Title: The prevalence of cam hip morphology in a general population sample

Introduction

Femoroacetabular impingement (FAI) syndrome is a motion related disorder of the hip that is characterised by the symptomatic premature contact between the proximal femur and the acetabulum.[1] This premature contact occurs as a result of certain hip shapes such as cam and pincer morphology.[2] Cam morphology describes a flattening or convexity to the femoral head neck junction, which during motion impinges against the acetabular rim.[2] Pincer morphology describes a focal or global over coverage of the femoral head by the acetabular rim, causing the rim to impinge on the femoral neck during motion.[2]

The presence of cam morphology has been associated with the development of hip osteoarthritis (OA) since the 1960s. Murray and later Stulberg noted the high prevalence of cam hip shapes in patient undergoing hip arthroplasty.[3, 4] In 2003 Ganz et al described FAI as cause of hip OA, and in 2005 Beck et al hypothesised a mechanism by which FAI syndrome causes hip OA.[2, 5] Since this description a number of cohort studies have shown an increased risk of developing OA in subjects with cam morphology.[6-8] The same association with OA has not been demonstrated with the presence of pincer morphology.[9]

Despite the increase in the recognition of cam morphology as a cause of hip OA the epidemiology is poorly defined. A systematic review attempted to define the point prevalence in the general population and reported a estimates from 5 to 75% of the population affected.[10] This systematic review was unable to identify any truly general population based studies. Meta-analysis was not possible due to the heterogeneity in study populations and the variety of measures used to define cam morphology.[10] A recent consensus meeting stated that hip morphology is best characterised with cross sectional imaging.[1] Only one study, Sutter et al, has reported the diagnostic accuracy of measuring cam morphology. Sutter et al defined the diagnostic accuracy of the most frequently used measure of cam morphology; the alpha (α) angle.[11] They described that an α angles measured in the antero-superior (1:30 o'clock) aspect of the femoral head neck junction had the best receiver operator characteristics.[11] Sutter et al reported that a threshold value of 60° provided a sensitivity of 80% and specificity of 73%, for the detection of cam morphology associated with FAI syndrome.[11] No existing studies of the prevalence of cam morphology have exclusively used this diagnostic criterion.

We aim to define the prevalence of cam morphology in the general population, using cross sectional imaging and a measure with a pre defined diagnostic accuracy.

Methods

Institutional and NHS research ethics committee approval was given on 27th August 2014 (14/NI/1078). This manuscript is reported in accordance with the STROBE guidelines.[12]

Population

All patients who presented to University Hospitals of Coventry and Warwickshire (UHCW) in 2015 and received a computed tomography (CT) scan following major trauma were screened. Major trauma is defined as an injury severity score of greater than 15.[13] All subjects between 16 and 65 years were deemed eligible. Subjects were excluded if they had sustained a pelvic, acetabular or femoral fracture or were deceased.

Eligible participants were divided into male and female groups and different age groups, of 10 years: 16-25, 26-35, 36-45, 46-55 and 56-65. A sample of 20 eligible participants within each group was randomly selected, using random number generation.

Included participants' date of birth, ethnicity (as coded on hospital records), postcode, and digital communication in medicine (DICOM) files were recorded.

Outcomes

Each subjects postcode was used to calculate their index of multiple deprivation (IMD) from the UK 2011 census data.[14] The IMD is the official measure of relative deprivation for neighbourhoods in England.[15] The IMD is based on 7 domains: income, employment, education, health, crime, barriers to housing and services, living environment. Areas are ranked in deciles according to these measures.

