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The morphologic characteristics and range of motion in the hips of athletes and non-athletes

Páll Jónasson[1],*, Olof Thoreson[1], Mikael Sansone[1], Karin Svensson[1],
Anna Swärd[2], Jon Karlsson[1] and Adad Baranto[1]

[1]Department of Orthopaedics, Institute of Clinical Sciences, Sahlgrenska Academy, University of Gothenburg and Sahlgrenska
University Hospital, Gothenburg, Sweden, and
[2]Department of pediatrics, Östersund Hospital, Östersund, Sweden
*Correspondence to: P. Jonasson. E-mail: pallsj@gmail.com
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ABSTRACT

The cam deformity may cause impingement and probably leads to osteoarthritis of the hip. The aetiology of the cam deformity is incompletely understood. Vigorous training during skeletal growth can lead to the development of cam and symptoms of femoro-acetabular impingement and subsequent osteoarthritis of the hip. The purpose of this study was to compare the radiographic characteristics and range of motion between a group of athletes and a non-athletic control group. Thirty-two male athletes (17 soccer players and 15 ice-hockey players) and thirty non-athletes, used as a control group, were examined clinically and radiographically. Hip range of motion was measured and the FADIR and FABER tests were performed. Standard radiographs of both hips were taken. The centre-edge angle, alpha angle, caput-collum-diaphysis angle, head-neck offset and Tönnis grade were registered. The athletes had a higher Tönnis grade (right $P = 0.009$, left $P = 0.004$), more pain on the FADIR test (right $P = 0.006$, left $P = 0.001$) and lower ROM in internal (right $P = 0.003$, left $P = 0.025$) and external rotation ($P < 0.001$). A superiorly placed cam deformity (seen on an AP pelvis view) was correlated with reduced external rotation (right $P = 0.001$, left $P = 0.004$) and mild osteoarthritis (Tönnis grade 1), ($P = 0.015$, left $P = 0.020$), while a more anteriorly placed cam deformity (seen on a modified Lauenstein view) was correlated with reduced internal rotation (right $P = 0.029$, left $P = 0.013$). A lower range of motion, more osteoarthritic changes and more pain were found in the athletes than the controls. The control group had more cam deformities than previously reported.

INTRODUCTION

In addition to hip and groin pain, reduced range of motion (ROM) is frequently reported in patients with femoro-acetabular impingement (FAI). Previous studies have reported that patients with FAI have reduced hip flexion and internal rotation on clinical examination [1, 2]. Several studies have reported that FAI is a common cause of hip and groin pain, reduced ROM and impaired performance in the athlete [3]. There is also growing evidence that cam deformity may lead to osteoarthritis of the hip [4–6].

The aetiology of the cam deformity is not completely understood. Theories, including evolutionary [7], genetic factors [8], abnormal ossification of the proximal femur

[9] and growth disorder or childhood condition like a silent capital slip or Perthes disease [9–12], have all been proposed as the cause. In recent years, evidence has emerged, supporting mechanical factors affecting the proximal femoral physis, as a cause of cam deformity. As early as 1971, Murray and Duncan showed that the tilt deformity was more prevalent in individuals who were active during adolescence as compared with less active controls [13]. The cam deformity has been shown to emerge from the physeal scar of the proximal femoral physis [3] and to develop during adolescence in response to vigorous sporting activity [14–16]. In a biomechanical study of young porcine hips, microfractures in the epiphyseal plate and

adjacent bone were seen after cyclical loading [17]. These findings may, at least in part, explain the cause of cam deformity in athletes.

The aim of this study was to compare the radiologic, morphological characteristics of the hip joint in a group of professional athletes (soccer and ice-hockey players) with an age-matched group of non-athletes. The hip ROM was also compared between the groups.

The hypothesis was that the athletes' hips would have more cam deformity characteristics and a smaller ROM, specifically internal rotation and flexion. Furthermore, it was hypothesized that subjects with more cam deformity characteristics would have lower ROM. Subjects with more cam deformity characteristics were hypothesized to have more osteoarthritis as defined by the Tönnis classification.

