AJSM PreView, published on October 13, 2015 as doi:10.1177/0363546515607000

Prevalence and Functional Consequences of Femoroacetabular Impingement in Young Male Ice Hockey Players

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Background: Femoroacetabular impingement (FAI), which is highly prevalent in adult ice hockey players, is often associated with negative clinical and functional outcomes. It is unclear, however, whether FAI-related bony deformities and symptoms may lead to functional alterations as reflected in hip muscle strength, range of motion (ROM), and on-ice physical performance in youth ice hockey players.

Hypothesis: Compared with players with neither structural signs nor symptoms related to FAI, players with symptomatic FAI would show hip muscle weakness and reduced hip ROM, which would in turn affect ice hockey physical performance.

Study Design: Controlled laboratory study.

Methods: A total of 74 young male ice hockey players were evaluated bilaterally for passive hip internal rotation ROM by use of a hip examination chair. Only the side with less internal rotation ROM was further investigated. FAI-related bony deformities were evaluated with magnetic resonance imaging (MRI). The involved hip was classified as symptomatic or asymptomatic based on the presence of hip pain during exercise and results from the flexion/adduction/internal rotation (FADIR) provocation test. Hip muscle strength, passive hip ROM, and on-ice physical performance were compared between players with no FAI, players with asymptomatic MRI-positive FAI, and players with symptomatic FAI.

Results: Fifty of 74 players (68%) had FAI-related bony deformities, of whom 16 (22%) were symptomatic. Hip muscle strength, hip ROM, and on-ice physical performance did not differ significantly between players with no FAI and those with asymptomatic or symptomatic FAI.

Conclusion: Despite a high prevalence of FAI-related bony deformities, youth ice hockey players with asymptomatic or symptomatic FAI did not show functional impairments in terms of hip muscle strength, hip ROM, or on-ice physical performance.

Clinical Relevance: Hip muscle strength, passive hip ROM, and on-ice physical performance do not seem to discriminate for FAI-related signs and symptoms in young male ice hockey players.

Keywords: femoroacetabular impingement; ice hockey; muscle strength; range of motion; physical performance

Femoroacetabular impingement (FAI) is a pathomechanical process causing abnormal contacts between the hip structures and loading within the hip joint.[11] It is a result of bony deformities of the proximal femur and/or acetabulum, which might lead to chondrolabral damage[18,20] and hip osteoarthritis.[11,20] FAI is generally associated with hip pain and functional impairments such as limited range of motion (ROM),[12,27] hip muscle weakness,[2] and disability in athletic performance.[15] There are 2 types of FAI, cam (abnormality of the proximal femur) and pincer (abnormality of the acetabulum), which can also occur as combined FAI.[11] A cam deformity is more common in men and in athletes such as ice hockey and soccer players.[15] The risk of a cam deformity is about 15 times higher in youth ice hockey players compared with their age-matched counterparts[20] and is 4.5 times higher in 16- to 19-year-old ice hockey players compared with age-matched skiers.[14] Many young ice hockey players with FAI-related bony deformities are asymptomatic, and the functional consequences of these deformities are not known.[14,20]

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The authors declared that they have no conflicts of interest in the authorship and publication of this contribution.

The American Journal of Sports Medicine, Vol. XX, No. X
DOI: 10.1177/0363546515607000

Compared with healthy subjects, adult patients with symptomatic FAI have weaker hip muscles, particularly hip adductors and flexors, followed by external rotators and abductors.[2] Similar alterations can occur in youth athletes, although this has not been verified. In addition, decreased hip internal rotation ROM was recently reported to be a predictor of FAI.[12,27] Hip internal rotation ROM was significantly lower in elite ice hockey players with symptomatic FAI compared with those with asymptomatic FAI.[20] It has been speculated that repetitive contacts between the femoral head-neck junction and the acetabulum during intensive physical exercise can also promote FAI.[1] In particular, skating and cutting positions during actual ice hockey play might place the hip joint in positions that can favor pathological contacts between the femur and the acetabulum.[21]

In the present study, we hypothesized that youth ice hockey players with FAI-related bony deformities and symptoms would show alterations in hip muscle strength, hip internal rotation ROM, and ice hockey physical performance compared with players with no structural signs and symptoms of FAI. Therefore, the aim of this study was to explore potential differences in hip muscle strength, hip ROM, and sport-specific function between players with no FAI, players with symptomatic FAI, and players with asymptomatic, magnetic resonance imaging (MRI)–positive FAI.