DICOM files were imported into OsiriX viewer (Geneva, Switzerland) version 8.0.1.[16] Multiplanar reconstruction of each hip were generated and α angles, as defined by Notzli et al, were measured in the antero-superior (1:30 o'clock) aspect of the femoral head neck junction relative to the long axis of the femur.[17] α angles are a widely used and easily reproducible method for objectively detecting cam morphology.[17, 18] When measuring α angles a high value, such as 70° indicates cam morphology, where hips with smaller value e.g. 45° are regarded as normal. In this study hips where the α angle was greater than 60°, in the antero-superior aspect of the femoral head neck junction, were defined as having cam morphology.[11] The presence of hip osteophytes at the femoral head neck junction was recorded.[19]

α angles were measured by ED, with repeat measures made one month later on a sample of 20 subjects to assess intra-observer reliability. PW made repeat measures on a sample of 20 subjects to assess inter-observer reliability.

Statistical Analysis

The inter- and intra-observer reliability of α angles was calculated by assessing the inter class correlation coefficient for absolute agreement. Summary statistics were generated to report the prevalence of cam morphology as a proportion of participants and hips affected, with 95% confidence intervals.[20] A secondary analysis excluding hips and subjects with head neck osteophytes was also performed.

Sample Size

A sample size calculation was performed in order to establish the number of participants that would be required to estimate the point prevalence with a power (β) of 0.8 and a confidence (α) of 0.05. The study by Hack et al was used to estimate the constant proportion (the anticipated prevalence of cam morphology- 34%) for the sample size calculation.[21] Including 200 participants provided 80% power, for a confidence interval width of 0.1, anticipating a prevalence of 0.35.[22] This sample size allowed 20 males and females in the 5 different age groups to be included.

Results

The 2015 UHCW major trauma database was screened over consecutive months. After nine months, a sufficient number of subjects had been identified to allow random sampling of each age and sex group. Figure 1 shows how the sample was identified.

<Insert Figure 1>

Participant Characteristics

Ethnicity

Of the 200 participants included 181 had their ethnicity recorded. The majority of patients (85.6%) were white. The ethnicity of the included subjects is compared to the UK general population (2011 census data) in Table 1.[14]

< Insert table 1>

Index of Multiple Deprivation

There was a broad representation in the sample from the most to the least deprived areas based on the IMD; see Table 2.

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Prevalence of Cam Morphology

The inter- and intra-observer reliability of measuring α angles was 0.873 (95%CI 0.85-90) and 0.903 (95%CI 0.87-0.93) respectively. The prevalence of cam morphology in the population sampled was 47% (95%CI 42-51), with 56% of men and 37% of women affected (see Table 3). The prevalence estimate of cam morphology at different ages and in men and women is displayed in Table 3. The prevalence of cam morphology, excluding subjects with osteophytes, was 45% (95%CI 37-52) (males 54% females 36%).

<Insert Table 3>

Discussion

In this study 47% of subjects' aged 16-65 (males 56% and females 37%) had cam morphology. The sample was broadly representative of the UK general population including similar proportions in terms of age, sex, ethnicity and social deprivation distribution. Cam morphology was measured using cross sectional imaging, in keeping with recent recommendations.[1] The measure of cam morphology used a measure with a pre-determined diagnostic accuracy.[11]

A recent systematic review attempted to define the prevalence of cam morphology in the general population.[10] This review reported that there were no general population based studies, studies used a wide range of diagnostic criteria and were of a high risk of bias.[10] Therefore the true prevalence could not be established.

Studies included in this systematic review that estimated the prevalence of cam morphology using cross sectional imaging include Omoumi et al, Hack et al and Kang et al.[10] Omoumi et al (n=77) report a prevalence of 61% when assessing α angles greater than 55° at 1:30 o'clock.[23] Hack et al (n=200) reported a prevalence of cam morphology of 34% using the same criteria.[21] While Kang et al (n=50) report a prevalence of cam morphology of just 12% when measuring α angles greater than 55° at 3 o'clock.[24] Each of these studies were rated as a high risk of bias due to the way in which their samples were derived and as a result they lack external validity. These studies also failed to use a measure of cam morphology with a pre-defined diagnostic utility.[10]

Our study sampled equal numbers of men and women of different ages and by reporting the ethnicity and the IMD this sample was shown to be broadly representative of the general population. The sampling frame was a clinical population which may have introduced bias in the prevalence estimate.[25] The hospital where the sample was obtained is the second busiest major trauma centre in the UK and receives patients from across the midlands region.[26] Despite the perception that the occurrence of major trauma is random in nature, it is recognised that young males are more frequently affected.[27] In our sampling of equal numbers of males and female, of different ages we attempted to correct for this. This ensured the sample reflected the general populations demographics and not the population who sustain major trauma.

