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The Prevalence of Radiographic Findings of Structural Hip Deformities in Female Collegiate Athletes

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Background: Structural deformities of the hip, including femoroacetabular impingement (FAI) and acetabular dysplasia, often limit athletic activity. Previous studies have reported an increased prevalence of radiographic cam FAI in male athletes, but data on the prevalence of structural hip deformities in female athletes are lacking.

Purpose: (1) To quantify the prevalence of radiographic FAI deformities and acetabular dysplasia in female collegiate athletes from 3 sports: volleyball, soccer, and track and field. (2) To identify possible relationships between radiographic measures of hip morphologic characteristics and physical examination findings.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: Anteroposterior (AP) pelvis and frog-leg lateral radiographs were obtained from 63 female athletes participating in Division I collegiate volleyball, soccer, and track and field. Lateral center edge angle (LCEA) and acetabular index were measured on AP films. Alpha angle and head-neck offset were measured on frog-leg lateral films. Pain during the supine impingement examination and hip rotation at 90° of flexion were recorded. Random-effects linear regression was used for group comparisons and correlation analyses to account for the lack of independence of observations made on left and right hips.

Results: Radiographic cam deformity (alpha angle $>50°$ and/or head-neck offset <8 mm) was found in 48% (61/126) of hips. Radiographic pincer deformity (LCEA $>40°$) was noted in only 1% (1/126) of hips. No hips had radiographic mixed FAI (at least 1 of the 2 cam criteria and LCEA $>40°$). Twenty-one percent (26/126) of hips had an LCEA $<20°$, indicative of acetabular dysplasia, and an additional 46% (58/126) of hips had borderline dysplasia (LCEA $\geq 20°$ and $\leq 25°$). Track and field athletes had significantly increased alpha angles ($48.2° \pm 7.1°$) compared with the soccer players ($40.0° \pm 6.8°$; $P < .001$) and volleyball players ($39.1° \pm 5.9°$; $P < .001$). There was no significant difference in the LCEA (all $P > .914$) or the prevalence of dysplasia (LCEA $<20°$) between teams (all $P > .551$). There were no significant correlations between the radiographic measures and internal rotation (all $P > .077$). There were no significant differences (all $P > .089$) in radiographic measures between hips that were painful (n = 26) during the impingement examination and those that were not.

Conclusion: These female athletes had a lower prevalence of radiographic FAI deformities compared with previously reported values for male athletes and a higher prevalence of acetabular dysplasia than reported for women in previous studies.

Keywords: hip; femoroacetabular impingement; acetabular dysplasia; female athletes; volleyball; football (soccer); track and field

Structural deformities of the hip, including femoroacetabular impingement (FAI) and acetabular dysplasia, may cause chondrolabral damage and early osteoarthritis by altering hip mechanics. In patients with FAI, damage is thought to result from abnormal contact between the femoral neck and acetabulum/acetabular labrum.[12] Chronic overload of cartilage is believed to cause progressive cartilage thinning and lesions in patients with dysplasia.[23,24]

Many patients with symptomatic FAI are athletes.[26] In addition, acetabular dysplasia has been suggested as a cause of hip instability and pain in athletes.[29] Repetitive impact and rotational loading and the large range of motion required by some sports may initiate symptoms in

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individuals with underlying hip deformities that would otherwise remain asymptomatic during activities of daily living. In addition, athletic activity itself may increase the risk for the formation of structural hip deformities, as has been suggested for cam FAI.[2,7] Specifically, recent studies support the hypothesis that sporting exposure during skeletal maturation may compromise normal growth of the epiphyseal plate, leading to cam-type deformities.[2,7]

It is important to understand the prevalence of structural hip deformities in different athletic populations as such data could assist in determining a timely and appropriate diagnosis when individuals of those populations have symptoms. A number of studies have highlighted the finding that although athletes are often asymptomatic at the time of the study, they have an increased prevalence of radiographic findings consistent with FAI deformities compared with control groups or previously reported values for the general population. To date, the majority these studies have focused on male athletes and cam-type FAI.[1,5,21,30,34-37] Two studies, both on competitive soccer players, have reported the prevalence of radiographic FAI deformities by sex, with female cohorts demonstrating average alpha angles 5.9° to 12.7° less than their male counterparts.[13,19] However, limited data exist on the prevalence of radiographic findings consistent with structural hip deformities in female athletes from other sports. Further, relationships between physical examination findings and radiographic measures have not been defined for female athletes, which may assist with screening if women are shown to have a high prevalence of radiographic findings.

