Radiology

Prevalence of Radiographic Findings Thought to Be Associated with Femoroacetabular Impingement in a Population-based Cohort of 2081 Healthy Young Adults[1]

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Purpose: To report the prevalence of qualitative radiographic findings for femoroacetabular impingement (FAI) and associations among them and to characterize the inter- and intraobserver variability of these interpretations.

Materials and Methods: This study is part of an institutional review board–approved population-based prospective follow-up of 2081 of 4006 (participation rate, 51.9%) young adults (874 [42.0%] male participants, 1207 [58.0%] female participants; mean age, 18.6 years) who took part in a randomized hip trial on developmental dysplasia of the hip. All participants gave informed consent. Two pelvic radiographs were obtained. Pistol-grip deformity, focal femoral neck prominence, and flattening of the lateral head, all suggestive of cam-type impingement, and the posterior wall sign, excessive acetabular coverage, and crossover sign, all suggestive of pincer-type impingement, were assessed subjectively by an experienced radiologist. To assess inter- and intraobserver agreement, images from 350 examinations were read independently twice by two observers.

Results: Cam-type deformities were seen in 868 male and 1192 female participants, respectively, as follows: pistol-grip deformity, 187 (21.5%) and 39 (3.3%); focal femoral neck prominence, 89 (10.3%) and 31 (2.6%); and flattening of the lateral femoral head, 125 (14.4%) and 74 (6.2%). Pincer-type deformities were seen in the same numbers of male and female participants, respectively, as follows: posterior wall sign, 203 (23.4%) and 131 (11.0%); and excessive acetabular coverage, 127 (14.6%) and 58 (4.9%) (all $P < .001$, according to sex distribution). The crossover sign was seen in 446 (51.4%) and 542 (45.5%) of the male and female participants, respectively ($P = .004$). There was a high degree of coexistence (odds ratio [OR] > 2) among most FAI findings. Interobserver agreement was good to very good (κ = 0.74–0.84) in rating cam- and pincer-type findings. Intraobserver agreement was moderate or good (κ = 0.49–0.80) for all findings for both observers.

Conclusion: Overall, radiographic FAI findings are quite common in a population of healthy young adults, especially in males, with a high degree of coexistence among most findings (OR > 2).

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Femoroacetabular impingement (FAI) has become a well-recognized clinical concept and is believed to increase the risk for early-onset osteoarthritis (1–3). The prevalence of FAI as a clinical diagnosis is estimated to be 10%–15% in a general adult population (4). The development of FAI results from femoral and acetabular abnormalities that cause abnormal contact between the proximal femur and the acetabular rim (2,5). It is classified as either cam or pincer type, on the basis of the underlying anatomic deformity (Fig 1) (6).

The diagnosis should be considered in patients with a history of long-standing hip pain; reduced hip motion, particularly internal rotation and flexion; and a positive test for anterior impingement (2,7,8). Initial radiographic examination includes assessment of the femoral head-neck junction, the shape of the femoral head and acetabular roof, and the contour of the acetabular rim (9). Assessment of acetabular depth, inclination, and version is important. Fibrocystic changes (FCCs) in the epiphyseal vicinity should also be noted, as there is growing evidence that these radiolucencies, first described in 1982 as herniation pits (11), may develop secondary to the impingement process (2,10).

During a long-term follow-up of a large randomized trial on developmental dysplasia of the hip, we noticed that qualitative radiographic features of FAI were quite frequent in a population-based cohort of 17–20-year-olds. We therefore set out to report on the prevalence of qualitative radiographic findings for FAI and the associations among them and to characterize the inter- and intraobserver variability of these interpretations.

Advances in Knowledge

- Radiographic features suggestive of femoroacetabular impingement (FAI) are quite common in a population of healthy young adults, especially in males.
- A high degree of coexistence is seen among most of these radiographic findings.
- The prevalence of fibrocystic changes (FCCs) in the epiphyseal vicinity was 5.8% (50 of 868) in male and 1.6% (19 of 1192) in female participants, and an association between FCCs and the presence of either a cam- or a pincer-type deformity was seen.

