclear whether the relevant exposure continued post-arthroplasty.

Excluding those studies which were subject to a high risk of bias, it was not clear as to how work activity may impact the risk of hip revision surgery. There was limited evidence from two studies that women in heavy work and in health services related jobs [165], and men in agricultural jobs [167] were more likely to undergo hip revision, whereas work-activities were not found to be related to the risk of hip revision surgery in a third study [168]. However, in the case of these last two studies, it was unclear whether people continued working post-operatively and whether this was in the same job. We only found one relevant study in which the outcome was the risk of knee revision, which showed no effect from either working activities or leisure activities, despite some of them being considered to be high intensity [172].

We found a few more studies that evaluated the risk of revision surgery associated with exposure to non-occupational physical activity. Those available suggested that leisure-time physical activity might have a negative impact on the hip arthroplasty. In particular, intermediate/intense leisure activities were suggested to be a risk factor for hip revision [168, 169], as well as doing regular exercise (weekly) [165]. However, as above, it was unclear whether participants had undertaken these activities post-operatively in one of these studies [168]. In one study, a higher level of physical activity in people with known radiographic osteolysis was shown to have a negative consequence on the hip joint [143]. However, this effect was not found either for the type of physical activity performed nor its frequency in another study [170].

To further address the research question, we sought to identify existing well-characterised cohorts of patients who had undergone lower limb arthroplasty at least five years earlier and were either under active follow-up or were contactable for a follow-up, and who had been aged ≤ 65 years at the time of the primary surgery, and were therefore likely to have considered returning to work after their surgery.

After an extensive search, two cohorts of patients were identified as meeting the above criteria and with principal investigators willing to collaborate with us in the follow-up study. One of them was based in England (COASt) and the other one in Switzerland (GAR). COASt included patients with primary hip, as well as knee arthroplasty, whilst GAR only contained hip arthroplasty recipients. COASt was a more recent cohort study so that few patients were available with follow-up of at least 5 years, but the GAR cohort dated back over 20 years and offered a greater period of follow-up, at least for hip arthroplasty recipients. A summary of our findings for each of the outcomes studied associated with occupational and leisure-time and daily physical activities was presented in Chapter 8 (Table 93 to Table 96). In each Table, the data presented come from the final analyses performed in Chapters 5-7, after full adjustments for all other factors that were associated with that outcome at a 10% level of significance ($p<0.1$). The outcomes assessed were: i) revision of the primary joint arthroplasty; ii) poor function according to PROMs at time of follow-up and iii) stopping work after returning to work post-arthroplasty partly because of the replaced joint. Exposure to work and non-work related activities were self-reported using a questionnaire and summarised as: occupational physically-demanding activities post-operatively, leisure-time and daily physical activities post-operatively by the type (low, medium, high impact) and frequency as well as the amount of time exposed (years exposed post-operation).

In this retrospective study based on the two arthroplasty recipient cohorts described above, we confirmed that lower limb arthroplasty is an effective orthopaedic procedure [205] with a low revision rate, especially in the case of those who underwent hip replacement, and a high prevalence of excellent or good function at medium-term (post-knee replacement) and long-term (post hip-replacement) follow-up. The majority of the people who were working at the time of the arthroplasty resumed work afterwards, for approximately five years post-operation. However, amongst people with a hip joint replaced, we found that needing to: stand for more than 4 hours on an average working day; lift/carry weight over 10 kg; and kneel/squat were associated with an increased risk of reporting leaving their job mainly or partly because of problems with the replaced joint. Moreover, further analyses revealed that out of these three activities that reduced the ability to continue working, kneeling or squatting was the key driver. Additionally, our findings suggested that this same activity (kneeling or squatting) was associated with an increased risk of hip revision surgery. Carrying or lifting heavy weights (≥25kg) was associated with having poor function at follow-up, regardless of whether the arthroplasty was performed for the hip or for the knee.

Our findings for leisure time and daily physical activities suggested that engaging in high impact activities at least once a week were associated with hip revision, whilst engaging in low and medium impact activities was beneficial for knee function in the mid-term, and for hip function in the long-term post arthroplasty.

Our results suggested that surgical factors related to the primary hip operation were associated with the risk of hip revision surgery, but not with stopping work post-operatively because of having difficulties with the replaced hip (GAR cohort). The average period of time worked after surgery was limited in our study as the majority of people were close to retirement age at the time of their primary operation. In a cohort of younger participants, for example below 60 years of age at the time of surgery, we might expect people to continue working for longer post-arthroplasty.

9.2 Limitations

To interpret our findings, it is necessary to account for the methodological limitations of the research.

There are a number of cohort studies of people with primary arthroplasties and over the past decade, most patients are included in joint registries. Despite this, the data needed to address our important research question were sparse. For one thing, registries do not collect any occupational information pre- or post-operatively. Secondly, we found it difficult to identify cohorts of patients in whom arthroplasties had been undertaken whilst the participants were sufficiently young to have returned to work, but who were currently not too elderly to be sent a new post-operative questionnaire enquiring about post-operative work experience. For instance, one such cohort which we were keen to include was the Knee Arthroplasty (KAT) study, but the data management group decided not to allow us to access this cohort, perceiving that their cohort members, now aged on average 80 years, were too elderly to be bothered with additional questionnaire burden.

As a result, our final numbers derived from the two cohorts were relatively lower than we had hoped. In particular, since the COASt cohort was relatively recently incepted, there were actually very small numbers of relevant events such as revision and poor function after the 6 years of follow-up. As a result, we recognise that we were relatively under-powered to estimate associations between occupational activities performed post-operation and the risk of the relevant outcomes.

Given the paucity of cohorts, we chose to recruit anyone who had their primary surgery before aged 65 years. This was a pragmatic decision to maximise our eligible population. However, we recognise that a large number of people undergoing major surgery between the ages of 60 and 65 years might choose not to return to work post-operatively, particularly if they are in a position to access their pension. As such, we found that amongst the respondents to the current study, there were a number of people with revision or poor function at follow-up who had not returned to work after their primary arthroplasty. Once again, this reduced the size of the sample available for the analysis and the statistical power. Given these concerns however, it is interesting that, even with relatively low power, we were able to detect that some of the physically-demanding occupational activities were associated with poorer outcomes. In particular, it was interesting that kneeling/squatting showed some fairly consistent evidence of poorer outcomes after primary hip arthroplasty. As summarised in chapter 1, kneeling and squatting has been widely assessed in relation to its effect on knee OA, but not as far as we are aware as an occupational risk factor for developing hip OA [206].

Because of the retrospective nature of this study, we asked respondents to recall their exposure to work, occupational exposures and leisure-time activities. Consequently, recall bias may have affected the responses of the participants, especially in the case of the people who have been followed-up at a longer period after their arthroplasty. There was some evidence that recall was more of a problem for those respondents followed-up after a longer period of time in that these were more likely to not provide a start and/or end date for the job in which they had worked after the surgery and in some cases, the respondents wrote “unable to remember” on their questionnaire.

We also asked respondents to recall how long it had taken them to obtain their best function after the primary surgery, and also how good their function was at that peak time. Once again, recall bias may have been operating particularly amongst those asked to recall over a longer period of time. Moreover, it is possible that people who rate their current function as particularly poor might tend to recall their “best” function less favourably because of their current situation, which would lead to a possible over-estimation of the numbers of people with poor function at their best. To mitigate this as far as possible, we enquired about different functional factors. Clearly, recollection of post-operative levels of pain “when at your best” is subjective, but we also asked about “using a stick to walk when at your best” which we hoped would be a more objective outcome to recall subsequently.

We found that the follow-up questionnaire was completed slightly differently by participants in the GAR cohort from Switzerland as compared with the COASt cohort in the UK. In general, the Switzerland based respondents were less likely to fully complete the more complex questions involving recalling periods of time, such as the start and end dates of their job pre- or post-operatively, but this was generally completed better by participants from the COASt cohort. These differences may be attributed to the longer duration of follow-up in Geneva participants, which on average was double that in the UK based cohorts (12 years vs 6 years), and also to the older age of the Geneva participants at the time of the follow-up. A quarter of the GAR respondents were over 75 years of age when they completed the survey. Another explanation for the differences observed in the successful completion of some items of the questionnaires might be a misinterpretation arising from the wording used in the version translated from English to French for use in the Geneva cohort. The original questionnaire was drafted in English, translated into French and then translated back into English by a person who was blinded to the original questionnaire, to check for possible inconsistencies. Despite the procedure we followed, there might still have been some room for misinterpretation in the way a sentence was worded, although it was grammatically correct.

In the GAR cohort, it was not possible to check whether the respondents who had completed our follow-up questionnaire had similar characteristics to those who had not returned the questionnaire, thus it is unknown whether there was a response bias in this sample, and if so the direction of it. This was however possible in the UK based COASt cohorts. Here we found lower rates of response from younger arthroplasty recipients compared with older ones and more obese at baseline. It is well-known that response rates are often poorer from younger populations [207]. However, these factors could have produced a systematic bias in our results if we believed that these characteristics were importantly associated with the risk of poor outcomes or with exposure to the factors in which we are interested. There is reason to believe that younger arthroplasty recipients are more likely to go back to work and other more intensive sporting activities post-operatively, and therefore we may have lost some of the people who were most likely to yield results of interest. If this is the case, then it makes our positive associations of greater interest. Also, some studies have suggested a higher risk of revision of those who are obese [120, 208]. Once again, this may suggest that we had slightly poorer response from those at greater risk of poor outcomes.

There is also an inevitable source of bias arising from unmeasured factors or other factors that were available but not used in the models to avoid using too many variables; for example National Statistics Socio-economic Classification at the time of the joint replacement and post-operation. A further source of bias relates to the incomplete responses obtained from the self-administered questionnaire in relation to the exposure. It is not possible to ascertain the reason why information was incomplete on occupational exposure post-arthroplasty but recall bias might be operating. The cohort with a longer period of follow-up (GAR) had a higher number of missing data on occupational activities post-arthroplasty than the cohort with a shorter follow-up (COASt study). Specifically, in the COASt-knee cohort all responses on occupational activities were completed. To deal with missing data on occupational exposure, where necessary, we generated a missing category for occupational activities. This approach has a potential of bias in the effect estimates. However, as missing data were assumed to be missing completely at random, the potential of bias is minimal. An alternative option would be complete case analyses, in which case big part of the data would not be used resulting in considerable loss of statistical power. Another available technique to minimise bias would be multiple imputation in which several copies of the analysed dataset are generated to replace missing values by imputed values from predictions based on the observed data. However, such an approach would considerably increase complexity in the statistical calculations, and statistical expertise. For function related outcomes the median score was imputed following the authors criteria (i.e. OHS and OKS) or participants with missing exposure for SF-12 questionnaire were excluded from the analysis.

Additionally, we acknowledge the possibility of overfitting some of the final occupational survival models containing people who worked after joint replacement given the number of events and covariates used in the models. The survival analysis may have overestimated the risk of revision as death may occur prior to joint failure. In the absence of occupational activity information we retrospectively collected data by contacting participants from each cohort who were available to complete the survey. For those people from the original cohort who were lost to follow-up at the time of sending out the survey no baseline or follow-up information was available, hence competing risk analyses could not be fitted.

Given the limited power described above, we combined data where possible to add to the person-years of follow-up. We were able to pool data from GAR and COASt hip participants with the outcome of hip revision, and with the outcome of having to stop work because of a problem with the replaced hip. However, it should be borne in mind that these cohorts were different. On the one hand, the GAR cohort was recruited earlier and includes a greater number of people who received metal-on-metal implants. There are more women than men having hip replacement, but in our sample from GAR more men than women returned the questionnaire. On the other hand, the COASt hip cohort includes more women than men; a characteristic of UK arthroplasty recipients [209]. Of course, men and women tend to generally undertake different types of occupations [210]. In particular, men tend to be more likely to undertake the more physically-demanding occupations, for example construction work and heavy industry. It is possible therefore that the finding of no effect in COASt is not just because of a lack of events but also the lower intrinsic risk associated with the work performed more typically by women.

The GAR participants showed a good response rate (56%), considering that: i) all patients who underwent lower limb arthroplasty in the Geneva University Hospitals are automatically enrolled in GAR, ii) the time elapsed from the surgery to the follow-up was on average 12 years, and iii) the participants completed our questionnaire at an median age of 69.5 years. Setting up a cohort study involves, amongst other things, inviting eligible participants to take part in a study. At this stage, more people tend to refuse instead of agreeing to be part of the study, so participants who enrol in the research study are expected to be more willing to provide information than people who are routinely added to a register such as GAR.

9.3 Strengths

As far as we know, this is the first study that has assessed whether physically-demanding occupational activities in a working age population sample post-arthroplasty may affect the prognosis and function of the replaced joint as well as workability post-operatively. Data about these exposures has been collected systematically using validated tools and analysed transparently taking into account as many known covariates as possible. We have used a number of different outcomes to make as thorough an assessment as possible as to whether there is any signal of an increased risk with physically-demanding activities.

We aimed to maximise the duration of the follow-up of our participants in order to give the highest chance of poorer outcomes. Although the duration varies between the cohorts, we achieved a minimum follow-up of five years since the primary surgery was performed, and in the case of the GAR cohort was up to a maximum of 22 years post hip arthroplasty. Other researchers have achieved longer-term follow-up, particularly in national joint registries [109, 211-213], but none of these included post-operative occupation or occupational exposures as risk factors.

We were very fortunate with the two cohorts in that they had carried out a detailed baseline assessment and recorded considerable pre-operative information, as well as information about the surgery, which was then available for inclusion in our analyses as potential confounders of the outcomes.

9.4 Reflections related to the findings

Occupational activities post-arthroplasty

We hypothesized that occupational activities that mechanically load the joint, and are recognised risk factors for lower limb OA, e.g. lifting weight manually in the case of hip OA, and kneeling for knee OA, might also affect the risk of joint failure or diminish function in the mid to long-term following arthroplasty. Our findings could not confirm that the same types of physically-demanding activities that contribute to primary OA are also associated with the risk of lower limb revision surgery. Nevertheless, our findings suggested that kneeling or squatting might contribute to hip revision, and walking more than 2 miles on an average working day, to knee revision. Additionally, exposure to lifting or carrying heavy weights (≥25kg) after arthroplasty showed deleterious effects to both the hip and knee joints.

Irrespective of the type of arthroplasty the participants had undergone (hip or knee), we used the same questions to obtain information about the type of occupational activities our participants had been exposed to post-operation. Based upon published OA literature, if kneeling/squatting had been expected to have any negative effect on a replaced joint this would have been more likely in the knee implant rather than the hip implant. As summarised in section 1.5.2.1, there is consistent evidence of a relationship between kneeling and squatting and the risk of knee OA, however this occupational activity has not been examined as a potential occupational risk factor for developing hip OA [206]. Thus in the absence of studies we were unable to compare this finding with existing literature.

Return to work after arthroplasty

Most of the participants who were working when the operation was performed reported that they returned to work afterwards, and just a few of them changed their occupational status pre and post arthroplasty, going from not working before to having an occupation after the primary surgery. In our study, the proportion of the participants who were working prior to hip surgery and were able to resume work post hip arthroplasty (90%) was similar to, but slightly higher than, the mean of 86% reported in another recent study [175]. However, in particular types of jobs involving very specific and heavy physical tasks (e.g. in the armed services), the prevalence of resuming service and being deployed after THA or hip resurfacing is considerably lower (31%)[214]. In the majority of studies, including all types of work, rates of return to work are much higher. We also found high rates of returning to work amongst those who were working at the time of undergoing TKA/UKA, with nine out of ten people going back to work after knee surgery. Once again, these results are similar to, but slightly higher than, the 82% reported in two studies, including a cohort of military personnel [215, 216]. However we cannot rule out a participation bias in which those who completed our follow-up questionnaire were more likely to do so if they had returned to work, perceiving that the study was relevant to them.

Our findings suggested that those who returned to work after arthroplasty were at lower risk of hip revision surgery and of having poor hip and knee function in the mid to long-term. However, in this cohort study, we are unable to exclude reverse causality i.e. that those who are most fit and active after their operation are able to, and choose to, return to work and consequently have a better prognosis subsequently. What we can say however, is that amongst those who return to work, there is a wide variation in the nature and types of work to which they are able to return. In most cases, a range of occupational activities do not appear to cause significant problems at follow-up. However, we did find some evidence to suggest that needing to kneel/squat at work may increase the risk of revision and jeopardise the ability to remain at work.

Workability post-arthroplasty

Although the ability to perform daily activities that burden the hip or knee joint improves following lower limb arthroplasty [217, 218], the improvement from an occupational perspective might be not as good as expected in jobs which involve physically-demanding tasks. Our analyses allowed us to explore whether any specific occupational activities were associated with an increased risk of self-reported stopping a job mainly or partly because of a problem with the replaced joint. These results were interesting as they hinted that a number of the more demanding physical work activities made it more likely that the recipient of a hip arthroplasty had to stop doing that particular job. Activities that were particularly associated were: prolonged standing (> 4 hours/day); lifting/carrying weights ≥10 kg; and kneeling/squatting. Amongst those doing combinations of activities, kneeling/squatting was the important risk factor. To our knowledge no study has looked at demanding occupational activities that may pose difficulties in performing a job following arthroplasty, hence we could not compare these results with existing literature. These findings merit further investigation as they suggest that workers needing to return to this type of work should be advised to discuss with their employer and aim to moderate these types of exposures as far as possible.

Two further occupational activities contributed mainly or partially to deciding to leave a job following a total or partial knee arthroplasty because of the difficulties they posed on the replaced knee; climbing over 30 flights of stairs per day and lifting/carrying ≥10kg. Surprisingly lifting/carrying ≥25 kg was not found to have effect on stopping work post-arthroplasty whilst lifting > 10kg was. A plausible explanation might be that only fitter workers continue in jobs that entail heavy lifting (≥25 kg) post-arthroplasty as this is a very demanding physical activity. Alternatively, too few workers were exposed to lifting these heavier loads in their work post-arthroplasty so that we lacked the statistical power to find an effect at heavier weights. At 2 years post-TKA Kievit et al found improvement of 36% in the ability to carry/lift and 39% in climbing stairs compared with three months before surgery. These two occupational activities described were similar to the ones we captured in our analyses. Conversely, kneeling showed the poorest improvement at 2 years post-TKA (19%) [96], but we did not find that this activity made people more prone to stop a job; perhaps because of the small numbers analysed, the fact that our sample also included UKAs and also that the exposure about which we enquired was kneeling or squatting.

Difficulties in coping with certain types of work-related activities post-arthroplasty, (either hip or knee) have been previously described in a small group of military personnel. In this highly physically-demanding job, personnel deployed in combat zones was able to perform their duties but reported slight difficulties in doing short springs (86%), and riding in military craft (58%) after their surgery [219].

Leisure-time physical activities and outcomes after arthroplasty

On the whole, the categories of leisure-time and daily physical activities studied here appeared to, if anything, have a beneficial effect on function at follow-up and workability. However, it is important to bear in mind that people with better outcomes from the arthroplasty are more prone to engage in leisure activities than those with a poor outcome as they might be more limited to do exercise or sports. The only signal against positive effect of practising leisure time activities, was found in a group of people performing high impact activities at least once a week. These participants had a significantly higher risk of hip revision surgery as compared with sedentary participants (HR: 4.05 95%CI 1.09,15.00). Our finding is to some extend similar to that described by Ollivier et al [169]in which people who engaged in high impact activities were more prone to hip revision as compared with those who engaged in low impact activities (OR:3.64 95CI% 1.49,8.9). However in this study revision included hip revision surgery as well as radiographic sign of aseptic loosening.

