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Prevalence of cam and pincer-type deformities on hip MRI in an asymptomatic young Swiss female population: a cross-sectional study

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SUMMARY

Objectives: Femoroacetabular impingement is proposed to cause early osteoarthritis (OA) in the non-dysplastic hip. We previously reported on the prevalence of femoral deformities in a young asymptomatic male population. The aim of this study was to determine the prevalence of both femoral and acetabular types of impingement in young females.

Methods: We conducted a population-based cross-sectional study of asymptomatic young females. All participants completed a set of questionnaires and underwent clinical examination of the hip. A random sample was subsequently invited to obtain magnetic resonance images (MRI) of the hip.

All MRIs were read for cam-type deformities, increased acetabular depths, labral lesions, and impingement pits. Prevalence estimates of cam-type deformities and increased acetabular depths were estimated, and relationships between deformities and signs of joint damage were examined using logistic regression models.

Results: The study included 283 subjects, and 80 asymptomatic females with a mean age of 19.3 years attended MRI. Fifteen showed some evidence of cam-type deformities, but none were scored to be definite. The overall prevalence was therefore 0% [95% confidence interval (95% CI) 0–5%]. The prevalence of increased acetabular depth was 10% (95% CI 5–19). No association was found between increased acetabular depth and decreased internal rotation of the hip. Increased acetabular depth was not associated with signs of labral damage.

Conclusions: Definite cam-type deformities in women are rare compared to men, whereas the prevalence of increased acetabular depth is higher, suggesting that femoroacetabular impingement has different gender-related biomechanical mechanisms.

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Introduction

The concept of femoroacetabular impingement (FAI)[1] indicates that non-dysplastic morphologic deviations of the acetabulum or the proximal femur can result in hip damage triggered by hip motions, such as flexion and internal rotation, which potentially leads to chondral and/or labral lesions and eventually osteoarthritis (OA)[2,3]. FAI can be a secondary phenomenon resulting from a variety of deformities, including femoral neck fractures[4], insufficient surgical interventions, slipped capital femoral epiphysis[5] and Legg–Calve–Perthes Disease[6]. However, most frequently it is due to primary morphological changes of the acetabulum and/or proximal femur[7].

Two different types of FAI are distinguished: the “cam” and the “pincer” types. The pincer type is caused by an increased acetabular depth resulting in acetabular overcoverage. Repetitive direct

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impact of the femoral head/neck junction and the acetabular rim leads to damage and degeneration of the anterosuperior rim with leverage and subsequent posteroinferior contrecoup damage[8]. Cam impingement is caused by an increased radius of the femoral head and/or an insufficient head–neck offset. The increased radius of the femoral head entering the acetabulum results in shearing forces, which in turn lead to an outside-in abrasion of the anterosuperior acetabular cartilage and to deep-reaching avulsions of the cartilage from the labrum and the subchondral bone, mostly at the anterior superior rim[2]. The etiology of the cam deformity remains unclear, with few studies suggesting abnormalities during organogenesis or abnormal growth of the capital physis[9]. A population-based cross-sectional study, a case–control study and a prospective cohort study found that cam impingement as diagnosed on conventional radiographs is associated with an increased risk of severe OA of the hip[10–12].

We previously reported a prospective population-based inception cohort study in 1094 male individuals with cam-type deformities found in one out of four young asymptomatic males, and in every second male with decreased internal rotation[13]. No information exists on the prevalence of these deformities in females. The aim of this study was to determine the prevalence of cam-type deformities in a population-based cross-sectional cohort study in asymptomatic young females and to compare the prevalence of cam-type deformities and increased acetabular depth as a measure of pincer-type deformity between females and males.

