**TITLE PAGE**

**TITLE:**

**Professional golfers hips: prevalence and predictors of hip pain with clinical and magnetic resonance examinations**

**Authors:**

Mr Edward Dickenson, Clinical Trials Unit, Warwick Medical School, Warwick, UK

Mr Imran Ahmed, Clinical Trials Unit, Warwick Medical School, Warwick, UK

Mr Miguel Fernandez, Clinical Trials Unit, Warwick Medical School, Warwick, UK

Dr Philip O’Connor, Leeds Musculoskeletal Biomedical Imaging Unit ,Leeds Teaching Hospitals, Leeds, UK

Dr Philip Robinson, Leeds Musculoskeletal Biomedical Imaging Unit ,Leeds Teaching Hospitals, Leeds, UK

Dr Robert Campbell, Radiology Department, Royal Liverpool University Hospital, Liverpool, UK

Andrew Murray, European Tour Performance Institute, European Tour, Virginia Water, UK

Martin Warner, Faculty of Health Sciences, University of Southampton, UK

Professor Charles Hutchinson, Clinical Imaging, Warwick Medical School, Warwick, UK

Dr Roger Hawkes, European Tour Performance Institute, European Tour, Virginia Water, UK

Professor Damian Griffin, Clinical Trials Unit, Warwick Medical School, Warwick, UK

Corresponding author:

Professor Damian R Griffin

Warwick Medical School, Clinical Sciences Research Institute, University Hospitals Coventry and Warwickshire, Clifford Bridge Rd, Coventry, CV2 2DX

Email: damian.griffin@warwick.ac.uk

Telephone: 02476 968618

Keywords:

Hip

Golf

Femoroacetabular Impingement

Manuscript word count: 2771

**ABSTRACT**

Aims

This study aimed to determine the prevalence of hip pain in professional golfers, comparing the lead (left hip in right handed golfer) and trail hips, and to establish what player characteristics predicted hip symptoms.

Methods

Male elite professional golf players were invited to complete questionnaires and undergo clinical and magnetic resonance examinations while attending the Scotish Hydro Challenge 2015. Questionnaires determined player demographics, self reported hip pain and an iHOT12 score (hip related quality of life). Clinical examinations determined hip range of motion and the presence of a positive impingement tests. Magnetic resonance scans determined the presence of labral pathology and player hip morphology with measures of alpha angle (cam), acetabular depth (pincer) and femoral neck antetorsion.

Results

A total of 109 (70% of tournament field) of players completed questionnaires, 73 (47%) underwent clinical examination and 55 (35%) underwent magnetic resonance examination.

19.3% of players complained of hip pain. 11.9% of lead and 9.1% of trail hips were painful (p=0.378), iHOT12 scores were lower in the lead (94.1) compared to the trail hip (95.3) (p=0.007).

Stepwise multiple linear regression modelling was able to predict 20.7% of the variance in iHOT12 scores with mean alpha angles between 12 and 3 o’clock and increasing age significant variables (R2= 0.207 p<0.001, β=-0.502 p<0.001 and β=-0.399 p0.031 respectively).

Conclusions

19.3% of male professional golfers reported hip pain. The presence of an increasing alpha angle and increasing age were significant predictors of reduced hip related quality of life.

Word count: 244

**Summary Box**

**What are the new findings?**

* 19.3% of professional golfers report hip pain.
* Despite greater rotational velocities in the lead hip, there was no clinically important difference in hip related quality of life between lead and trail hips.
* 21% of the variance in hip related quality of life can be predicted by the presence of an increasing alpha angle (a measure of cam morphology) and increasing age.

**How might it impact on clinical practice in the near future?**

* Understanding the epidemiology of hip pain in golfers can help to guide prevention and treatment programs.
* Raising awareness that hip pain is present in 1/5 of professional golfers will promote identification of pathology.

**INTRODUCTION**

Golf is one of the most popular global sports with an estimated 57 million participants worldwide and 4 million in the UK.[1] Regular participation in golf has been shown to be beneficial to an individual’s health with a mean increased life expectancy of 5 years amongst players regardless of gender, age, and socio-economic groups.[2] Golf likely confers the physical, mental, and economic benefits associated with regular physical activity. However participation comes with the risk of injury.