METHODS

Participants

A total of 74 young male players (age range, 12-20 years), performing at the highest national level and from the same professional ice hockey club, volunteered to participate in the study. Players were excluded if they had undergone any hip surgery or were unable to perform at least one of the functional tests. None of the players were excluded based on these criteria. The study was conducted according to the Declaration of Helsinki, and the protocol was approved by the local ethics committee. All participants and the parents of minor participants were informed about the aim of the study and signed the informed consent before data collection.

The sample size was calculated based on the difference in hip flexor strength between FAI patients and healthy controls reported by Casartelli et al[2] using an unpaired t test. The calculated sample size to achieve a power of 80% with a significance level of .05 was n = 29, which is compatible with the expected number of ice hockey players with FAI (based on an expected prevalence of approximately 50%).[9,18]

Experimental Procedure

Internal rotation ROM was first measured bilaterally for all participants (n = 74) by use of a recently developed hip examination chair.[17] Since decreased hip internal rotation ROM is generally associated with a high prevalence of FAI,[18] especially in ice hockey players,[20,26] only the hip with less internal rotation ROM was further evaluated for structural signs and subsequently for symptoms related to FAI. In 2 cases, hip internal rotation ROM differed by less than 1° between the 2 hips. The tested side was therefore randomized by use of a computer random number generator.

Thereafter, unilateral MRI assessment of the selected hip was conducted by 2 experienced hip radiologists using specific criteria (ie, cam deformity grade, alpha angle, acetabular depth, acetabular version, femoral antetorsion) and impingement morphologic categories (ie, cam, pincer, combined).[18] For cam deformities, a severity score $\geq$2 (range, 0-3; 0 = no cam deformity; 1 = possible mild cam deformity; 2 = definite cam deformity; 3 = severe cam deformity) was considered positive based on an established large decrease of the anterior head-neck offset.[18] Alpha angles were assessed with radial oblique reconstructions at the anterosuperior segment.[23] A pincer-type morphologic category was considered positive when the acetabular depth was $\leq$3 mm (coxa profunda) and/or when a negative angle of the cranial portion of the acetabulum (acetabular retroversion) was observed.[11,19] The measurement of acetabular depth was performed on the oblique transverse MRI at the level of the center of the femoral head, with positive values indicating that the center of the femoral head was located lateral to the line connecting the anterior and posterior border of the acetabulum, whereas negative values indicated that the femoral head was located medial to this line. The measurement of acetabular version was performed on the oblique transverse MRI at the level 2.5 mm below the most cranial portion of the acetabular rim, with an angle drawn between the sagittal plane and a line connecting the anterior and posterior border of the acetabulum. Positive values for this angle indicated an acetabular anteversion and negative values indicated an acetabular retroversion.[22] Femoral antetorsion was measured on transverse axial MRI sequences over the proximal and distal femur. Positive values (ie, values $>0°$) indicate femoral antetorsion, while negative values (ie, values $<0°$) indicate femoral retrotorsion.[22]

Symptoms that players experienced in the selected hip during exercise were assessed by means of 1 question ("Did you experience hip pain during skating on the ice and/or off-ice training during the last 3 months?") and 2 response options ("yes" or "no"). In addition, an experienced investigator, blinded for the MRI outcome, conducted the flexion/adduction/internal rotation (FADIR) maneuver (also called *impingement test*) on the selected hip.[6] During the FADIR test, the participant was in the supine position on a treatment table with the hip passively flexed at 90° and forcefully adducted and internally rotated.[6,25] The FADIR test was considered positive when it caused groin pain.[8,25] A hip was classified as symptomatic if the player reported hip pain during exercise and had a positive FADIR test. Players who showed positive MRI signs and FAI-related symptoms were therefore allocated to the symptomatic FAI (sFAI) group. Players with only MRI-positive signs but no symptoms were categorized as asymptomatic FAI (aFAI), and players with neither FAI signs nor symptoms were allocated to the no FAI group (Figure 1).