The first objective of this study was to identify the prevalence of radiographic findings of structural hip deformities in female athletes participating in National Collegiate Athletic Association (NCAA) Division I soccer, track and field, and volleyball. The second objective was to identify possible relationships between radiographic measures of hip morphologic characteristics and physical examination findings in female athletes.

METHODS

With institutional review board approval (No. 55028) and in accordance with the ethical standards of the Helsinki Declaration, female athletes from the University of Utah NCAA Division I volleyball, soccer, and track and field teams were invited to participate in this study. Sixty-three athletes (22/28 soccer, 28/45 track and field, and 13/16 volleyball players) provided informed consent and participated. Each team was designated a single day for radiographic and physical examination. In addition, each subject completed the Hip Outcome Score (HOS) assessment.

Radiographic Evaluation

After a negative urine pregnancy test was obtained for each subject, supine anteroposterior pelvis and bilateral frog-leg lateral radiographs were acquired.[9,39] The radiographs were evaluated in a virtual environment (iSite PACS; Philips Healthcare) by an orthopaedic physician's assistant (J.A.E.) with 15 years of experience in a combined adult reconstruction and hip preservation practice. To evaluate interobserver repeatability, the corresponding author (C.E.P.), an orthopaedic surgeon, evaluated the radiographs of 20 randomly selected subjects (40 hips).

The lateral center edge angle (LCEA) and acetabular index were measured on the anteroposterior films. The alpha angle and head-neck offset were measured on the frog-leg lateral films. The prevalence of radiographic findings of structural hip deformities was determined as follows. Radiographic cam-type deformity was identified with an alpha angle $>50°$ and/or femoral head-neck offset <8 mm.[39] Radiographic pincer-type deformity was identified by the primary finding of an LCEA $>40°$, alone or in combination with an acetabular index $<0°$.[3,39] Dysplasia was diagnosed by the primary finding of an LCEA $<20°$, alone or in combination with an acetabular index $>10°$.[14,41] Borderline dysplasia was defined by an LCEA $\geq 20°$ and $\leq 25°$.[41]

Physical Examination

Verbal reports of pain during the supine impingement examination (~90° of flexion and then simultaneous adduction and internal rotation to maximum) were recorded.[25] Hip rotation was assessed with the subject supine in 90° of hip and knee flexion.[22] With 1 hand, the observer applied downward pressure to the knee to limit motion of the hip and, with the other hand, positioned a handheld dynamometer (Lafayette Instrument Company) superior to the medial (for internal rotation) or lateral (for external rotation) malleolus. The hip was rotated until 3.6 kg (8 lb) of force was achieved; this was deemed the terminal rotation position. Using a goniometer, a second observer measured the angle between the midline of the leg in the neutral and terminal rotation positions. One soccer player did not undergo physical examination of the left hip due to recent surgery unrelated to the hip. Another track and field player did not complete the impingement examination on her left hip. These players were excluded from analyses of the physical examination measurements.

Statistical Analysis

All statistical analyses were completed in Stata/IC 12.1 (StataCorp LP). Interobserver repeatability of radiographic measurements was quantified following a random-effects consistency of agreement approach to calculate the intraclass correlation coefficient (ICC). The ICCs were interpreted as follows: minimal <0.2, poor 0.2 to <0.4, moderate 0.4 to <0.6, strong 0.6 to $\leq$ 0.8, and almost perfect >0.8.[33] Independent t tests were used for group comparisons when the dependent variable represented a single observation per individual (ie, age, HOS). Random-effects linear regression was used for group comparisons to account for the lack of independence in continuous dependent variables representing observations made on both left and right hips (ie, alpha angle, internal rotation). Similarly. random-effects logistic regression was used for group comparisons of dichotomous dependent variables (ie, dysplasia). For comparisons between soccer, volleyball, and track and

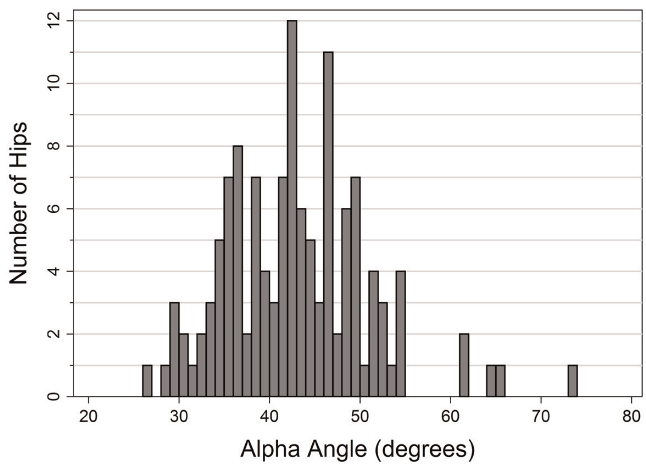

Figure 1. Histogram showing distribution of alpha angle for all hips. Bins defined as the number of hips > n and ≤ n+1 to facilitate direct calculation of the prevalence of radiographic cam femoroacetabular impingement based on the number hips greater than any given cutoff value.