MATERIALS AND METHODS

Subjects

A group of 40 professional male athletes from the local ice-hockey team and the local soccer team were invited to take part in the present study (20 ice-hockey players and 20 soccer players). Both teams play in the highest league in Sweden in their respective sports. Players born and raised outside Scandinavia were excluded, as were players that had undergone surgery on either hip.

The control group was recruited through flyers at Gothenburg University.

The inclusion criteria for the control group were male gender, 18–40 years of age and not participating or competing in any organized sports before or at present. Participants who had undergone previous surgery on either hip were also excluded.

Clinical examination

All subjects were examined in a supine position by the first author. Hip flexibility and internal and external rotation in $90°$ flexion were measured using a goniometer. Hip flexion was measured as the angle between the examination table and a line between the palpable major trochanter and the lateral femoral condyle. Rotation was measured as the angle between a line $90°$ perpendicular to a line between the spinae iliaca anterior, and the palpable anterior margin of the tibia. A hip impingement test was performed in a supine position, with $90°$ flexion, adduction and internal rotation (FADIR). It was registered as positive if the subject reported pain during the performance of the test. A FABER (flexion, abduction, external rotation) test was performed in a supine position, by placing the lateral malleoli of the examined side above the patella of the

contralateral knee with the contralateral lower extremity lying extended on the examination table. The hip was then abducted until full ROM or until the subject reported pain. During the examination, care was taken to keep the pelvis stable so the movement registered only occurred in the hip joint. A positive hip impingement test and pain on the FABER test were registered. The angle between the lower leg and the examination table during the FABER test was also measured using a goniometer.

Plain radiographic examinations and investigations

Radiologic measurements and investigations were performed by the first author (orthopaedic surgeon) using plain radiographs of both hips with Osirix software (Pixmeo, Geneva, Switzerland). All subjects underwent standardized supine anteroposterior (AP) radiographs of both hips and pelvis and modified Lauenstein view with the patient supine and the hip in $45°$ flexion and $45°$ abduction.

The alpha angle of Nötzli was measured according to Clohisy et al [18] on all radiographs. The diameter of the femoral head was measured as the diameter of a best fit circle drawn around the femoral head. The anterior offset and anterior offset ratio were measured on the modified Lauenstein view radiographs, as described by Tannast et al. [19]. Superior offset was measured in the same way on the AP hip and pelvis radiographs. The centre-edge (CE) angle was measured on the AP pelvic view by measuring the angle between a vertical line (perpendicular to a line drawn between the pelvis teardrops) and a line drawn from the centre of the femoral head to the lateral border of the acetabulum. A cross-over sign (a line drawn along the anterior margin of the acetabulum crosses a line drawn along the posterior margin of the acetabulum), [20], an ischial spine sign (the ischial spine projects medially from the pelvic brim towards the pelvic inlet) [21] and a posterior wall sign (the posterior margin of the acetabulum lies medially to the center of the femoral head) [20] were registered if present. The acetabular depth was classified on the AP pelvic view as protrusio (the femoral head contacts the ilio-ischial line), profunda (the acetabular fovea contacts the ilio-ischial line) or normal.

The presence of osteoarthritis was defined according to the Tönnis classification with grade $0 =$ normal, grade $1 =$ sclerosis, osteophytes and/or slight narrowing of the joint space, grade $2 =$ small cysts, moderate joint space narrowing and grade $4 =$ large cysts, severe narrowing or obliteration of the joint space.

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) (version 20, 2010 SPSS Inc., Chicago, Illinois, USA).

Range of motion and radiologic measurements (angles and distances) between groups were compared with the independent Student t test. Pearson's correlation coefficient was used to quantify the association between range of motion and radiological measurements. The chi-square test or Fisher's exact test was used for categorical variables. P-values of < 0.05 were considered significant.

We estimated that we would require 16 subjects in each group to detect a difference in alpha angle of $10°$ assuming a standard deviation of $10°$ at a power of 80%.