Strengths of this study are that the sampling frame included equal numbers of men and women of different ages and that the definition of cam morphology had an established diagnostic accuracy. The use of CT scanning also strengthens this study as it offers an improved sensitivity compared to plain radiographs.

A potential source of bias from sampling major trauma patients could depend on the activity level of patients. Increased levels of activity in adolescence are associated with the development of cam morphology.[28] If those who have increased levels of activity are more likely to suffer major trauma this could result in an over estimate of the prevalence of cam morphology. The incidence of acetabular fractures (a group excluded in our study) and posterior instability is reported to be higher amongst those with cam morphology; this is a further potential source of bias, which may result in an under estimate of the true prevalence.[29, 30] Any effect of this bias on the overall prevalence estimate is likely to very small given the low incidence of these injuries.[31]

Due to the retrospective nature of the study design the authors were unable to collect data on the presence of hip symptoms or examination signs. The presence of cam morphology alone does not constitute a diagnosis of FAI syndrome. In order to be diagnosed with FAI syndrome patients' must have hip symptoms, positive examination features and associated radiographic signs (such as cam morphology).[1] Therefore we must be cautious when interpreting this studies prevalence estimate in the context of FAI syndrome.

The number of patients assessed in this study is modest compared to other studies of cam morphology.[6, 32, 33] The number of subjects assessed by Agricola et al, Gosvig et al and Laborie et al was much greater, but these studies were limited by only assessing plain radiographs. Sutter et al found that measuring in the anterosuperior aspect (1:30 o'clock) of the head neck junction offered the best receiver operator characteristics.[11] Rakhra et al also reported that measuring cam morphology on plain radiographs lacks sensitivity.[34] This view was supported in a recent consensus meeting.[1] Despite the modest size of this study, the sample size calculation showed that assessing 200 subjects could estimate the prevalence to a confidence interval width of 0.1. Indeed the 95% confidence intervals for the prevalence estimate in this study were 42-51%.

Given the relatively high prevalence reported in this study we should question whether the specificity of the chosen measure (73%) was high enough.[11] Using a measure with a greater specificity, and therefore higher α angle threshold, will have resulted in a lower prevalence estimate. However this would reduce the sensitivity of the measure to detect cam morphology associated with FAI syndrome. In their study determining the diagnostic utility of measuring α angles on cross sectional imaging Sutter et al, gave equal emphasis to sensitivity and specificity.[11] This is not unreasonable in a measure of this type, compared to, for example, a cancer-screening tool where greater emphasis on sensitivity might be desirable.[35]

Different criteria for the presence of cam morphology were used in this study and those that associate cam morphology and hip OA.[6, 7] Agricola et al and Nelson et al measured α angles on antero-posterior radiographs (measuring 12 o'clock- superior aspect of head neck junction) to determine the association between cam morphology and OA.[6, 7] In the study by Agricola et al they found α angles greater than 83°, at 12 o'clock, had the greatest risk of developing OA. It is plausible that different sizes of cam morphology (e.g. larger) may be required to cause OA, while smaller cam morphology, and therefore lower α angles, may not cause OA but are associated with FAI syndrome.

In this study different age groups up to 65 years were sampled. It was expected that some subjects, particularly in the older age groups, would have evidence of hip osteoarthritis.[36] In osteoarthritic hips, osteophytes form at the femoral head neck junction.[37] The presence of osteophytes in participants would increase their α angles, potentially creating a false positive result for the presence of cam morphology. A sub group prevalence estimate was provided that excluded cases with radiographic OA. This reduced the prevalence estimate of cam morphology to 45% of subjects (males 54% females 36%).In order to improve our understanding of the epidemiology of FAI syndrome prospective studies that assess the association between hip pain, clinical findings and hip morphology are required; this would establish the prevalence of FAI syndrome in the population. Longitudinal studies are required to determine the factors that associate cam morphology and the development of FAI syndrome and hip OA.