Similarly, a higher risk of revision for the femoral component has been reported in people with osteolytic lesions engaging in higher levels of physical activity [143]. Additionally, an increased risk of revision of hip arthroplasty has been reported among people who returned to judo and tennis after the primary operation: in a group of 35 people with a judo license who continued doing judo demonstrations, two out of 22 hips were revised [220], and three out of 58 people playing tennis more than once a week were revised at a mean follow-up of 8 years after hip arthroplasty [221]. In contrast, one study which included a group of 13 people who jogged more than once a week following a THA found no revision procedures were reported at 4.8 years post-surgery [222].

According to our results there were no increased risks of any of the poorer outcomes associated with categories of exercise after knee arthroplasty, a fact that despite agreement with the absence of knee revision in people who engaged in judo post-arthroplasty [220] should be taken cautiously as the sample analysed was very small. Instead, risks of poor function were significantly reduced by all levels and types of physical and daily activities.

Our data would appear to suggest that encouragement of exercise at all levels possible after TKA would have benefits for everybody. However, based on these data, it is possible that high levels of vigorous sport participation may increase the risk of revision of a hip arthroplasty. Surgeons have mooted such an association in the past. Even in the absence of high-quality evidence, a consensus was reached recommending that participation in some high-intensity activities (jogging, martial arts, high impact aerobics, contact sports, snowboarding) should be avoided post-operatively [191, 223, 224]. It is interesting that there are small numbers of contemporary case studies in which professional athletes in some sports (e.g. tennis, golf) are successfully returning to their career post-operatively. Of course, they are receiving the most conservative surgery done by the most experienced surgeons followed by the best rehabilitation, but it will be interesting to see how this evolves our understanding of the risk of arthroplasty failure associated with very high-intensity sport participation.

9.5 Future studies

The effect of going back to physically-demanding activities (work and non-work related) post-arthroplasty is a relevant question that will gain importance over time as lower limb arthroplasty forecasts predict an increasing burden in the number of operations over the next decades [225, 226]. In the UK an increasing number of patients who were less than 60 years of age underwent lower limb replacement between 2010 and 2018, although the proportion of arthroplasties by age range remained constant (hip arthroplasties) or slightly increased (knee arthroplasties). For example, there were 23,722 more hip interventions (including patients of all ages)[92] . This fact coupled with a drive to encourage people to work to older ages will mean that people need to remain in work for a longer period of time between arthroplasty and retirement.

Younger adults should receive advice from their surgeons on the type of physical activity that would be suitable to carry out post-operation, since this younger population tends to be more physically active and continue working post-operation, including in occupations that may entail strain on the operated joint. For health reasons people are encouraged to keep active (depending on peoples' capability) since physical inactivity has been suggested to be a major cause of chronic diseases such as earlier onset of sarcopenia or osteoporosis [227]. However, inadequate physical activity might also be harmful for the joint replaced.

The Royal College of Surgeons advises that the time to go back to work after hip arthroplasty depends, amongst other things, on the type of work performed [94]. It has been reported that returning to occupations with physically-demanding activities takes longer than to sedentary or moderate demanding jobs [228]. However, the effect of carrying out these type of activities in the mid or long-term is unknown. Our findings have suggested that kneeling or squatting may have a harmful effect on the hip joint replaced.

Some recommendations might be made concerning future research in relation to the impact of occupation post-arthroplasty on a replaced joint. It proved very difficult to obtain access to existing arthroplasty cohorts that included a working age population with an appropriate length of follow-up to evaluate the effect of occupational exposures post-arthroplasty. The success of the operation makes scarce the outcomes studied (mainly revision), hence the number of participants necessary to detect significant differences between exposed and not exposed to physically-demanding occupational activities in relation to implant failure, is high. Moreover, this study has shown that most of the participants who did not obtain good function post-operatively did not resume work after arthroplasty.

One way to address this research question would be to set up a multicentre inception cohort with arthroplasty recipients from different countries and long-term follow-up of 5-10 years. Importantly though, as we have seen, the majority of those who are in paid work at the time of their surgery return to work but a substantial minority do not.

Alternatively, national joint registries could assist if they could be encouraged to collect occupational information amongst those patients who are of working age at the time of undergoing arthroplasty. For example in the UK the NJR, which is the largest joint replacement registry [229] with more than 2.8 million orthopaedic procedures recorded, collects data on every patient receiving an elective implant. If prospective data could be collected on occupation and occupational activities as part of this, it would be feasible to evaluate these risk factors at follow-up.

9.6 Conclusion

In this thesis we undertook research to explore the effects of going back to physically-demanding activities (work and non-work related) following lower extremity arthroplasty at a minimum of 5 years post-operation. Based on our findings, we conclude that:

There is very limited epidemiological evidence in the current literature to address this question, particularly in relation to outcomes following knee arthroplasty.

One of the physically-demanding activities we examined, kneeling and squatting, may harm the hip implant survival, and affect workability.

There is also a signal that other work-related demanding activities might have a negative impact on the replaced joint, but this needs further investigation.

Our results for the knee arthroplasty recipients provided very limited evidence on failure, function or workability, hence these findings need to be taken with caution. Further research is needed using a larger cohort, followed for a longer period of time.

Patients should be encouraged to carry out sports or leisure activities post-arthroplasty to prevent poor function, although engaging in high impact activities more than once a week, (e.g. running or playing cricket) may be less advisable in people with a hip implant.

There is no evidence-based guideline available about what physical activity should be recommended following lower limb arthroplasty. The advice provided by health professionals should be extended to cover occupation and/or occupational activities because this is an important outcome from the surgery, especially for the working-aged population.

It is not possible to differentiate cause from effect in the current study but we conjecture that certain occupational activities are more difficult after successful hip arthroplasty. Hip arthroplasty recipients should be advised to discuss with their employers about strategies to avoid or minimise these exposures (e.g. through task rotation) thus possibly enabling safer longer work participation.

Appendix A : data extraction sheet

A.1 Case-control studies

A) Case-control

<table>
<tr><td colspan="6">Reviewer 1:</td></tr>
<tr><td colspan="6">Title:</td></tr>
<tr><td colspan="2">Author:</td><td>Publication year:</td><td colspan="2">Joint: THA / TKA</td><td>Country:</td></tr>
<tr><td rowspan="8">Sample</td><td rowspan="4">Case</td><td colspan="4">Individuals</td></tr>
<tr><td>Total N(%)</td><td colspan="2">Men N(%)</td><td>Women N(%)</td></tr>
<tr><td colspan="4">Number of hips / knees</td></tr>
<tr><td>☐ Unilateral
N=
☐ Not specify</td><td colspan="2">☐ Bilateral
N=
☐ Not specify</td><td>☐ First implant considered
☐ Not specify</td></tr>
<tr><td rowspan="4">Control</td><td colspan="4">Individuals</td></tr>
<tr><td>Total N(%)</td><td colspan="2">Men N(%)</td><td>Women N(%)</td></tr>
<tr><td colspan="4">Number of hips o knees</td></tr>
<tr><td>☐ Unilateral
N=
☐ Not specify</td><td colspan="2">☐ Bilateral
N=
☐ Not specify</td><td>☐ First implant considered
☐ Not specify</td></tr>
<tr><td colspan="2">Diagnosis (N,%)</td><td colspan="4">☐ Primary OA
☐ Secondary arthritis: RA
Osteonecrosis / avascular necrosis
Posttraumatic arthritis
Others, please specify:</td></tr>
<tr><td colspan="2">Case definition</td><td colspan="4"></td></tr>
<tr><td colspan="2">Control definition</td><td colspan="4"></td></tr>
<tr><td colspan="2">Case/control ratio</td><td colspan="4"></td></tr>
<tr><td colspan="2" rowspan="2">Age at the time of surgery</td><td colspan="4">Mean (SD)</td></tr>
<tr><td colspan="2"><u>Case</u></td><td colspan="2"><u>Control</u></td></tr>
<tr><td colspan="2">Response rate (%)</td><td colspan="2">Case (%)</td><td colspan="2">Control (%)</td></tr>
</table>

Appendix A:

<table>
<tr><td rowspan="6">Operative related factors</td><td colspan="4">Hip</td></tr>
<tr><td>Implant</td><td>Fixation technique</td><td>Cup</td><td>Stem</td></tr>
<tr><td>☐ Same type:
☐ Different implants
☐ Not detailed</td><td>☐ Cemented
☐ Cementless
☐ Hybrid
☐ Not detailed</td><td>☐ Detailed
☐ Not detailed</td><td>☐ Detailed
☐ Not detailed</td></tr>
<tr><td colspan="4">Knee</td></tr>
<tr><td colspan="2">Implant</td><td colspan="2">Fixation technique</td></tr>
<tr><td colspan="2">☐ Same type:
☐ Different
☐ Not detailed</td><td colspan="2">☐ Cemented
☐ Uncemented
☐ Hybrid
☐ Not detailed</td></tr>
<tr><td>Number of events</td><td colspan="4"></td></tr>
<tr><td rowspan="4">Exposure/ how it is defined or measured (interview, questionnaire, relatives…)</td><td colspan="4">Case</td></tr>
<tr><td colspan="4">☐ Occupation/occupational activities
☐ Leisure activities</td></tr>
<tr><td colspan="4">Control</td></tr>
<tr><td colspan="4">☐ Occupation/occupational activities
☐ Leisure activities</td></tr>
<tr><td>Controlled confounders</td><td colspan="4">☐ Controlling by confounders:
☐ Matching by variables:
☐ Restricting the sample studied (i.e; by age)</td></tr>
<tr><td>Statistical methods</td><td colspan="4"></td></tr>
<tr><td>Risk estimate</td><td colspan="4"></td></tr>
<tr><td>Source of funding</td><td colspan="4"></td></tr>
</table>

A.2 Cohort studies

Longitudinal studies			
Researcher:			
Title:			
Author:	**Publication year:**	**Joint:** THA / TKA	**Country:**

Study design	☐ Prospective / retrospective ☐ Cross sectional ☐ RCT or control trial			
Sample (individuals/hips or knees)	***Individuals***			
	Total N(%)	Men N(%)	Women N(%)	
	Number of hips o knees			
	☐ Unilateral N= ☐ Not specify	☐ Bilateral N= ☐ Not specify	☐ First implant considered	
Follow-up	**Duration (years)**	**Loss to follow up**		
	Mean (SD)	N (%)		
Diagnosis (N,%)	☐ Primary OA ☐ Secondary arthritis: RA Osteonecrosis / avascular necrosis Posttraumatic arthritis Others, please specify:			
Age at the time of surgery	Mean (SD)			
Response rate of eligible participants	<u>If applicable</u>			
Operative	**Implant**	**Fixation technique**	**Cup**	**Stem**
	☐ Same type: ☐ Different implants ☐ Not detailed	☐ Cemented ☐ Cementless ☐ Hybrid Not detailed	☐ Detailed ☐ Not detailed	Detailed Not detailed
Definition of the outcome				
Number of events				

Appendix A:

Exposure/ how it is defined or measured	☐ Occupation/occupational activities ☐ Leisure activities
Controlled confounders	☐ Controlling by confounders: ☐ Matching by variables: ☐ Restricting the sample studied (i.e; by age)
Statistical methods	
Risk estimate	HR RR OR Probability
Source of funding	

Appendix B :Quality assessment check list

B.1 Case – control studies

Case-control study

	Notes	Yes	No	Can't this	Does not apply
1. The study addresses an appropriate and clearly focused question / hypothesis					
SELECTION OF THE SUBJECTS					
2. The cases and controls are taken from comparable populations (define the source of population of the cases)					
3. The same exclusion criteria are used for both cases and controls					
4. What percentage of each group (cases and controls) participated in the study					
5. Comparison is made between participants and non-participants to establish their similarities or differences					
6. Cases are clearly defined and differentiated from controls					
7. It is clearly established that controls are non-cases					
8. For matched studies, give matching criteria and the number of controls per case (SL)					
ASSESMENT					
9. Measures will have been taken to prevent knowledge of primary exposure influencing case ascertainment					
10. Exposure status is measured in a standard, valid and reliable way					
11. Blind assessment to compare information given by cases and controls. If it is not feasible uniform data collection in all subjects (Kopec et al 1990_JECH)					
12. High response rate in cases and controls (Kopec et al 1990_JECH)					
13. Report numbers of individuals at each stage of study (strobe list)					
CONFOUNDING					
14. The main potential confounders are identified and taken into account in the design and analysis (matching by age gender, time of the op)					
STATISTICAL ANALYSIS					
15. Describe all statistical methods, including those used to control for confounding (SL)					
16. Explain how missing data were addressed					
17. Confidence intervals are provided (OR)?					
OVERALL ASSESSMENT OF THE STUDY					
18. How well was the study done to minimise the risk of bias or confounding?					
19. Discuss both direction and magnitude of any potential bias (strobe list)					

The risk of bias and its direction, the effort made to address them and the confounders controlled by are the most important items to score the quality of the studies as: very poor (1), poor (2), acceptable (3), good (4) or very good (5).

1	2	3	4	5

Appendix B:

B.2 Cohort studies

	Notes	Yes	No	Can't say	Does not apply
1. The study addresses an appropriate and clearly focused question /hypothesis?					
2. Are the exclusion and inclusion criteria clearly reported?					
SELECTION OF SUBJECTS					
3. The two groups being studied are selected from source populations that are comparable in all respects other than the factor under investigation					
4. The study indicates how many of the people asked to take part did so, in each of the groups being studied					
5. What percentage of individuals or clusters recruited into each arm of the study dropped out before the study was completed? (number of deaths, lost to follow-up, amputation /response rate)					
6. Periods of recruitment, exposure, follow-up, and data collection (strobe list)					
7. Comparison is made between full participants and those lost to follow up, by exposure status					
ASSESSMENT					
8. The **outcomes** are clearly defined					
9. The assessment of outcome is made blind to exposure status. If the study is retrospective this may not be applicable /not applicable					
10. Where blinding was not possible, there is some recognition that knowledge of exposure status could have influenced the assessment of outcome					
11. The method of assessment of **exposure** is reliable (registry, validated questionnaire, exposure measured before/ at the surgery/ after surgery)					
12. Evidence from other sources is used to demonstrate that the method of outcome assessment is valid and reliable					
13. Exposure level or prognostic factor is assessed more than once					
QUALITY ITEMS					
14. Is the information regarding the number of patients who did not give informed consent and who were not willing to participate adequately reported?					
15. Are the baseline characteristics of included patients reported?					
16. Is the surgical technique adequately reported?					

	Notes	Yes	No	Can't	Does not apply
17. Are the prosthesis brand and fixation reported with enough detail?					
18. Are the reasons or definitions for revision adequately reported?					
19. Are the number of revisions and revision rates regarding aseptic loosening (either Kaplan Meier or life table of revisions per 100 observed component years) adequately reported?					
METHODOLOGICAL QUALITY ITEMS					
20. How were the cohorts constructed? Consecutively/ Non-consecutively / unknown					
21. How adequate was the follow-up?					
22. How was the FU performed? Predefined eg. early / non-predefined (when patients had complaints / unknown					
23. How many arthroplasties are at risk at the FU of interest? 20 or more/ less than 20 / unknown					
CONFOUNDING					
24. The main potential confounders are identified and taken into account in the design and analysis.					
STATISTICAL ANALYSIS					
25. Associations are presented as OR, RR, HR? Have confidence intervals been provided?					
26. Has a worst case analysis or competing risks analysis for competing endpoints been performed?					
27. How well was the study done to minimise the **risk of bias or confounding** (recall bias for retrospective studies for prospective not so strong / healthy worker)					

*Confounders to look at: age, gender, diagnosis, BMI, physical activity (work or exercise depending on the outcome), smoking.

**Aquila was constructed to assess cohorts in total hip and total knee arthroplasty focus on aseptic loosening.

The risk of bias and its direction, the effort made to address them and the confounders controlled by are the most important items to score the quality of the studies as: very poor (1), poor (2), acceptable (3), good (4) or very good (5).

OVERALL ASSESSMENT OF THE STUDY	1	2	3	4	5

Appendix C

C.1 Strategy search

Medline

- exp Arthroplasty, Replacement, Knee/ or exp knee prosthesis/, (total knee replacement$ or knee replacement$ or knee arthroplast$ or gonarthroplasty or TKA or knee prosthesis).mp., exp Arthroplasty, Replacement, Hip/ or exp Hip Prosthesis/, (hip prosthesis or hip replacement$ or total hip replacement$ or total hip arthroplast$ or THA).mp.
- exp Survival/ or exp Survival Rate/ or exp Survival Analysis/ or exp disease-free survival/ or exp kaplan-meier estimate/ or exp Prosthesis Failure/ or exp Prosthesis-Related Infections/, (survivorship or survival$ analy$ or Kaplan meier or Survival Rate$ or reoperation or re-operation or prosthesis fail$ or joint$ fail$).mp.
- exp Occupations/ or exp Employment/ or exp Work/ or exp occupational groups/ or exp farmers/ or exp military personnel/ or exp miners/ or exp Weight Lifting/, (employment or employment status).mp. orwork.ab,ti. or work activit$.ab,ti. or work$ status.ab,ti. or work$ situation$.ab,ti. or occupation$.ab,ti. or occupational activit$.mp. or occupational exposure$.mp. or (manual labor or manual labour).mp.
- exp Sports/ or exp Snow Sports/ or exp Skiing/ or exp Exercise/ or sport.mp. or winter sport.mp. or physical activity.mp. or exercise.mp.
- exp risk factors/, risk factor$.mp.
- (long term or long-term or longterm).mp.
- exp return to work/ or return$ to work.mp. or work resumption.mp. or back to work.mp.

Appendix C:

Embase

- exp total knee arthroplasty/ or exp knee replacement/ or exp knee arthroplasty/ or exp knee prosthesis/ or (total knee replacement$ or knee replacement$ or knee arthroplast$ or gonarthroplasty or TKA or knee prosthesis).mp.
- exp total hip arthroplasty/ or exp hip replacement/ or exp hip arthroplasty/ or exp hip prosthesis or (hip prosthesis or hip replacement$ or total hip replacement$ or total hip arthroplast$ or THA).mp.
- (long term or long-term or longterm).mp.
- risk factor.mp.
- exp return to work/
- exp employment/ or exp employment status/ or exp manual labor/ or employ$.tw. or exp work/ or exp work capacity/ or work or activit$.tw. or work$ status.tw. or work$ situation$.tw. or exp occupation/ or occupation$.tw. orexp soldier/ or exp fire fighter/ or agricultural worker/ or exp construction worker/ or exp army/ or agricultur$.mp. or Military Personnel.mp. or military.mp. or construction.mp. or occupation$.tw. or occupational activit$.tw. or occupational exposure$.tw.
- exp prosthesis failure/ or exp failure free survival/ or exp Kaplan meier method/ or exp survival rate/ or exp survival/ or exp / or reoperation/ or (prosthesis failure or joint$ fail$ or survival rate$ or survivorship or survival analy$ or reoperation or revision).mp.
- exp exercise/ or exp sport/ or exp physical activity/ or (exercise or sport$ or physical activit$).mp.