Methods

Participants

We set up a population-based inception cohort study of young female individuals aged 18–19 attending vocational school for manual or non-manual occupations or grammar school. A two-stage sampling strategy was used for subject recruitment. During the first stage, we selected grammar school or vocational school classes representing the target population of 18- to 19-year-old individuals in the Canton of Bern. All female students of the selected classes were asked to participate in the study, to complete a questionnaire that included items related to pain, stiffness, and physical function of the hip, and to undergo measurement of internal rotation of the hip. During the second stage, we used random sampling of all participants of the first stage, stratified according to the extent of internal rotation, to select participants for magnetic resonance imaging (MRI) examination. The study was approved by the Research Ethics Committee of the Canton of Bern. All of the participants provided written informed consent prior to data collection. The comparator population of male participants was previously reported[13–15]. In brief, young attendees of one recruiting center of the Swiss army, representing the same Canton of Bern from which we recruited the current female cohort, were asked to participate in the study. A total of 1096 (96%) out of 1141 consecutive males consented and underwent measurement of internal rotation of the hips[14]. Two hundred forty-four males underwent MRI examination.

Study procedures

Identical procedures as previously reported for males[13–15] were used for females included in this study. We screened all of the individuals for hip pain using a modified version of the question used in the First National Health and Nutrition Examination Survey[16]: “During the past 3 months, have you had pain in or around either of your hips?” Individuals who reported hip pain of at least 3 on a Likert scale ranging from 1 (no pain) to 5 (extreme pain) were excluded from the inception cohort. Additional exclusion criteria were previous surgery in either hip joint, metabolic or inflammatory rheumatic disease, or a history of hemophilia, age below 18 years, and an inability to give written informed consent. Self-report questionnaires included the subscales on pain, stiffness, and function of the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), version 3.1, to quantify symptoms within the previous 48 h[17], and the European Quality of Life (EuroQol) questionnaire, which includes five dimensions and a visual analog scale (VAS) on health-related quality of life[18]. We measured internal rotation using a recently developed examination chair[14], which enabled us to reliably measure internal rotation of the hip in a sitting position with the hips and knees flexed 90° and the lower legs hanging unsupported[14].

MRI assessment

We used a central computer-generated randomization schedule to randomly select participants for MRI. Stratification was performed according to the extent of internal rotation, with oversampling in the strata with the lowest ($\leq 40^\circ$) and highest ($>50^\circ$) degrees of internal rotation. Oversampling was used to increase statistical precision for populations of individuals at both ends of the distribution. Only one hip per participant was examined. In individuals whose hips had different ranges of motion, the hip with the lower degree of internal rotation was selected. When hips had similar internal rotation (within 1°), the hip to be studied was randomly selected using a concealed central computer-generated randomization schedule[13].

All MRI studies were performed with a 1.5 T high-field system (Magnetom Avanto, Siemens, Erlangen, Germany) using a flexible surface coil with high spatial resolution protocol, with patients lying supine with the hip joint in a neutral position. Radial proton density-weighted sequences were acquired with all slices oriented parallel to the femoral neck axis, which was used as the axis of rotation. Sequences were performed using a sagittal oblique localizer, which was marked on the proton density-weighted coronal sequence and which ran parallel to the sagittal oblique course of the acetabulum[19]. For further details see Appendix, MRI protocol. For ethical reasons, neither intraarticular nor intravenous contrast was injected.

To determine the presence of cam-type deformities, we graded the maximum offset at the head–neck junction on the radial sequences using a semi-quantitative scoring system. This system involved grades ranging from 0 to 3, as follows: 0 = normal, no evidence of a nonspherical femoral shape (cam deformity) on any sequence; 1 = possible deformity with cortical irregularity and a possible mild decrease of the anterior head–neck offset; 2 = definite deformity with an established decrease of the anterior head–neck offset (cam deformity of less than 10 mm); and 3 = severe deformity with a large decrease in the anterior head–neck offset (cam deformity of more than 10 mm)[13]. Grades 2 and 3 were prespecified as indicating a definite cam-type deformity. We determined the alpha angle on radial sequences, which is located in the middle of the anterosuperior quadrant, as recommended by Pfirrmann *et al.*[20] In males, the mean ± standard deviation (SD) alpha angle was 44.8° ± 8.4° for grade 0, 48.4° ± 10.1° for grade 1, 57.7°± 12.7° for grade 2, and 76.4° ± 9.7° for grade 3 deformities ($P = 0.001$ for trend)[13].