In an efficient golf swing hip rotation is an essential part of the kinetic chain in generating power with the lead hip (left hip in a right handed player) moving rapidly from external to maximal internal rotation and the trail hip (right hip in a right handed player) moving from internal to external rotation. The internal rotational velocities in the lead hip have been measured to peak at 228 **°**/sec and in the trail hip an external rotational velocity of 145**°**/sec.[3] Professional golfers typically hit 200 balls in practice and play four rounds of 18 holes a week channeling large joint torque forces in a repetitive fashion. [4] In a closed kinetic chain these repetitive asymmetrical forces risk injuries to the hip such as labral tears.[3] An increasingly recognised cause of labral tears is the presence of subtle hip shape abnormalities such as the cam and pincer morphologies associated with femoroacetabular impingement (FAI). [5 6] FAI is frequently proposed as a cause of hip pain in different groups of professional athletes including golfers. [7-9] [10]

Within the general population 3-4% of adults aged 16-44 report hip pain.[11] A recent systematic review demonstrated the wide range in the reported prevalence of hip injuries in golfers from 2-18%.[12] However none of the papers included in this review highlight predictors of hip pain in golfers or established whether there were differences in the prevalence of hip pain between the lead and trail hips.

This study aims to determine the prevalence of hip pain in professional golfers, comparing lead and trail hips, and to establish what demographic, clinical and morphological characteristics predict hip pain.

**METHODS**

The study is a prospective cross-sectional clinical and magnetic resonance (MR) imaging study of the hips in elite golfers.

After institutional ethical approval a group of researchers attended the Scottish Hydro Challenge, Aviemore 2015, where a European Challenge Tour (the second tier men's professional golf tour in Europe) tournament was being held.

When registering for the event all professional golfers were invited to take part in the study completing questionnaires, undergoing clinical examination and having magnetic resonance (MR) imaging of both their hips.

**Questionnaires**

Questionnaires determined player demographics including age, height, mass, years playing golf, hours of practice per week and any past history of hip injuries. The presence of hip pain was determined by asking players: “In the past month have you had any pain in the hip or groin lasting one day or longer?”. Where players answered “yes” they were asked which hip was affected. Players´ hip related function was determined, for each hip, using the international hip outcomes tool 12 (iHOT12), a hip related quality of life survey validated for use in assessing young adult hips.[13 14] The iHOT12 provides a score from 0-100 and does not show a ceiling effect. Subjects requiring surgery for a range of hip pathologies have been shown to have a mean score of 66 (+/- 19.3).[13]

**Clinical Examination**

Standardised clinical examinations were undertaken by the first, second and third authors (Orthopaedic surgeons). Passive hip flexion and abduction were measured, with the players supine, using a handheld long arm goniometer with the end point determined as the point at which movement ceased or the pelvis moved.[15] Hip internal rotation at 90**°** of flexion (IR90) was determined with the players seated using an electronic goniometer aligned to the medial aspect of the tibial crest using the technique described by Reichenbach et al.[16] This technique uses weights and pulleys to apply a consistent force moving the joint into internal rotation and has been demonstrated to have an improved inter-observer reliability compared to conventional methods of assessing the range of internal rotation.[16] Flexion adduction internal rotation (FADIR) and flexion abduction external rotation (FABER) impingement tests were also undertaken.[15]

**Magnetic Resonance Examination**

A portable 1.5tesla MR scanner (Siemens, Erlangen, Germany) was used to assess players’ hip morphology. All players who completed questionnaires and clinical examinations were invited to undergo an MR scan. Players who agreed to undergo MR examination were allocated appointment times on a first come basis with the researchers blinded to the results of their questionnaires and clinical examinations. MR imaging was conducted with participants supine and feet held together in neutral rotation with ties. The following MR sequences used were: an axial fast spoiled gradient echo fat saturated 3D sequence from the anterior superior iliac spine to the lesser trochanters to assess hip morphology (Field of view 34cm, echo time (TE) 2.7ms, relaxation time (TR) 7.9ms, slice thickness 2mm, flip angle 0), coronal and sagittal proton density fat saturated (TE 44.4, TR 2000, slice thickness 3mm) sequences of each hip were additionally used to assess intra articular pathology. In order to assess femoral antetorsion the axis of the femoral condyles was determined using a localiser sequence was used (TE 1.3, TR 4.9, slice thickness 3mm).