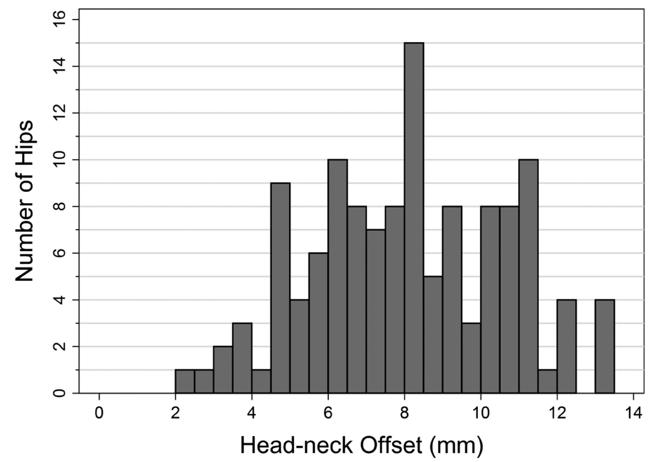

Figure 2. Histogram showing distribution of head-neck offset for all hips. Bins defined as the number of hips ≥ n and < n+1 to facilitate direct calculation of the prevalence of radiographic cam femoroacetabular impingement based on the number of hips less than any given cutoff value.

field teams, the *P* values were adjusted following the Finner procedure.[11] Random-effects linear regression models were analyzed to identify possible relationships between the 4 radiographic measurements and internal rotation. The resulting 4 *P* values were adjusted following the Finner procedure.

RESULTS

A range of radiographic findings were observed in these athletes (Figures 1-3). Radiographic cam-type deformity (an alpha angle >50° and/or head-neck offset <8 mm) was found in 48% (61/126) of hips (Table 1). Radiographic pincer FAI deformity, defined by an LCEA >40°, was found in only 1% (1/126) of hips. No hips had radiographic mixed FAI, defined as at least 1 of the 2 cam criteria and an LCEA >40°. Twenty-one percent (26/126) of hips had an LCEA <20°, indicative of acetabular dysplasia, and an additional 46% (58/126) of hips had borderline dysplasia (LCEA ≥20° and ≤25°) (Table 2).

Track and field athletes had significantly decreased head-neck offset and increased alpha angles, compared with both the soccer (both $P < .001$) and volleyball players (both $P < .001$) (Table 3). There was no significant difference in the LCEA (all $P > .914$) or the prevalence of dysplasia (LCEA <20°) between teams (all $P > .551$).

There were no significant correlations between the radiographic measures and internal rotation (all $P > .077$). Twenty-one percent (26/124) of hips were painful during the impingement examination. Eight subjects reported pain bilaterally, while 10 subjects reported pain in a single hip. There were no significant differences (all $P > .089$) in radiographic measures between hips that were painful during the impingement examination and those that were not. The sensitivity and specificity of the impingement examination to detect hips with at least 1 of the primary FAI findings (LCEA<40°, alpha angle >50°, and/or head-neck offset <8 mm) were 20% and 77%, respectively.

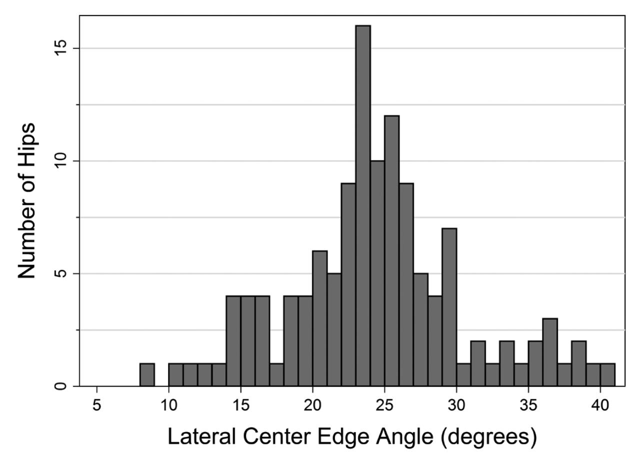

Figure 3. Histogram showing distribution of lateral center edge angle for all hips. Bins defined as the number of hips ≥ n and < n+1 to facilitate direct calculation of the prevalence of dysplasia based on the number of hips less than any given cutoff value. With these bins, the prevalence of radiographic pincer femoroacetabular impingement can only be calculated by the number of hips greater than or equal to a chosen cutoff value, which is slightly different that the criterion used in the text (lateral center edge angle >40°).