We defined the depth of the acetabulum as the distance (in mm) between the center of the femoral neck and the line connecting the anterior acetabular rim to the posterior acetabular rim on the axial oblique plane[20]. The value was positive if the center of the femoral head was lateral to the line connecting both acetabular rims. Values ≤ 3 mm were considered to represent increased acetabular depth (Appendix Fig. 1).

We used a clock face system to record the localization of cam-type deformities and signs of joint damage on MR, such as labral disorders on radial sequences, with 12 o'clock denoting a superior location, 3 o'clock anterior, 6 o'clock inferior, and 9 o'clock posterior[13]. We previously described in detail the structural damage patterns on MRI and used the same definitions in the female cohort[15]. The normal labrum has a pointed, triangular shape with sharp margins. Deformed labra were defined as those with any shape other than triangular: oval, round, or irregular at 12 o'clock[19,21]. A labral lesion was defined as a linear band of high signal intensity detected in the labrum at any location from 1 to 12 o'clock. We distinguished two types of labral lesions: labral avulsion if detected at the basis, i.e., at the transition between labrum and acetabular cartilage, and intralabral signal alterations if detected in the body of the labrum. In a labral avulsion the linear signal change reaches the surface, whereas in an intralabral signal alteration the linear signal intensity remains within the labrum and does not reach the surface[21,22]. Labral ganglia were recorded at any location from 1 to 12 o'clock[19]. Impingement pits, formerly called herniation pits, are well-delineated, round to oval fibrocystic changes of the femoral neck with increased or decreased signal intensity[23–25]. These alterations are deemed to be a consequence of repetitive microcontusions of the femoral neck against the acetabular rim. We recorded the presence and locations of such cysts. All MRIs were read by one experienced radiologist (SW) who had also read MRIs in the previous study in males[13,15]. A random sample of 30 MRIs was in addition read by an experienced radiologist (CP) for the assessment of acetabular depth, with intraclass correlation coefficients of 0.79 [95% confidence interval (CI) 0.64–0.94], and 0.82 (95% CI 0.71–0.94) for the intra- and interrater agreement, respectively. Intra- and interrater agreements[26] for the other types of structural damages were reported previously[15].

Statistical analysis

The study was set up to allow a comparison between males and females in terms of the prevalence of cam-type deformity. With an estimated prevalence of cam-type deformity in males of 24%[13], a sample size of 80 females with MRI and 240 males would yield >80% power to detect a risk difference of −15% and >90% power to detect a risk difference of −17% of cam-type deformity in females as compared to males. Clinical characteristics are reported as means (±SD) for continuous variables and proportions for the binary variable both weighted to account for the oversampling of participants in the strata with lowest (≤40°) and highest (>50°) internal rotation. Comparisons between female attenders and nonattenders and between female attenders and male attenders were performed using weighted linear regression for continuous variables and weighted logistic regression for binary variables. WOMAC scores were standardized to range from 0 to 10, with higher values indicating more severe symptoms. The five dimensions of the EuroQol were mapped onto a single health state index based on the European value set and standardized to range from 0 to 10[27], with higher values indicating better health-related quality of life. Stratum-specific prevalences of radiological characteristics according to the extent of internal rotation were derived from conventional logistic regression models, along with 95%-CIs and *P*-values for trends across strata.

We assessed associations of different signs of hip joint damage with cam-type deformity and increased acetabular depth using odds ratios with 95%-CIs and compared associations between females and males using interaction tests from weighted logistic regression, crude or adjusted for age and body mass index (BMI). An odds ratio above one indicates that hips with cam-type deformities (or hips with increased acetabular depth) are more likely to have signs of joint damage than those without. We then used histograms to determine the distribution of cam-type deformities, labral tears, intralabral tears, labral avulsions, and labral ganglia across locations on radial sequences, starting from 12 o'clock in a clockwise manner, with widths of bins of 1 h. All *P*-values are two-sided. Analyses were performed using Stata 11 (Stata Corporation, College Station, Texas).