MR 3D volume sequences were subsequently reconstructed using Osirix DICOM viewer (version 6.0.1 32 bit) to assess hip morphology.[17] Femoral neck antetorsion was measured on axial slices of the hip, using slices through the posterior condyles of the knee as a reference.[18] Femoral neck morphology was assessed by measuring alpha (α) angles around the axis of the femoral neck at 30**°** intervals with 12 o’clock being superior (relative to long axis of femur) and 3 o’clock representing the anterior neck.[19] Acetabular morphology was assessed by measuring the acetabular depth as described by Pfirrman et al. [20] α angles, acetabular depth and femoral neck antetorsion measures were made by the first author, with repeated measurements made on 20 randomly selected cases independently by the fifth author (Consultant Radiologist).

A hip with an α angle greater than 55**°** at 3 o’clock (anterior) was considered to have a cam deformity, [19 21 22] a negative acetabular depth was considered to represent pincer morphology [20] and femoral neck antetorsion of less than 0**°** was considered retrotorsion and pathological.[23] Hips were referred to as lead (left hip in a right handed or right hip in a left handed golfer) and trail (right hip in right handed player or left hip in a left handed golfer).

Three experienced musculoskeletal radiologists each with more than 15 years experience blind double scored all MR scan for signs acetabular labral tears or degeneration/deformity. Where there was disagreement the third observer blind scored the abnormality with the majority score then taken as the consensus score.

**Statistical Analysis**

Summary statistics were used to describe baseline player demographics and differences in player reported pain, iHOT12 scores, hip range of motion, α angles, acetabular depth and femoral neck antetorsion between the lead and trail hips. Differences in the presence of pain between the lead and trail hips were assessed with a Chi squared test. Inter-class correlation coefficients (ICC) were calculated to determine inter rater reliability for measures of alpha angle, femoral neck antetrosion and acetabular depth using a two way fixed effects model for absolute agreement. Wilcoxon signed rank test and paired T tests were used to assess differences between lead and trail hips for parametric and non-parametric data respectively with an alpha value of 0.05. As 12 separate measures of alpha angle were made on each hip a Bonferonni correction was applied giving an alpha value of 0.004.[24] A stepwise multiple linear regression was used to assess the relationship between iHOT12 scores and the mean α angles between 12-3 o’clock (positions where cam morphology is identified [25]), femoral antetorsion, acetabular depth, presence of a labral tear, BMI, age and practice time. Statistical analysis was conducted using SPSS statistics v22 (IBM, Armonk, USA).

**RESULTS**

The Scottish Hydro Challenge was attended by 156 professional male golfers, 109 competitors (70% of the field) completed questionnaires, 73 (47% of the field) underwent clinical examination and 55 (35% of the field) underwent MR examination (see Figure 1). Six players were left handed (right hip lead hip) while 103 were right handed (left hip lead hip).

Table 1 Player Demographics

|  |  |
| --- | --- |
| Players | 109 |
| Mean age years | 29 (+/-5.6) |
| Mean years playing golf | 19 (+/-6.6) |
| Mean hours of practice/ week | 38 (+/-12.0) |
| Height /cm | 182 (+/-6) |
| Mass/ kg | 82 (+/-10) |
| Mean BMI | 24.6 (+/-2.6) |

**Questionnaires**

Twenty-one players (19.3%) complained of hip pain lasting one day or longer over the preceding month. The lead hip was painful in 14 (11.9%) and the trail hip in 9 (9.1%) players (p=0.378). The median iHOT12 scores for the lead hip was significantly lower 94 (IQR 86-98) compared to the trail hip 95 (IQR 90-99) (p=0.007) meaning the hip related quality of life was statistically lower for the lead hip compared to the trail. The first of the iHOT12 questions relates to hip pain (Overall how much pain do you have in your hip/groin?) pain scores were statistically lower in the lead hip compared to the trail with median scores of 97 (IQR 86-100) versus 98 (IQR 93-100) (p=0.039) meaning golfers reported more pain in their lead hips.