Materials and Methods

Study Population and Design

During February 2007 to March 2009, our cohort (*n* = 4006) was approached by letter and invited to participate in a long-term prospective clinical and radiographic follow-up of a randomized hip trial (12). The initial cohort comprised all 5068 newborns delivered at our institution (Maternity Unit, Haukeland Hospital, Bergen, Norway) in 1989, of which a total of 1062 were excluded from the follow-up because of death (*n* = 61), because of emigration abroad (*n* = 256), or because they did not live in the catchment area of our hospital at the time of birth (*n* = 745), leaving a total of 4006 subjects to be invited for participation. A total of 2081 of 4006 (51.9%, after one reminder) were enrolled (874 [42.0%] male participants, 1207 [58.0%] female participants; mean age, 18.6 years; range, 17.2–20.1 years for both sexes). Of 2081 of the subjects, 68 (3.3%) had developmental dysplasia of the hip as newborns (14 of 874 [1.6%] of the male participants and 54 of 1207 [4.5%] of the female participants). Exclusion criteria were radiographs of suboptimal technical quality (excessive pelvic rotation as assessed by an obturator foramen index outside 0.6–1.8 [13]) or uncertain pregnancy status. All participants gave written informed consent according to the Helsinki declaration. The research protocol was approved by the Medical Research Ethics Committee of the Western Region of Norway, and this committee also approved further analyses in regard to the nonresponders. Data on sex, age, birth weight, and weight and height (body mass index) at age 7 years were collected from the community health care centers in Bergen, Norway, and suburbs for all those born during the study period, including the nonresponders.

Implication for Patient Care

- Radiographic features suggestive of FAI may be seen in a large percentage of the general young population.

Radiographic Examination

This examination was performed at the Department of Radiology, Section of Paediatrics, Haukeland University Hospital, University of Bergen, Bergen, Norway, by one radiographer using a low-dose digital radiographic technique (DigitalDiagnost System, version 1.5; Philips Medical Systems, Hamburg, Germany). Gonadal shields were applied for both sexes. Two standardized views were obtained, one weight-bearing anteroposterior (AP) view and one supine frog-leg view. For the AP view, hips were kept in a neutral abduction-adduction position, with toes directed forward. The radiographer, who had undergone specific training for the examination, ensured correct posture during the exposures. We used a film-focus distance of 1.2 m with the beam centered at 2 cm proximal to the symphysis for the AP view and at the symphysis for the frog-leg view.

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Abbreviations:
AP = anteroposterior
COS = crossover sign
FAI = femoroacetabular impingement
FCC = fibrocystic change
OR = odds ratio

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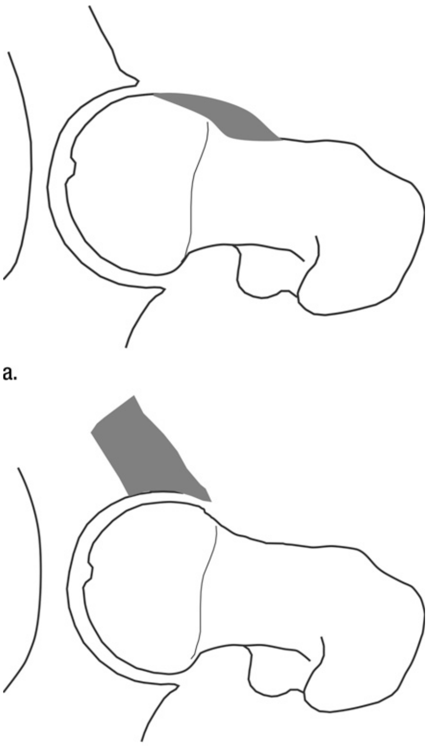
Guarantors of integrity of entire study, L.B.L., L.B.E., K.R.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; literature research, L.B.L., T.G.L., D.M.E., K.R.; clinical studies, L.B.L., T.G.L., L.B.E., K.R.; experimental studies, K.R.; statistical analysis, L.B.L., T.G.L., L.B.E., K.R.; and manuscript editing, all authors

Potential conflicts of interest are listed at the end of this article.