The following functional outcomes were then assessed by the same experienced investigator: isometric hip muscle strength, passive hip ROM, and ice hockey–specific physical

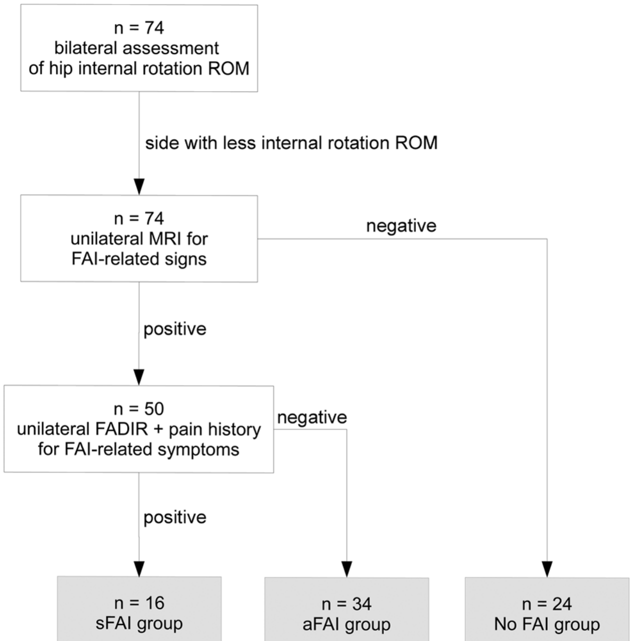

Figure 1. Flow chart for the classification of players into 3 groups. aFAI, asymptomatic femoroacetabular impingement; FADIR, flexion/adduction/internal rotation; FAI, femoroacetabular impingement; MRI, magnetic resonance imaging; ROM, range of motion; sFAI, symptomatic femoroacetabular impingement.

performance. The order of hip muscle strength and ROM assessments was randomized by use of a simple computer random number generator to avoid systematic bias.

MRI Assessment

Noncontrast MRI of the hip was performed on a 1.5-T scanner (Magnetom Avanto; Siemens Medical Solutions) with a body matrix phased-array surface coil and a spine matrix coil. The following sequences were acquired: a coronal intermediate-weighted sequence with fat saturation, a coronal T1-weighted sequence, a sagittal water-excitation 3-dimensional (3D) double-echo steady-state sequence, a transverse short-tau inversion recovery (STIR) sequence, and a transverse oblique water-excitation true fast imaging with steady-state precession (FISP) 3D sequence. Further, a transverse T2-weighted half-Fourier acquisition single-shot turbo spin-echo (HASTE) sequence was acquired both over the proximal femur and over the distal femur to measure femoral antetorsion. After the MRI examination, additional radial reformations of the transverse oblique true FISP 3D sequence were reconstructed to assess the osseous contour of the head-neck junction of the femur.

Hip ROM Assessment

ROM was evaluated on the selected hip in a randomized order for hip adduction, abduction, internal rotation, external rotation, flexion, and extension. The mean duration for ROM assessment was approximately 30 minutes. Hip internal rotation ROM was measured by use of an examination chair[10] according to the method described by Reichenbach et al.[17] Briefly, participants sat on the chair with both hips and knees flexed at 90° and with the hips in 0° of abduction. The arms were placed beside the body for stabilization. A standard load of 5 kg was applied on a lever arm positioned behind the chair, which passively moved both legs in hip internal rotation (Figure 2). This movement was ensured by 2 other lever arms parallel to the shank of the subject, whose distal parts were positioned at the level of the medial malleoli. Maximal hip internal rotation was held for 30 seconds. Maximal internal rotation ROM was measured bilaterally with 2 inclinometers (Mini Digital Protractor; Gain Express Holdings Ltd) that were fixed on the distal lever arms.