Results

Characteristics of the study sample

Participants were recruited between September 2007 and January 2008. The flow of participants through the study is shown in Appendix Fig. 2. A total of 283 (94%) of 301 consecutive females consented to participate. Ten participants were subsequently excluded because of relevant hip pain. Of the remaining individuals, 62 (23%) had an internal rotation of less than 40°, 157 (58%) between 40 and 50°, and 50 (18%) had an internal rotation of more than 50°. Internal rotation was not measured in four individuals. A total of 136 participants were invited for MR examination and 80 (59%) attended. The right hip was imaged in 35 cases (44%). Reasons for nonattendance were refusal to undergo MRI [11 (20%)], time constraints [15 (27%)], and claustrophobia [14 (25%)]. Miscellaneous reasons were given by 16 participants (29%). Appendix Table 1 shows a comparison of attenders, nonattenders, and noninvited participants, with little evidence for differences. The mean age of the participants attending MRI was 19.3 years, and the mean BMI was 21.2 kg/m^2. Table I compares females and males who

Table I

Comparison of clinical characteristics between female and male attenders of MRI examination

	Females ($n = 80$)	Males ($n = 244$)	Difference (95%-CI)	*P*-value
Age (years)	19.3 ± 1.3	20.0 ± 0.9	0.7 (0.4–1.0)	<0.001
Height (cm)	166.0 ± 6.6	178.1 ± 7.6	12.2 (10.4–13.9)	<0.001
Weight (kg)	58.6 ± 8.1	73.0 ± 13.5	14.4 (11.9–16.8)	<0.001
BMI (kg/cm^2)	21.2 ± 2.2	23.0 ± 4.0	1.7 (1.1–2.4)	<0.001
WOMAC overall†	0.11 ± 0.21	0.18 ± 0.52	0.08 (0.00–0.16)	0.06
WOMAC pain†	0.11 ± 0.39	0.23 ± 1.00	0.12 (−0.04–0.27)	0.14
WOMAC stiffness†	0.27 ± 0.70	0.67 ± 1.92	0.40 (0.11–0.68)	0.007
WOMAC function†	0.09 ± 0.19	0.11 ± 0.45	0.03 (−0.04–0.10)	0.47
EuroQol health state index‡	9.1 ± 1.3	9.3 ± 1.5	0.3 (−0.1–0.6)	0.12
EuroQol VAS	8.6 ± 1.2	8.5 ± 1.3	−0.1 (−0.4–0.2)	0.46
RGSC social class I, II, III N*	76%	70%	−5% (−17–7)	0.39

Data are reported as weighted means (±SD) for continuous variables and weighted proportions for the binary variable. *P*-values are derived from a weighted linear regression for continuous variables and a weighted logistic regression for the binary variable.

[*] Social class I, II, III N of at least one parent.

[†] WOMAC: Western Ontario and McMaster University Osteoarthritis Index standardized to range from 0 to 10.

[‡] EuroQol: European Quality of Life standardized to range from 0 to 10.

Table II

Prevalence of radiological characteristics among female and male attenders of MRI examination

	Females ($n = 80$)	Males ($n = 244$)	Difference (95%-CI)	P-value
Cam-type deformity $\geq$ grade 1 [%]	22 (13–34)	71 (64–77)	−49 (−61 to −37)	<0.001
Cam-type deformity $\geq$ grade 2 [%]	0 (0–5)*	24 (19–30)	−24 (−30 to −19)	<0.001
Increased acetabular depth $\leq$ 3 mm [%]	10 (5–19)	6 (4–11)	3 (−4–11)	0.32
Labral tears [%]	19 (12–30)	70 (64–76)	−51 (−62 to −40)	<0.001
Intralabral tears [%]	13 (6–23)	34 (28–41)	−21 (−32 to −11)	0.002
Labral avulsions [%]	14 (8–24)	62 (55–69)	−49 (−59 to −38)	<0.001
Labrum deformity [%]	5 (2–15)	10 (6–14)	−4 (−11 to 3)	0.32
Labral ganglion [%]	4 (1–12)	26 (20–33)	−22 (−29 to −14)	<0.001
Impingement pits [%]	0 (0–5)*	17 (12–23)	−17 (−22 to −11)	<0.001