Scopus

TITLE-ABS-KEY (("knee prosthesis" OR "tka" OR "gonarthroplasty" OR "knee arthroplast*" OR "knee replacement*" OR "total knee replacement*" OR "total hip replacement*" OR "hip replacement" OR "total hip arthroplast*" OR "THA" OR "hip prosthesis") AND ("Survivorship" OR " survival* analy*" OR "Kaplan Meier" OR "survival rate*" OR "reoperation" OR "prosthesis fail*" OR "joint* fail*") AND ("risk factor*" OR "long-term" OR "long term" OR "longterm" OR "employment" OR "employment status" OR "work" OR "work activit*" OR "work* status" OR "work* situation" OR "occupation*" OR "occupational activit*" OR "occupational exposure*" OR "manual labour" OR "weight lifting" OR "squatting" OR "kneeling" OR "military personnel" OR "farmer*" OR "miners" OR "agriculture work*" OR exercise OR sport* OR "physical activit*" OR "winter sport*" OR "racquet sport*" OR "running"))

C.2 Reason to discard full text papers

Title and reasons to discard full-text papers identified from the search

Title of the study	Reasons for exclusion
Abe H, Sakai T, Nishii T et al. Jogging after total hip arthroplasty. Am J Sports Med. 2014 Jan;42(1):131-7.	No revision reported
Baker RP, Pollard TCB, Eastaugh-Waring SJ, Bannister GC. A medium-term comparison of hybrid hip replacement and Birmingham hip resurfacing in active young patients. J Bone Joint Surg Br. 2011;93 B(2):158-63.	Comparison of Birmingham Hip Resurfacing versus hybrid total hip replacement
Camus T, Long WJ. Total knee arthroplasty in young patients: Factors predictive of aseptic failure in the 2nd-4th decade. J Orthop. 2017 Nov 6;15(1):28-31.	Physical activity not assessed
Chandler HP, Reineck FT, Wixson RL et al. Total hip replacement in patients younger than thirty years old. A five-year follow-up study. J Bone Joint Surg Am. 1981 Dec;63(9):1426-34.	Case series
Del Piccolo N, Carubbi C, Mazzotta A et al. Return to sports activity with short stems or standard stems in total hip arthroplasty in patients less than 50 years old. Hip Int. 2016 May 14;26 Suppl 1:48-51.	Radiographic assessment of the implant
Effenberger H, Ramsauer T, Dorn U et al. Factors influencing the revision rate of Zweymueller acetabular cup. Int Orthop. 2004 Jun;28(3):155-8	Physical activity not assessed
Electricwala AJ, Narkbunnam R, Huddleston JI et al. Obesity is Associated With Early Total Hip Revision for Aseptic Loosening. J Arthroplasty. 2016 Sep;31(9 Suppl):217-20. Mar 15	Physical activity not assessed
Feller JA, Kay PR, Hodgkinson JP et al. Activity and socket wear in the Charnley low-friction arthroplasty. J Arthroplasty. 1994 Aug;9(4):341-5.	Outcome other than revision (wear)
Goldsmith AA, Dowson D, Wroblewski BM, et al. The effect of activity levels of total hip arthroplasty patients on socket penetration. J Arthroplasty 2001 Aug;16(5):620-7	Outcome other than revision (wear)
Gschwend N, Frei T, Morscher E et al. Alpine and cross-country skiing after total hip replacement: 2 cohorts of 50 patients each, one active, the other inactive in skiing, followed for 5-10 years. Acta Orthop Scand. 2000 Jun;71(3):243-9	Radiographic assessment of the implant
Hernández-Vaquero D, Suárez-Vazquez A, Fernandez-Lombardia J. Charnley low-friction arthroplasty of the hip. Five to 25 years survivorship in a general hospital. BMC Musculoskelet Disord. 2008 May 15;9:69.	Physical activity not assessed
Hofstaedter T, Fink C, Dorn U, Pötzelsberger B et al. Alpine Skiing With total knee ArthroPlasty (ASWAP): clinical and radiographic outcomes. Scand J Med Sci Sports. 2015 Aug;25 Suppl 2:10-5	Outcome other than revision (wear)
Kloen P, De Man HR, Marti RK. Down-hill skiing after a total hip replacement? Hip int. 2000;10(2):77-82	No control group

Appendix C:

Title of the study	Reasons for exclusion
Lefevre N, Rousseau D, Bohu Y et al. Return to judo after joint replacement. Knee Surg Sports Traumatol Arthrosc. 2013;21(12):2889-94	No control group
Mallon WJ, Callaghan JJ. Total hip arthroplasty in active golfers. J Arthroplasty. 1992;7(Suppl.):339-46	Radiographic assessment of the implant
McBeath AA, Foltz RN. Femoral component loosening after total hip arthroplasty. Clin Orthop Relat Res. 1979 Jun;(141):66-70	No control group
Migaud H, Putman S, Krantz N et al. Cementless metal-on-metal versus ceramic-on-polyethylene hip arthroplasty in patients less than fifty years of age: A comparative study with twelve to fourteen-year follow-up. Journal of Bone and Joint Surgery - Series A. 2011;93(Suppl. 2):137-42.	Compared different type of implants
Mont MA, LaPorte DM, Mullick T et al. Tennis after total hip arthroplasty. Am J Sports Med. 1999;27(1):60-4	No control group
Munuera L, Garcia-Cimbrelo E. The femoral component in low-friction arthroplasty after ten years. Clin Orthop Relat Res. 1992 Jun;(279):163-75	Radiographic assessment of the implant
Namba RS, Cafri G, Khatod M et al. Risk factors for total knee arthroplasty aseptic revision. J Arthroplasty. 2013;28(8 Suppl):122-7	Physical activity not assessed
Needham J, Burns T, Gerlinger T. Catastrophic failure of ceramic-polyethylene bearing total hip arthroplasty. J Arthroplasty. 2008;23(4):627-30	Case report
Peltola M, Järvelin J. Association between household income and the outcome of arthroplasty: a register-based study of total hip and knee replacements. Arch Orthop Trauma Surg. 2014 Dec;134(12):1767-74	Physical activity not assessed
Plate JF, Issa K, Wright C et al. Patient activity after total hip arthroplasty: A comparison of three different bearing surfaces. J Long Term Eff Med Implants. 2013;23(4):315-21	Compared outcomes by bearing surface
Pollard TCB, Baker RP, Eastaugh-Waring SJ et al. Treatment of the young active patient with osteoarthritis of the hip. J Bone Joint Surg Br. 2006;88(5):592-600	Compare clinical and radiological results between Birmingham HR and THA
Prakash U, Mulgrew S, Espley AJ. Effect of activity levels on polyethylene wear in Charnley low-friction arthroplasty. J R Coll Surg Edinb. 1999;44(3):193-6	Outcome other than revision (wear)
Pritchett JW. Adventure sports and sexual freedom hip replacement: the tripolar hip. Eur J Orthop Surg Traumatol. 2018 Jan;28(1):37-43	No control group
Ritter MA, Meding JB. Total hip arthroplasty. Can the patient play sports again? Orthopedics. 1987 Oct;10(10):1447-52	Case series
Sechriest Ii VF, Kyle RF, Marek DJ, Spates JD, Saleh KJ, Kuskowski M. Activity Level in Young Patients With Primary Total Hip Arthroplasty. A 5-Year Minimum Follow-up. J Arthroplasty. 2007;22(1):39-47	Outcome other than revision (wear)
Sutherland CJ, Wilde AH, Borden LS, Marks KE. A ten-year follow-up of one hundred consecutive Müller curved-stem total hip-replacement arthroplasties. J Bone Joint Surg Am. 1982 Sep;64(7):970-82	No control group
Sutherland CJ, Wilde AH, Borden LS, Marks KE. A ten-year follow-up of one hundred consecutive Müller curved-stem total hip-replacement arthroplasties. J Bone Joint Surg Am. 1982 Sep;64(7):970-82	No control group
Weller IMR, Kunz M. Physical activity and pain following total hip arthroplasty. Physiotherapy. 2007;93(1):23-9	Outcome other than revision (pain)
White SH. The fate of cemented total hip arthroplasty in young patients. Clin Orthop Relat Res. 1988 Jun;(231):29-34	Radiographic assessment of the implant

Appendix D Questionnaires

D.1 Knee replacement questionnaire – COASt cohort

Coast Study ID: ____________________

Post Operative Five Year Follow Up (Part II)- Knee

Oxford University Hospitals NHS Foundation Trust

University Hospital Southampton NHS Foundation Trust

COASt
Clinical Outcomes in Arthroplasty Study

Post operative: Five year follow up (Part II)

Unicompartmental Knee Replacement /
Total Knee Replacement (TKR)

Please complete this booklet as soon as possible and return it in the enclosed envelope – No stamp required

Date Booklet Completed on: D D M M Y Y

ABOUT YOURSELF

1. **Please confirm your month and year of birth** M M Y Y Y Y
2. **And your sex** Male ☐ Female ☐
3. **Please give your height and your weight**

Height: ☐ ft ☐☐ inches **OR** ☐☐☐ cm

Weight ☐☐ st ☐☐ lbs **OR** ☐☐☐ kg

Appendix D:

SURGERY TO HIP AND KNEES

The following questions are about any operation you may have had on your hip or knee

4. **Please tick all of the operations** that you have had to your **hips and knees** and the month and year of the operation

Examples of type of operations

	Surgery to cartilage or ligaments	**Resurfacing**	**Osteotomy**	**Joint replacement**	**Other *(Please specify)***
Right hip	☐	☐	☐	☐	☐ ________
Month/year	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y
Left hip	☐	☐	☐	☐	☐ ________
Month/year	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y
Right knee	☐	☐	☐	☐	☐ ________
Month/year	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y
Left knee	☐	☐	☐	☐	☐ ________
Month/year	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y

Questions 5 to 51 ALL RELATE TO THE KNEE SURGERY YOU HAD IN ____________________

5. **Before your knee replacement, did you take part in the Enhanced Recovery Programme through the hospital?**

   No ☐ Yes ☐

6. **After your knee replacement, did you have outpatient physiotherapy on discharge from the hospital?**

   No ☐ Yes ☐

   If yes, who was the provider? (*please tick any that apply*)

   NHS ☐ Private ☐

7. **After you had your knee replaced, have you ever had the same knee replaced again?**

   No ☐ Yes ☐

   If yes, when was this? D D M M Y Y Y Y

PAID WORK BEFORE YOUR KNEE SURGERY

The questions that follow concern paid work before your knee replacement in ____________________

8. **Before your knee surgery, did you ever have a paid job (either employed or self-employed)?**

   No ☐ Yes ☐

   *If no, please go to **Question 15***

   *If yes, please continue with **Question 9***

9. **What was the last paid job that you held before your knee surgery?**

   Please give the occupation (e.g. carpenter, teacher)

10. **In what year did you start your job?**

Y	Y	Y	Y

11. **Were you self-employed or an employee?**

    Self-employed ☐ Employee ☐

12. **Was that still your job at the time of your knee surgery?**

    No ☐ Yes ☐

    *If no, please go to **Question 13***

    *If yes, please continue with **Question 15***

13. **In what year did you leave that job?**

Y	Y	Y	Y

14. **And did you leave the job because of the problem with your knee?**

    a) Yes, my knee problem was the main reason for leaving ☐

    b) Yes, my knee problem was part of the reason for leaving ☐

    c) No, entirely for other reasons ☐

PAID WORK SINCE YOUR KNEE SURGERY

The questions that follow concern paid work that you may have done since your knee surgery in ___________________________

15. **Since your knee surgery, have you held a job (employed or self-employed) for a month or longer?** No ☐ Yes ☐

*If **no**, please go to **Question 17***
*If **yes**, please continue with **Question 16***

16. **Please fill in the table below for each job that you have held for a month or longer since your knee surgery. There is space for up to three jobs. If you have had more than three jobs since your knee surgery, please give the extra details on a separate sheet of paper.**

	Job 1	**Job 2**	**Job 3**
Occupation (e.g. carpenter, teacher)	________	________	________
Date started	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y
Date finished	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y
(if you are still in the job please tick box)	Still working ☐	Still working ☐	Still working ☐
Please tick if you left the job at least partly because of problems with your knee	☐	☐	☐

Did an average day in a job involve any of the following? (*please tick all that apply*)

	Job 1	**Job 2**	**Job 3**
Standing or walking for longer than 4 hours in total	☐	☐	☐
Walking for more than 2 miles in total	☐	☐	☐
Lifting or carrying weights of 10 kg (25 lbs) or more by hand	☐	☐	☐
Running for more than 30 minutes	☐	☐	☐
Lifting or carrying weights of 25 kg (56 lbs) or more by hand	☐	☐	☐
Digging or shovelling	☐	☐	☐
Kneeling or squatting	☐	☐	☐
Climbing up and down more than 30 flights of stairs	☐	☐	☐
Climbing ladders	☐	☐	☐

PAIN AND FUNCTION SINCE YOUR KNEE SURGERY

In the next section, we are interested in the best that you have been since your knee surgery in ____________________

17. **How soon after your knee surgery did you reach your best in terms of your knee?**

a) Less than 6 months ☐

b) More than 6 months but less than a year ☐

c) Between 1 and 2 years ☐

d) Longer than 2 years ☐

18. **In the time since your knee surgery, when you were at your best, how well were you able to do the following?**

(Please tick one box on each line)

		Easily	With little difficulty	With moderate difficulty	With extreme difficulty	Impossible
a)	Walk for a mile on the flat	☐	☐	☐	☐	☐
b)	Walk on rough ground	☐	☐	☐	☐	☐
c)	Walk uphill	☐	☐	☐	☐	☐
d)	Walk downhill	☐	☐	☐	☐	☐
e)	Walk up a flight of stairs	☐	☐	☐	☐	☐
f)	Walk down a flight of stairs	☐	☐	☐	☐	☐
g)	Do household shopping on your own	☐	☐	☐	☐	☐
h)	Wash and dry yourself (all over)	☐	☐	☐	☐	☐
i)	Get in and out of a car	☐	☐	☐	☐	☐
j)	Stand up from a chair	☐	☐	☐	☐	☐
k)	Kneel down and get up again	☐	☐	☐	☐	☐

19. **In the time since your knee surgery, when you were at your best, did you use a stick when walking?**

a) No, not at all ☐ b) Occasionally ☐ c) Most of the time ☐ d) All of the time ☐

20. **In the time since your knee surgery, when you were at your best, how troubled were you by pain in that knee at night?**

a) No nights ☐ b) Only 1 or 2 nights ☐ c) Some nights ☐ d) Most nights ☐ d) Every night ☐

21. **In the time since your knee surgery, when you were at your best, how troubled were you by pain in that knee during the day?**

a) Never ☐ b) Occasionally ☐ c) Often ☐ d) All of the time ☐

Appendix D:

LEISURE ACTIVITIES SINCE YOUR KNEE SURGERY

The next few questions are about any leisure activities that you may have done after you had your knee replaced in ______________________________. The following light grey boxes have similar questions, but each group relates to different types of activities that load the hips: repeatedly, moderately and lightly. Please read and fill them in if they apply.

22. **In the time since your knee surgery, have you done any leisure activities that load the knees REPEATEDLY?** *(e.g. running, jogging, football, basketball, tennis singles, badminton singles)*

    No ☐ Yes ☐

    *If no, please go to **Question 28***
    *If yes, please continue with **Question 23***

23. **Which activities of this sort have you done?** *(please list up to three that you have done most)*
    1) ______________________ 2) ______________________
    3) ______________________

24. **Approximately how long after your knee surgery, did you first do leisure activities of this sort?** ☐☐ months

25. **Approximately how long is it since you last did one of these activities?** ☐☐ months
    (please write 0 if you are still doing the activities)

26. **In the time since your knee surgery that you were doing activities of this sort, how often did/do you do them?**
    a) Less than 3 times per year ☐
    b) 3-10 times per year ☐
    c) 11-50 times per year ☐
    d) More than 50 times per year ☐

27. **In an average week, how much time did/do you spend on these types of leisure activities?**

    ☐☐ Hours ☐☐ Minutes

28. **In the time since your knee surgery, have you done any leisure activities that load the knees more MODERATELY?** *(e.g. cycling, dancing, horse riding, golf, bowls, weight machines, sailing)?*

    No ☐ Yes ☐

    *If no, please go to **Question 34***
    *If yes, please continue with **Question 29***

29. **Which activities of this sort have you done?** *(please list up to three that you have done most)*

    ____
    ____
    ____

30. **Approximately how long after your knee surgery, did you first do leisure activities of this sort?** ☐☐ **months**

31. **Approximately how long is it since you last did one of these activities?** ☐☐ **months**
(*please write 0 if you are still doing the activities)*

32. **In the time since your knee surgery that you were doing activities of this sort, how often did/do you do them?**

a) Less than 3 times per year ☐

b) 3-10 times per year ☐

c) 11-50 times per year ☐

d) More than 50 times per year ☐

33. **In an average week, how much time did/do you spend on these types of leisure activities?**

☐☐ Hours ☐☐ Minutes

34. **In the time since your knee surgery, have you done any leisure activities that load the knees <u>LIGHTLY</u>?** *(e.g. housework, light gardening, ball room dancing, swimming, golf, walking for pleasure, yoga)*

No ☐ Yes ☐

*If no, please go to **Question 40***
*If yes, please continue with **Question 35***

35. **Which activities of this sort have you done?** *(please list up to three that you have done most)*

____

____

____

36. **Approximately how long after your knee surgery, did you first do leisure activities of this sort?** ☐☐ **months**

37. **Approximately how long is it since you last did one of these activities?** ☐☐ **months**
(*please write 0 if you are still doing the activities).*

38. **In the time since your knee surgery that you were doing activities of this sort, how often did/do you do them?**

a) Less than 3 times per year ☐

b) 3-10 times per year ☐

c) 11-50 times per year ☐

d) More than 50 times per year ☐

39. **In an average week, how much time did/do you spend on these types of leisure activities?**

☐☐ Hours ☐☐ Minutes

Appendix D:

Coast Study ID: ____________________ Post Operative Five Year Follow Up (Part II)- Knee

YOUR HEALTH NOW

The next questions concern the knee for which you had surgery in_______________

During the past 4 weeks …

40. How would you describe the pain you usually have from the knee?

None ☐ i Very mild ☐ ii Mild ☐ iii Moderate ☐ iv Severe ☐ v

During the past 4 weeks …

41. Have you had any trouble with washing and drying yourself (all over) because of your knee?

No trouble at all ☐ i Very little trouble ☐ ii Moderate trouble ☐ iii Extremely difficult ☐ iv Impossible to do ☐ v

During the past 4 weeks …

42. Have you had any trouble getting in and out of a car or using public transport because of your knee (whichever you tend to use)?