RESULTS

A total of 32 male athletes (17 soccer players, 15 ice-hockey players) were enrolled. Three soccer players and 5 ice-hockey players had previous surgery on either hip. Four athletes (two soccer players and two ice-hockey players) were only examined clinically before moving to other clubs. Two ice-hockey players changed clubs before they were examined but after the radiographs were taken. As a result, 30 athletes were examined clinically and 28 athletes radiologically.

A total of 30 controls were enrolled in this study. All controls were examined clinically and with radiographs, according to the study protocol.

The average age of the athlete group was 26.5 (SD 5.9) years, while it was 25.0 (SD 2.3) years in the control group. No difference was found between the mean age of the groups ($P = 0.9$). The mean age of the soccer players was 26.5 years (SD 6.5), the same as that of the ice-hockey players, 26.5 years (SD 5.4).

The results of the clinical examination are summarized in Tables I and II. The athletes had lower external and internal rotation than the control group. Lower flexion of the right hip was also noted in the athlete group compared with the control group. Pain or discomfort on the FADIR test was more common in the athlete group, as was pain or discomfort on the FABER test of the right hip.

The results of the radiologic examination are summarized in Tables III–V. The femoral head diameter was larger ($P < 0.001$) in the athletes compared with the control group. There were no differences between the groups in terms of cam characteristics (alpha angle, head-neck offset) or pincer characteristics (CE angle) (Table IIIa–c). Signs of retroversion of the acetabulum tended to be more common in the control group, but the cross-over sign on the left side was the only difference ($P = 0.032$). The occurrence of coxa profunda was more common

TABLE I. Range of movement in degrees between the groups on clinical examination. Mean (standard deviation; SD) values

	Athletes n = 30	Controls n = 30	P values
Flexion right	106.9 (8.8)	111.4 (8.0)	0.044
Flexion left	108.1 (8.5)	111.0 (7.2)	n.s.
Internal rotation right	11.2 (8.6)	19.7 (12.1)	0.003
Internal rotation left	11.1 (10.4)	17.3 (10.6)	0.025
External rotation right	30.4 (8.9)	50.5 (18.5)	<0.001
External rotation left	34.4 (11.1)	51.3 (17.9)	<0.001
Faber right	23.0 (17.9)	16.3 (12.7)	n.s.
Faber left	22.5 (17.2)	14.4 (11.3)	0.035

TABLE II. Pain on FADIR and FABER tests

		Athletes n = 30	Controls n = 30	P values
FADIR	Right	9	1	0.006
	Left	11	1	0.001
FABER	Right	5	0	0.026
	Left	4	1	n.s.

(right $P = 0.001$, left $P = 0.006$) in the control group (Table IV).

Osteoarthritic changes as classified on the Tönnis scale were more common (right $P = 0.009$, left $P = 0.004$) in the athletes (Table V). Only two subjects (both athletes) had a Tönnis grade 2, one bilaterally and one in the left hip. No subjects had Tönnis grade 3 osteoarthritis.

ROM in external rotation and the FABER test correlated for both the right ($P < 0.001$) and the left ($P < 0.001$) hips.

There were negative correlations between the CE angle and the femoral head diameter (right $P = 0.019$, left $P = 0.003$). The alpha angle measurements correlated with the offset measurements on both the AP pelvic and modified Lauenstein views ($P < 0.001$–0.020).

Subjects with large alpha angles and low head-neck offset on the AP pelvic view had lower ROM on the FABER test ($P < 0.001$–0.001) and external rotation ($P = 0.001$–0.027). A larger femoral head diameter on the AP pelvic view correlated with lower external rotation in both hips

TABLE IIIa. Radiologic measurements in degrees and millimeters on the pelvis AP. Mean (standard deviation; SD) values