Weighted prevalences with 95%-CIs and P-values for the comparison between females and males are derived from weighted logistic regression models.

* Exact binomial CI.

underwent MRI. Compared to males, the females were slightly younger, shorter, and had a lower BMI. The two cohorts did not differ regarding WOMAC, EuroQol or social class.

Prevalence of cam-type deformities, increased acetabular depths, and other MRI characteristics

A total of 15 out of 80 MRI showed some evidence of a cam-type deformity, all scored as grade 1. None satisfied our pre-specified definition of a definite cam-type deformity, which required grade 2 or more. The overall adjusted prevalence of a definite cam-type deformity was therefore 0%, with an upper 95% CI of 5% (Table II). The overall adjusted prevalence of a grade 1 deformity was 22% (95% CI 13–34%). A total of nine out of 80 MRI showed an increased acetabular depth of ≤ 3 mm, yielding an adjusted prevalence of 10% (95% CI 5–19). Labral lesions were found in 17 MRI [adjusted prevalence 19% (95% CI 12–30)]; intralabral signal alterations in 10 MRI [adjusted prevalence 13% (95% CI 6–23)]; labral avulsions in 13 MRI [adjusted prevalence 14% (95% CI 8–24)]; labral deformities in four MRI [adjusted prevalence 5% (95% CI 2–15)]; and labral ganglions in four MRI [adjusted prevalence 4% (95% CI 1–12)]. No impingement pits were recorded (adjusted prevalence 0%, with an upper 95% CI of 5%). The mean alpha angle was 43.1°, SD 6.6° for grade 0 and 47.0°, SD 9.2° for grade 1, P-value = 0.06.

Table II provides prevalence comparison with estimates for males as previously published[13]. The difference in weighted prevalence of definite cam-type deformities between females and males was −24% (95% CI −30 to −19). The difference in weighted prevalence of any cam-type deformity was −49% (95% CI −61 to −37). An increased acetabular depth was more prevalent in females than males (difference 3%, 95% CI −4–11). All labral pathologies were less prevalent in females than in males[15]. Differences reached conventional levels of statistical significance for all labral pathologies, except for labral deformities (Table II).

Relationship of cam-type deformities and increased acetabular depth to internal rotation of the hip

On average, the internal rotation of the hip was 12° higher in females (45.2, SD 6.7) than in males (33.3, SD 8.5). Therefore cutoffs chosen for stratification by internal rotation presented in Table III are 10° higher in females than in males. Previously published prevalence estimates in males stratified according to internal rotation were 48% in participants with the low internal rotation, 21% in those with moderate and 12% in those with high internal rotation[13] ($P < 0.001$ for trend). This trend cannot be explored in females because of the absence of definite cam-type deformities of grade 2 or more. Table III shows prevalence estimates of any cam-type deformity according to internal rotation. The strata with the highest internal rotation in both females and males had the lowest prevalence of cam-type deformities, with an increase in prevalence of cam-type deformities with decreasing internal rotation (P-value for trend 0.01 in the female cohort, and 0.003 in the male cohort).