No trouble at all ☐ i Very little trouble ☐ ii Moderate trouble ☐ iii Extremely difficult ☐ iv Impossible to do ☐ v

During the past 4 weeks …

43. For how long have you been able to walk before the pain from your knee became severe (with or without a stick)?

No pain / More than 30 minutes ☐ i 16 to 30 minutes ☐ ii 5 to 15 minutes ☐ iii Around the house *only* ☐ iv Unable to walk at all ☐ v

During the past 4 weeks …

44. After a meal (sat at table), how painful has it been for you to stand up from a chair because of your knee?

Not at all painful ☐ i Slightly painful ☐ ii Moderately painful ☐ iii Very painful ☐ iv Unbearable ☐ v

During the past 4 weeks …

45. Have you been limping when walking, because of your knee?

Rarely/ never ☐ i Sometimes or just at first ☐ ii Often, not just at first ☐ iii Most of the time ☐ iv All of the time ☐ v

During the past 4 weeks …

46. Could you kneel down and get up again afterwards?

Yes, easily ☐ i With little difficulty ☐ ii With moderate difficulty ☐ iii With extreme difficulty ☐ iv No, impossible ☐ v

During the past 4 weeks …

47. Have you been troubled by pain from your knee in bed at night?

No nights ☐ i Only 1 or 2 nights ☐ ii Some nights ☐ iii Most nights ☐ iv Every night ☐ v

During the past 4 weeks …

48. How much has pain from your knee interfered with your usual work (including housework)?

Not at all ☐ i A little bit ☐ ii Moderately ☐ iii Greatly ☐ iv Totally ☐ v

During the past 4 weeks …

49. Have you felt that your knee might suddenly "give way" or let you down?

Rarely/ never ☐ i | Sometimes or just at first ☐ ii | Often, not just at first ☐ iii | Most of the time ☐ iv | All of the time ☐ v

During the past 4 weeks …

50. Could you do the household shopping <u>on your own</u>?

Yes, easily ☐ i | With little difficulty ☐ ii | With moderate difficulty ☐ iii | With extreme difficulty ☐ iv | No, impossible ☐ v

During the past 4 weeks …

51. Could you walk down a flight of stairs?

Yes, easily ☐ i | With little difficulty ☐ ii | With moderate difficulty ☐ iii | With extreme difficulty ☐ iv | No, impossible ☐ v

52. **Apart from your knee you had replaced do you currently suffer from pain or stiffness?** *Please tick an answer in each line*

Do you currently suffer from pain or stiffness ….	**No**	**Occasionally**	**Frequently**	**All the time**
… in your other knee?	☐	☐	☐	☐
… in your right hip?	☐	☐	☐	☐
… in your left hip?	☐	☐	☐	☐

53. **Apart from any problems with your hips and knees, do you have any other health problems that limit your activities?**

No ☐ Yes ☐

If no, please go to Question 55
If yes, please continue with Question 54

54. **Please list up to three health problems that you feel are most important**

____

____

____

55. *Please tick the option for each item that best describes how you have been feeling* ***during the last week.***

I feel tense or 'wound up':
- Most of the time ☐
- A lot of the time ☐
- Time to time, occasionally ☐
- Not at all ☐

I still enjoy the things I used to enjoy:
- Definitely as much ☐
- Not quite so much ☐
- Only a little ☐
- Not at all ☐

I get a sort of frightened feeling like something awful is about to happen:
- Very definitely and quite badly ☐
- Yes, but not too badly ☐
- A little, but it doesn't worry me ☐
- Not at all ☐

I can laugh and see the funny side of things:
- As much as I always could ☐
- Not quite so much now ☐
- Definitely not so much now ☐
- Not at all ☐

Worrying thoughts go through my mind:
- A great deal of the time ☐
- A lot of the time ☐
- From time to time but not too often ☐
- Only occasionally ☐

I feel cheerful:
- Not at all ☐
- Not often ☐
- Sometimes ☐
- Most of the time ☐

I can sit at ease and feel relaxed:
- Definitely ☐
- Usually ☐
- Not often ☐
- Not at all ☐

I feel as if I am slowed down:
- Nearly all of the time ☐
- Very often ☐
- Sometimes ☐
- Not at all ☐

I get a sort of frightened feeling like 'butterflies in the stomach':
- Not at all ☐
- Occasionally ☐
- Quite often ☐
- Very often ☐

I have lost interest in my appearance:
- Definitely ☐
- I don't take as much care as I should ☐
- I may not take quite as much care ☐
- I take just as much care as ever ☐

I feel restless as if I have to be on the move:
- Very much indeed ☐
- Quite a lot ☐
- Not very much ☐
- Not at all ☐

I look forward with enjoyment to things:
- As much as I ever did ☐
- Rather less than I used to ☐
- Definitely less than I used to ☐
- Hardly at all ☐

I get sudden feelings of panic:
- Very often indeed ☐
- Quite often ☐
- Not very often ☐
- Not at all ☐

I can enjoy a good book or radio or TV programme:
- Often ☐
- Sometimes ☐
- Not often ☐
- Very seldom ☐

PRESCRIBED MEDICINES

Finally we would like to ask you about medicines that you may have been prescribed by a doctor.

56. **Have you ever taken bisphosphonates** *(e.g. alendronate, risendronate, pamidronate or zoledronate)?* No ☐ Yes ☐

    If no, please go to ***Question 58***

    If yes, **in what year did you first take them?** Y Y Y Y

57. **Do you still take them?** No ☐ Yes ☐

    If no, **in what year did you last take them?** Y Y Y Y

58. **Have you ever taken hormone replacement therapy (HRT)?** No ☐ Yes ☐

    If no, please go to ***Question 60***

    If yes, **in what year did you first take them?** Y Y Y Y

59. **Do you still take them?** No ☐ Yes ☐

    If yes, **in what year did you last take them?** Y Y Y Y

60. **Have you ever taken statins** *(e.g. atorvastatin, fluvastatin, pravastatin, rosuvastatin, and simvastatin)?* No ☐ Yes ☐

    If yes, **in what year did you first take them?** Y Y Y Y

61. **Do you still take them?** No ☐ Yes ☐

    If no, **in what year did you last take them?** Y Y Y Y

Thank you for completing this booklet

Please post back in the prepaid envelope supplied

D.2 Hip replacement questionnaire – COASt cohort

Coast Study ID: ______________________

Post Operative Five Year Follow Up (Part II) - Hip

Oxford University Hospitals NHS
NHS Foundation Trust

University Hospital Southampton NHS
NHS Foundation Trust

COASt
Clinical Outcomes in Arthroplasty Study

Post operative: Five year follow up (Part II)

Total Hip Replacement (THR)

Please complete this booklet as soon as possible and return it in the enclosed envelope – No stamp required

Date Booklet Completed on: D D M M Y Y

ABOUT YOURSELF							
1.	**Please confirm your month and year of birth**				M M Y Y Y Y		
2.	**And your sex**				Male ☐	Female ☐	
3.	**Please give your height and your weight**						
	Height:	☐ ft	☐☐ inches	**OR**	☐☐☐	cm	
	Weight	☐☐ st	☐☐ lbs	**OR**	☐☐☐	kg	

Coast Study ID: ____________________

Post Operative Five Year Follow Up (Part II) - Hip

SURGERY TO HIP AND KNEES

The following questions are about any operation you may have had on your hip or knee

4. **Please tick all of the operations** that you have had to your <u>**hips and knees**</u> and the month and year of the operation

Examples of type of operations

	Surgery to cartilage or ligaments	**Resurfacing**	**Osteotomy**	**Joint replacement**	**Other *(Please specify)***
Right hip	☐	☐	☐	☐	☐ ________
Month/year	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y
Left hip	☐	☐	☐	☐	☐ ________
Month/year	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y
Right knee	☐	☐	☐	☐	☐ ________
Month/year	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y
Left knee	☐	☐	☐	☐	☐ ________
Month/year	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y

QUESTIONS 5 to 51 ALL RELATE TO THE HIP SURGERY YOU HAD IN

____

5. **Before your hip replacement, did you take part in the Enhanced Recovery Programme through the hospital?**

   No ☐ Yes ☐

6. **After your hip replacement, did you have outpatient physiotherapy on discharge from the hospital?**

   No ☐ Yes ☐

   If yes, who was the provider? (Please tick any that apply)

   NHS ☐ Private ☐

7. **After you had your hip replaced, have you ever had the same hip replaced again?**

   No ☐ Yes ☐

   If yes, when was this? D D M M Y Y Y Y

PAID WORK BEFORE YOUR HIP SURGERY

The questions that follow concern paid work before your hip replacement in ________________________

8. **Before your hip surgery, did you ever have a paid job (either employed or self-employed?**

   No ☐ Yes ☐

   *If **no**, please go to **Question 15***

   *If **yes**, please continue with **Question 9***

9. **What was the last paid job that you held before your hip surgery?**

   Please give the occupation (e.g. carpenter, teacher)

   ____

10. **In what year did you start this job?**

Y	Y	Y	Y

11. **Were you self-employed or an employee?**

    Self-employed ☐ Employee ☐

12. **Was that still your job at the time of your hip surgery?**

    No ☐ Yes ☐

    *If **no**, please go to **Question 13***

    *If **yes**, please continue with **Question 15***

13. **In what year did you leave that job?**

Y	Y	Y	Y

14. **And did you leave the job because of the problem with your hip?** *(please tick one box)*

    a) Yes, my hip problem was **the main** reason for leaving ☐

    b) Yes, my hip problem was **part of** the reason for leaving ☐

    c) No, entirely for other reasons ☐

PAID WORK SINCE YOUR HIP SURGERY

The questions that follow concern paid work that you may have done since your hip surgery in ______________________

15. **Since your hip surgery, have you held a job (employed or self-employed) for a month or longer?** No ☐ Yes ☐

    If no, please go to ***Question 17***
    If yes, please continue with ***Question 16***

16. **Please fill in the table below for each job that you have held for a month or longer since your hip surgery. There is space for up to three jobs. If you have had more than three jobs since your hip surgery, please give the extra details on a separate sheet of paper.**

	Job 1	Job 2	Job 3
Occupation (e.g. carpenter, teacher)	______	______	______
Date started	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y
Date finished	M M Y Y Y Y	M M Y Y Y Y	M M Y Y Y Y
(if you are still in the job please tick box)	Still working ☐	Still working ☐	Still working ☐
Please tick if you left the job at least partly because of problems with your hip	☐	☐	☐

Did an average day in a job involve any of the following? (please tick all that apply)

	Job 1	Job 2	Job 3
Standing or walking for longer than 4 hours in total	☐	☐	☐
Walking for more than 2 miles in total	☐	☐	☐
Lifting or carrying weights of 10 kg (25 lbs) or more by hand	☐	☐	☐
Running for more than 30 minutes	☐	☐	☐
Lifting or carrying weights of 25 kg (56 lbs) or more by hand	☐	☐	☐
Digging or shovelling	☐	☐	☐
Kneeling or squatting	☐	☐	☐
Climbing up and down more than 30 flights of stairs	☐	☐	☐
Climbing ladders	☐	☐	☐

PAIN AND FUNCTION SINCE YOUR HIP SURGERY

In the next section, we are interested in the best that you have been since your hip surgery in ______________________.

17. How soon after your hip surgery did you reach your best in terms of your hip?

a)	Less than 6 months	☐
b)	More than 6 months but less than a year	☐
c)	Between 1 and 2 years	☐
d)	Longer than 2 years	☐

18. In the time since your hip surgery, when you were at your best, how well were you able to do the following?

(Please tick one box on each line)

		Easily	With little difficulty	With moderate difficulty	With extreme difficulty	Impossible
a)	Walk for a mile on the flat	☐	☐	☐	☐	☐
b)	Walk on rough ground	☐	☐	☐	☐	☐
c)	Walk uphill	☐	☐	☐	☐	☐
d)	Walk downhill	☐	☐	☐	☐	☐
e)	Walk up a flight of stairs	☐	☐	☐	☐	☐
f)	Walk down a flight of stairs	☐	☐	☐	☐	☐
g)	Do household shopping on your own	☐	☐	☐	☐	☐
h)	Wash and dry yourself (all over)	☐	☐	☐	☐	☐
i)	Get in and out of a car	☐	☐	☐	☐	☐
j)	Stand up from a chair	☐	☐	☐	☐	☐
k)	Kneel down and get up again	☐	☐	☐	☐	☐

19. In the time since your hip surgery, when you were at your best, did you use a stick when walking?

a) No, not at all ☐ b) Occasionally ☐ c) Most of the time ☐ d) All of the time ☐

20. In the time since your hip surgery, when you were at your best, how troubled were you by pain in that hip at night?

a) No nights ☐ b) Only 1 or 2 nights ☐ c) Some nights ☐ d) Most nights ☐ d) Every night ☐

21. In the time since your hip surgery, when you were at your best, how troubled were you by pain in that hip during the day?

a) Never ☐ b) Occasionally ☐ c) Often ☐ d) All of the time ☐

Coast Study ID: ______________________   Post Operative Five Year Follow Up (Part II) - Hip

LEISURE ACTIVITIES <u>SINCE</u> YOUR HIP SURGERY

The next few questions are about any leisure activities that you may have done after you had your hip replaced in ________________________. The following light grey boxes have similar questions, but each group relates to different types of activities that load the hips: repeatedly, moderately and lightly. Please read and fill them in if they apply.

22. **In the time since your hip surgery, have you done any leisure activities that <u>LOAD THE HIPS REPEATEDLY</u>?** *(e.g. running, jogging, football, basketball, tennis singles, badminton singles)*

No ☐ Yes ☐

*If **no**, please go to **Question 28***
*If **yes**, please continue with **Question 23***

23. **Which activities of this sort have you done?** *(please list up to three that you have done most)*

____
____
____

24. **Approximately how long after your hip surgery, did you first do leisure activities of this sort?** ☐☐ **months**

25. **Approximately how long is it since you last did one of these activities?** ☐☐ **months**
(*please write 0 if you are still doing the activities)*

26. **In the time since your hip surgery that you were doing activities of this sort, how often did/do you do them?**

a) Less than 3 times per year ☐
b) 3-10 times per year ☐
c) 11-50 times per year ☐
d) More than 50 times per year ☐

27. **In an average week, how much time did/do you spend on these types of leisure activities?**

☐☐ Hours ☐☐ Minutes

28. **In the time since your hip surgery, have you done any leisure activities that <u>LOAD THE HIPS MORE MODERATELY</u>?** *(e.g. cycling, dancing, horse riding, golf, bowls, weight machines, sailing)*

No ☐ Yes ☐

*If **no**, please go to **Question 34***
*If **yes**, please continue with **Question 29***

29. **Which activities of this sort have you done?** *(please list up to three that you have done most)*

____
____
____

Appendix D:

30 **Approximately how long after your hip surgery, did you first do leisure activities of this sort?** ☐☐ **months**

31. **Approximately how long is it since you last did one of these activities?** ☐☐ **months**
(*please write 0 if you are still doing the activities)*

32. **In the time since your hip surgery that you were doing activities of this sort, how often did/do you do them?**

a) Less than 3 times per year ☐

b) 3-10 times per year ☐

c) 11-50 times per year ☐

d) More than 50 times per year ☐

33. **In an average week, how much time did/do you spend on these types of leisure activities?**

☐☐ Hours ☐☐ Minutes

34. **In the time since your hip surgery, have you done any leisure activities that <u>LOAD THE HIPS LIGHTLY</u>?** *(e.g housework, light gardening, ball room dancing, swimming, golf, walking for pleasure, yoga)*

No ☐ Yes ☐

*If no, please go to **Question 40***
*If yes, please continue with **Question 35***

35. **Which activities of this sort have you done?** *(please list up to three that you have done most)*

____

____

____

36. **Approximately how long after your hip surgery, did you first do leisure activities of this sort?** ☐☐ **months**

37. **Approximately how long is it since you last did one of these activities?** ☐☐ **months**
(*please write 0 if you are still doing the activities)*

38. **In the time since your hip surgery that you were doing activities of this sort, how often did/do you do them?**

a) Less than 3 times per year ☐

b) 3-10 times per year ☐

c) 11-50 times per year ☐

d) More than 50 times per year ☐

39. **In an average week, how much time did/do you spend on these types of leisure activities?**

☐☐ Hours ☐☐ Minutes

Coast Study ID: ______________________ Post Operative Five Year Follow Up (Part II) - Hip

YOUR HEALTH NOW

The next questions concern the hip for which you had surgery in ______________________

52. **Please tick an answer in each line. Apart from your hip you had replaced do you currenly suffer from pain or stiffness?**

Do you currently suffer from pain or stiffness	**No**	**Occasionally**	**Frequently**	**All the time**
… in your other hip?	☐	☐	☐	☐
… in your right knee?	☐	☐	☐	☐
… in your left knee?	☐	☐	☐	☐

53. **Apart from any problems with your hips and knees, do you have any other health problems that limit your activities?**

No ☐ Yes ☐

*If **no**, please go to **Question 55***
*If **yes**, please continue with **Question 54***

54. **Please list up to three health problems that you feel are most important**

____

____

____

55. *Please tick the option for each item that best describes how you have been feeling **during the last week.***

I feel tense or 'wound up':
- Most of the time ☐
- A lot of the time ☐
- Time to time, occasionally ☐
- Not at all ☐

I still enjoy the things I used to enjoy:
- Definitely as much ☐
- Not quite so much ☐
- Only a little ☐
- Not at all ☐

I get a sort of frightened feeling like something awful is about to happen:
- Very definitely and quite badly ☐
- Yes, but not too badly ☐
- A little, but it doesn't worry me ☐
- Not at all ☐

I can laugh and see the funny side of things:
- As much as I always could ☐
- Not quite so much now ☐
- Definitely not so much now ☐
- Not at all ☐

Worrying thoughts go through my mind:
- A great deal of the time ☐
- A lot of the time ☐
- From time to time but not too often ☐
- Only occasionally ☐

I feel cheerful:
- Not at all ☐
- Not often ☐
- Sometimes ☐
- Most of the time ☐

I can sit at ease and feel relaxed:
- Definitely ☐
- Usually ☐
- Not often ☐
- Not at all ☐

I feel as if I am slowed down:
- Nearly all of the time ☐
- Very often ☐
- Sometimes ☐
- Not at all ☐

I get a sort of frightened feeling like 'butterflies in the stomach':
- Not at all ☐
- Occasionally ☐
- Quite often ☐
- Very often ☐

I have lost interest in my appearance:
- Definitely ☐
- I don't take as much care as I should ☐
- I may not take quite as much care ☐
- I take just as much care as ever ☐

I feel restless as if I have to be on the move:
- Very much indeed ☐
- Quite a lot ☐
- Not very much ☐
- Not at all ☐

I look forward with enjoyment to things:
- As much as I ever did ☐
- Rather less than I used to ☐
- Definitely less than I used to ☐
- Hardly at all ☐

I get sudden feelings of panic:
- Very often indeed ☐
- Quite often ☐
- Not very often ☐
- Not at all ☐

I can enjoy a good book or radio or TV programme:
- Often ☐
- Sometimes ☐
- Not often ☐
- Very seldom ☐

PRESCRIBED MEDICINES

Finally we would like to ask you about medicines that you may have been prescribed by a doctor.

56. **Have you ever taken bisphosphonates** *(e.g. alendronate, risendronate, pamidronate or zoledronate)?* No ☐ Yes ☐

    *If no, please go to **Question 58***

    If yes, **in what year did you first take them?** Y Y Y Y

57. **Do you still take them?** No ☐ Yes ☐

    If no, **in what year did you last take them?** Y Y Y Y

58. **Have you ever taken hormone replacement therapy (HRT)?** No ☐ Yes ☐

    *If no, please go to **Question 60***

    If yes, **in what year did you first take them?** Y Y Y Y

59. **Do you still take them?** No ☐ Yes ☐

    If no, **in what year did you last take them?** Y Y Y Y

60. **Have you ever taken statins?** *(e.g. atorvastatin, fluvastatin, pravastatin, rosuvastatin, and simvastatin)* No ☐ Yes ☐

    If yes, **in what year did you first take them?** Y Y Y Y

61. **Do you still take them?** No ☐ Yes ☐

    If no, **in what year did you last take them?** Y Y Y Y

Thank you for completing this booklet

Please post back in the prepaid envelope supplied

D.3 Hip questionnaire –GAR cohort

Geneva ID: ____________________

Clinique d'orthopédie et de chirurgie de l'appareil moteur
Département de chirurgie
Hôpitaux Universitaires de Genève

Questionnaire de suivi PTH

ACTIVITÉ PHYSIQUE SUIVANT UNE PROTHESE TOTALE DE HANCHE

NOM ………………………………… **PRENOM** …………………………………

DATE DE NAISSANCE ……………… **DATE DU JOUR** ………………

Quel est votre poids (kg) ? ……… **Quelle est votre taille (cm) ?** ………

Indiquez votre niveau d'étude :

○ Ecole obligatoire (≤ 8 ans d'études, jusqu'à 14 ans)

○ Ecole secondaire (9-12 ans d'études, jusqu'à 18 ans)

○ Ecole supérieure (≥ 13 ans d'études, après 18 ans)

Merci de lire les instructions suivantes avant de compléter ce questionnaire. Toutes les questions font référence à la hanche qui a été remplacée. Si vous avez eu un remplacement des deux hanches, merci de répondre à ces questions en référence à votre premier remplacement de hanche.