Members of the track team were significantly older than those of the soccer team ($P = .008$) (Table 3). Volleyball players were significantly taller and weighed more than both the soccer ($P < .001$ and $P = .002$, respectively) and track and field players ($P < .001$ and $P = .005$, respectively)

TABLE 1
Prevalence of Structural Deformities, as Percentage of All Hips and All Subjects[a]

Structural Deformity	Radiographic Criteria	Hips, %	Subjects, %[b]
Cam FAI	Primary findings: AA >50° and/or HNO <8 mm	48	60
	Combined: AA >50° and HNO <8 mm	13	14
Pincer FAI	Primary finding: LCEA >40°	1	2
	Combined: LCEA >40° and AI <0°	1	2
Mixed FAI	(AA >50° and/or HNO <8 mm) and LCEA >40°	0	0
Dysplasia	Primary finding: LCEA <20°	21	30
	Combined: LCEA >20° and AI >10°	12	17
Dysplasia and cam	(AA >50° and/or HNO <8 mm) and LCEA <20°	11	17

[a]AA, alpha angle; AI, acetabular index; FAI, femoroacetabular impingement; HNO, head-neck offset; LCEA, lateral center edge angle.
[b]Percentage of subjects with at least 1 hip meeting the stated criteria.

TABLE 2
Prevalence of Each Radiographic Finding, in Entire Cohort and by Sport[a]

Structural Deformity	Radiographic Criterion	Entire Cohort, %	Soccer, %	Track and Field, %	Volleyball, %
Cam FAI	AA >50°	14	5	27	4
	HNO <8 mm	48	32	66	35
Pincer FAI	LCEA >40°	1	0	0	4
	AI <0°	6	0	7	15
Dysplasia	LCEA <20°	21	16	20	31
	AI >10°	13	9	11	23
Borderline dysplasia	LCEA ≥20° and ≤25°	46	50	43	46

[a]AA, alpha angle; AI, acetabular index; FAI, femoroacetabular impingement; HNO, head-neck offset; LCEA, lateral center edge angle.

(Table 3). Self-reported race/ethnicity was 81.0% white non-Hispanic, 4.8% white Hispanic, 4.8% black or African American, 3.2% Native Hawaiian or other Pacific Islander, and 6.4% other.

Interobserver repeatability was strong or almost perfect for all radiographic measures (ICCs: alpha angle, 0.73; acetabular index, 0.74; head-neck offset, 0.76; and LCEA, 0.88).

DISCUSSION

Structural deformities of the hip and associated symptoms can greatly limit athletic activity. While previous studies have highlighted that male athletes have a high prevalence of radiographic cam FAI, there were limited data regarding the prevalence of structural hip deformities in female athletes. In this study, female athletes from 3 different sports were shown to have a low prevalence of radiographic pincer FAI due to global overcoverage (1% hips). Radiographic cam FAI was more prevalent than pincer FAI (48% hips), especially in athletes from the track and field team. Acetabular undercoverage was the most common finding in these athletes, with 67% of hips categorized as dysplastic or borderline dysplastic. There were no clinically significant relationships between radiographic measures and physical examination findings.

Approximately half of the hips evaluated in this study demonstrated at least 1 radiographic sign of cam FAI. Many studies have investigated the prevalence of cam FAI in football, hockey, soccer, basketball, and skiing athletes.[1,5,13,19,21,30,34-37] While direct comparisons between studies are difficult due to varying imaging modalities (ie, magnetic resonance imaging vs frog-leg lateral radiograph) and cutoff values (ie, alpha angle cutoffs 50°-60°), it does appear that male athletes have a higher prevalence of cam FAI compared with the female athletes evaluated herein and in 2 prior soccer studies, based on the alpha angle (Table 4). Recent studies have identified an association between athletic activity and cam-type deformities,[2,7,35] supporting the theory that cam-type deformities develop in males athletes as a result of overloading during skeletal maturation at the time preceding and including physeal closure. However, more work is needed to determine whether a similar response occurs in female athletes.

In this study, the track and field players had significantly greater alpha angles than the soccer and volleyball players. However, female soccer players evaluated by Johnson et al[19] and Gerhardt et al[13] had a higher prevalence of cam FAI compared with all 3 female teams evaluated herein (Table 4). Previous studies have demonstrated a higher prevalence of cam FAI deformities in male athletes compared with male nonathlete controls.[1,5,19,35] However, Johnson et al[19] found no significant difference in alpha angles between female soccer players and female nonathlete controls. In their study, 32% of the female controls had an alpha angle >55° on frog-leg lateral radiographs.[19] For direct comparison, 4% of female athlete hips evaluated herein had an alpha angle >55°.