Figure 1

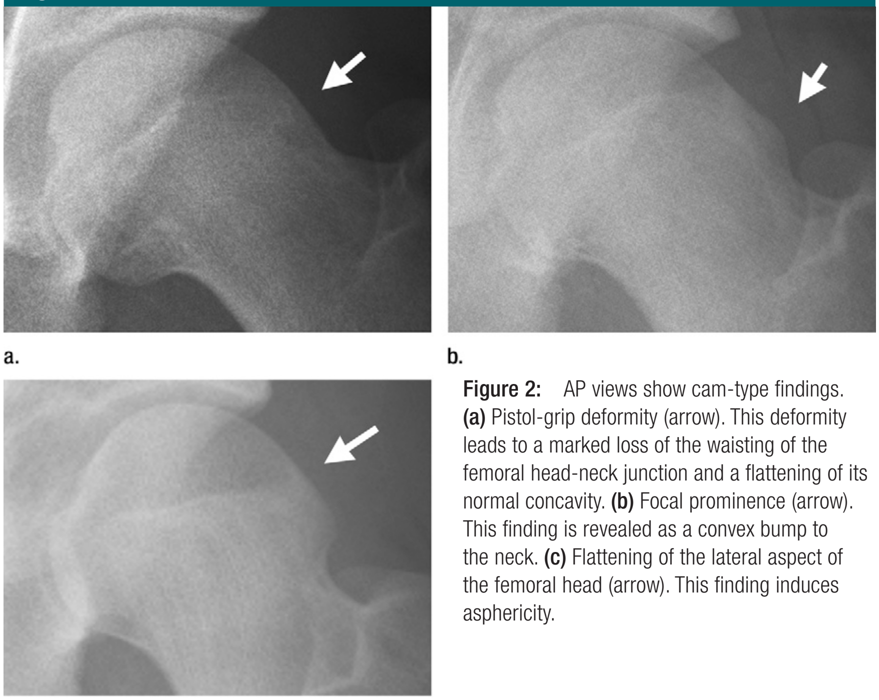


a.

b.

Figure 1: Normal anatomy of the hip joint allows sufficient space for the head to rotate properly into the acetabulum. In cam- and pincer-type impingement, abnormal contact between the proximal femur and the acetabular rim disturbs adequate movement. **(a)** Cam-type impingement. In this type of impingement, the prominence of bone and the reduced waist to the head-neck junction cause squeezing of the aspherical part of the head-neck junction underneath the acetabular rim, further damaging both the cartilage and the labrum. **(b)** Pincer-type impingement. Global or focal overcoverage of the femoral head by the acetabulum may lead to this type of impingement, disturbing adequate rotation of the head inside the acetabulum.

Figure 2



a.

b.

c.

Figure 2: AP views show cam-type findings. **(a)** Pistol-grip deformity (arrow). This deformity leads to a marked loss of the waisting of the femoral head-neck junction and a flattening of its normal concavity. **(b)** Focal prominence (arrow). This finding is revealed as a convex bump to the neck. **(c)** Flattening of the lateral aspect of the femoral head (arrow). This finding induces asphericity.

Image Evaluation

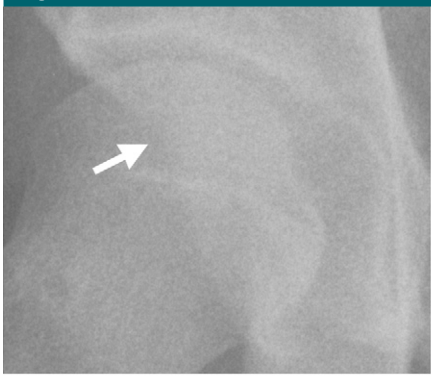
Patient identification was removed from all radiographs for patient confidentiality, and radiographs were analyzed on a high-resolution screen by one pediatric musculoskeletal radiologist (K.R., with 25 years of experience in reading them). The presence of the following features suggestive of impingement were assessed by means of gross visual inspection: *(a)* cam-type findings (Fig 2)—pistol-grip deformity, focal prominence of the femoral neck, and flattening of the lateral aspect of the femoral head (14–16); and *(b)* pincer-type findings (Fig 3)—COS, posterior wall sign, and excessive acetabular coverage (2,17–19). The presence of FCCs (Fig 4) was also noted (10). The pistol-grip deformity and the focal prominence, as well as the FCCs, were subjectively assessed from both the AP and the frog-leg views and were scored as positive if present in one or both views. The other four features were subjectively assessed from the AP view. Definitions were derived from the literature or in consensus (2,10,14–19). According to Bardakos and Villar (1), we classified the COS as mild, moderate, or severe, corresponding to the level of intersection between the anterior and the posterior rim, namely the superior third, the middle third, and the lower third, respectively. For the purpose of this study, all of them were noted as a positive COS. Images in a subset of 350 examinations were reread by the first observer (K.R.) after an interval of at least 3 months, and they were also read twice independently and with blinding by a second observer (L.B.L., with 1 year of experience). Prior to study initiation, these readers evaluated a sample set of 20 images not included in the study cohort and held several face-to-face meetings to review them and refine the standardized definitions.