Geneva ID: ____________________

Section 1: Votre santé AUJOURD'HUI

Les questions suivantes font référence à votre état de santé actuel et concernent les activités que vous êtes capable de réaliser durant une journée classique. *(Si vous avez eu un remplacement des deux hanches, ces questions font uniquement référence à votre premier remplacement de hanche)*

1.1 ***Durant les 4 dernières semaines…***Comment décririez-vous la douleur que vous avez habituellement ressentie dans votre hanche?

Aucune ☐ i — Minime ☐ ii — Légère ☐ iii — Modérée ☐ iv — Sévère ☐ v

1.2 ***Durant les 4 dernières semaines…***Avez-vous eu des difficultés pour vous laver et vous sécher le corpsvous même (des pieds à la tete) à cause de votre hanche?

Aucune difficulté ☐ i — Difficultés minimes ☐ ii — Difficultés modérées ☐ iii — Difficultés majeures ☐ iv — Impossible à réaliser ☐ v

1.3 **Durant les 4 *dernières* semaines…**Avez-vous eu des difficultés à cause de votre hanche pour entrer ou sortir d'une voiture ou pour utiliser les transports en commun? *(quelque soit le mode de transport* utilisé*)*

Aucune difficulté ☐ i — Difficultés minimes ☐ ii — Difficultés modérées ☐ iii — Difficultés majeures ☐ iv — Impossible à réaliser ☐ v

1.4 ***Durant les 4 dernières semaines…*****Avez-vous été capable de mettre seul(e) vos bas, collants ou chaussettes?**

Oui, facilement ☐ i — Avec très peu de difficultés ☐ ii — Avec quelques difficultés ☐ iii — Avec beaucoup de difficultés ☐ iv — Non, impossible ☐ v

1.5 ***Durant les 4 dernières semaines…*****Avez-vous pu faire tout(e) seul(e) des courses pour la maison?**

Oui, facilement ☐ i — Avec très peu de difficultés ☐ ii — Avec quelques difficultés ☐ iii — Avec beaucoup de difficultés ☐ iv — Non, impossible ☐ v

1.6 ***Durant les 4 dernières semaines…*****Combien de temps pouviez vous marcher (sans vous arreter) avant que la douleur dans votre hanche ne devienne tres importante?** *(avec ou* sans *canne)?*

Pas de douleur ou plus de 30 minutes ☐ i — De 16 à 30 minutes ☐ ii — De 5 à 15 minutes ☐ iii — Autour de la maison seulement ☐ iv — Marche Impossible ou douleur sévère ☐ v

1.7 ***Durant les 4 dernières semaines…*****Avez-vous pu monter un étage par les escaliers?**

Oui, facilement ☐ i — Avec très peu de difficultés ☐ ii — Avec quelques difficultés ☐ iii — Avec beaucoup de difficultés ☐ iv — Non, impossible ☐ v

1.8 ***Durant les 4 dernières semaines...*** Après être resté assis (pour un repas par exemple), quel degré de douleur avez-vous ressenti en vous levant de la chaise à cause de votre hanche?

Pas douloureux du tout ☐ i — Légèrement douloureux ☐ ii — Moderement douloureux ☐ iii — Très douloureux ☐ iv — Insupportable ☐ v

1.9 ***Durant les 4 dernières semaines…***Avez-vous boité en marchant, à cause de votre hanche?

Rarement ou jamais ☐ i — Quelquefois, ou juste au début ☐ ii — Souvent, pas seulement au début ☐ iii — La plupart du temps ☐ iv — Tout le temps ☐ v

1.10 ***Durant les 4 dernières semaines…*****Avez-vous ressenti au niveau de votre hanche malade (ou opéreé) une douleur soudaine, vive et intense (en coup de poignard, spasme, en vrille, etc ...) ?**

Jamais ☐ i — Seulement 1 ou 2 jours ☐ ii — Quelques jours ☐ iii — La plupart desjours ☐ iv — Chaque jour ☐ v

1.11 ***Durant les 4 dernières semaines…***La douleur de votre hanche vous a-t-elle géné(e) dans votre travail ou vos activités habituelles (taches ménagères comprises)?

Pas du tout ☐ i — Un peu ☐ ii — Modérément ☐ iii — Fortement ☐ iv — Tout le temps ☐ v

1.12 ***Durant les 4 dernières semaines…***Avez-vous souffert de douleurs de votre hanche au lit la nuit?

Jamais ☐ i — Seulement 1 ou 2 nuits ☐ ii — Quelques nuits ☐ iii — La plupart des nutis ☐ iv — Toutes les nuites ☐ v

2 of **11**

Geneva ID: ____________________

2. **En dehors de votre prothèse de hanche, souffrez-vous actuellement de douleurs ou de raideurs …** (Merci de cocher une seule réponse par ligne)

	Non	**Occasionnellement**	**Souvent**	**Tout le temps**
… dans votre autre hanche?	☐	☐	☐	☐
… dans votre genoux droit?	☐	☐	☐	☐
… dans votre genoux gauche?	☐	☐	☐	☐

3. **En dehors de vos problèmes de hanche et de genoux, avez-vous d'autres problèmes de santé qui limitent vos activités quotidiennes?** Non ☐ Oui ☐

*Si **non**, merci de passer à la **Question 5***
*Si **oui**, merci de continuer à la **Question 4***

4. **Merci de lister jusqu'à trois problèmes de santé que vous considérez comme les plus importants**

____

____

____

5. Veuillez répondre à toutes les questions en cochant une case. Si vous ne savez pas très bien comment répondre, choisissez la réponse la plus proche de votre situation.

Question: quelle est l'importance de la DOULEUR de votre hanche opérée?

5.1 Lorsque vous marchez sur une surface plane?

○ Aucune ○ Légère ○ Modérée ○ Sévère ○ Extrêmement sévère

5.2 Lorsque vous montez ou descendez les escaliers?

○ Aucune ○ Légère ○ Modérée ○ Sévère ○ Extrêmement sévère

5.3 La nuit, au lit?

○ Aucune ○ Légère ○ Modérée ○ Sévère ○ Extrêmement sévère

5.4 Lorsque vous vous levez d'une chaise ou que vous vous assoyez?

○ Aucune ○ Légère ○ Modérée ○ Sévère ○ Extrêmement sévère

5.5 Lorsque vous vous tenez debout?

○ Aucune ○ Légère ○ Modérée ○ Sévère ○ Extrêmement sévère

Geneva ID: ______________________

Question: quelle est l'importance de la DIFFICULTE que vous éprouvez à:

5.6 Monter les escaliers?

◯ Aucune ◯ Légère ◯ Modérée ◯ Sévère ◯ Extrêmement sévère

5.7 Vous levez de la position assise?

◯ Aucune ◯ Légère ◯ Modérée ◯ Sévère ◯ Extrêmement sévère

5.8 Marcher en terrain plat?

◯ Aucune ◯ Légère ◯ Modérée ◯ Sévère ◯ Extrêmement sévère

5.9 Entrer et sortir d'une automobile?

◯ Aucune ◯ Légère ◯ Modérée ◯ Sévère ◯ Extrêmement sévère

5.10 Mettre des bas?

◯ Aucune ◯ Légère ◯ Modérée ◯ Sévère ◯ Extrêmement sévère

5.11 Sortir du lit?

◯ Aucune ◯ Légère ◯ Modérée ◯ Sévère ◯ Extrêmement sévère

5.12 Vous asseoir?

◯ Aucune ◯ Légère ◯ Modérée ◯ Sévère ◯ Extrêmement sévère

COMMENTAIRES

____

____

COMMENT REPONDRE: Les questions qui suivent portent sur votre santé, telle que vous la ressentez
Ces informations nous permettront de mieux savoir comment vous vous sentez dans votre vie de tous les jours.

6. Veuillez répondre à toutes les questions en cochant une case. Si vous ne savez pas très bien comment répondre, choisissez la réponse la plus proche de votre situation.

6.1 Dans l'ensemble, pensez-vous que votre santé est :

◯ Excellente ◯ Très bonne ◯ Bonne ◯ Médiocre ◯ Mauvaise

Voici une liste d'activités que vous pouvez avoir à faire dans votre vie de tous les jours. Pour chacune d'entre-elles indiquez si vous êtes limité(e) en raison de votre état de santé actuel.

6.2 Efforts physiques modérés tels que déplacer une table, passer l'aspirateur, jouer aux boules

◯ Oui, beaucoup limité(e) ◯ Oui, un peu limité(e) ◯ Non, pas du tout limité(e)

Geneva ID: ____________________

6.3 Monter **plusieurs étages** par l'escalier

◯ Oui, beaucoup limité(e) ◯ Oui, un peu limité(e) ◯ Non, pas du tout limité(e)

Au cours de ces 4 dernières semaines, et en raison de votre état physique,

6.4 Avez-vous **accompli moins** de choses que vous auriez souhaité ◯ Oui ◯ Non

6.5 Avez-vous dû arrêter de faire **certaines** choses ◯ Oui ◯ Non

Au cours des 4 dernières semaines, et en raison de votre état émotionnel (comme vous sentir triste, nerveux(se), ou déprimé(e))

6.6 Avez-vous **accompli moins** de choses que vous auriez souhaité ◯ Oui ◯ Non

6.7 Avez-vous eu des difficultés à faire ce que vous aviez à faire **avec autant de soin et d'attention** que d'habitude ◯ Oui ◯ Non

6.8 Au cours des 4 dernières semaines, dans quelle mesure vos douleurs physiques vous ont-elles limité(e) dans votre travail ou vos activités domestiques?

◯ Pas du tout ◯ Un petit peu ◯ Moyennement ◯ Beaucoup ◯ Enormément

Les questions qui suivent portent sur comment vous vous êtes senti(e) au cours de ces 4 dernières semaines. Pour chaque question indiquer la réponse qui vous semble la plus appropriée. Au cours de ces 4 dernières semaines, y a-t-il eu des moments oú:

6.9 Vous vous êtes senti(e) calme et détendu(e)?

◯ En permanence ◯ Très souvent ◯ Souvent ◯ Quelques fois ◯ Rarement ◯ Jamais

6.10 Vous vous êtes senti(e) débordant(e) d'énergie?

◯ En permanence ◯ Très souvent ◯ Souvent ◯ Quelques fois ◯ Rarement ◯ Jamais

6.11 Vous vous êtes senti(e) triste et abattu(e)?

◯ En permanence ◯ Très souvent ◯ Souvent ◯ Quelques fois ◯ Rarement ◯ Jamais

6.12 Au cours de ces 4 dernières semaines, y a-t-il eu des moments oú votre état de santé, physique ou émotionnel, vous a géné(e) dans votre vie sociale et vos relations avec les autres, votre famille, vos amis, vos connaissances?

◯ En permanence ◯ De temps en temps ◯ Jamais
◯ Une bonne partie du temps ◯ Rarement

Geneva ID: ______________________

Section 2: Emploi rémunéré effectué AVANT votre opération de la hanche

Les questions suivantes concernent tout emploi rémunéré effectué avant le placement de votre prothèse de hanche. *(Si vous avez eu un remplacement des deux hanches, ces questions font uniquement référence à votre premier remplacer de hanche)*

7. **Avant votre opération de la hanche, aviez-vous eu un travail rémunéré (en tant qu'employé ou indépendant)?**

   Non ☐ Oui ☐

   *Si **non**, merci de passer à la **Question 14***
   *Si **oui**, merci de continuer à la **Question 8***

8. **Quel était le dernier travail rémunéré que vous avez effectué avant votre opération de la hanche?**
   Merci d'indiquer la nature de ce travail (ex: charpentier, enseignant, etc.) ______________________

9. **En quelle année avez-vous commencé ce travail?** | A | A | A | A |

10. **Travailliez-vous en tant qu'employé ou indépendant?** Indépendant ☐ Employé ☐

11. **Était-ce toujours votre travail au moment de votre opération de la hanche?** Non ☐ Oui ☐

    *Si **non**, merci de passer à la **Question 12***
    *Si **oui**, merci de continuer à la **Question 14***

12. **En quelle année avez-vous arrêté ce travail?** | A | A | A | A |

13. **Avez-vous arrêté ce travail en raison de votre problème de hanche?** *(Merci de ne cocher qu'une seule case)*

    a) Oui, mon problème de hanche était la **principale raison** de mon arrêt de travail ☐

    b) Oui, mon problème de hanche était **une des raisons** de mon arrêt de travail ☐

    c) Non, j'ai arrêté ce travail pour une tout autre raison ☐

Section 3: Emploi rémunéré effectué DEPUIS votre opération de la hanche

Les questions suivantes concernent tout emploi rémunéré que vous avez effectué depuis la mise en place de votre prothèse de hanche. *(Si vous avez eu un remplacement des deux hanches, ces questions font uniquement référence à votre premier remplacement de hanche)*

14. **Depuis votre opération de la hanche, avez-vous occupé un emploi (d'employé ou d'indépendant) pour une durée d'un mois ou plus?**

    Non ☐ Oui ☐

Geneva ID: ______________________

15. **Merci de compléter la table ci-dessous pour chaque emploi occupé depuis votre opération de la hanche pour une durée d'un mois ou plus. 3 emplois différents peuvent être détaillés dans cette table. Si vous avez effectué plus de 3 emplois différents depuis votre opération de la hanche, nous vous demandons de fournir les détails relatifs à ces emplois supplémentaires sur une feuille de papier séparée de ce questionnaire.**

	Emploi n°1	**Emploi n°2**	**Emploi n°3**
Type d'emploi (ex: charpentier, enseignant, etc.)	______________	______________	______________
Date d'embauche	M M A A A A	M M A A A A	M M A A A A
Date d'arrêt de travail *(si vous êtes toujours occupé par cet emploi, merci de cocher cette case)*	M M A A A A Toujours occupé par cet emploi ☐	M M A A A A Toujours occupé par cet emploi ☐	M M A A A A Toujours occupé par cet emploi ☐
Merci de cocher cette case si vous avez arrêté ce travail partiellement à cause de votre problème de hanche	☐	☐	☐

Une journée classique de votre travail implique t-elle les activités suivantes? (Merci de cocher toutes les cases applicables)

	Emploi n°1	**Emploi n°2**	**Emploi n°3**
Se tenir debout ou marcher plus de 4 heures au total	☐	☐	☐
Marcher plus de 3 kms au total	☐	☐	☐
Porter ou soulever manuellement des poids de 10 kg ou plus	☐	☐	☐
Courir pendant plus de 30 minutes	☐	☐	☐
Porter ou soulever manuellement des poids de 25 kg ou plus	☐	☐	☐
Bècher ou pelleter	☐	☐	☐
S'accroupir ou s'agenouiller	☐	☐	☐
Monter ou descendre plus de 30 marches d'escalier	☐	☐	☐
Monter sur une échelle	☐	☐	☐

Geneva ID: ______________________

Section 4: A propos de vous-même, AU MOMENT OÙ VOUS VOUS ÊTES SENTI LE MIEUX depuis votre remplacement de hanche.

Dans la section suivante, nous nous intéressons à la manière dont vous vous déplaciez et preniez soin de vous AU MOMENT OÙ VOUS VOUS ÊTES SENTI LE MIEUX depuis votre remplacement de hanche (cela peut être MAINTENANT ou n'importe quand dans le passé). *(Si vous avez eu un remplacement des deux hanches, ces questions font uniquement référence à votre premier remplacement de hanche).*

16. **Après votre chirurgie de la hanche, combien de temps vous a-t-il fallut pour atteindre ce moment où vous vous sentiez le mieux?**
    - a) Moins de 6 mois ☐
    - b) Plus de 6 mois mais moins d'un an ☐
    - c) Entre 1 et 2 ans ☐
    - d) Plus de 2 ans ☐

17. **Depuis votre opération, au moment où vous vous sentiez le mieux, dans quelle mesure étiez-vous capable de réaliser les activités suivantes?** *Commentaire: ces questions sont identiques à celles auxquelles vous avez déjà répondu dans la section 1; cependant nous souhaiterions que vous y répondiez à nouveau mais cette fois par rapport à un MOMENT OÙ VOUS VOUS ÊTES SENTI LE MIEUX depuis votre remplacement de hanche. (Cela peut être MAINTENANT ou n'importe quand dans le passé).*

(Merci de ne cocher qu'une seule case par ligne)

	Aucune	Légère	Modérée	Sévère	Extrêmement sévère
a) Monter les escaliers	☐	☐	☐	☐	☐
b) Vouz levez de la position assise	☐	☐	☐	☐	☐
c) Marcher en terrain plait	☐	☐	☐	☐	☐
d) Entrer et sortir d'une automobile	☐	☐	☐	☐	☐
e) Mettre des bas	☐	☐	☐	☐	☐
f) Sortir du lit	☐	☐	☐	☐	☐
g) Vous asseoir	☐	☐	☐	☐	☐

18. **Depuis votre opération, au moment où vous vous êtes sentis le mieux, utilisiez-vous une canne pour aider la marche?**

    a) Non, absolument pas ☐ b) Occasionnellement ☐ c) La plupart du temps ☐ d) Tout le temps ☐

19. **Depuis votre opération, au moment où vous vous êtes sentis le mieux, à quelle fréquence la douleur liée à votre hanche a-t-elle perturbée vos nuits?**

    a) Aucune nuit ☐ b) Une ou deux nuits eulement ☐ c) Quelques nuits ☐ d) La plupart des nuits ☐ e) Toutes les nuits ☐

20. **Depuis votre opération, au moment où vous vous êtes sentis le mieux, à quelle fréquence la douleur liée à votre hanche a-t-elle perturbée vos journées?**

    a) Jamais ☐ b) Occasionnellement ☐ c) Souvent ☐ d) Tout le temps ☐

Geneva ID: ____________________

Section 5: Activités de loisir DEPUIS votre opération de la hanche

Les questions suivantes concernent toute activité de loisirs réalisées après votre remplacement de hanche. Dans les cases colorées suivantes, vous trouverez des questions similaires. Cepedant, chaque couleur se réfère à un type différent d'activité qui entraine une charge sur les hanches: cases bleues (charge répétitive), cases roses (charge modérée) et cases vertes (charge légère). Merci de lire chaque case et d'y répondre si elle s'applique à vous.