TABLE 3
Demographic, Questionnaire, Radiographic, and Physical Examination Results for All Subjects and by Sport[a]

Variable	All Subjects	Soccer	Track and Field	Volleyball
Age, y	19.6 ± 1.4	19 ± 1.1[b]	20.3 ± 1.6[b]	19.2 ± 1.1
Height, cm	171 ± 7.9	168 ± 6.9[c]	169 ± 6.4[d]	180 ± 6.8[c,d]
Weight, kg	64.3 ± 9.7	62.1 ± 6.7[c]	62.1 ± 10[d]	72.5 ± 9.8[c,d]
Body mass index, kg/m^2	22 ± 2.5	21.9 ± 2	21.8 ± 3	22.4 ± 2
HOS–ADL	96.5 ± 10.6	92 ± 16.9	99.2 ± 1.9	98.5 ± 4.4
HOS–Sports	96.4 ± 10.6	93.5 ± 15.6	98.4 ± 4	97 ± 9.9
Head-neck offset, mm	7.9 ± 2.5	9.1 ± 2.24[b]	6.6 ± 2.09[b,d]	9 ± 2.4[d]
LCEA, deg	23.9 ± 6.3	24.2 ± 4.67	24.1 ± 6.4	23 ± 8.2
Acetabular index, deg	5.1 ± 4.7	5.1 ± 3.4	4.7 ± 4.8	5.9 ± 6.3
Alpha angle, deg	43.5 ± 7.9	40.0 ± 6.8[b]	48.2 ± 7.1[b,d]	39.1 ± 5.9[d]
Internal rotation, deg	31.2 ± 10.2	34.1 ± 10.3	29.02 ± 10.2	31.2 ± 8.9
External rotation, deg	43.8 ± 10.7	37.4 ± 7.7[b]	48.9 ± 10.3[b]	43.2 ± 10.3

[a]Values expressed as mean ± SD. ADL, activities of daily living; HOS, Hip Outcome Score; LCEA, lateral center edge angle.
Significant difference ($P < .05$) between the following: [b]soccer and track and field, [c]soccer and volleyball, [d]track and field and volleyball. All other comparisons nonsignificant ($P > .05$).

TABLE 4
Prevalence of Radiographic Cam FAI Deformity Among Sports Based on Varying Alpha Angle Cutoff Values[a]

						Prevalence of Cam FAI[b]			
Study	Year	Sex	n	Sport	Imaging Modality	>50°	>55°	>60°	Alpha Angle, deg, mean ± SD
Current	2014	Female	13	Volleyball	Frog-leg lateral	4	0	0	42 ± 5.6
Current	2014	Female	24	Soccer	Frog-leg lateral	5	2	2	42 ± 6.4
Current	2014	Female	28	Track and field	Frog-leg lateral	27	7	7	51 ± 7
Kapron et al[21]	2011	Male	67	Football	Frog-lateral	54			52 ± 10
Ayeni et al[5]	2014	Both	20	Hockey	MRI	55			54 ± 12
Johnson et al[19]	2012	Female	25	Soccer	Frog-leg lateral		36		50[c]
Silvis et al[37]	2011	Male	39	Hockey	MRI		39		
Philippon et al[30]	2013	Male	27	Skiing	MRI		42		55 ± 7
Gerhardt et al[13]	2012	Female	20	Soccer	Frog-leg lateral		50[d]		53
Siebenrock et al[36]	2013	Male	43[e]	Hockey	MRI		56[f]		
Johnson et al[19]	2012	Male	25	Soccer	Frog-leg lateral		60		56[c]
Gerhardt et al[13]	2012	Male	75	Soccer	Frog-leg lateral		68[d]		66
Philippon et al[30]	2013	Male	61	Hockey	MRI		75		60 ± 7.4
Siebenrock et al[35]	2011	Male	37[e]	Basketball	MRI		89[f]		
Agricola et al[1]	2012	Male	89	Soccer	Frog-leg lateral			26	

[a]Empty cells indicate data not reported. FAI, femoroacetabular impingement; MRI, magnetic resonance imaging.
[b]Expressed as the percentage of subjects with alpha angle >50°, >55°, and >60°.
[c]Average values reported separately for right and left hips. Values averaged for this table.
[d]Gerhardt et al[13] reported a positive finding of cam FAI if any of the following criteria were met: excessive bone at head-neck junction, loss of normal head sphericity, flattening of head-neck offset, or alpha angle >55°.
[e]Hips with physeal closure.
[f]A positive finding of cam FAI included an alpha angle >55° in any MRI slice.