**Clinical Examinations**

Flexion adduction internal rotation testing was positive in 22 players (30%; 9 lead, 8 trail, 5 bilateral hips affected). FABER impingement testing was positive in 12 players (16%; 7 lead, 3 trail, 2 bilateral hips affected). The mean IR90 was 32**°** (+/- 8.5) in lead and 31**°** (+/- 6.5) in the trail hip. The mean passive hip flexion was 101**°** (+/- 6.5) for the lead and 101**°** (+/- 6.8) for the trail hip.

**MR Examinations**

α angles around the femoral neck were significantly higher in the trail compared to lead hips (p=0.001), meaning lead hips had greater head neck offset. The greatest difference between lead and trail hip α angles were between 12 and 3 o’clock (see table 2). Mean femoral neck antetorsion was significantly greater for lead hips at 16.7° (+/- 7.5) compared to 13.0° (+/- 7.2) in trail hips (p<0.001). Acetabular depth was 11.6mm (+/- 4.0) in the lead hip and 11.5mm (+/- 3.9) in the trail hips (p=0.81).

ICC were 0.92 (0.85-0.96), 0.85 (0.64-0.94) and 0.85 (0.64-0.94) for α angles, femoral neck antetorsion and acetabular depth measurements respectively*.*

Cam morphology was present in 11 players (20%); the lead hip was affected in 1 player, the trail hip in 5 players and both hips in 5 players. Femoral retrotorsion was present in 2 players (3.6%) with the trail hip affected in isolation in both cases. No player had pincer morphology. Labral tears were identified in 21 players (39%) with 9 (16%) lead hips and 20 (37%) trail hips affected (paired T test p=0.022).

Table 2 Proximal Femoral Morphology

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | α angle/ ° | | | | | | | | | | | | |
| Position on femoral neck (o’clock) | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Trail hip median (IQR) | 45  (42-49) | 66  (55-80) | 56  (48-68) | 45  (40-52) | 40  (37-44) | 42  (40-44) | 43  (41-45) | 38  (36-41) | 36  (36-38) | 39  (36-42) | 42  (39-45) | 41  (39-42) |
| Lead hip  Median (IQR) | 46  (44-48) | 62  (52-73) | 51  (46-57) | 41  (38-46) | 39  (37-43) | 43  (40-45) | 44  (42-46) | 39  (37-43) | 37  (35-40) | 39  (36-42) | 40  (38-43) | 39  (38-42) |
| p value | 0.661 | 0.053 | <0.001\* | 0.001\* | 0.885 | 0.094 | 0.006 | 0.069 | 0.027 | 0.584 | 0.016 | 0.075 |

\* = p values that reached statistical significance

A stepwise multiple linear regression was used to predict the relationship between iHOT12 scores and the mean α angles between 12 and 3 o’clock, femoral antetorsion, acetabular depth, presence of a labral tear, BMI, age and practice time. Preliminary analysis was conducted to ensure there was no violation of the assumption of normality, linearity, multicollinearity and homoscedacity.

A multivariate regression model revealed an R2 of 0.207 (p<0.001) for a mean α angle between 12 and 3 o’clock (β=-0.502 p<0.001) and for age (β=-0.399 p0.031) to be significant predictors for hip quality of life, see table 3. This model is able to predict 21% of the variance in iHOT12 scores.

Femoral neck antetorsion (β=0.02 p=0.83), BMI (β=0.33 p=0.74), practice time (β=0.007 p=0.942), acetabular depth (β=-0.033 p=0.73) and the presence of a labral tear (β=0.087 p=0.38) were not significant predictors.