(Si vous avez eu un remplacement des deux hanches, ces questions font uniquement référence à votre premier remplacement de hanche)

Activités entrainant une CHARGE RÉPÉTITIVE sur de les hanches

21. **Depuis votre opération de la hanche, avez-vous réalisé une activité entrainant une CHARGE RÉPÉTITIVE sur les hanches** *(ex: course, jogging, football, basket, tennis de simple, badminton de simple etc.)?*

Non ☐ Oui ☐ *Si **non**, merci de passer à la **Question 27***
*Si **oui**, merci de continuer à la **Question 22***

22. **Quelles activités de ce type avez-vous réalisé?** *(Merci de lister les trois principales activités réalisées)*

1) ____________________ 2) ____________________

3) ____________________

23. **Suite à votre chirurgie de la hanche, quel délai approximatif vous a-t-il fallu avant de pouvoir réaliser pour la première fois une activité de ce type?** ☐☐ Mois

24. **Depuis approximativement combien de temps avez-vous réalisé pour la dernière fois une de ces activités ?** (*Merci d'indiquer 0 si vous réalisez toujours ces activités)*

☐☐ Années ☐☐ Mois

25. **Depuis votre opération de la hanche, à quelle fréquence pratiquez-vous les activités de ce type?**

a) Moins de trois fois par an ☐ c) 11-50 fois par an ☐

b) 3-10 fois par an ☐ d) Plus de 50 fois par an ☐

26. **Sur une semaine classique, combien de temps consacrez-vous à la réalisation d'activités de ce type?** ☐☐ Heures ☐☐ Minutes

Activités entrainant une CHARGE MODÉRÉE sur de les hanches

27. **Depuis votre opération de la hanche, avez-vous réalisé une activité entrainant une CHARGE MODÉRÉE sur les hanches** *(ex: vélo, dance, équitation, golf, pétanque, musculation, voile, etc.)?*

Non ☐ Oui ☐ *Si **non**, merci de passer à la **Question 33***
*Si **oui**, merci de continuer à la **Question 28***

Geneva ID: ____________________

28. **Quelles activités de ce type avez-vous réalisé?** *(Merci de lister les trois principales activités réalisées)*
1) ____________________ 2) ____________________
3) ____________________

29 **Suite à votre chirurgie de la hanche, quel délai approximatif vous a-t-il fallu avant de pouvoir réaliser pour la première fois une activité de ce type?** ☐☐ Mois

30. **Depuis approximativement combien de temps avez-vous réalisé pour la dernière fois une de ces activités.** *(Merci d'indiquer 0 si vous réalisez toujours ces activités)*

☐☐ Années ☐☐ Mois

31. **Depuis votre opération de la hanche, à quelle fréquence pratiquez-vous les activités de ce type?**

a) Moins de trois fois par an ☐ c) 11-50 fois par an ☐

b) 3-10 fois par an ☐ d) Plus de 50 fois par an ☐

32 **Sur une semaine classique, combien de temps consacrez-vous à la réalisation d'activités de ce type?** ☐☐ Heure ☐☐ Minutes

Activités entraînant une CHARGE LÉGÈRE sur les hanches

33. **Depuis votre opération de la hanche, avez-vous réalisé une activité entrainant une CHARGE LÉGÈRE** sur les hanches *(ex : ménage, jardinage léger, danse de bal, natation, golf, marche, yoga, etc.)?*

Non ☐ Oui ☐

*Si **non**, merci de passer à la **Question 39***
*Si **oui**, merci de continuer à la **Question34***

34. **Quelles activités de ce type avez-vous réalisé?** *(Merci de lister les trois principales activités réalisées)*
1) ____________________ 2) ____________________
3) ____________________

35. **Suite à votre chirurgie de la hanche, quel délai approximatif vous a-t-il fallu avant de pouvoir réaliser pour la première fois une activité de ce type?** ☐☐ Mois

36. **Depuis approximativement combien de temps avez-vous réalisé pour la dernière fois une de ces activités?** *(Merci d'indiquer 0 si vous réalisez toujours ces activités)*

☐☐ Années ☐☐ Mois

37. **Depuis votre opération de la hanche, à quelle fréquence pratiquez-vous les activités de ce type?**

a) Moins de trois fois par an ☐ c) 11-50 fois par an ☐

b) 3-10 fois par an ☐ d) Plus de 50 fois par an ☐

38. **Sur une semaine classique, combien de temps consacrez-vous à la réalisation d'activités de ce type?** ☐☐ Heures ☐☐ Minutes

Geneva ID: ______________________

Section 6: Médicaments prescrits

Enfin, nous souhaitons vous questionner sur les éventuels traitements qui vous auraient été prescrits par un médecin.

39. **Avez-vous déjà pris des bisphosphonates?**
(ex. Alendronate, Risédronate, Pamidronate ou Zolédronate)

Non ☐ Oui ☐

*Si **non**, merci de passer à la **Question 41***
Si oui, en quelle année en avez-vous pris pour la première fois? | A | A | A | A |

40. **En prenez-vous toujours?**

Non ☐ Oui ☐

Si non, en quelle année en avez-vous pris pour la dernière fois? | A | A | A | A |

41. **Avez-vous déjà pris un traitement hormonal de substitution?**

Non ☐ Oui ☐

*Si **non**, merci de passer à la **Question 43***
Si oui, en quelle année en avez-vous pris pour la première fois? | A | A | A | A |

42. **En prenez-vous toujours?**

Non ☐ Oui ☐

Si non, en quelle année en avez-vous pris pour la dernière fois? | A | A | A | A |

43. **Avez-vous déjà pris des statines?**
(ex. Atorvastatine, Fluvastatine, Pravastatine, Rosuvastatine ou Simvastatine)

Non ☐ Oui ☐

Si non, merci, vous avez terminé
Si oui, en quelle année en avez-vous pris pour la première fois? | A | A | A | A |

44. **En prenez-vous toujours?**

Non ☐ Oui ☐

Si non, en quelle année en avez-vous pris pour la dernière fois? | A | A | A | A |

MERCI POUR VOTRE TEMPS

MERCI DE RETOURNER CE QUESTIONNAIRE DANS L'ENVELOPPE PRÉ-AFFRANCHIE FOURNIE À CET EFFET

Appendix E : Cover letter

Post Operative: Five Year Follow Up (Part II)

University Hospital Southampton NHS
NHS Foundation Trust

COASt
Clinical Outcomes in Arthroplasty Study

Dear Patient

Over the past five years you have kindly helped us by answering some questions as part of our COASt study. We are now interested in finding out about your occupation and what physical activities you have been able to do since you had your joint replaced.

If you are still able to help us, please could you answer the questions in the enclosed booklet and then send the booklet back in the pre-paid envelope provided.

We are aware that the questionnaire is detailed but it will help us to gather valuable information for the study.

Please answer all the questions in clear print using a black or blue pen, and tick all relevant option boxes.

Once you have completed this booklet please return in the enclosed envelope- No stamp required.

For any further questions or information, please feel free to contact us:

Thank you very much for being part of this study

Lisa Shipway or Elena Zaballa
Tel: 023 80 764005 or 023 80795279
E-mail: ls2@mrc.soton.ac.uk
ez@mrc.soton.ac.uk

COASt PI 019 28th November 2016
Final version 1.0

Appendix F : Supplementary material

Table 97. Description of the cup/stem combination in the GAR cohort

Cup/stem combination	n (%)
Moscher/CLS	63 (11)
Moscher/ Muller cemented	81 (14)
Moscher/Virtec/PF	45 (8)
Fitmore/CLS	93 (16)
Other combination	98 (16)
Durom/CLS	21 (4)
Morscher MoM/Müller cemented	129 (22)
Fitmore MoM/CLS	28 (5)
Fitmore MoM/Müller cemented	24 (4)

Table 98. Associations between clinical and surgical characteristics and hip revision in men

	Revision		Mean time to (years)		
	No n (%)	Yes n (%)	Follow-up	Revision	HR[1] (95% CIs)
Indication for THA					
OA	188 (94)	12 (6)	12.5	8.2	1
Dysplasia	18 (95)	1 (5)	12.0	13.7	0.64 (0.08,5.18)
Inflammatory arthritis	5(100)	-	15.1	-	-
Fracture	28 (85)	5 (15)	9.9	7.8	3.08 (1.02,9.27)
Aseptic necrosis	54 (92)	5 (8)	11.9	7.9	1.32 (0.44,3.93)

[1] Age at operation and sex–adjusted estimates

Bibliography

1. Heberden W. Commentaries on the history and cure of diseases. Digitorum nodi.: Boston; 1802.

2. National Institute for Health and Care Excellecence. Osteoarthritis [Internet]. 2015 [Available from: https://cks.nice.org.uk/osteoarthritis.

3. Osteoarthritis Research Society International. What is osteoarthritis? [Internet]. 2013 [Available from: https://www.oarsi.org/what-osteoarthritis.

4. Altman R, Asch E, Bloch D, Bole G, Borenstein D, Brandt K, et al. Development of criteria for the classification and reporting of osteoarthritis. Classification of osteoarthritis of the knee. Diagnostic and Therapeutic Criteria Committee of the American Rheumatism Association. Arthritis Rheum. 1986;29(8):1039-49.

5. Altman R, Alarcon G, Appelrouth D, Bloch D, Borenstein D, Brandt K, et al. The American College of Rheumatology criteria for the classification and reporting of osteoarthritis of the hip. Arthritis Rheum. 1991;34(5):505-14.

6. Kellgren J.H, Lawrence J.S. Radiological Assessment of Osteo-Arthrosis. Ann Rheum Dis1957. p. 494-502.

7. Cross M, Smith E, Hoy D, Nolte S, Ackerman I, Fransen M, et al. The global burden of hip and knee osteoarthritis: estimates from the global burden of disease 2010 study. Ann Rheum Dis. 2014;73(7):1323-30.

8. Murray CJ, Richards MA, Newton JN, Fenton KA, Anderson HR, Atkinson C, et al. UK health performance: findings of the Global Burden of Disease Study 2010. Lancet. 2013;381(9871):997-1020.

9. Arthritis Research UK. Osteoarthritis in general practice. Data and perspectives. [Internet]. 2013 [Available from: www.arthritisresearchuk.org.

10. Kim C, Linsenmeyer KD, Vlad SC, Guermazi A, Clancy MM, Niu J, et al. Prevalence of radiographic and symptomatic hip osteoarthritis in an urban United States community: the Framingham osteoarthritis study. Arthritis Rheumatol. 2014;66(11):3013-7.

11. Iidaka T, Muraki S, Akune T, Oka H, Kodama R, Tanaka S, et al. Prevalence of radiographic hip osteoarthritis and its association with hip pain in Japanese men and women: the ROAD study. Osteoarthritis Cartilage. 2016;24(1):117-23.

12. Guillemin F, Rat AC, Mazieres B, Pouchot J, Fautrel B, Euller-Ziegler L, et al. Prevalence of symptomatic hip and knee osteoarthritis: a two-phase population-based survey. Osteoarthritis Cartilage. 2011;19(11):1314-22.

13. Dillon CF, Rasch EK, Gu Q, Hirsch R. Prevalence of knee osteoarthritis in the United States: arthritis data from the Third National Health and Nutrition Examination Survey 1991-94. J Rheumatol. 2006;33(11):2271-9.

14. Felson DT, Naimark A, Anderson J, Kazis L, Castelli W, Meenan RF. The prevalence of knee osteoarthritis in the elderly. The Framingham Osteoarthritis Study. Arthritis Rheum. 1987;30(8):914-8.

15. Jordan JM, Helmick CG, Renner JB, Luta G, Dragomir AD, Woodard J, et al. Prevalence of knee symptoms and radiographic and symptomatic knee osteoarthritis in African Americans and Caucasians: the Johnston County Osteoarthritis Project. J Rheumatol. 2007;34(1):172-80.

16. Zhang Y, Xu L, Nevitt MC, Aliabadi P, Yu W, Qin M, et al. Comparison of the prevalence of knee osteoarthritis between the elderly Chinese population in Beijing and whites in the United States: The Beijing Osteoarthritis Study. Arthritis Rheum. 2001;44(9):2065-71.

17. Oliveria SA, Felson DT, Reed JI, Cirillo PA, Walker AM. Incidence of symptomatic hand, hip, and knee osteoarthritis among patients in a health maintenance organization. Arthritis Rheum. 1995;38(8):1134-41.

18. Grotle M, Hagen KB, Natvig B, Dahl FA, Kvien TK. Obesity and osteoarthritis in knee, hip and/or hand: an epidemiological study in the general population with 10 years follow-up. BMC Musculoskelet Disord. 2008;9:132.

19. Muraki S, Akune T, Oka H, Ishimoto Y, Nagata K, Yoshida M, et al. Incidence and risk factors for radiographic knee osteoarthritis and knee pain in Japanese men and women: a longitudinal population-based cohort study. Arthritis Rheum. 2012;64(5):1447-56.

20. Kopec JA, Rahman MM, Berthelot JM, Le Petit C, Aghajanian J, Sayre EC, et al. Descriptive epidemiology of osteoarthritis in British Columbia, Canada. J Rheumatol. 2007;34(2):386-93.

21. Arden N, Nevitt MC. Osteoarthritis: epidemiology. Best Pract Res Clin Rheumatol. 2006;20(1):3-25.

22. Prieto-Alhambra D, Judge A, Javaid MK, Cooper C, Diez-Perez A, Arden NK. Incidence and risk factors for clinically diagnosed knee, hip and hand osteoarthritis: influences of age, gender and osteoarthritis affecting other joints. Ann Rheum Dis. 2014;73(9):1659-64.

23. Martel-Pelletier J, Barr AJ, Cicuttini FM, Conaghan PG, Cooper C, Goldring MB, et al. Osteoarthritis. Nat Rev Dis Primers. 2016;2:16072.

24. Blagojevic M, Jinks C, Jeffery A, Jordan KP. Risk factors for onset of osteoarthritis of the knee in older adults: a systematic review and meta-analysis. Osteoarthritis Cartilage. 2010;18(1):24-33.

25. Reyes C, Leyland KM, Peat G, Cooper C, Arden NK, Prieto-Alhambra D. Association Between Overweight and Obesity and Risk of Clinically Diagnosed Knee, Hip, and Hand Osteoarthritis: A Population-Based Cohort Study. Arthritis Rheumatol. 2016;68(8):1869-75.

26. Leyland KM, Judge A, Javaid MK, Diez-Perez A, Carr A, Cooper C, et al. Obesity and the Relative Risk of Knee Replacement Surgery in Patients With Knee Osteoarthritis: A Prospective Cohort Study. Arthritis Rheumatol. 2016;68(4):817-25.

27. Jiang L, Rong J, Wang Y, Hu F, Bao C, Li X, et al. The relationship between body mass index and hip osteoarthritis: a systematic review and meta-analysis. Joint Bone Spine. 2011;78(2):150-5.

28. Jordan JM, Helmick CG, Renner JB, Luta G, Dragomir AD, Woodard J, et al. Prevalence of hip symptoms and radiographic and symptomatic hip osteoarthritis in African Americans and Caucasians: the Johnston County Osteoarthritis Project. J Rheumatol. 2009;36(4):809-15.

29. Muthuri SG, McWilliams DF, Doherty M, Zhang W. History of knee injuries and knee osteoarthritis: a meta-analysis of observational studies. Osteoarthritis Cartilage. 2011;19(11):1286-93.

30. Richmond SA, Fukuchi RK, Ezzat A, Schneider K, Schneider G, Emery CA. Are joint injury, sport activity, physical activity, obesity, or occupational activities predictors for osteoarthritis? A systematic review. J Orthop Sports Phys Ther. 2013;43(8):515-b19.

31. Gosvig KK, Jacobsen S, Sonne-Holm S, Palm H, Troelsen A. Prevalence of malformations of the hip joint and their relationship to sex, groin pain, and risk of osteoarthritis: a population-based survey. J Bone Joint Surg Am. 2010;92(5):1162-9.

32. Croft P, Cooper C, Wickham C, Coggon D. Osteoarthritis of the hip and acetabular dysplasia. Annals of the rheumatic diseases. 1991;50(5):308-10.

33. Smith RW, Egger P, Coggon D, Cawley MI, Cooper C. Osteoarthritis of the hip joint and acetabular dysplasia in women. Ann Rheum Dis. 1995;54(3):179-81.

34. Cheng Y, Macera CA, Davis DR, Ainsworth BE, Troped PJ, Blair SN. Physical activity and self-reported, physician-diagnosed osteoarthritis: is physical activity a risk factor? J Clin Epidemiol. 2000;53(3):315-22.

35. Rogers LQ, Macera CA, Hootman JM, Ainsworth BE, Blairi SN. The association between joint stress from physical activity and self-reported osteoarthritis: an analysis of the Cooper Clinic data. Osteoarthritis Cartilage. 2002;10(8):617-22.

36. Alentorn-Geli E, Samuelsson K, Musahl V, Green CL, Bhandari M, Karlsson J. The Association of Recreational and Competitive Running With Hip and Knee Osteoarthritis: A Systematic Review and Meta-analysis. J Orthop Sports Phys Ther. 2017;47(6):373-90.

37. Ikegawa S. A short history of the genome-wide association study: where we were and where we are going. Genomics Inform. 2012;10(4):220-5.

38. The European Bioinformatics Institute. Buscar [Internet]. [Available from: https://www.ebi.ac.uk/.

39. Dulay GS, Cooper C, Dennison EM. Knee pain, knee injury, knee osteoarthritis & work. Best Pract Res Clin Rheumatol. 2015;29(3):454-61.

40. Ezzat AM, Li LC. Occupational physical loading tasks and knee osteoarthritis: a review of the evidence. Physiother Can. 2014;66(1):91-107.

41. Palmer KT. Occupational activities and osteoarthritis of the knee. Br Med Bull. 2012;102:147-70.

42. McWilliams DF, Leeb BF, Muthuri SG, Doherty M, Zhang W. Occupational risk factors for osteoarthritis of the knee: a meta-analysis. Osteoarthritis Cartilage. 2011;19(7):829-39.

43. Verweij LM, van Schoor NM, Deeg DJ, Dekker J, Visser M. Physical activity and incident clinical knee osteoarthritis in older adults. Arthritis Rheum. 2009;61(2):152-7.

44. Mounach A, Nouijai A, Ghozlani I, Ghazi M, Achemlal L, Bezza A, et al. Risk factors for knee osteoarthritis in Morocco. A case control study. Clin Rheumatol. 2008;27(3):323-6.

45. Department for Work and Pensions. Industrial Injuries Disablement Benefits: technical guidance [Internet]. 2019 [updated 2019 Dec 9,. Available from: www.gov.uk/government/publications/industrial-injuries-disablement-benefits-technical-guidance/industrial-injuries-disablement-benefits-technical-guidance#appendix-1-list-of-diseases-covered-by-industrial-injuries-disablement-benefit.

46. Andersen S, Thygesen LC, Davidsen M, Helweg-Larsen K. Cumulative years in occupation and the risk of hip or knee osteoarthritis in men and women: a register-based follow-up study. Occup Environ Med. 2012;69(5):325-30.

47. Verbeek J, Mischke C, Robinson R, Ijaz S, Kuijer P, Kievit A, et al. Occupational Exposure to Knee Loading and the Risk of Osteoarthritis of the Knee: A Systematic Review and a Dose-Response Meta-Analysis. Saf Health Work. 2017;8(2):130-42.

48. Zhang W, McWilliams DF, Ingham SL, Doherty SA, Muthuri S, Muir KR, et al. Nottingham knee osteoarthritis risk prediction models. Ann Rheum Dis. 2011;70(9):1599-604.

49. Schouten JS, van den Ouweland FA, Valkenburg HA. A 12 year follow up study in the general population on prognostic factors of cartilage loss in osteoarthritis of the knee. Ann Rheum Dis. 1992;51(8):932-7.

50. Industrial Injuries Advisory Council. Ostearthritis of the hip [Internet]. Department for Work and Pensions 2003 [Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/327916/ostearthritis-of-the-hip-cm5977.pdf.

51. Industrial Injuries Advisory Council. Osteoarthritis of the knee and work in the construction industry [Internet]. 2016 [Available from: https://www.gov.uk/government/publications/osteoarthritis-of-the-knee-and-work-in-the-construction-industry-iiac-information-note.

52. Sulsky SI, Carlton L, Bochmann F, Ellegast R, Glitsch U, Hartmann B, et al. Epidemiological evidence for work load as a risk factor for osteoarthritis of the hip: a systematic review. PLoS One. 2012;7(2):e31521.