The prevalence of radiographic pincer FAI was low in this female athlete population (1 hip had an LCEA >40°, and only 13% had acetabular index <0°). The prevalence of radiographic pincer FAI was slightly higher in a previous study of 67 male collegiate football players (7% of hips had an LCEA >40° and 16% of hip had an acetabular index <0).[21] This comparison was surprising, as symptomatic pincer FAI has been both anecdotally and quantitatively reported to occur more frequently in women.[8,12] Another study of athletes used the crossover sign to determine the prevalence of acetabular retroversion, considered a subtype of pincer FAI, in 27% of male and 10% of female soccer players.[13] This measure was not evaluated in the present study, because the ability to diagnose a crossover sign is subject to pelvic tilt and has been shown to overestimate the presence of pincer FAI.[16,43]

The prevalence of acetabular dysplasia and borderline dysplasia was substantially higher than previously reported values for the general population. Specifically, in 1199 Norwegian and 2430 Danish female study participants, the reported prevalence of an LCEA <20° was 4.3% and 3.5%, respectively.[10,18] Other studies used a less stringent cutoff of 25° and reported a prevalence of 4% to 23% in female European and Japanese cohorts.[10,17,42] The increased prevalence in the present study may be explained in part by differences in the technique used to measure LCEA. In the present study, the LCEA was measured to the lateral margin of the sclerotic line,[27] which, in some cases, can result in a smaller LCEA than measurements made to the lateral border of the acetabular rim.[28]

While previous studies have identified significant correlations between internal rotation and alpha angle,[20,21] there were no significant correlations between hip rotation and radiographic measures in the current study. Other factors, such as flexibility, soft tissue, or femoral version, may have obscured a relationship between hip morphologic characteristics and rotation in this mixed group of athletes. The impingement examination, which is almost always positive in symptomatic FAI patients,[31] had a low sensitivity to identify radiographic FAI deformities in the female athletes. This finding was consistent with a prior football study in which 95% of players had radiographic evidence of FAI, but the impingement examination was positive in only 4%.[22]

As the largest cohort of female athletes evaluated to date, our study provides insights into the radiographic prevalence of structural hip deformities in a mixed group of female athletes. However, the number of athletes in each sport was relatively low, and therefore comparisons among sports should be interpreted with caution. Also, the athletes were not screened or excluded for previous hip history. Further, a control population was not included, so no direct conclusions can be made regarding the influence of athletic activity on the prevalence of structural hip deformities in women. Next, structural deformities of the hip may be best captured with 3-dimensional imaging. However, the 2 radiographic views used in this study are commonly used to diagnose FAI in the clinic.[9,39] Also, there is limited consensus on the radiographic cutoff values used to identify structural deformities, especially FAI. However, histograms presented in Figures 1 through 3 enable calculation of prevalence based on any desired cutoff criteria. As a lateral film was not obtained in the interest of limiting radiation exposure, neutral pelvic tilt in the supine AP radiographs could not be confirmed. However, recent studies have shown that changes in pelvic tilt do not result in clinically significant changes in the LCEA and acetabular index.[32,38,40] In contrast, pelvic tilt does influence the presence or absence of the crossover sign.[38,40] As a result, the crossover sign was not evaluated, and our study is unable to comment on the prevalence of pincer FAI due to retroversion or focal acetabular overcoverage. Finally, while prevalence studies provide better insights into which groups are more at risk for underlying hip deformities, they do not indicate who is at risk for developing symptoms. In the case of FAI, there are many individuals (including those with elevated activity levels) who have radiographic FAI deformities but do not develop symptoms, chondrolabral damage, or early osteoarthritis.[4,6,15] A prospective, longitudinal study following athletes and controls from childhood to adulthood is needed to fully define the variables that predict symptomatic FAI and dysplasia.

While the symptoms of FAI can affect both male and female athletes, there was a lower prevalence of radiographic cam FAI in these female collegiate soccer, volleyball, and track and field athletes compared with previously reported values for male athletes. In this study, the track and field athletes had higher rates of cam deformity than soccer and volleyball players. Acetabular dysplasia was higher in this cohort of female athletes than in previous population studies.