Cadaveric Study

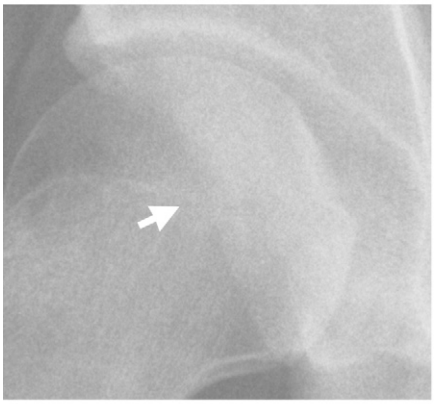
A cadaveric study that included 10 pairs of intact femora of unknown sex was performed to examine the effect of hip rotation on the contour of the femoral head and neck (ie, whether an excessive inward rotation would produce a false-positive cam deformity). Each femur was placed on the x-ray table with the distal femoral condyles abutting the table. AP radiographs were obtained in a neutral position and with internal and external rotation with 10° increments for both hips separately, by using a film-focus distance of 1.2 m and with the beam centered at 2 cm proximal to an imagined symphysis.

All images were read subjectively, in a blinded fashion, by one of the authors (K.R.), and the presence of a pistol-grip deformity, focal prominence of the femoral neck, or flattening of the lateral aspect of the femoral head was noted.

Figure 3



a.



b.

c.

Figure 3: AP views show pincer-type findings. **(a)** Crossover sign (COS) (arrow). This sign is positive when the anterior wall of the acetabulum crosses the posterior border of the acetabulum medial to the lateral rim of the weight-bearing sourcil area. **(b)** Posterior wall sign (arrow). This sign is positive when the posterior wall lies medial to the center of the femoral head. **(c)** Excessive acetabular coverage (arrow). This finding is seen as an extension of the lateral acetabular rim in the inferior and/or lateral direction.

Figure 4

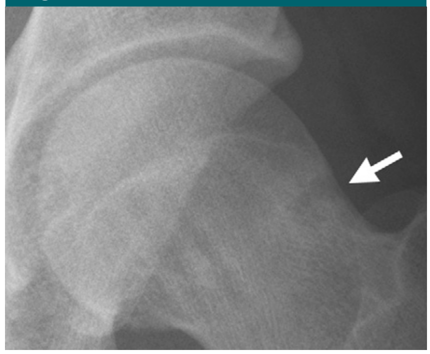


Figure 4: AP view shows FCC (arrow). FCC in the epiphyseal vicinity may develop secondary to the impingement process and is seen as a small area of cystic radiolucency surrounded by a thinner sclerotic margin.