Table IV shows the prevalence estimates for increased acetabular depths stratified according to internal rotation. In females, prevalence estimates did not depend on internal rotation (P-value for trend = 0.71). In males, the lowest prevalence was found in the stratum with the highest internal rotation, with an increase in prevalence with decreasing internal rotation, but a negative P-value for trend ($P = 0.14$). In a sensitivity analysis with different cutoffs to define increased acetabular depths of ≤ 2 mm and ≤ 4 mm (see Appendix Table 2), overall prevalence dropped to 1% (95% CI 0–5) and 3% (95% CI 2–7) for females and males, respectively (P for difference 0.17) with acetabular depth defined as ≤ 2 mm and increased considerably when acetabular depth was defined as ≤ 4 mm: 27% (95% CI 18–39) for women and 17% (95% CI 12–23) for men (P for difference = 0.07). No trend with extent of internal rotation was found for acetabular depth defined as ≤ 2 mm, neither in females nor in males. For acetabular depth defined as

Table III

Estimated prevalence of grade 1 cam-type deformities in young asymptomatic females according to extent of internal rotation and comparison to prevalence estimates in males

IR	Females				Males			
	Number of MRIs examined	Number of cam-type deformities	Prevalence [%] of cam-type deformities (95% CI)	P-value for trend	Number of MRIs examined	Number of cam-type deformities	Prevalence [%] of cam-type deformities (95% CI)	P-value for trend
Low IR	26	7	27 (13–47)	0.01	83	72	87 (78–93)	0.003
Medium IR	30	8	27 (14–45)		81	55	68 (57–77)	
High IR	24	0	0 (0–14)*		80	52	65 (54–75)	
Overall	**80**	**15**	**22 (13–34)**		**244**	**179**	**71 (64–77)**	

IR: internal rotation (for females, the IR stratum is defined as low if $\mathrm{IR} \leq 40^\circ$; medium if $40^\circ < \mathrm{IR} \leq 50^\circ$; high if $\mathrm{IR} > 50^\circ$; for males, the IR stratum is defined as low if $\mathrm{IR} < 30^\circ$; medium if $30^\circ \leq \mathrm{IR} < 40^\circ$; high if $\mathrm{IR} \geq 40^\circ$). Cam-type deformity is defined as any grade ≥ 1 deformation. (There were no grade ≥ 2 deformations in the female population). Stratum-specific prevalences with 95%-CIs and P-values for a trend across strata are derived from logistic regression models. Overall weighted prevalences with 95%-CI are derived from weighted logistic regression models.

* Exact binomial CI.

Table IV

Estimated prevalence of increased acetabular depth in young asymptomatic females according to extent of internal rotation and comparison to prevalence in males

IR	Females				Males			
	Number of MRIs examined	Number with increased depth	Prevalence [%] of increased depth (95% CI)	*P*-value for trend	Number of MRIs examined	Number with increased depth	Prevalence [%] of increased depth (95% CI)	*P*-value for trend
Low IR	26	4	15 (6–35)	0.71	83	8	10 (5–18)	0.14
Medium IR	30	2	7 (2–23)		81	5	6 (3–14)	
High IR	24	3	13 (4–32)		80	3	4 (1–11)	
Overall	**80**	**9**	**10 (5–19)**		**244**	**16**	**6 (4–11)**	

For females, IR stratum is defined as low if IR ≤ 40°; medium if 40° < IR ≤ 50°; high if IR > 50°; for males IR stratum is defined as low if IR < 30°; medium if 30° ≤ IR < 40°; high if IR ≥ 40°. Increased acetabular depth is defined as a depth of ≤3 mm.

Stratum-specific prevalences with 95%-CIs and *P*-values for a trend across strata are derived from logistic regression models. Overall weighted prevalences with 95%-CIs are derived from weighted logistic regression models.

≤4 mm, there appeared no association with extent of internal rotation in females, but in males, with prevalence estimates increasing with decreasing internal rotation (*P* for trend = 0.02).

Localization of grade 1 cam-type deformities and signs of acetabular damage in females

All of the 15 grade 1 cam-type deformities were located anterosuperiorly between 1 and 3 o'clock, with most of them recorded at 2 o'clock (78%). Labral lesions were also recorded predominantly in anterosuperior locations, with the exception of one intralabral signal alteration at 4 o'clock and one ganglion recorded at 7 o'clock. Appendix Fig. 3 shows the localization of cam-type deformities (top) and signs of acetabular damage.