53. Harris EC, Coggon D. HIP osteoarthritis and work. Best Pract Res Clin Rheumatol. 2015;29(3):462-82.

54. Seok H, Choi SJ, Yoon JH, Song GG, Won JU, Kim JH, et al. The Association between Osteoarthritis and Occupational Clusters in the Korean Population: A Nationwide Study. PLoS One. 2017;12(1):e0170229.

55. Rubak TS, Svendsen SW, Soballe K, Frost P. Risk and rate advancement periods of total hip replacement due to primary osteoarthritis in relation to cumulative physical workload. Scand J Work Environ Health. 2013;39(5):486-94.

56. Rubak TS, Svendsen SW, Soballe K, Frost P. Total hip replacement due to primary osteoarthritis in relation to cumulative occupational exposures and lifestyle factors: a nationwide nested case-control study. Arthritis Care Res (Hoboken). 2014;66(10):1496-505.

57. Office for National Statistics. Overview of the UK population: March 2017 [Internet]. 2017 [Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/articles/overviewoftheukpopulation/mar2017.

58. Dobson F, Hinman RS, Roos EM, Abbott JH, Stratford P, Davis AM, et al. OARSI recommended performance-based tests to assess physical function in people diagnosed with hip or knee osteoarthritis. Osteoarthritis Cartilage. 2013;21(8):1042-52.

59. Forestier R, Francon A, Briole V, Genty C, Chevalier X, Richette P. Prevalence of generalized osteoarthritis in a population with knee osteoarthritis. Joint Bone Spine. 2011;78(3):275-8.

60. Gunther KP, Sturmer T, Sauerland S, Zeissig I, Sun Y, Kessler S, et al. Prevalence of generalised osteoarthritis in patients with advanced hip and knee osteoarthritis: the Ulm Osteoarthritis Study. Ann Rheum Dis. 1998;57(12):717-23.

61. Conaghan PG, Porcheret M, Kingsbury SR, Gammon A, Soni A, Hurley M, et al. Impact and therapy of osteoarthritis: the Arthritis Care OA Nation 2012 survey. Clin Rheumatol. 2015;34(9):1581-8.

62. Fautrel B, Hilliquin P, Rozenberg S, Allaert FA, Coste P, Leclerc A, et al. Impact of osteoarthritis: results of a nationwide survey of 10,000 patients consulting for OA. Joint Bone Spine. 2005;72(3):235-40.

63. Dibonaventura M, Gupta S, McDonald M, Sadosky A. Evaluating the health and economic impact of osteoarthritis pain in the workforce: results from the National Health and Wellness Survey. BMC Musculoskelet Disord. 2011;12:83.

64. Wilkie R, Hay EM, Croft P, Pransky G. Exploring how pain leads to productivity loss in primary care consulters for osteoarthritis: a prospective cohort study. PLoS One. 2015;10(4):e0120042.

65. Bohm ER. Employment status and personal characteristics in patients awaiting hip-replacement surgery. Can J Surg. 2009;52(2):142-6.

66. Palmer KT, Milne P, Poole J, Cooper C, Coggon D. Employment characteristics and job loss in patients awaiting surgery on the hip or knee. Occup Environ Med. 2005;62(1):54-7.

67. Chen A, Gupte C, Akhtar K, Smith P, Cobb J. The Global Economic Cost of Osteoarthritis: How the UK Compares. Arthritis. 2012;2012:698709.

68. Arthritis: The big picture [Internet]. Arthritis Research Campaign 2002 [Available from: https://www.bl.uk/collection-items/arthritis-the-big-picture.

69. Parsons Sarah, Ingram Mary, M. Clarke-Cornwell Alexandra, P. M. Symmons Deborah. A heavy burden. The occurence and impact of musculoskeletal conditions in the United Kingdom today [Internet]. 2011 [Available from: https://www.escholar.manchester.ac.uk/uk-ac-man-scw:123774.

70. Hunter DJ, Schofield D, Callander E. The individual and socioeconomic impact of osteoarthritis. Nat Rev Rheumatol. 2014;10(7):437-41.

71. Oxford Economics. The economic costs of arthritis for the UK economy 2010 [Available from: https://www.oxfordeconomics.com/my-oxford/projects/128882.

72. Zhang W, Moskowitz RW, Nuki G, Abramson S, Altman RD, Arden N, et al. OARSI recommendations for the management of hip and knee osteoarthritis, Part II: OARSI evidence-based, expert consensus guidelines. Osteoarthritis Cartilage. 2008;16(2):137-62.

73. National Institute for Health and Care Excellence. Management of osteoarthritis [Internet]. 2017 [Available from: https://pathways.nice.org.uk/pathways/osteoarthritis.

74. Knight SR, Aujla R, Biswas SP. Total Hip Arthroplasty - over 100 years of operative history. Orthop Rev (Pavia). 2011;3(2):e16.

75. Smith-Petersen MN. The classic: Evolution of mould arthroplasty of the hip joint by M. N. Smith-Petersen, J. Bone Joint Surg. 30B:L:59, 1948. Clin Orthop Relat Res. 1978(134):5-11.

76. Wiles P. The surgery of the osteoarthritic hip. Br J Surg. 1958;45(193):488-97.

77. McKee GK, Watson-Farrar J. Replacement of arthritic hips by the McKee-Farrar prosthesis. The Journal of Bone and Joint Surgery British volume. 1966;48-B(2):245-59.

78. Nissen KI. The Judet Arthroplasty of the Hip via Gibson's Lateral Approach. Postgraduate Medical Journal. 1952;28(321):412-23.

79. Charnley J. Arthroplasty of the hip. A new operation. Lancet. 1961;1(7187):1129-32.

80. Kumar N, Arora GN, Datta B. Bearing surfaces in hip replacement - Evolution and likely future. Med J Armed Forces India. 2014;70(4):371-6.

81. Song E, Seon J, Moon J, Hyoun Y. Arthroplasty - update 2013. Available from: https://www.intechopen.com/books/arthroplasty-update/the-evolution-of-modern-total-knee-prostheses.

82. Total Knee Replacement. The Lancet. 1976;307(7967):1002-3.

83. Walldius B. Arthroplasty of the knee using an endoprosthesis. 8 years' experience. Acta Orthop Scand. 1960;30:137-48.

84. Gunston FH. Polycentric knee arthroplasty: prosthetic simulation of normal knee movement. 1971. Clin Orthop Relat Res. 2006;446:11-2.

85. Coventry B. Mark, Finerman A.M. Gerald, Riley H. Lee, Turner H. Roderick, Upshaw E. Jackson. A new geometric knee for total knee arthroplasty. 1972;83:157-62.

86. Goodfellow JW, Kershaw CJ, Benson MK, O'Connor JJ. The Oxford Knee for unicompartmental osteoarthritis. The first 103 cases. J Bone Joint Surg Br. 1988;70(5):692-701.

87. Mohammad HR, Strickland L, Hamilton TW, Murray DW. Long-term outcomes of over 8,000 medial Oxford Phase 3 Unicompartmental Knees-a systematic review. Acta Orthop. 2018;89(1):101-7.

88. Robertsson O, Lewold S, Knutson K, Lidgren L. The Swedish Knee Arthroplasty Project. Acta Orthop Scand. 2000;71(1):7-18.

89. Cohen D. Out of joint: the story of the ASR. BMJ. 2011;342:d2905.

90. The Royal College of Surgeons of England. An Investigation of the Performance of the 3M Capital Hip System [Internet]. 2001 [Available from: https://www.rcseng.ac.uk/library-and-publications/rcs-publications/docs/capital-hip-system/.

91. National Joint Registry. National Joint Registry for England and Wales: 14th Annual Report [Internet]. 2017 [Available from: http://www.njrreports.org.uk/.

92. National Joint Registry. Age of patients undergoing primary hip replacement [Internet]. 2019 [Available from: https://reports.njrcentre.org.uk/.

93. National Joint Registry. Age for primary knee replacement patients from 2008 to 2016 [Internet]. 2017 [Available from: https://reports.njrcentre.org.uk/knees-primary-procedures-patient-characteristics.

94. The Royal College of Surgeons of England. Get Well Soon. Helping you to make a speedy recovery after total hip replacement [Internet]. 2014 [Available from: https://www.rcseng.ac.uk/patient-care/recovering-from-surgery/total-hip-replacement/.

95. The Royal College of Surgeons of England. Get well soon. Helping you to make a speedy recovery after a total knee replacement [Internet]. 2014 [Available from: https://www.rcseng.ac.uk/patient-care/recovering-from-surgery/total-knee-replacement/download-full-pdf-version/.

96. Kievit AJ, van Geenen RC, Kuijer PP, Pahlplatz TM, Blankevoort L, Schafroth MU. Total knee arthroplasty and the unforeseen impact on return to work: a cross-sectional multicenter survey. J Arthroplasty. 2014;29(6):1163-8.

97. Lenguerrand E, Wylde V, Gooberman-Hill R, Sayers A, Brunton L, Beswick AD, et al. Trajectories of Pain and Function after Primary Hip and Knee Arthroplasty: The ADAPT Cohort Study. PLoS One. 2016;11(2):e0149306.

98. Wood A, Keenan A, Arthur C, Aitken S, Walmsley P, Brenkel I. The Functional Outcome of Total Knee Replacement in Young Patients: A 10-Year Matched Case Control Study Open J Orthopedics. 2013;3(2):128-32.

99. Bachmeier CJM, March LM, Cross MJ, Lapsley HM, Tribe KL, Courtenay BG, et al. A comparison of outcomes in osteoarthritis patients undergoing total hip and knee replacement surgery. Osteoarthritis and Cartilage. 2001;9(2):137-46.

100. Fitzgerald JD, Orav EJ, Lee TH, Marcantonio ER, Poss R, Goldman L, et al. Patient quality of life during the 12 months following joint replacement surgery. Arthritis Rheum. 2004;51(1):100-9.

101. Nilsdotter AK, Toksvig-Larsen S, Roos EM. A 5 year prospective study of patient-relevant outcomes after total knee replacement. Osteoarthritis Cartilage. 2009;17(5):601-6.

102. Long WJ, Bryce CD, Hollenbeak CS, Benner RW, Scott WN. Total knee replacement in young, active patients: long-term follow-up and functional outcome: a concise follow-up of a previous report. J Bone Joint Surg Am. 2014;96(18):e159.

103. Nilsdotter AK, Isaksson F. Patient relevant outcome 7 years after total hip replacement for OA - a prospective study. BMC Musculoskelet Disord. 2010;11:47.

104. Bruyere O, Ethgen O, Neuprez A, Zegels B, Gillet P, Huskin JP, et al. Health-related quality of life after total knee or hip replacement for osteoarthritis: a 7-year prospective study. Arch Orthop Trauma Surg. 2012;132(11):1583-7.

105. Beswick AD, Wylde V, Gooberman-Hill R, Blom A, Dieppe P. What proportion of patients report long-term pain after total hip or knee replacement for osteoarthritis? A systematic review of prospective studies in unselected patients. BMJ Open. 2012;2(1):e000435.

106. Price AJ, Longino D, Rees J, Rout R, Pandit H, Javaid K, et al. Are pain and function better measures of outcome than revision rates after TKR in the younger patient? Knee. 2010;17(3):196-9.

107. Rajpura A, Board T. Complications Following Total Hip Arthroplasty: InTech; 2013. Available from: https://www.intechopen.com/books/arthroplasty-update/complications-following-total-hip-arthroplasty.

108. Healy WL, Della Valle CJ, Iorio R, Berend KR, Cushner FD, Dalury DF, et al. Complications of total knee arthroplasty: standardized list and definitions of the Knee Society. Clin Orthop Relat Res. 2013;471(1):215-20.

109. Havelin LI, Robertsson O, Fenstad AM, Overgaard S, Garellick G, Furnes O. A Scandinavian experience of register collaboration: the Nordic Arthroplasty Register Association (NARA). J Bone Joint Surg Am. 2011;93 Suppl 3:13-9.

110. Blum MA, Singh JA, Lee GC, Richardson D, Chen W, Ibrahim SA. Patient race and surgical outcomes after total knee arthroplasty: an analysis of a large regional database. Arthritis Care Res (Hoboken). 2013;65(3):414-20.

111. Bayliss LE, Culliford D, Monk AP, Glyn-Jones S, Prieto-Alhambra D, Judge A, et al. The effect of patient age at intervention on risk of implant revision after total replacement of the hip or knee: a population-based cohort study. The Lancet. 2017;389(10077):1424-30.

112. Castiello E, Affatato S. Progression of osteoarthritis and reoperation in unicompartmental knee arthroplasty: A comparison of national joint registries. Int J Artif Organs. 2019:391398819879697.

113. Cherian JJ, Jauregui JJ, Banerjee S, Pierce T, Mont MA. What Host Factors Affect Aseptic Loosening After THA and TKA? Clin Orthop Relat Res. 2015;473(8):2700-9.

114. Harrysson OL, Robertsson O, Nayfeh JF. Higher cumulative revision rate of knee arthroplasties in younger patients with osteoarthritis. Clin Orthop Relat Res. 2004(421):162-8.

115. Rand JA, Trousdale RT, Ilstrup DM, Harmsen WS. Factors affecting the durability of primary total knee prostheses. J Bone Joint Surg Am. 2003;85-a(2):259-65.

116. Fehring TK, Murphy JA, Hayes TD, Roberts DW, Pomeroy DL, Griffin WL. Factors influencing wear and osteolysis in press-fit condylar modular total knee replacements. Clin Orthop Relat Res. 2004(428):40-50.

117. Bass AR, McHugh K, Fields K, Goto R, Parks ML, Goodman SM. Higher Total Knee Arthroplasty Revision Rates Among United States Blacks Than Whites: A Systematic Literature Review and Meta-Analysis. J Bone Joint Surg Am. 2016;98(24):2103-8.

118. Dy CJ, Bozic KJ, Pan TJ, Wright TM, Padgett DE, Lyman S. Risk factors for early revision after total hip arthroplasty. Arthritis Care Res (Hoboken). 2014;66(6):907-15.

119. Burn E, Edwards CJ, Murray DW, Silman A, Cooper C, Arden NK, et al. The impact of BMI and smoking on risk of revision following knee and hip replacement surgery: evidence from routinely collected data. Osteoarthritis Cartilage. 2019;27(9):1294-300.

120. Kerkhoffs GMMJ, Servien E, Dunn W, Dahm D, Bramer JAM, Haverkamp D. The influence of obesity on the complication rate and outcome of total knee arthroplasty: a meta-analysis and systematic literature review. J Bone Joint Surg Am. 2012;94(20):1839-44.

121. Wu C, Qu X, Mao Y, Li H, Liu F, Zhu Z. Developmental dysplasia of the hip, age, BMI, place of residence and tobacco abuse increase the odds of aseptic loosening in Chinese patients. PLoS One. 2014;9(1):e85562.

122. Boyer B, Bordini B, Caputo D, Neri T, Stea S, Toni A. What are the influencing factors on hip and knee arthroplasty survival? Prospective cohort study on 63619 arthroplasties. Orthop Traumatol Surg Res. 2019;105(7):1251-6.

123. Sebilo A, Casin C, Lebel B, Rouvillain JL, Chapuis S, Bonnevialle P. Clinical and technical factors influencing outcomes of unicompartmental knee arthroplasty: Retrospective multicentre study of 944 knees. Orthop Traumatol Surg Res. 2013;99(4 Suppl):S227-34.

124. Ferguson RJ, Silman AJ, Combescure C, Bulow E, Odin D, Hannouche D, et al. ASA class is associated with early revision and reoperation after total hip arthroplasty: an analysis of the Geneva and Swedish Hip Arthroplasty Registries. Acta Orthop. 2019;90(4):324-30.

125. Johnsen SP, Sorensen HT, Lucht U, Soballe K, Overgaard S, Pedersen AB. Patient-related predictors of implant failure after primary total hip replacement in the initial, short- and long-terms. A nationwide Danish follow-up study including 36,984 patients. J Bone Joint Surg Br. 2006;88(10):1303-8.

126. Jamsen E, Peltola M, Eskelinen A, Lehto MU. Comorbid diseases as predictors of survival of primary total hip and knee replacements: a nationwide register-based study of 96 754 operations on patients with primary osteoarthritis. Ann Rheum Dis. 2013;72(12):1975-82.

127. Rolfson O, Dahlberg LE, Nilsson J, Malchau H, Garellick G. Variables determining outcome in total hip replacement surgery. J Bone Joint Surg Br 2009;91-B(2):157-61.

128. Namba RS, Cafri G, Khatod M, Inacio MC, Brox TW, Paxton EW. Risk factors for total knee arthroplasty aseptic revision. J Arthroplasty. 2013;28(8 Suppl):122-7.

129. Kreder HJ, Grosso P, Williams JI, Jaglal S, Axcell T, Wal EK, et al. Provider volume and other predictors of outcome after total knee arthroplasty: a population study in Ontario. Can J Surg. 2003;46(1):15-22.

130. Singh JA, Jensen M, Lewallen D. Predictors of periprosthetic fracture after total knee replacement: an analysis of 21,723 cases. Acta Orthop. 2013;84(2):170-7.

131. Teng S, Yi C, Krettek C, Jagodzinski M. Smoking and risk of prosthesis-related complications after total hip arthroplasty: a meta-analysis of cohort studies. PLoS One. 2015;10(4):e0125294.

132. Kapadia BH, Issa K, Pivec R, Bonutti PM, Mont MA. Tobacco use may be associated with increased revision and complication rates following total hip arthroplasty. J Arthroplasty. 2014;29(4):777-80.

133. Phedy P, Ismail HD, Hoo C, Djaja YP. Total hip replacement: A meta-analysis to evaluate survival of cemented, cementless and hybrid implants. World J Orthop. 2017;8(2):192-207.

134. Paxton E, Cafri G, Havelin L, Stea S, Palliso F, Graves S, et al. Risk of revision following total hip arthroplasty: metal-on-conventional polyethylene compared with metal-on-highly cross-linked polyethylene bearing surfaces: international results from six registries. J Bone Joint Surg Am. 2014;96 Suppl 1:19-24.

135. Lopez-Lopez JA, Humphriss RL, Beswick AD, Thom HHZ, Hunt LP, Burston A, et al. Choice of implant combinations in total hip replacement: systematic review and network meta-analysis. BMJ. 2017;359:j4651.

136. Dy CJ, Marx RG, Bozic KJ, Pan TJ, Padgett DE, Lyman S. Risk factors for revision within 10 years of total knee arthroplasty. Clin Orthop Relat Res. 2014;472(4):1198-207.

137. Badawy M, Fenstad AM, Bartz-Johannessen CA, Indrekvam K, Havelin LI, Robertsson O, et al. Hospital volume and the risk of revision in Oxford unicompartmental knee arthroplasty in the Nordic countries -an observational study of 14,496 cases. BMC Musculoskelet Disord. 2017;18(1):388.

138. Meding JB, Wing JT, Ritter MA. Does high tibial osteotomy affect the success or survival of a total knee replacement? Clin Orthop Relat Res. 2011;469(7):1991-4.

139. Niinimaki T, Eskelinen A, Ohtonen P, Puhto AP, Mann BS, Leppilahti J. Total knee arthroplasty after high tibial osteotomy: a registry-based case-control study of 1,036 knees. Arch Orthop Trauma Surg. 2014;134(1):73-7.

140. Badawy M, Fenstad AM, Indrekvam K, Havelin LI, Furnes O. The risk of revision in total knee arthroplasty is not affected by previous high tibial osteotomy. Acta Orthop. 2015;86(6):734-9.