Statistical Analysis

Differences in the distribution of the radiographic findings according to sex were investigated by using the χ^2 test (Fisher exact test). Associations among the radiographic findings were analyzed by calculating the odds ratio (OR) between each of the features separately, and an OR greater than 2 was considered to indicate an association. The probability of false-positive findings owing to chance is nonnegligible because of multiple statistical tests performed on the same data. The relationship between the presence of FCCs and the radiographic findings was investigated by using the χ^2 statistic (Fisher exact test) and a model of binary logistic regression for male and female participants, right and left sides, separately. Inter- and intraobserver agreement for the categorical variables for the experienced and nonexperienced radiologists were examined by using the κ value for measurement of agreement. Guidelines were slightly adapted from those in the report of Landis and Koch in 1977 (20), as follows: κ less than 0.20, poor agreement; κ of 0.21–0.40, fair agreement; κ of 0.41–0.60, moderate agreement; κ of 0.61–0.80, good agreement; and κ of 0.81–1.00, very good agreement. All calculations were performed by using statistical software (SPSS, version 17.0, release 2008; SPSS, Chicago, Ill). A significance level of .05 was decided a priori, and all the reported *P* values are two tailed.

Results

Of 2081 subjects who accepted the invitation to participate in this study, 2060 were included for further analysis; of 2060, 868 (42.1%) were male participants and 1192 (57.9%) were female participants. Twenty-one of 2081 subjects were excluded because of suboptimal radiographs or because of an uncertain pregnancy status. Baseline characteristics for participants and nonparticipants are given in Table 1. Fifteen subjects with uncertain or severe clinical and/or radiographic pathologic findings were immediately scheduled for a radiographic follow-up consultation or for a consultation as appropriate. Prevalence of radiographic findings for cam- and pincer-type impingement on the basis of the worse hip and also for bilateral findings are shown in Table 2. No major differences were seen between left and right hips. As for the COS, 31 of 446 male participants and 48 of 542 female participants had a positive score for COS in the middle third, and one of 446 male participants had a positive score for COS in the lower third. All the other subjects had a positive score for COS in the upper third.

Investigation of Associations among the Radiographic Features for FAI

There was a high degree of coexistence among most FAI findings (OR > 2), in particular for the coexistence between the COS and the posterior wall sign (OR, 7.45 and 13.49 in male and female participants, respectively). Results are shown in Table 3.

Association of FCCs and the Radiographic Features for FAI

When grouping the three cam-type findings in one single cam-type finding and the three pincer-type findings in one single pincer-type finding, the χ^2 statistic (Fisher exact test) showed associations between FCCs in the epiphyseal vicinity and the presence of either a cam-type finding (male participants, P = .001 for the right hip and P = .013 for the left hip; female participants, P = .003 for the right hip and P = .033 for the left hip) or a pincer-type finding (male participants, $P > .99$ for the right hip and P = .017 for the left hip; female participants, P = .125 for the right hip and P =.030 for the left hip). An adjusted model of binary logistic regression with FCC as the outcome and the six radiographic FAI findings as predictors showed significant associations in male participants for right-sided femoral neck prominence (P = .001) and also left-sided acetabular coverage (P = .002), and in females for right-sided femoral neck prominence (P = .029) and right-sided laterally flattened head (P = .009), and also left-sided femoral neck prominence (P = .002). For all other findings, the binary logistic regression model yielded high P values of greater than .05.

Table 1

Characteristics for 4006 Subjects Invited to Participate in a Long-term Clinical and Radiographic Follow-up

Characteristics	Participants (n = 2081)	Nonparticipants (n = 1925)	P Value*
Sex			<.001
No. male	874	1194	
No. female	1207	731	
Age (y)†	18.6 (0.6)	18.7 (0.5)	<.001
Body mass index (kg/m^2)‡	23.2 (3.9)	NA	...
No. with birth weight data available§	1691 (81.3)	1289 (67.0)	<.001
No. male	724	814	
No. female	967	475	
Birth weight (g)‖	3529 (0.54)	3521 (0.55)	.684
No. with growth data available§	827 (39.7)	619 (32.2)	<.001
No. male	362	383	
No. female	465	236	
Weight at 7 y (kg)#	26.4 (4.6)	26.5 (4.8)	.62
Body mass index at 7 y (kg/m^2)#	16.3 (2.0)	16.4 (2.0)	.404

* P values were determined with the χ^2 test for sex and with the two-sided independent-samples t test for all other characteristics.

† Data are the means, and numbers in parentheses are the standard deviations except where otherwise indicated.

‡ Datum is the mean, and number in parentheses is the standard deviation. NA = not available.