Association with signs of joint damage on MRI in females

Because of the lack of definite cam-type deformities in females, we cannot report on associations between definite cam-type deformities and signs of joint damage. Table V shows results of exploratory analyses on crude and adjusted odds ratios for the associations with grade 1 cam-type deformities. We did not find evidence for any association. Table VI presents crude and adjusted odds ratios for the association between increased acetabular depth and signs of joint damage. Again, we did not find evidence for any association.

Discussion

In our population-based cross-sectional study of 80 asymptomatic young Swiss women, we found no definite cam-type deformities. The overall prevalence of grade 1 cam-type deformities, which are of doubtful clinical relevance, was 22%. There was no evidence to suggest that prevalence estimates of grade 1 deformities did vary with the extent of internal rotation and grade 1 deformities were not associated with signs of hip joint damage. Conversely, we found a prevalence of 24% of definite (grades 2 or 3) cam-type deformities in males[13], and an association of these deformities with signs of hip joint damage[15]. The overall prevalence of increased acetabular depth was 10% and there was no evidence for an association of increased acetabular depth with signs of joint damage. The overall prevalence of increased acetabular depth was 6% in males, again with no association with signs of hip joint damage (data available on request).

To our knowledge, this is the first population-based MRI study to examine the role of deformities leading either to cam- or pincer-type impingement in women. Unlike the cohort in males[13,15], the cohort in females was set up as a pilot study because of limited resources, and CIs are therefore wider than in the male cohort. However, this does not affect our main conclusions since differences in MRI signs between the two cohorts are large. The nature of current analysis is cross-sectional. Therefore, no firm causal inferences are possible yet. Only prospectively collected data from longer-term follow-up in female and male cohorts will clarify the clinical relevance of our findings and whether different extents of cam-type deformities or increased acetabular depth are associated with increased risk of developing symptomatic OA of the hip and/or clinically relevant pain and disability. Due to ethical considerations, we were unable to perform MR arthrography because of the invasiveness of the intervention. Nonetheless, the high-resolution protocol of the 1.5 T MR device used in our study was sophisticated, and anatomical structures could be adequately evaluated even in the absence of intraarticular contrast. Another limitation of our study is that we cannot rule out that an anterior or lateral instability, associated, for example, with mild hip dysplasia, caused some of the labral damage observed in our study in females. Finally, our pre-specified outcome of pincer-type deformity, acetabular depth, is a measure of global acetabular overcoverage. We did not assess acetabular retroversion, which is a measure of focal overcoverage and might therefore have underestimated the frequency of factors predisposing to pincer-type impingement. However, it remains controversial whether focal overcoverage results indeed in pincer-type impingement[28].

Our population-based MRI study should be interpreted in the context of a recently published study by Hack *et al.*, which was a hospital based cross-sectional MRI study in asymptomatic young females and males, who were on average 10 years older than individuals included in our study[29]. Individuals were classified to have a cam-type deformity if their alpha angle was greater than 50.5°, resulting in prevalence estimates of 24.7% in males and 5.4%

Table V

Associations between characteristics of hip joint damages and cam-type deformities ≥1, crude and adjusted for age and BMI

Characteristic	Cam-type = yes *N* = 15	Cam-type = no *N* = 65	Crude odds ratio (95% CI)	Adjusted odds ratio (95% CI)
Labral tears	4 (27)	13 (20)	1.14 (0.28–4.61)	1.19 (0.29–4.93)
Intralabral tears	2 (13)	8 (12)	1.06 (0.17–6.46)	1.13 (0.18–7.10)
Labral avulsions	2 (13)	11 (17)	0.48 (0.09–2.46)	0.49 (0.09–2.57)
Labrum deformity	1 (7)	3 (5)	2.10 (0.18–24.21)	2.04 (0.17–23.82)
Labral ganglion	1 (7)	3 (5)	0.90 (0.08–9.96)	1.00 (0.08–12.35)

Odds ratios with 95%-CIs are derived from weighted logistic regression models. There were no impingement pits recorded.

