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The prevalence of cam hip morphology in a general population sample

E.J. Dickenson † ‡, P.D.H. Wall † ‡, C.E. Hutchinson † ‡, D.R. Griffin † ‡ *

† University of Warwick, Coventry, CV4 7AL, UK
‡ University Hospitals of Coventry and Warwickshire NHS Trust, Coventry, CV2 2DX, UK

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SUMMARY

Objective: Cam hip morphology is associated with femoroacetabular impingement (FAI) syndrome and causes hip osteoarthritis (OA). We aimed to assess the prevalence of cam hip morphology in a sample representative of the general population, using a measure with a predefined diagnostic accuracy.
Design: Patients aged 16–65, who were admitted to a major trauma centre and received a computed tomography (CT) pelvis were retrospectively screened for eligibility. Subjects with proximal femoral, acetabular or pelvic fractures and those who were deceased were excluded. Eligible subjects were divided into 10 groups based on gender and age. 20 subjects from each group were included. Subjects' index of multiple deprivation (IMD) and ethnicity were recorded. CT imaging was assessed and alpha angles (a measure of cam morphology) measured in the anterosuperior aspect of the femoral head neck junction. An alpha angle greater than 60° was considered to represent cam morphology. This measure and technique has a predefined sensitivity of 80% and specificity of 73% to detect cam morphology associated with FAI syndrome. The prevalence of cam morphology was reported as a proportion of subjects affected with 95% confidence intervals.
Results: 200 subjects were included. The sample was broadly representative of the UK general population in terms of IMD. 155 subjects (86%) identified as white. Cam morphology was present in 47% (95% CI 42,51) of subjects.
Conclusions: In this sample, broadly representative of the UK general population 47% of subjects had cam hip morphology; a hip shape associated with FAI syndrome and OA.

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)

* Address correspondence and reprint requests to: D.R. Griffin, University of Warwick, Coventry, CV4 7AL, UK.
E-mail addresses: E.J.L.Dickenson@warwick.ac.uk (E.J. Dickenson), P.D.H.Wall@warwick.ac.uk (P.D.H. Wall), C.E.Hutchinson@warwick.ac.uk (C.E. Hutchinson), Damian.Griffin@warwick.ac.uk (D.R. Griffin).

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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 seven 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 1 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 five different age groups to be included.

Results

The 2015 UHCW major trauma database was screened over consecutive months. After 9 months, a sufficient number of subjects had been identified to allow random sampling of each age and sex group. Fig. 1 shows how the sample was identified.

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 I[14].

IMD

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

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 III). The prevalence estimate of cam morphology at different ages and in men and women is displayed in Table III. The prevalence of cam morphology, excluding subjects with osteophytes, was 45% (95% CI 37–52) (males 54% females 36%).

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

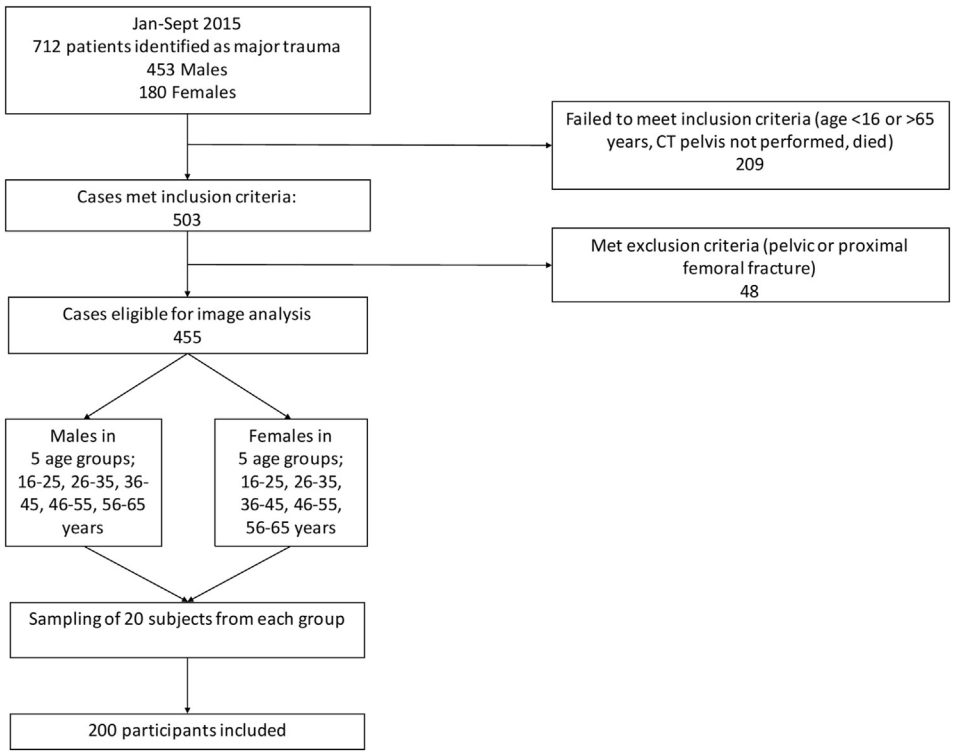

Fig. 1. Participant flow diagram.

Table I
Ethnicity of included subjects

Ethnicity	Number of subjects (%)	% of UK general population (2011 census data)[14]
White including:	155 (85.6)	86
1. English/Welsh/Scottish/Northern Irish/British		
2. Irish		
3. Gypsy or Irish Traveller		
4. Any other White background		
Mixed/Multiple ethnic groups including:	2 (1.1)	2.2
5. White and Black Caribbean		
6. White and Black African		
7. White and Asian		
8. Any other Mixed/Multiple ethnic background		
Asian/Asian including:	10 (5.5)	7.5
9. Indian		
10. Pakistani		
11. Bangladeshi		
12. Chinese		
13. Any other Asian		
Black/African/Caribbean/Black British including:	1 (0.6)	3.3
14. African		
15. Caribbean		
16. Any other Black/African/Caribbean background		
Other ethnic group including:	13 (7.2)	1
17. Arab		
18. Any other ethnic group		
Not stated	19 (n/a)	n/a

n/a = not applicable.

Table II
Index of multiple deprivation

IMD decile	% of participants
Most deprived – 1	11
2	10
3	11
4	9
5	10
6	10
7	8
8	9
9	8
Least deprived – 10	9
No data	7

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

Table III
Prevalence of cam morphology

5 Population and age group, years	Number of hips affected (%)	Number of participants affected (%)
Males and females aged 16–65 years	150 (38)	93 (47)
Males		
16–25	16 (40)	10 (50)
26–35	12 (30)	7 (35)
36–45	20 (50)	13 (65)
46–55	17 (43)	13 (65)
56–65	18 (45)	13 (65)
16–65	83 (42)	56 (56)
Females		
16–25	10 (25)	7 (35)
26–35	10 (25)	6 (30)
36–45	20 (50)	5 (25)
46–55	22 (55)	14 (70)
56–65	5 (13)	5 (25)
16–65	67 (34)	37 (37)
Excluding cases of OA		
Males and females aged 16–65	125 (75)	74 (45)
Males aged 16–65	66 (41)	43 (54)
Female aged 16–65	59 (34)	31 (36)

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

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.

Competing interests statement

The authors declare they have no conflicts of interest.

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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.

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