Table 3 Multiple Linear Regression model of iHOT12 scores

|  |  |  |  |
| --- | --- | --- | --- |
| Predictor | β coefficient | 95% CI | p Value |
| Mean alpha angle 12-3 o’clock | -0.502 | -0.740 to -0.265 | 0.001\* |
| Age | -0.399 | -0.761 to -0.038 | 0.031\* |
| Femoral neck antetorsion | 0.02 | n/a | 0.83 |
| Acetabular depth | -0.033 | n/a | 0.73 |
| Practice time | 0.007 | n/a | 0.942 |
| BMI | 0.33 | n/a | 0.74 |
| Presence of labral tears | 0.087 | n/a | 0.38 |
| CI = confidence intervals \*= significant values | | | |

**DISCUSSION**

This is the first study to describe the prevalence of hip pain and predictors of a lower hip related quality of life in professional golfers. Hip pain (defined as pain lasting for one day or longer in the preceding month) was found to be present in 19.3% of professional golfers. Pain was reported more frequently in the lead hip 11.9 vs 9.1% of hips) although this was not statistically significant. However the lead hip iHOT12 scores (hip related quality of life) were statistically lower for the lead compared to the trail hip (median 94 vs 95). Twenty one per cent of the variance in hip related quality of life (iHOT12) scores could be predicted by an increasing α angle between 12 and 3 o’clock (the anterio-superior portion of femoral head neck junction) and increasing age.

A previous systematic review by Cabri et al assessing golfing injuries reported the prevalence of hip injuries was between 2 and 18%.[12] However it is unclear from this review how hip injuries were defined and if the included studies were homogenous. In professional tennis, where rapid hip rotation is also required, hip pain is reported in 8-27% of players compared to 19.3% of golfers in this study.[26] Our study has specifically assessed self-reported hip pain lasting 1 day or longer at any time in the preceding month and not the point prevalence of diagnosed hip injuries. Although golfers iHOT12 scores were statistically lower in the lead hips (94 vs 95) this is of uncertain clinical significance given the iHOT12 has a minimal clinically important difference of 6.1.[13] It would not be surprising if there was a greater degree of hip pain in the lead hip given the greater rotational velocities experienced and the cumulative load (200 swings and 4 rounds of 18 holes a week), which might be expected to result in exceeding the soft tissue tolerance to injury.[3 4] However as well as understanding the difference in biomechanics of the lead and trail hips, we must also appreciate the difference between lead and trail hip morphology, *(see “Hip morphology in elite golfers: a new finding of asymmetry between lead and trail hips” Dickenson et al (Also submitted for IOC edition of BJSM))* the morphology of the lead hip, which is advantageous to internal rotation, may reduce the possibility of injury despite greater rotational velocities.

The results of this study have allowed us to predict 21% of the variance of iHOT12 hip related quality of life scores in golfers with increasing mean α angles between 12 and 3 o’clock and increasing age proving significant predictors. The association of an increasing α angle predicts a lower iHOT12 score may be the result of premature contact of the femoral neck and acetabulum as described in FAI.[6] This premature contact risks labral tears and cartilage delamination.[3 5] Given this finding clinicians could consider appropriate conservative care for FAI in a golfer reporting hip pain.[27] The presence of cam morphology was also found to predict groin pain in capoeira competitors.[10] Although not assessed in this study the presence of hip morphologies that limit internal rotation; such as cam, pincer and retrotorsion, may also contribute to pain elsewhere in the kinematic chain. For example where limited lead hip rotation is observed in golfers with lower back pain, this may be due to them adapting a compensatory swing that increases the likelihood of injury elsewhere in the kinematic chain.[28]

Increasing age was also found to be a predictor of a lower iHOT12 score, with every additional year lowering the iHOT12 by 0.4. This change may reflect the cumulative load that is placed on an athlete over the duration of his/her career, eventually reaching a critical threshold resulting in injury and pain.[4 12] This pattern may be a reflection of the increased probability of athletes, including professional golfers, developing hip osteoarthritis compared to non athletes, even in the absence of a specific hip injury.[29]

**Strengths and Limitations**

The strengths of this study are that it includes a large group of professional golfers in which both clinical and radiological measures were collected. The response rate to questionnaires was high with 70% of the field completing them. Limitations occurred due to the practicalities of undertaking the study at a professional golf tournament, include a sub-optimal uptake in terms of consent to examination (47%), and the limited number of MR appointments meaning only 35% of eligible players could be imaged. As described in the methods the authors attempted to limit bias in those assessed with questionnaires, clinical and MR examinations so that those imaged were broadly representative of the golfers who attended this event and across the Challenge Tour. The Challenge Tour is a male only professional event and therefore the results are not applicable to female golfers and golfers of other abilities.