§ Numbers in parentheses are percentages except where otherwise indicated.

‖ Data are the means, and numbers in parentheses are the standard deviations except where otherwise indicated. Data were available for 2980 of 4006 of those invited to participate (1691 participants and 1289 nonparticipants).

\# Data are the means, and numbers in parentheses are the standard deviations except where otherwise indicated. Data were available for 1446 of 4006 of those invited to participate (827 participants and 619 nonparticipants).

Inter- and Intraobserver Agreement

Interobserver agreement was good to very good (κ = 0.74–0.84) in rating cam-type and pincer-type findings. Intraobserver agreement was moderate or good (κ = 0.49–0.80) for all findings for both observers. The results are shown in Table 4.

Cadaveric Study Results

We did not detect any visual changes of the femoral head-neck contour that might indicate that excessive internal or external rotation would produce a false-positive cam deformity.

Discussion

Clinicians are increasingly aware of the diagnosis of FAI: The cam type is characterized by anatomic femoral abnormalities, seen as a decreased femoral head-neck offset and/or an asphericity of the lateral femoral head (2,14–16). Cam-type radiographic features include a pistol-grip deformity or a focal prominence or bump to the anterolateral aspect of the femoral neck (14–16). Also, an aspherical part of the head-neck junction can extend proximally, causing asphericity of the lateral femoral head (2). The pincer-type is characterized by acetabular abnormalities, and imaging typically demonstrates global or focal overcoverage of the femoral head (2). The global type often is associated with protrusio acetabuli or coxa profunda, while the focal type is seen in acetabular retroversion (19,21,22). Radiographic features suggestive of a pincer-type impingement include the COS, the posterior wall sign, and excessive coverage of the femoral head by the lateral acetabulum (2,17–19).

We showed that, overall, radiographic features suggestive of FAI, both cam and pincer types, are quite common in a population of healthy young adults, especially in males, with a high degree of coexistence among most findings.

With respect to the findings suggestive of a cam deformity, our results are similar to those of others (23,24). In a recently published study of 244 unselected, asymptomatic young male subjects, cam-type deformities, as assessed with magnetic resonance (MR) imaging, were seen in nearly one-fourth of all subjects (24). Similarly, in a cross-sectional population-based study of 3620 subjects (mean age, 60 years) (23), a pistol-grip deformity was found in one-fifth of male and in 5% of female subjects. If biased, this would be toward underestimation because only one AP view was used for the assessment, with the possibility of missing anterolateral deformities. The frequent findings among healthy adolescents, with male adolescents being three- to fourfold more likely to have findings suggestive of a cam deformity than are female adolescents, are intriguing, and we speculate that these findings may reflect anatomic variation rather than true pathologic abnormalities.

According to the literature, cam deformities are predominantly seen in young athletic male subjects, whereas pincer deformities are more often seen in

Table 2

Radiographic Findings for FAI in 868 Male and 1192 Female Healthy Participants at Skeletal Maturity on Basis of Worse Hip and Bilateral Findings

	Worse Hip			Bilateral Findings	
Radiographic Feature	Male Participants	Female Participants	*P* Value*	Male Participants	Female Participants
Cam					
Pistol-grip deformity	187 (21.5)	39 (3.3)	<.001	135 (15.6)	23 (1.9)
Focal prominence	89 (10.3)	31 (2.6)	<.001	47 (5.4)	17 (1.4)
Flattening of lateral head	125 (14.4)	74 (6.2)	<.001	85 (9.8)	41 (3.4)
Cam type (one or more findings)	304 (35.0)	121 (10.2)	<.001	214 (24.7)	75 (6.3)
Pincer					
Posterior wall sign	203 (23.4)	131 (11.0)	<.001	104 (12.0)	63 (5.3)
Excessive acetabular overage	127 (14.6)	58 (4.9)	<.001	99 (11.4)	43 (3.6)
COS	446 (51.4)	542 (45.5)	.004	307 (35.4)	367 (30.8)
Pincer type (one or more findings)	298 (34.3)	198 (16.6)	<.001	188 (21.7)	116 (9.7)
FCC	50 (5.8)	19 (1.6)	<.001	18 (2.1)	5 (0.4)

Note.—Data are numbers of findings, and numbers in parentheses are percentages except where otherwise indicated.