Conclusion

In a sample broadly representative of the UK general population, using criteria with a known diagnostic accuracy, cam morphology was identified in 47% of the participants aged between

16-65 (males 56% and females 37%). When excluding subjects with hip OA this estimate reduced to 45% of subjects (males 54% females 36%).

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Contributions

ED, PW, CH and DG all helped design the study, interpreted the data, drafted the manuscript and approved the final version. ED collected and analysed the data.

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Disclaimer

The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR or the Department of Health.

Competing interests Statement

The authors declare they have no conflicts of interest.

References

1. Griffin DR, Dickenson EJ, Agricola R, Awan T, Beck M, Dijkstra P, et al. The 2016 Warwick Agreement on Femoroacetabular Impingement. British journal of sports medicine 2016; 50: 1169-1176.

2. 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: 112-120.

3. Murray R. The aetiology of primary osteoarthritis of the hip. The British journal of radiology 1965; 38: 810-824.

4. Stulberg SD, Cordell LD, Harris W, Ramsey P, MacEwen G. Unrecognized childhood hip disease: a major cause of idiopathic osteoarthritis of the hip. The Hip: Proceedings of the Third Open Scientific Meeting of the Hip Society. St Louis, MO: CV Mosby1975:212-228.

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 early osteoarthritis of the hip. Journal of Bone & Joint Surgery - British Volume 2005; 87: 1012-1018.

6. Agricola R, Heijboer MP, Bierma-Zeinstra SM, Verhaar JA, Weinans H, Waarsing JH. Cam impingement causes osteoarthritis of the hip: a nationwide prospective cohort study (CHECK). Annals of the rheumatic diseases 2012; 72: 918-923.

7. Nelson AE, Stiller JL, Shi XA, Leyland KM, Renner JB, Schwartz TA, et al. Measures of hip morphology are

related to development of worsening radiographic hip osteoarthritis over 6 to 13 year follow-up: The Johnston County Osteoarthritis Project. Osteoarthritis and Cartilage 2016; 24: 443-450.

8. Thomas G, Palmer A, Batra R, Kiran A, Hart D, Spector T, et al. Subclinical deformities of the hip are significant predictors of radiographic osteoarthritis and joint replacement in women. A 20 year longitudinal cohort study. Osteoarthritis and Cartilage 2014; 22: 1504-1510.

9. Agricola R, Heijboer MP, Roze RH, Reijman M, Bierma-Zeinstra SM, Verhaar JA, et al. Pincer deformity does not lead to osteoarthritis of the hip whereas acetabular dysplasia does: acetabular coverage and development of osteoarthritis in a nationwide prospective cohort study (CHECK). Osteoarthritis and Cartilage 2013; 21: 1514-1521.

10. Dickenson E, Wall PD, Robinson B, Fernandez M, Parsons H, Buchbinder R, et al. Prevalence of Cam Hip Shape Morphology: A Systematic Review. Osteoarthritis and Cartilage 2016; 24: 949-961.

11. Sutter R, Dietrich TJ, Zingg PO, Pfirrmann CW. How useful is the alpha angle for discriminating between symptomatic patients with cam-type femoroacetabular impingement and asymptomatic volunteers? Radiology 2012; 264: 514-521.

12. Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. PLoS medicine 2007; 4: e296.

13. Baker SP, o'Neill B, Haddon Jr W, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. Journal of Trauma-Injury, Infection, and Critical Care 1974; 14: 187-196.

14. Statistics OfN. Ethnicity and National Identity in England and

Wales: 2011. Office for National Statistics 2012.

15. Statistics OfN. 2011 Census Aggregate data. vol. 2017, June 2016 ed2011.

16. Rosset A, Spadola L, Ratib O. OsiriX: an open-source software for navigating in multidimensional DICOM images. Journal of digital imaging 2004; 17: 205-216.