141. Ritter MA, Meding JB. Total hip arthroplasty. Can the patient play sports again? Orthopedics. 1987;10(10):1447-52.

142. Chandler HP, Reineck FT, Wixson RL, McCarthy JC. Total hip replacement in patients younger than thirty years old. A five-year follow-up study. J Bone Joint Surg Am. 1981;63(9):1426-34.

143. Lubbeke A, Garavaglia G, Barea C, Stern R, Peter R, Hoffmeyer P. Influence of patient activity on femoral osteolysis at five and ten years following hybrid total hip replacement. J Bone Joint Surg Br. 2011;93(4):456-63.

144. Majewski M, Widmer KH, Pfister AJ, Friederich NF. Sports and Total Hip Arthroplasty – A Contradiction in Terms? Analysis with a minimum Follow-up of Ten Years. Sports Orthopaedics and Traumatology Sport-Orthopädie - Sport-Traumatologie. 2014;30(4):359-65.

145. Vogel LA, Carotenuto G, Basti JJ, Levine WN. Physical activity after total joint arthroplasty. Sports Health. 2011;3(5):441-50.

146. Hofstaedter T, Fink C, Dorn U, Potzelsberger B, Hepperger C, Gordon K, et al. Alpine Skiing With total knee ArthroPlasty (ASWAP): clinical and radiographic outcomes. Scand J Med Sci Sports. 2015;25 Suppl 2:10-5.

147. Prieto-Alhambra D, Javaid MK, Judge A, Maskell J, Cooper C, Arden NK, et al. Hormone replacement therapy and mid-term implant survival following knee or hip arthroplasty for osteoarthritis: a population-based cohort study. Ann Rheum Dis. 2015;74(3):557-63.

148. Khatod M, Inacio MC, Dell RM, Bini SA, Paxton EW, Namba RS. Association of Bisphosphonate Use and Risk of Revision After THA: Outcomes From a US Total Joint Replacement Registry. Clin Orthop Relat Res. 2015;473(11):3412-20.

149. Lubbeke A, Garavaglia G, Rothman KJ, Bonvin A, Roussos C, Miozzari H, et al. Statins may reduce femoral osteolysis in patients with total Hip arthroplasty. J Orthop Res. 2013;31(5):814-20.

150. Thillemann TM, Pedersen AB, Mehnert F, Johnsen SP, Soballe K. The risk of revision after primary total hip arthroplasty among statin users: a nationwide population-based nested case-control study. J Bone Joint Surg Am. 2010;92(5):1063-72.

151. National Joint Registry. National Joint Registry for England and Wales: 13th Annual Report [Internet]. 2016 [Available from: http://www.njrcentre.org.uk/njrcentre/.

152. Culliford D, Maskell J, Judge A, Cooper C, Prieto-Alhambra D, Arden NK. Future projections of total hip and knee arthroplasty in the UK: results from the UK Clinical Practice Research Datalink. Osteoarthritis Cartilage. 2015;23(4):594-600.

153. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am. 2007;89(4):780-5.

154. Nemes S, Gordon M, Rogmark C, Rolfson O. Projections of total hip replacement in Sweden from 2013 to 2030. Acta Orthop. 2014;85(3):238-43.

155. Mahomed NN, Barrett JA, Katz JN, Phillips CB, Losina E, Lew RA, et al. Rates and outcomes of primary and revision total hip replacement in the United States medicare population. J Bone Joint Surg Am. 2003;85-a(1):27-32.

156. Lavernia CJ, Drakeford MK, Tsao AK, Gittelsohn A, Krackow KA, Hungerford DS. Revision and primary hip and knee arthroplasty. A cost analysis. Clin Orthop Relat Res. 1995(311):136-41.

157. Crowe JF, Sculco TP, Kahn B. Revision total hip arthroplasty: hospital cost and reimbursement analysis. Clin Orthop Relat Res. 2003(413):175-82.

158. Swanson EA, Schmalzried TP, Dorey FJ. Activity recommendations after total hip and knee arthroplasty: a survey of the American Association for Hip and Knee Surgeons. J Arthroplasty. 2009;24(6 Suppl):120-6.

159. Laursen MK, Andersen JB, Andersen MM, Simonsen OH, Laursen MB. Danish surgeons allow the most athletic activities after total hip and knee replacement. Eur J Orthop Surg Traumatol. 2014;24(8):1571-7.

160. Sanderson S, Tatt ID, Higgins JP. Tools for assessing quality and susceptibility to bias in observational studies in epidemiology: a systematic review and annotated bibliography. Int J Epidemiol. 2007;36(3):666-76.

161. The Scottish Intercollegiate Guidelines Network. Critical appraisal notes and checklists [Internet]. 2012 [Available from: http://www.sign.ac.uk/checklists-and-notes.html.

162. Pijls BG, Dekkers OM, Middeldorp S, Valstar ER, van der Heide HJ, Van der Linden-Van der Zwaag HM, et al. AQUILA: assessment of quality in lower limb arthroplasty. An expert Delphi consensus for total knee and total hip arthroplasty. BMC Musculoskelet Disord. 2011;12:173.

163. Dubs L, Gschwend N, Munzinger U. Sport after total hip arthroplasty. Arch Orthop Trauma Surg. 1983;101(3):161-9.

164. Kilgus DJ, Dorey FJ, Finerman GA, Amstutz HC. Patient activity, sports participation, and impact loading on the durability of cemented total hip replacements. Clin Orthop Relat Res. 1991(269):25-31.

165. Espehaug B, Havelin LI, Engesaeter LB, Langeland N, Vollset SE. Patient-related risk factors for early revision of total hip replacements. A population register-based case-control study of 674 revised hips. Acta Orthop Scand. 1997;68(3):207-15.

166. Inoue K, Ushiyama T, Tani Y, Hukuda S. Sociodemographic factors and failure of hip arthroplasty. Int Orthop. 1999;23(6):330-3.

167. Maurer TB, Ochsner PE, Schwarzer G, Schumacher M. Increased loosening of cemented straight stem prostheses made from titanium alloys. An analysis and comparison with prostheses made of cobalt-chromium-nickel alloy. Int Orthop. 2001;25(2):77-80.

168. Flugsrud GB, Nordsletten L, Espehaug B, Havelin LI, Meyer HE. The effect of middle-age body weight and physical activity on the risk of early revision hip arthroplasty: a cohort study of 1,535 individuals. Acta Orthop. 2007;78(1):99-107.

169. Ollivier M, Frey S, Parratte S, Flecher X, Argenson JN. Does impact sport activity influence total hip arthroplasty durability?. Clin Orthop Relat Res. 2012;470(11):3060-6.

170. Delfin I, Persson G, Ekvall Hansson E. Does physical activity affect risk of revision of total hip arthroplasty? A matched pairs study. Eur J Physiother. 2017;19(3):124-30.

171. Heck DA, Clingman JK, Kettelkamp DG. Gross polyethylene failure in total knee arthroplasty. Orthopedics. 1992;15(1):23-8.

172. Jones DL, Cauley JA, Kriska AM, Wisniewski SR, Irrgang JJ, Heck DA, et al. Physical activity and risk of revision total knee arthroplasty in individuals with knee osteoarthritis: a matched case-control study. J Rheumatol. 2004;31(7):1384-90.

173. Han HS, Kang SB. Brief followup report: Does high-flexion total knee arthroplasty allow deep flexion safely in Asian patients? Clin Orthop Relat Res. 2013;471(5):1492-7.

174. Delfin I, Persson G, Ekvall Hansson E. Does physical activity affect risk of revision of total hip arthroplasty? A matched pairs study. Eur J Physiother. 2017.

175. Hoorntje A, Janssen KY, Bolder SBT, Koenraadt KLM, Daams JG, Blankevoort L, et al. The Effect of Total Hip Arthroplasty on Sports and Work Participation: A Systematic Review and Meta-Analysis. Sports Med. 2018;48(7):1695-726.

176. Tilbury C, Schaasberg W, Plevier JW, Fiocco M, Nelissen RG, Vliet Vlieland TP. Return to work after total hip and knee arthroplasty: a systematic review. Rheumatology (Oxford). 2014;53(3):512-25.

177. Krischak G, Kaluscha R, Kraus M, Tepohl L, Nusser M. Return to work after total hip arthroplasty. Unfallchirurg. 2013;116(8):755-9.

178. Healy WL, Sharma S, Schwartz B, Iorio R. Athletic activity after total joint arthroplasty. J Bone Joint Surg Am. 2008;90(10):2245-52.

179. Witjes S, Gouttebarge V, Kuijer PP, van Geenen RC, Poolman RW, Kerkhoffs GM. Return to Sports and Physical Activity After Total and Unicondylar Knee Arthroplasty: A Systematic Review and Meta-Analysis. Sports Med. 2016;46(2):269-92.

180. Zahiri CA, Schmalzried TP, Szuszczewicz ES, Amstutz HC. Assessing activity in joint replacement patients. J Arthroplasty. 1998;13(8):890-5.

181. Saltin B, Grimby G. Physiological analysis of middle-aged and old former athletes. Comparison with still active athletes of the same ages. Circulation. 1968;38(6):1104-15.

182. Kriska A, Caspersen C. Modifiable activity questionnaire. In: a Collection of Physical Activity Questionnaires for Health-Related Research1997. S73-S8 p.

183. Prakash U, Mulgrew S, Espley AJ. Effect of activity levels on polyethylene wear in Charnley low-friction arthroplasty. J R Coll Surg Edinb. 1999;44(3):193-6.

184. Gschwend N, Frei T, Morscher E, Nigg B, Loehr J. Alpine and cross-country skiing after total hip replacement: 2 cohorts of 50 patients each, one active, the other inactive in skiing, followed for 5-10 years. Acta Orthop Scand. 2000;71(3):243-9.

185. Lübbeke A, Barea C. Annual Report 1996-2015. Geneva Joint Arhtroplasty Registry. 2016.

186. Wylde V, Blom AW, Whitehouse SL, Taylor AH, Pattison GT, Bannister GC. Patient-reported outcomes after total hip and knee arthroplasty: comparison of midterm results. J Arthroplasty. 2009;24(2):210-6.

187. Arden N, Altman D, Beard D, Carr A, Clarke N, Collins G, et al. Programme Grants for Applied Research. Southampton (UK): NIHR Journals Library; 2017.

188. Palmer KT, Walker-Bone K, Harris EC, Linaker C, D'Angelo S, Sayer AA, et al. Health and Employment after Fifty (HEAF): a new prospective cohort study. BMC Public Health. 2015;15:1071.

189. Coggon D, Kellingray S, Inskip H, Croft P, Campbell L, Cooper C. Osteoarthritis of the hip and occupational lifting. Am J Epidemiol. 1998;147(6):523-8.

190. Healy WL, Iorio R, Lemos MJ. Athletic activity after joint replacement. Am J Sports Med. 2001;29(3):377-88.

191. Klein GR, Levine BR, Hozack WJ, Strauss EJ, D'Antonio JA, Macaulay W, et al. Return to athletic activity after total hip arthroplasty. Consensus guidelines based on a survey of the Hip Society and American Association of Hip and Knee Surgeons. J Arthroplasty. 2007;22(2):171-5.

192. Dawson J, Fitzpatrick R, Carr A, Murray D. Questionnaire on the perceptions of patients about total hip replacement. J Bone Joint Surg Br. 1996;78(2):185-90.

193. Murray DW, Fitzpatrick R, Rogers K, Pandit H, Beard DJ, Carr AJ, et al. The use of the Oxford hip and knee scores. J Bone Joint Surg Br. 2007;89(8):1010-4.

194. Delaunay C, Epinette JA, Dawson J, Murray D, Jolles BM. Cross-cultural adaptations of the Oxford-12 HIP score to the French speaking population. Orthop Traumatol Surg Res. 2009;95(2):89-99.

195. Kalairajah Y, Azurza K, Hulme C, Molloy S, Drabu KJ. Health outcome measures in the evaluation of total hip arthroplasties--a comparison between the Harris hip score and the Oxford hip score. J Arthroplasty. 2005;20(8):1037-41.

196. Dawson J, Fitzpatrick R, Murray D, Carr A. Questionnaire on the perceptions of patients about total knee replacement. J Bone Joint Surg Br. 1998;80(1):63-9.

197. Collins NJ, Misra D, Felson DT, Crossley KM, Roos EM. Measures of knee function: International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form,

Knee Injury and Osteoarthritis Outcome Score (KOOS), Knee Injury and Osteoarthritis Outcome Score Physical Function Short Form (KOOS-PS), Knee Outcome Survey Activities of Daily Living Scale (KOS-ADL), Lysholm Knee Scoring Scale, Oxford Knee Score (OKS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Activity Rating Scale (ARS), and Tegner Activity Score (TAS). Arthritis Care Res (Hoboken). 2011;63 Suppl 11:S208-28.

198. Whitehouse SL, Lingard EA, Katz JN, Learmonth ID. Development and testing of a reduced WOMAC function scale. J Bone Joint Surg Br. 2003;85(5):706-11.

199. Whitehouse SL, Crawford RW, Learmonth ID. Validation for the reduced Western Ontario and McMaster Universities Osteoarthritis Index function scale. J Orthop Surg (Hong Kong). 2008;16(1):50-3.

200. John E. Ware J, Mark Kosinski, Keller SD. SF-12: How to Score the SF-12 Physical and Mental Health Summary Scales. The Health Institute, New England Medical Center; 1995.

201. Sherk HH. The Long-Term Results of Low-Friction Arthroplasty of the Hip Performed as a Primary Intervention. Clin Orthop Relat Res. 2005(430):3-11.

202. Fitz-Henry J. The ASA classification and peri-operative risk. Ann R Coll Surg Engl. 2011;93(3):185-7.

203. Office for National Statistics. Standard Occupational Classification 2010 [Internet]. 2010 [Available from: https://www.ons.gov.uk/methodology/classificationsandstandards/standardoccupationalclassificationsoc/soc2010/soc2010volume2thestructureandcodingindex#the-job-title-coding-index.

204. Kee JR, Mears SC, Edwards PK, Barnes CL. Modifiable Risk Factors Are Common in Early Revision Hip and Knee Arthroplasty. J Arthroplasty. 2017;32(12):3689-92.

205. Ethgen O, Bruyere O, Richy F, Dardennes C, Reginster JY. Health-related quality of life in total hip and total knee arthroplasty. A qualitative and systematic review of the literature. J Bone Joint Surg Am. 2004;86(5):963-74.

206. Schram B, Orr R. Risk factors for development of lower limb osteoarthritis in physically demanding occupations: A narrative umbrella review. J Occup Health. 2020;62(1):e12103.

207. Hutchings A, Neuburger J, Grosse Frie K, Black N, van der Meulen J. Factors associated with non-response in routine use of patient reported outcome measures after elective surgery in England. Health Qual Life Outcomes. 2012;10:34.

208. Schiffner E, Latz D, Thelen S, Grassmann JP, Karbowski A, Windolf J, et al. Aseptic Loosening after THA and TKA - Do gender, tobacco use and BMI have an impact on implant survival time? J Orthop. 2019;16(3):269-72.

209. Culliford DJ, Maskell J, Beard DJ, Murray DW, Price AJ, Arden NK. Temporal trends in hip and knee replacement in the United Kingdom: 1991 to 2006. J Bone Joint Surg Br. 2010;92(1):130-5.

210. Syddall. H, D'Angelo. S, Ntani. G, Stevens. M, Harris. EC, Linnaker. C, et al. Work participation and risk factors for health-related job loss among older workers in the Health and Employment after Fifty (HEAF) study: evidence from a two year follow-up period 2020 (Unpublished).

211. Evans JT, Evans JP, Walker RW, Blom AW, Whitehouse MR, Sayers A. How long does a hip replacement last? A systematic review and meta-analysis of case series and national registry reports with more than 15 years of follow-up. Lancet. 2019;393(10172):647-54.

212. Junnila M, Laaksonen I, Eskelinen A, Pulkkinen P, Ivar Havelin L, Furnes O, et al. Implant survival of the most common cemented total hip devices from the Nordic Arthroplasty Register Association database. Acta Orthop. 2016;87(6):546-53.

213. Evans JT, Walker RW, Evans JP, Blom AW, Sayers A, Whitehouse MR. How long does a knee replacement last? A systematic review and meta-analysis of case series and national registry reports with more than 15 years of follow-up. Lancet. 2019;393(10172):655-63.

214. Jorgensen AY, Waterman BR, Hsiao MS, Belmont PJ. Functional outcomes of hip arthroplasty in active duty military service members. J Surg Orthop Adv. 2013;22(1):16-22.

215. Foote JA, Smith HK, Jonas SC, Greenwood R, Weale AE. Return to work following knee arthroplasty. Knee. 2010;17(1):19-22.

216. Belmont PJ, Jr., Heida K, Keeney JA, Hamilton W, Burks R, Waterman BR. Return to Work and Functional Outcomes Following Primary Total Knee Arthroplasty in U.S. Military Servicemembers. J Arthroplasty. 2015;30(6):968-72.

217. van der Wees PJ, Wammes JJ, Akkermans RP, Koetsenruijter J, Westert GP, van Kampen A, et al. Patient-reported health outcomes after total hip and knee surgery in a Dutch University Hospital Setting: results of twenty years clinical registry. BMC Musculoskelet Disord. 2017;18(1):97.

218. Williams DP, Blakey CM, Hadfield SG, Murray DW, Price AJ, Field RE. Long-term trends in the Oxford knee score following total knee replacement. Bone Joint J. 2013;95-b(1):45-51.

219. Glebus GP, Feather TW, Hsu JR, Gerlinger TL. Return to duty and deployment after major joint arthroplasty. J Arthroplasty. 2013;28(8):1270-3.

220. Lefevre N, Rousseau D, Bohu Y, Klouche S, Herman S. Return to judo after joint replacement. Knee Surg Sports Traumatol Arthrosc. 2013;21(12):2889-94.

221. Mont MA, LaPorte DM, Mullick T, Silberstein CE, Hungerford DS. Tennis after total hip arthroplasty. Am J Sports Med. 1999;27(1):60-4.

222. Abe H, Sakai T, Nishii T, Takao M, Nakamura N, Sugano N. Jogging after total hip arthroplasty. Am J Sports Med. 2014;42(1):131-7.

223. Meester SB, Wagenmakers R, van den Akker-Scheek I, Stevens M. Sport advice given by Dutch orthopaedic surgeons to patients after a total hip arthroplasty or total knee arthroplasty. PLoS One. 2018;13(8):e0202494.

224. Bradley BM, Moul SJ, Doyle FJ, Wilson MJ. Return to Sporting Activity After Total Hip Arthroplasty-A Survey of Members of the British Hip Society. J Arthroplasty. 2017;32(3):898-902.

225. Ackerman IN, Bohensky MA, Zomer E, Tacey M, Gorelik A, Brand CA, et al. The projected burden of primary total knee and hip replacement for osteoarthritis in Australia to the year 2030. BMC Musculoskelet Disord. 2019;20(1):90.

226. Pilz V, Hanstein T, Skripitz R. Projections of primary hip arthroplasty in Germany until 2040. Acta Orthop. 2018;89(3):308-13.

227. Booth FW, Roberts CK, Laye MJ. Lack of exercise is a major cause of chronic diseases. Compr Physiol. 2012;2(2):1143-211.

228. Malviya A, Wilson G, Kleim B, Kurtz SM, Deehan D. Factors influencing return to work after hip and knee replacement. Occup Med (Lond). 2014;64(6):402-9.

229. Porter M, Armstrong R, Howard P, Porteous M, Wilkinson JM. Orthopaedic registries - the UK view (National Joint Registry): impact on practice. EFORT Open Rev. 2019;4(6):377-90.