* The *P* value refers to significant differences according to sex.

Table 3

Associations among Radiographic Features for FAI

Radiographic Feature and Participants	Focal Prominence	Flattening of Lateral Head	Posterior Wall Sign	Excessive Acetabular Coverage	COS
Pistol-grip deformity					
Male	2.84 (1.66, 4.89)*	3.00 (1.89, 4.75)*	1.54 (1.01, 2.35)	1.31 (0.78, 2.16)	1.02 (0.71, 1.46)
Female	10.42 (3.29, 33.02)*	5.30 (1.93, 14.67)*	2.56 (0.95, 6.95)*	6.22 (2.24, 17.27)*	1.17 (0.53, 2.57)
Focal prominence					
Male	...	2.81 (1.53, 5.16)*	1.20 (0.65, 2.23)	4.40 (2.53, 7.64)*	1.44 (0.86, 2.39)
Female	...	4.38 (1.44, 13.29)*	2.13 (0.72, 6.37)*	2.22 (0.51, 9.71)*	1.90 (0.84, 4.28)
Flattening of lateral head					
Male	...	...	1.81 (1.12, 2.93)	5.15 (3.20, 8.30)*	1.40 (0.90, 2.15)
Female	...	...	1.56 (0.69, 3.55)	3.19 (1.30, 7.87)*	0.93 (0.53, 1.64)
Posterior wall sign					
Male	...	...	...	0.92 (0.54, 1.56)	7.45 (4.83, 11.48)*
Female	...	...	...	1.52 (0.63, 3.67)	13.49 (7.44, 24.45)*
Excessive acetabular coverage					
Male	...	...	...	...	1.19 (0.79, 1.79)
Female	...	...	...	...	1.69 (0.94, 3.04)

Note.—Data are ORs, and numbers in parentheses are 95% confidence intervals. Data for the right hip are shown. The findings were similar for the left hip in both male and female participants.

* OR greater than two.

middle-aged, athletic women (2,3,14). In contrast, we found that pincer deformities were quite frequent in subjects of both sexes, and more so in male subjects. It is outside the scope of this article to examine possible explanations for this finding.

The high degree of coexistence (OR > 2) was true in particular for the coexistence of the COS and the posterior wall sign. This multicolinearity has already been described in the literature (1,19). Approximately one-half of the subjects, both male and female subjects, had a positive COS, indicating acetabular retroversion in the weight-bearing position, as the upper part of the anterior acetabular wall lies more laterally than usual, and crosses over the posterior wall. A positive posterior wall sign indicates a deficient posterior wall (19). According to Clohisy et al (25), the combination of these two signs indicates a true acetabular retroversion, while a positive COS alone indicates anterior overcoverage. Our prevalence numbers for both the COS and the posterior wall sign are high as compared with those of others (26), in part reflecting differences in pelvic positioning and definitions

Table 4

Intra- and Interobserver Measurements: Radiographic Features of FAI

Measurements	Intraobserver κ Value		Interobserver κ Value
	Observer 1	Observer 2	
Pistol-grip deformity	0.65	0.78	0.74
Focal prominence	0.65	0.77	0.84
Flattening of lateral head	0.55	0.77	0.76
Posterior wall sign	0.55	0.73	0.83
Excessive acetabular coverage	0.49	0.71	0.75
COS	0.59	0.80	0.82

used for a positive COS. Obviously, pelvic positioning (ie, the pelvic tilt) influences the two-dimensional projection of the acetabulum and, hence, the prevalence of both the COS and the posterior wall sign. Several techniques have been suggested to control for pelvic tilt on an AP pelvic view (17,21,27,28). We considered using the distance between the coccyx and the symphysis (2,27) but found it difficult to assess in a high proportion of images owing to overlying bowel content. In another article, Kalberer et al (29) found a high correlation between the projection of the ischial spine into the pelvis and the COS. Although others have observed this ischial spine sign to be a valid marker for acetabular retroversion regardless of pelvic tilt and rotation (30), we were not able to reproduce their findings in a subset of 146 cases and, as such, did not include the ischial spine sign in our analysis.