Further studies that delineate the precise diagnosis in players who report pain and the time loss due to hip injuries would add to the understanding of hip pathology in professional golfers.

**CONCLUSION**

Hip pain affects 19% of professional golfers, with the lead hip more frequently affected than the trail. Variability in a players’ hip related quality of life can be partially predicted by an increasing α angle between 12 and 3 o’clock (anterio-superior aspect of the head neck junction) and increasing age.

**Funding:**

Professor D Griffin received a grant from Orthopaedic Research UK to facilitate this research. No specific grant number applicable.

Dr PJ O’Connor and Dr P Robinson would like to thank the British Society of Skeletal Radiologists for grant support towards performance of the MR imaging - No specific grant number applicable.

Dr R Hawkes received financial support from the European Tour to support his research.

**Competing Interests:**

The authors have no competing interests to declare

**Acknowledgements:**

Perform, Spire Health Care, provided the MR scanner.

**REFERENCES**

1. Farrally M, Cochran A, Crews D, et al. Golf science research at the beginning of the twenty-first century. Journal of sports sciences 2003;**21**(9):753-65

2. Farahmand B, Broman G, De Faire U, Vågerö D, Ahlbom A. Golf: a game of life and death–reduced mortality in Swedish golf players. Scandinavian journal of medicine & science in sports 2009;**19**(3):419-24

3. Gulgin H, Armstrong C, Gribble P. Hip rotational velocities during the full golf swing. Journal of sports science & medicine 2009;**8**(2):296

4. Gosheger G, Liem D, Ludwig K, Greshake O, Winkelmann W. Injuries and overuse syndromes in golf. The American journal of sports medicine 2003;**31**(3):438-43

5. Beck M, Kalhor M, Leunig M, Ganz R. Hip morphology influences the pattern of damage to the acetabular cartilage femoroacetabular impingement as a cause of osteoarthrtis of the hip. Journal of Bone & Joint Surgery, British Volume 2005;**87**(7):1012-18

6. Ganz R, Parvizi J, Beck M, Leunig M, Nötzli H, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. Clinical orthopaedics and related research 2003;**417**:112-20

7. Philippon M, Schenker M, Briggs K, Kuppersmith D. Femoroacetabular impingement in 45 professional athletes: associated pathologies and return to sport following arthroscopic decompression. Knee Surgery, Sports Traumatology, Arthroscopy 2007;**15**(7):908-14

8. Philippon MJ, Ho CP, Briggs KK, Stull J, LaPrade RF. Prevalence of increased alpha angles as a measure of cam-type femoroacetabular impingement in youth ice hockey players. The American journal of sports medicine 2013;**41**(6):1357-62 doi: 10.1177/0363546513483448[published Online First: Epub Date]|.

9. Larson CM, Sikka RS, Sardelli MC, et al. Increasing alpha angle is predictive of athletic-related "hip" and "groin" pain in collegiate National Football League prospects. Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association 2013;**29**(3):405-10 doi: 10.1016/j.arthro.2012.10.024[published Online First: Epub Date]|.