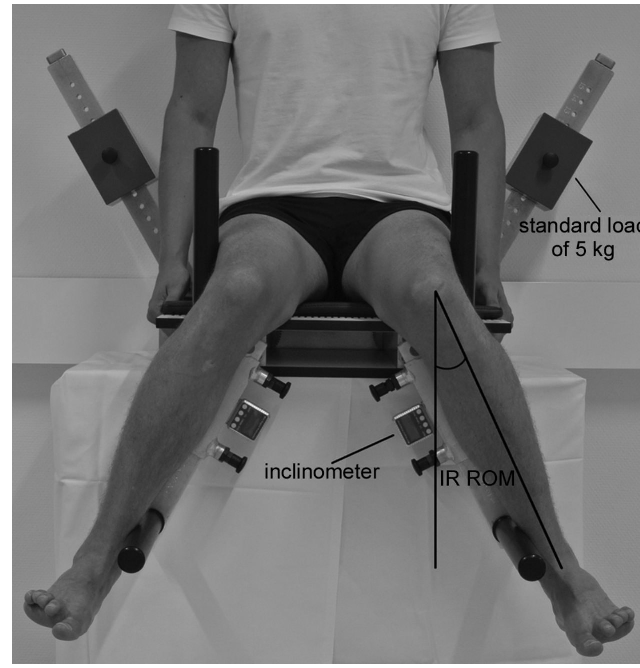

Figure 2. Assessment of hip internal rotation range of motion (IR ROM) with the examination chair.

The other hip ROM movements were measured by use of a simple long-arm goniometer (Orthopedic Equipment Co) according to the protocols proposed by Nussbaumer et al[13] for adduction, abduction, external rotation, and flexion and by Clapis et al[3] for extension. For these ROM assessments, participants lay supine on a treatment table. For adduction, abduction, external rotation, and flexion, the pelvis was held in the neutral position using a fixation belt. For adduction and abduction, the contralateral leg was hanging over the edge of the treatment table. The fulcrum and the stationary arm of the goniometer were placed over the ipsilateral and the contralateral anterior superior iliac spine, respectively, and the moveable arm pointed toward the center of the patella apex. For external rotation, the tested knee and hip were flexed at 90° while the contralateral limb was held in a neutral position. The fulcrum of the goniometer was placed over the center of the patella apex, the stationary arm pointed toward the contralateral anterior superior iliac spine, and the moveable arm was held along the longitudinal axis of the leg. For hip flexion, the fulcrum of the goniometer was placed over the greater trochanter, the stationary arm was aligned to the horizontal axis, and the moveable arm was aligned to the lateral midline of the thigh, with the lateral femoral condyle used as a reference. For extension, the modified Thomas test was applied.[3] The participant was instructed to sit as close as possible to the edge of the treatment table, hold the contralateral knee flexed, and slowly roll backward with the help of the investigator until the participant was lying supine. The fulcrum of the goniometer was placed over the great trochanter, the stationary arm was positioned along the horizontal axis, and the moveable arm was aligned to the lateral midline of the thigh, with the lateral femoral condyle used as a reference.