17. 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. Bone & Joint Journal 2002; 84: 556-560.

18. Mast NH, Impellizzeri F, Keller S, Leunig M. Reliability and agreement of measures used in radiographic evaluation of the adult hip. Clinical Orthopaedics and Related Research 2011; 469: 188-199.

19. Kellgren J, Lawrence J. Radiological assessment of osteo-arthrosis. Annals of the rheumatic diseases 1957; 16: 494.

20. Newcombe RG. Two- sided confidence intervals for the single proportion: comparison of seven methods. Statistics in medicine 1998; 17: 857-872.

21. Hack K, Di Primio G, Rakhra K, Beaule PE. Prevalence of cam-type femoroacetabular impingement morphology in asymptomatic volunteers. Journal of Bone & Joint Surgery - American Volume 2010; 92: 2436-2444.

22. Machin D, Campbell MJ, Tan S-B, Tan S-H. Sample size tables for clinical studies, John Wiley & Sons 2011.

23. Omoumi P, Thiery C, Michoux N, Malghem J, Lecouvet FE, Vande Berg BC. Anatomic features associated with femoroacetabular impingement are equally common in hips of old and young asymptomatic individuals without CT signs of osteoarthritis. American Journal of Roentgenology 2014; 202: 1078-1086.

24. Kang AC, Gooding AJ, Coates MH, Goh TD, Armour P, Rietveld J. Computed tomography assessment of hip joints in asymptomatic individuals in relation to femoroacetabular impingement. American Journal of Sports Medicine 2010; 38: 1160-1165.

25. Hoy D, Brooks P, Woolf A, Blyth F, March L, Bain C, et al. Assessing risk of bias in prevalence studies: modification of an existing tool and evidence of interrater agreement. Journal of clinical epidemiology 2012; 65: 934-939.

26. Network TAaR. TARN: University Hosptial of Coventry and Warwickshire. vol. 20172017.

27. Lecky F, Woodford M, Bouamra O, Yates D. Lack of change in trauma care in England and Wales since 1994. Emergency medicine journal 2002; 19: 520-523.

28. Agricola R, Heijboer MP, Ginai AZ, Roels P, Zadpoor AA, Verhaar JA, et al. A cam deformity is gradually acquired during skeletal maturation in adolescent and young male

soccer players: a prospective study with minimum 2-year follow-up. American Journal of Sports Medicine 2014; 42: 798-806.

29. Krych AJ, Thompson M, Larson CM, Byrd JT, Kelly BT. Is posterior hip instability associated with cam and pincer deformity? Clinical Orthopaedics and Related Research 2012; 470: 3390-3397.

30. Clegg TE, Roberts CS, Greene JW, Prather BA. Hip dislocations-Epidemiology, treatment, and outcomes. Injury 2010; 41: 329-334.

31. Thompson VP, Epstein HC. Traumatic dislocation of the hip. J Bone Joint Surg Am 1951; 33: 746-792.

32. 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. Journal of Bone & Joint Surgery - American Volume 2010; 92: 1162-1169.

33. Laborie LB, Lehmann TG, Engesaeter IO, Eastwood DM, Engesaeter LB, Rosendahl K. Prevalence of radiographic findings thought to be associated with femoroacetabular impingement in a population-based cohort of 2081 healthy young adults. Radiology 2011; 260: 494-502.

34. 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: 660-665.

35. Usher-Smith JA, Sharp SJ, Griffin SJ. The spectrum effect in tests for risk prediction, screening, and diagnosis. BMJ 2016; 353: i3139.

36. Felson DT, Zhang Y. An update on the epidemiology of knee and hip osteoarthritis with a view to prevention. Arthritis & Rheumatology 1998; 41: 1343-1355.

37. Harrison M, Schajowicz F, Trueta J. Osteoarthritis of the hip: a study of the nature and evolution of the disease. Bone & Joint Journal 1953; 35: 598-626.