		Athletes n = 28	(SD)	Controls n = 30	(SD)	P values
Center-edge angle	Right	32.0	(6.6)	33.2	(5.4)	n.s.
	Left	31.8	(7.4)	33.5	(5.6)	n.s.
Caput-collum-diaphysis angle	Right	129.0	(4.0)	127.1	(5.0)	n.s.
	Left	127.7	(3.0)	126.7	(4.5)	n.s.
Alpha angle	Right	58.1	(15.2)	53.7	(13.7)	n.s.
	Left	55.9	(13.8)	52.8	(13.1)	n.s.
Head neck offset (mm)	Right	6.6	(4.6)	7.4	(3.9)	n.s.
	Left	8.2	(5.0)	8.1	(3.8)	n.s.
Caput diameter (mm)	Right	66.5	(2.9)	63.0	(3.0)	<0.001
	Left	66.1	(3.0)	62.7	(2.6)	<0.001

TABLE IIIb. Radiologic measurements on the hip AP. Mean (standard deviation; SD) values

		Athletes n = 28	(SD)	Controls n = 30	(SD)	P values
Alpha angle	Right	57.7	(15.3)	54.4	(13.6)	n.s.
	Left	56.1	(13.7)	52.1	(10.9)	n.s.
Head neck offset (mm)	Right	6.2	(4.4)	7.5	(4.1)	n.s.
	Left	7.3	(4.5)	7.7	(3.5)	n.s.
Caput diameter (mm)	Right	66.9	(3.4)	63.5	(2.8)	<0.001
	Left	66.5	(3.6)	63.5	(3.1)	0.001

TABLE IIIc. Radiologic measurements in degrees and millimeters on the modified Lauenstein projection. Mean (standard deviation; SD) values

		Athletes n = 28	(SD)	Controls n = 30	(SD)	P values
Alpha angle	Right	62.0	(12.9)	62.5	(12.0)	n.s.
	Left	57.9	(11.5)	57.0	(12.0)	n.s.
Head neck offset (mm)	Right	4.9	(3.6)	4.3	(3.2)	n.s.
	Left	5.9	(3.9)	5.3	(3.8)	n.s.
Caput diameter (mm)	Right	67.0	(3.7)	64.5	(2.8)	0.005
	Left	67.2	(3.5)	64.9	(3.2)	0.011

TABLE IV. Radiologic signs of acetabular retroversion and presence of Coxa profunda

		Athletes n = 28	Controls n=30	P values
Cross-over sign	Right	15	21	n.s.
	Left	15	24	0.032
Ischial spine sign	Right	15	22	n.s.
	Left	17	24	n.s.
Posterior wall sign	Right	13	17	n.s.
	Left	16	19	n.s.
Coxa profunda	Right	0	10	0.001
	Left	0	7	0.006

TABLE V. Osteoarthritic (OA) changes in the different groups as classified with the Tönnis grade

	Right hip		Left hip	
	No OA	OA	No OA	OA
Athletes N = 28	12	16	11	17
Controls N = 30	23	7	23	7
P values	0.009		0.004	

(right $P < 0.001$, left $P = 0.002$). Negative correlations were found between internal rotation and the alpha angle on the modified Lauenstein view in both the right ($P = 0.029$) and the left hip ($P = 0.013$).

When comparing individuals with osteoarthritis, as classified on the Tönnis grade (Tönnis grade 1 or higher), with individuals without osteoarthritis (Tönnis 0), differences between the groups were found for the alpha angle (right $P = 0.021$, left $P = 0.004$), head-neck offset (right $P = 0.015$, left $P = 0.020$) and femoral head diameter (right $P = 0.037$, left $P = 0.020$), as measured on the AP pelvis view (Table VII). The same differences were not seen on the modified Lauenstein view measurements. Subjects with osteoarthritis had lower flexion in the right hip ($P = 0.012$) but no other difference in ROM was found between subjects with osteoarthritis and those without Table VI).

DISCUSSION

In this study the presence of the cam deformity and hip ROM was compared between a group of athletes and a non-athletic control group. Furthermore, a correlation between the presence of cam deformity and ROM and osteoarthritic changes was accounted for.