Table VI
Associations between characteristics of hip joint damages and increased acetabular depth, crude and adjusted for age and BMI

Characteristic	Increased depth $N = 9$	Normal depth $N = 71$	Crude odds ratio (95% CI)	Adjusted odds ratio (95% CI)
Labral tears	2 (22)	15 (21)	0.76 (0.14–4.20)	0.70 (0.14–3.59)
Intralabral tears	2 (22)	8 (11)	1.36 (0.23–8.01)	1.27 (0.23–6.96)
Labral avulsions	1 (11)	12 (17)	0.51 (0.05–4.71)	0.47 (0.05–4.36)
Labrum deformity	0 (0)	4 (6)	0.79 (0.04–15.85)*	
Labral ganglion	0 (0)	4 (6)	0.78 (0.04–15.62)*	

Increased acetabular depth is defined as a depth of ≤3 mm.
Odds ratios with 95%-CIs are derived from weighted logistic regression models. There were no impingement pits recorded.
* Continuity correction.

in females[29]. These estimates are in agreement with our results, despite differences in setting and methods. No data was reported on increased acetabular depths. Gosvig *et al.* published a population-based study using conventional anterioposterior radiographs of the pelvis to determine the prevalence of cam-type deformities in a random sample of individuals aged 22–93 years[11]. They reported an overall prevalence of cam-type deformities of 19.6% in males and 5.2% in females, again concordant with our study. The estimated prevalence of a deep acetabular socket was 15.2% in males and 19.4% in females, however. These estimates are considerably higher than ours. Most likely explanations include differences in methodology (conventional radiographs versus MRI), differences in cutoffs used to define deep acetabular sockets, or an age dependent increase in the risk of deep acetabular socket, which, however, has not previously been described. The primary cutoff used in our study to define increased acetabular depth was 3 mm. Using a secondary cutoff of 4 mm in a sensitivity analysis (Appendix Table 2), we found an increase in prevalence estimates from 16% to 27% in females and from 6% to 17% in males. These latter estimates are more in line with estimates by Gosvig *et al.* based on conventional radiographs and it remains unclear which of the two alternate cutoffs is clinically more useful.

Our results suggest that morphologic configurations of the hip joint differ between males and females, and different hypotheses regarding causation are discussed in the context of FAI. First, one needs to realize that the pelvis and hips mature differently in males and females[30,31], with earlier ossification of the secondary ossification centers and closure of the growth plates in girls than boys. Second, Pollard *et al.* reported the importance of genetic influences in both types of impingement, cam and pincer. Sibling risks for cam-type morphology were more striking than for pincer deformity, but the gender of the probands appeared to be less important for cam-type deformity[32]. Third, cam-type deformities in particular have been discussed as a consequence of high-impact sports activities that influence the maturation of the proximal femoral shape, such as basketball[33], football[34], soccer[35], and hockey[36]. All of these sports activities are more frequently performed among males than females.

In conclusion, definite cam-type deformities in women are rare compared to men, whereas the prevalence of increased acetabular depth is higher, suggesting that FAI has different gender-related biomechanical mechanisms. Finally, increased acetabular depth was not associated with signs of labral damage.

Author contributions

All authors were involved in drafting the article of revising it critically for important intellectual content, and all authors approved the final version to be published. Dr Reichenbach had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study conception and design: Leunig, Jüni, Trelle, Odermatt, Hofstetter, Ganz, Reichenbach.

Acquisition of data: Jüni, Werlen, Pfirrmann, Reichenbach.

Analysis and interpretation of data: Leunig, Jüni, Limacher, Nüesch, Trelle, Odermatt, Hofstetter, Ganz, Reichenbach.

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Conflict of interest

RG and ML contributed to the development of the concept of FAI and regularly perform surgery on individuals with cam-type impingement. All other authors have no conflicts of interest.

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Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.joca.2013.01.003.

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