Hips with impingement are often thought to represent hips with a mixed type of both cam and pincer features (2,3,22). Our findings show little overlap between cam and pincer findings (Table 2) and lend support to findings in a recent article by Cobb et al (31) in which the authors conclude that hips with cam and pincer deformities are distinct pathoanatomic entities.

The prevalence of FCCs in the epiphyseal vicinity was 5.8% in male participants and 1.6% in female participants. An association between FCCs and the presence of either a cam-type or a pincer-type deformity was seen, especially the femoral neck prominence, indicating that FCC may be a radiographic indicator of FAI. This confirms findings described by Leunig and colleagues in 2005 (10), although it has also been shown that herniation pits are not necessarily correlated with FAI findings (32).

We found high agreement both within and between observers for the reliability for most of the findings, which is in accordance with data in studies by others (17,33). Jamali and colleagues (17) report on κ values between 0.6 and 0.7 for both intra- and interobserver studies for the COS. Kappe and colleagues (33) report on the reliability of radiographic signs for acetabular retroversion, with κ results for the COS (r = 0.53) and the posterior wall sign (r = 0.74). Clohisy and colleagues (34) reviewed the reliability of the head-neck offset and the head sphericity on both AP and frog-leg views and found κ values below 0.6 for both intra- and interobserver reliability.

The prospective, population-based design and the large numbers strengthen the findings in our study. So does the standardized imaging protocol used. We, however, acknowledge several limitations to our study. First, only two radiographic views were available, namely an AP and a frog-leg view. For the purpose of the main study focusing on hip dysplasia and secondary osteoarthritis, the AP view was obtained with the subject in a weight-bearing, anatomic, and physiologic position, as a supine position tends to give different findings of acetabular version (35).

We are aware that several protocols have been suggested for the radiographic assessment of impingement, of which a supine AP and a cross-table lateral view seem to be preferred over others (9,36). The supine AP view has traditionally been obtained with internally rotated hips, as the femoral necks project better in this position; thus, fractures are more easily detected. For the assessment of the acetabulum, however, a weight-bearing view in the anatomic position appears to be more appropriate as acetabular version is more correctly visualized. Further, weight-bearing images are preferred for the measurements of joint space width (17,21,28,35). It is reasonable to believe that two-dimensional imaging, as performed in our study, yields an underestimation of the prevalence of features suggestive of FAI. However, in a recent MR imaging study by Reichenbach and colleagues (24), most of the cam deformities were located in a superoanterior position and, as such, should be possible to detect on a lateral view. As for the pistol-grip deformity, Clohisy and colleagues (37) found that the femoral head-neck offset in patients with FAI is accurately visualized on a frog-leg lateral radiograph. Others (36) believe that the femoral head-neck asphericity is best visualized on the Dunn view in 45° or 90° flexion or on a cross-table projection in internal rotation.

Another limitation to our study was the subjective assessments; thus, measurements for acetabular shape were not included. However, the radiographs were evaluated by an experienced radiologist with a special interest in developmental dysplasia of the hip. Radiographic criteria for anterior impingement are not yet well established. The alpha angle, which was initially based on MR images (15), is a commonly used measurement to quantify the head-neck offset in cam impingement. However, the accuracy of this measurement has been questioned in a recent article (38). Gosvig and colleagues (39) suggested another measurement, the triangular index, for the same purpose; however, to our knowledge its accuracy has not been validated in later studies.

Other limitations include that of a quite small catchment area of our cohort, which could possibly have resulted in stronger relationships among our data, most likely caused by genetic or environmental factors. As for the high degree of coexistence among most FAI findings, the probability of false-positive findings owing to chance is nonnegligible because multiple statistical tests were performed on the same data. It is also important to acknowledge the possibility of an induced correlation between the radiologists' readings, affecting the interrater variability, as a result of the standardization of 20 images prior to interobserver readings.

Our study emphasizes the need for further work on this topic, as the radiographic FAI findings in the general population seem to be relatively common. These features should be interpreted carefully and related closely to the clinical findings.

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