The main finding in the present study is that, although there were no differences in the radiographic criteria used to quantify either the cam or the pincer deformity, the athletes had a lower range of motion compared with the controls. This reduced ROM may be caused by other factors than by the presence of FAI alone.

The ROM differed mainly in external and internal rotation. The internal and external rotation of the athletes is similar to that previously reported by Kapron et al. [22]. The external rotation in the control group is somewhat higher than that reported in an asymptomatic population, while the internal rotation is lower [1]. The external rotation appears to be more affected in individuals where the cam deformity is located superiorly on the head neck junction (as seen on an AP pelvis view), while the internal rotation is more affected if the deformity is located more anteriorly (as seen on a modified Lauenstein view).

The alpha angle in an asymptomatic male population has been reported to be between 45 and 55° [8,23]. These studies used an AP pelvis view and cross table lateral. The alpha angle in the control population was much higher (62°) which could be explained to a certain degree by the difference in radiological projections. In a recent systematic review of the prevalence of FAI in an asymptomatic population the cam deformity was found to be more prevalent in athletes as compared to the general population [24]. In the present study, the athletes tended to have higher alpha angles, although this was not statistically significant. Larger groups might have displayed a significant difference in alpha angles.

The athletes had larger femoral heads. We doubt whether this had any relevance to the results in the present study and hypothesize that it was simply a product of the advantage larger players have in both ice-hockey and soccer. Larger players are therefore more likely to being picked by professional clubs with smaller players not becoming professionals in the same degree. The average height of the subjects in both groups was unknown.

The presence of osteoarthritis of the hip as measured with the Tönnis classification was more common in the athletes. Hip osteoarthritis is known to cause reduced ROM [25], but individuals with osteoarthritis, as classified by the Tönnis classification, did not have lower ROM, except in flexion of the right hip. The difference in pain on the FADIR and FABER tests can also be caused by the

TABLE VI:Differences in ROM in degrees between individuals with osteoarthritis as classsified on the Tönnis grade and individuals without arthritic changes.

		No arthritis n = 34		Arthritis n = 22		
		Mean	*(SD)*	*Mean*	*(SD)*	*P values*
Flexion	Right	111.5	(8.8)	105.4	(8.1)	0.012
	Left	109.9	(7.4)	109.4	(9.4)	n.s.
Internal rotation	Right	17.2	(11.9)	12.6	(10.7)	n.s.
	Left	15.1	(11.1)	14.3	(11.2)	n.s.
External rotation	Right	43.8	(17.6)	37.7	(17.6)	n.s.
	Left	45.9	(16.9)	39.1	(18.1)	n.s.
FABER	Right	17.4	(13.5)	23.5	(18.7)	n.s.
	Left	15.9	(10.6)	21.5	(20.3)	n.s.

SD = standard deviation.

increase in osteoarthritic changes seen in the athletes. Pain on FABER correlated with arthritic changes in the right hip, but this did not apply to pain on the FADIR test. For the left hip, it was the other way around, as correlations were found between arthritic changes and pain on the FADIR test but not for pain on the FABER test. Pain on the FADIR and FABER tests can be caused by other injuries not detected on plain radiographs, such as cartilage or labrum damage or extra-articular pathology, such as muscular or tendon injuries.

It can also be speculated that, in the presence of FAI, high-load athletic activities lead to early degenerative osteoarthritis and might explain why osteoarthritis of the hip is more common in the athletic population [26]. In the present study, it was shown that there were correlations between osteoarthritis and cam morphology in the superior head-neck junction (pistol grip deformity on the AP pelvic view). These correlations were not found between the more anteriorly placed cam morphology (cam deformity on the modified Lauenstein view) and osteoarthritis. This might indicate that, when the cam deformity is located more superiorly on the head-neck junction (as seen on an AP pelvis view), the risk of developing osteoarthritis is higher than if it is placed more anteriorly (as seen on a modified Lauenstein view), especially in the professional athlete. Further studies are needed before any firm conclusions about this finding can be drawn.