10. Mariconda M, Cozzolino A, Di Pietto F, Ribas M, Bellotti V, Soldati A. Radiographic findings of femoroacetabular impingement in capoeira players. Knee Surgery, Sports Traumatology, Arthroscopy 2014;**22**(4):874-81

11. Urwin M, Symmons D, Allison T, et al. Estimating the burden of musculoskeletal disorders in the community: the comparative prevalence of symptoms at different anatomical sites, and the relation to social deprivation. Annals of the rheumatic diseases 1998;**57**(11):649-55

12. Cabri J, Sousa JP, Kots M, Barreiros J. Golf-related injuries: A systematic review. European Journal of Sport Science 2009;**9**(6):353-66

13. Mohtadi NG, Griffin DR, Pedersen ME, et al. The development and validation of a self-administered quality-of-life outcome measure for young, active patients with symptomatic hip disease: the International Hip Outcome Tool (iHOT-33). Arthroscopy: The Journal of Arthroscopic & Related Surgery 2012;**28**(5):595-610. e1

14. Griffin DR, Parsons N, Mohtadi NG, Safran MR. A short version of the International Hip Outcome Tool (iHOT-12) for use in routine clinical practice. Arthroscopy: The Journal of Arthroscopic & Related Surgery 2012;**28**(5):611-18

15. Prather H, Harris-Hayes M, Hunt DM, Steger-May K, Mathew V, Clohisy JC. Reliability and agreement of hip range of motion and provocative physical examination tests in asymptomatic volunteers. PM&R 2010;**2**(10):888-95

16. Reichenbach S, Jüni P, Nüesch E, Frey F, Ganz R, Leunig M. An examination chair to measure internal rotation of the hip in routine settings: a validation study. Osteoarthritis and Cartilage 2010;**18**(3):365-71

17. Rosset A, Spadola L, Ratib O. OsiriX: an open-source software for navigating in multidimensional DICOM images. Journal of digital imaging 2004;**17**(3):205-16

18. Dandachli W, Islam SU, Tippett R, Hall-Craggs MA, Witt JD. Analysis of acetabular version in the native hip: comparison between 2D axial CT and 3D CT measurements. Skeletal radiology 2011;**40**(7):877-83

19. Nötzli H, Wyss T, Stoecklin C, Schmid M, Treiber K, Hodler J. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. Journal of Bone & Joint Surgery, British Volume 2002;**84**(4):556-60

20. Pfirrmann CW, Mengiardi B, Dora C, Kalberer F, Zanetti M, Hodler J. Cam and pincer femoroacetabular impingement: characteristic MR arthrographic findings in 50 patients. Radiology-Radiological Society of North America 2006;**240**(3):778-85

21. Lahner M, Bader S, Walter PA, et al. Prevalence of femoro-acetabular impingement in international competitive track and field athletes. International orthopaedics 2014;**38**(12):2571-76

22. Lahner M, Walter PA, von Schulze Pellengahr C, Hagen M, von Engelhardt LV, Lukas C. Comparative study of the femoroacetabular impingement (FAI) prevalence in male semiprofessional and amateur soccer players. Archives of Orthopaedic & Trauma Surgery 2014;**134**(8):1135-41

23. Sutter R, Dietrich TJ, Zingg PO, Pfirrmann CW. Femoral antetorsion: comparing asymptomatic volunteers and patients with femoroacetabular impingement. Radiology 2012;**263**(2):475-83

24. Holm S. A simple sequentially rejective multiple test procedure. Scandinavian journal of statistics 1979:65-70

25. Rakhra KS, Sheikh AM, Allen D, Beaulé PE. Comparison of MRI alpha angle measurement planes in femoroacetabular impingement. Clinical orthopaedics and related research 2009;**467**(3):660-65

26. Abrams GD, Renstrom PA, Safran MR. Epidemiology of musculoskeletal injury in the tennis player. British journal of sports medicine 2012;**46**(7):492-98

27. Wall PD, Fernandez M, Griffin DR, Foster NE. Nonoperative treatment for femoroacetabular impingement: a systematic review of the literature. PM&R 2013;**5**(5):418-26

28. Murray E, Birley E, Twycross-Lewis R, Morrissey D. The relationship between hip rotation range of movement and low back pain prevalence in amateur golfers: an observational study. Physical Therapy in Sport 2009;**10**(4):131-35

29. Cooper C, Inskip H, Croft P, et al. Individual risk factors for hip osteoarthritis: obesity, hip injury and physical activity. American Journal of Epidemiology 1998;**147**(6):516-22