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REFERENCES

1. Agricola R, Bessems JH, Ginai AZ, et al. The development of cam-type deformity in adolescent and young male soccer players. *Am J Sports Med*. 2012;40(5):1099-1106.
2. Agricola R, Heijboer MP, Ginai AZ, 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. *Am J Sports Med*. 2014;42(4):798-806.
3. Anderson LA, Peters CL, Park BB, Stoddard GJ, Erickson JA, Crim JR. Acetabular cartilage delamination in femoroacetabular impingement: risk factors and magnetic resonance imaging diagnosis. *J Bone Joint Surg Am*. 2009;91(2):305-313.
4. Audenaert EA, Peeters I, Van Onsem S, Pattyn C. Can we predict the natural course of femoroacetabular impingement? *Acta Orthop Belg*. 2011;77(2):188-196.
5. Ayeni OR, Banga K, Bhandari M, et al. Femoroacetabular impingement in elite ice hockey players. *Knee Surg Sports Traumatol Arthrosc*. 2014;22(4):920-925.
6. Bardakos NV, Villar RN. Predictors of progression of osteoarthritis in femoroacetabular impingement: a radiological study with a minimum of ten years follow-up. *J Bone Joint Surg Br*. 2009;91(2):162-169.
7. Carsen S, Moroz PJ, Rakhra K, et al. The Otto Aufranc Award: on the etiology of the cam deformity: a cross-sectional pediatric MRI study. *Clin Orthop Relat Res*. 2014;472(2):430-436.
8. Clohisy JC, Baca G, Beaule PE, et al. Descriptive epidemiology of femoroacetabular impingement: a North American cohort of patients undergoing surgery. *Am J Sports Med*. 2013;41(6):1348-1356.
9. Clohisy JC, Nunley RM, Otto RJ, Schoenecker PL. The frog-leg lateral radiograph accurately visualized hip cam impingement abnormalities. *Clin Orthop Relat Res*. 2007;462:115-121.
10. Engesaeter IO, Laborie LB, Lehmann TG, et al. Prevalence of radiographic findings associated with hip dysplasia in a population-based cohort of 2081 19-year-old Norwegians. *Bone Joint J*. 2013; 95(2):279-285.
11. Finner H. On a monotonicity problem in step-down multiple test procedures. *J Am Stat Assoc*. 1993;88(423):920-923.
12. Ganz R, Parvizi J, Beck M, Leunig M, Notzli H, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. *Clin Orthop Relat Res*. 2003;417:112-120.
13. Gerhardt MB, Romero AA, Silvers HJ, Harris DJ, Watanabe D, Mandelbaum BR. The prevalence of radiographic hip abnormalities in elite soccer players. *Am J Sports Med*. 2012;40(3):584-588.