The average age in both groups was comparable. The controls were medical students and their friends that had never participated in any organized sporting activities. The results for the control group may not be generalizable for the normal population but should be for the non-athletic population. No differences were found between the hockey and soccer players regarding clinical or radiologic investigations. Combining these two groups of athletes into one athlete group was acceptable although the results may not be generalizable for all athletes regardless of sport.

We did not test for intra- or inter-observer reliability. Previous studies have shown that standardized ROM measurements using a goniometer have good reliability [27, 28]. The reliability of clinical tests for FAI varies in different studies. The FABER test usually shows good reliability and the FADIR test is the one most usually reported in studies of FAI and we deem its reliability adequate [28–31]. Both tests have been shown to be sensitive, but, with regard to FAI, they often lack specificity with false positives due to labral or cartilage injury or extraarticular pathology such as pain from a muscle or tendon insertion [2,32]. In the present study the quantification of the FABER tests ROM was done by measuring the angle created between the lower leg and the examination table. The FABER distance test is used to compare the affected and the unaffected side of the individual patient [33]. By measuring the ROM during the FABER test comparisons between different individuals and groups can be performed.

Numerous studies of the reliability of radiographic evaluation of the hip have been reported. The reliability of the different measurements varies [34], but the alpha angle, head-neck offset, center-edge angle, cross-over sign and Tönnis grade generally show good reliability [18,23,34,35]. The accuracy of a modified Lauenstein view in detecting the cam deformity is established although some studies show that the Dunn's view may be more sensitive in that aspect [18,36].

The cross-over sign has been shown to overestimate acetabular retroversion as the morphology of the anterior-inferior iliac spine can contribute to its appearance (37). Assessing for both the ischial spine sign and the posterior wall sign decreases the risk for this overestimation but for more accurate measurement of acetabular version a 3D CT analysis would be better.

The Tönnis classification defines grade 1 as mild osteoarthritis. Studies have found the Tönnis classification system to be reliable [34,38]. Other authors have recommended excluding hips with mild osteoarthritis when using global visual assessment grading classifications [39]. In the present study only two subjects (both athletes) were graded with a Tönnis classification of 2 or

TABLE VII. Differences in radiographic measurements between individuals with osteoarthritis as classified on the Tönnis grade and individuals without osteoarthritic changes.

| | | No arthritis n = 35 right 34 left | | Arthritis n = 23 right 24 left | | |
		Mean	SD	Mean	SD	P values
Center-edge angle	Right	31.7	(6.5)	34.0	(4.8)	n.s.
	Left	32.9	(6.6)	32.3	(6.5)	n.s.
Caput-collum-diaphysis angle	Right	127.8	(3.9)	128.3	(5.6)	n.s.
	Left	127.8	(4.0)	126.4	(3.6)	n.s.
Alpha angle	Right	52.1	(12.5)	61.5	(15.8)	0.021
	Left	49.8	(9.3)	60.7	(15.8)	0.004
Superior head-neck offset	Right	8.0	(3.9)	5.3	(4.3)	0.015
	Left	9.2	(3.6)	6.4	(4.9)	0.020
Femoral head diameter	Right	63.9	(3.6)	65.8	(2.7)	0.037
	Left	63.6	(3.3)	65.5	(2.8)	0.020
Alpha angle Lauenstein view	Right	61.4	(12.1)	63.5	(12.9)	n.s.
	Left	55.8	(11.0)	59.8	(12.4)	n.s.
Anterior head-neck offset	Right	4.7	(3.4)	4.4	(3.5)	n.s.
	Left	5.8	(3.7)	5.4	(4.0)	n.s.

higher. Therefore a grade 1 Tönnis was defined as osteoarthritis.

CONCLUSIONS
A lower ROM and higher occurrence of pain on FADIR and FABER tests were found in the athlete group. This could be partly explained by the osteoarthritic changes more commonly found in that group. No differences in cam morphology were found between top-level athletes (ice-hockey and soccer players) and non-athletes, although the occurrence of cam in the control group was higher than previously reported.

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