14. Harris NH. Acetabular growth potential in congenital dislocation of the hip and some factors upon which it may depend. *Clin Orthop Relat Res*. 1976;119:99-106.
15. Hartofilakidis G, Bardakos NV, Babis GC, Georgiades G. An examination of the association between different morphotypes of femoroacetabular impingement in asymptomatic subjects and the development of osteoarthritis of the hip. *J Bone Joint Surg Br*. 2011;93(5):580-586.
16. Henebry A, Gaskill T. The effect of pelvic tilt on radiographic markers of acetabular coverage. *Am J Sports Med*. 2013;41(11):2599-2603.
17. Inoue K, Wicart P, Kawasaki T, et al. Prevalence of hip osteoarthritis and acetabular dysplasia in French and Japanese adults. *Rheumatology (Oxford)*. 2000;39(7):745-748.
18. Jacobsen S, Sonne-Holm S, Soballe K, Gebuhr P, Lund B. Hip dysplasia and osteoarthrosis: a survey of 4151 subjects from the Osteoarthrosis Substudy of the Copenhagen City Heart Study. *Acta Orthop*. 2005;76(2):149-158.
19. Johnson AC, Shaman MA, Ryan TG. Femoroacetabular impingement in former high-level youth soccer players. *Am J Sports Med*. 2012;40(6):1342-1346.
20. Johnston TL, Schenker ML, Briggs KK, Philippon MJ. Relationship between offset angle alpha and hip chondral injury in femoroacetabular impingement. *Arthroscopy*. 2008;24(6):669-675.
21. Kapron AL, Anderson AE, Aoki SK, et al. Radiographic prevalence of femoroacetabular impingement in collegiate football players: AAOS exhibit selection. *J Bone Joint Surg Am*. 2011;93(19):e111(111-110).
22. Kapron AL, Anderson AE, Peters CL, et al. Hip internal rotation is correlated to radiographic findings of cam femoroacetabular impingement in collegiate football players. *Arthroscopy*. 2012;28(11):1661-1670.
23. Klaue K, Durnin CW, Ganz R. The acetabular rim syndrome: a clinical presentation of dysplasia of the hip. *J Bone Joint Surg Br*. 1991;73(3):423-429.
24. Kosuge D, Yamada N, Azegami S, Achan P, Ramachandran M. Management of developmental dysplasia of the hip in young adults: current concepts. *Bone Joint J*. 2013;95(6):732-737.
25. Martin HD, Kelly BT, Leunig M, et al. The pattern and technique in the clinical evaluation of the adult hip: the common physical examination tests of hip specialists. *Arthroscopy*. 2010;26(2):161-172.
26. Nawabi DH, Bedi A, Tibor LM, Magennis E, Kelly BT. The demographic characteristics of high-level and recreational athletes undergoing hip arthroscopy for femoroacetabular impingement: a sports-specific analysis. *Arthroscopy*. 2014;30(3):398-405.
27. Ogata S, Moriya H, Tsuchiya K, Akita T, Kamegaya M, Someya M. Acetabular cover in congenital dislocation of the hip. *J Bone Joint Surg Br*. 1990;72(2):190-196.
28. Omeroglu H, Bicimoglu A, Agus H, Tumer Y. Measurement of center-edge angle in developmental dysplasia of the hip: a comparison of two methods in patients under 20 years of age. *Skeletal Radiol*. 2002;31(1):25-29.
29. Philippon M, Zehms C, Briggs K, Manchester D, Kuppersmith D. Hip instability in the athlete. *Oper Tech Sports Med*. 2007;15(4):189-194.
30. Philippon MJ, Ho CP, Briggs KK, Stull J, LaPrade RF. Prevalence of increased alpha angles as a measure of cam-type femoroacetabular impingement in youth ice hockey players. *Am J Sports Med*. 2013;41(6):1357-1362.
31. Philippon MJ, Maxwell RB, Johnston TL, Schenker M, Briggs KK. Clinical presentation of femoroacetabular impingement. *Knee Surg Sports Traumatol Arthrosc*. 2007;15(8):1041-1047.
32. Pullen WM, Henebry A, Gaskill T. Variability of acetabular coverage between supine and weightbearing pelvic radiographs. *Am J Sports Med*. 2014;42(11):2643-2648.
33. Rosenkrantz AB, Lim RP, Haghighi M, Somberg MB, Babb JS, Taneja SS. Comparison of interreader reproducibility of the prostate imaging reporting and data system and Likert scales for evaluation of multiparametric prostate MRI. *AJR Am J Roentgenol*. 2013;201(4):W612-W618.
34. Siebenrock KA, Behning A, Mamisch TC, Schwab JM. Growth plate alteration precedes cam-type deformity in elite basketball players. *Clin Orthop Relat Res*. 2013;471(4):1084-1091.
35. Siebenrock KA, Ferner F, Noble PC, Santore RF, Werlen S, Mamisch TC. The cam-type deformity of the proximal femur arises in childhood in response to vigorous sporting activity. *Clin Orthop Relat Res*. 2011;469(11):3229-3240.
36. Siebenrock KA, Kaschka I, Frauchiger L, Werlen S, Schwab JM. Prevalence of cam-type deformity and hip pain in elite ice hockey players before and after the end of growth. *Am J Sports Med*. 2013;41(10):2308-2313.
37. Silvis ML, Mosher TJ, Smetana BS, et al. High prevalence of pelvic and hip magnetic resonance imaging findings in asymptomatic collegiate and professional hockey players. *Am J Sports Med*. 2011;39(4):715-721.
38. Tannast M, Fritsch S, Zheng G, Siebenrock KA, Steppacher SD. Which radiographic hip parameters do not have to be corrected for pelvic rotation and tilt? [published online September 18, 2014]. *Clin Orthop Relat Res*. doi:10.1007/s11999-014-3936-8.
39. Tannast M, Siebenrock KA, Anderson SE. Femoroacetabular impingement: radiographic diagnosis—what the radiologist should know. *AJR Am J Roentgenol*. 2007;188(6):1540-1552.
40. Troelsen A, Jacobsen S, Romer L, Soballe K. Weightbearing anteroposterior pelvic radiographs are recommended in DDH assessment. *Clin Orthop Relat Res*. 2008;466(4):813-819.
41. Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. *Acta Chir Scand*. 1939;83(suppl 58):5-135.
42. Yoshimura N, Campbell L, Hashimoto T, et al. Acetabular dysplasia and hip osteoarthritis in Britain and Japan. *Br J Rheumatol*. 1998;37(11):1193-1197.
43. Zaltz I, Kelly BT, Hetsroni I, Bedi A. The crossover sign overestimates acetabular retroversion. *Clin Orthop Relat Res*. 2013;471(8):2463-2470.