For each hip ROM direction, the main outcome measure was maximal ROM in degrees. These hip ROM test procedures demonstrated high reliability in previous studies, with intraclass correlation coefficients (ICCs) $\geq$0.90.[3,13]

Hip Muscle Strength Assessment

Isometric maximal voluntary contraction (MVC) strength was quantified with a stabilized dynamometer (Nicholas Manual Muscle Tester; Lafayette Inc) in a randomized order for hip adductors, abductors, internal rotators, and external rotators and with an isokinetic dynamometer (Biodex System 4; Biodex Medical Systems) for hip flexors and extensors. The dynamometer was stabilized to a specially designed metal frame that was fixed on the wall for the assessment of hip internal and external rotator muscle strength and on a treatment table for hip adductor and abductor muscle strength. The testing procedure was conducted as described by Casartelli et al.[2] For every player, the assessment of unilateral hip muscle strength as well as height, body mass, and ice hockey experience ("At what age did you start playing ice hockey?") lasted approximately 1.5 hours.

For adductors, the participant lay on the tested side with the hip and knee at 0° of flexion. The contralateral limb was placed on a padded box with 45° of hip flexion and 60° of knee flexion. To provide comfort and stabilization, the participant was asked to hold the edge of the treatment table. For abductors, the participant lay on the nontested side with the ipsilateral hip and knee flexed at approximately 45° and 60°, respectively. The tested leg was held straight at 0° of hip flexion and rotation but abducted at approximately 10°. To correct for gravity, the examiner quantified the mass of the tested limb before each test by placing the dynamometer 5 cm proximal to the medial malleolus. For internal and external rotators, the participant sat on the edge of the treatment table with both hips and knees flexed at 90° and 0° of hip abduction. The arms were placed beside the body for stabilization. For these assessments, the dynamometer was placed 5 cm proximal to the medial or lateral malleolus and the ankle was held in a neutral position. For flexors and extensors, the participant lay supine on the dynamometer chair with the backrest at 15° with respect to the horizontal and the pelvis fixed with a strap. The dynamometer pad was placed 5 cm proximal to the lateral femoral condyle, and the dynamometer rotational axis was aligned with the greater trochanter. The mass of the tested limb was consistently measured to correct for gravity.

For each muscle group, 2 submaximal contractions were performed for warm-up and familiarization. Then, participants performed 3 or 4 MVCs, during which they were asked to perform maximal efforts for 3 to 4 seconds, with a gradual build-up of force. Rest time between trials was 30 to 60 seconds. Verbal encouragement was consistently provided by the investigator. Only the highest MVC was considered, and the main outcome measure was MVC torque normalized to body mass. These hip strength test procedures demonstrated high reliability in previous studies, with ICCs ranging from 0.80 to 0.97.[4,7,24]

On-Ice Physical Performance Assessment

Ice skating agility, acceleration, and speed were evaluated in a nonrandomized order by use of a wireless photocell system (Witty; Microgate). The testing procedure was conducted as described by Gilenstam et al.[5] The mean duration for all of the on-ice assessments was approximately 3 hours. All participants wore full ice hockey equipment, except the goal keepers, who wore regular clothes with a helmet and gloves and carried their ice hockey stick during testing. Players completed a usual warm-up routine of approximately 15 minutes under the supervision of the trainer.

For agility, the players completed a cornering test (agility test), consisting of an S-shaped pattern around the face-off circles. The testing area was 18.90 m wide and 23.98 m long. One photocell was located at the starting point (middle of goal line) and another photocell was placed at the end of the pattern (blue line) to measure total time. For acceleration and speed, the players performed a sprint in one continuous skating line, where acceleration time was measured for the first 6.10 m and speed time was measured for the entire distance of 47.85 m. Photocells were located at the starting line and 6.10 m and 47.85 m after the starting line.

All players completed the cornering and sprint tests 3 times. The main outcome measure was time associated with the fastest trial. These performance test procedures showed high reliability in a previous study, with ICCs of 0.96, 0.80, and 0.76 for agility, acceleration, and speed, respectively.[5]

Statistical Analysis

Normality was verified with Shapiro-Wilk tests. One-way analyses of variance (ANOVAs) were used to investigate differences in age, anthropometric characteristics, ice hockey experience, MRI findings, hip muscle strength, hip ROM, and ice hockey performance between the 3 groups of players (sFAI, aFAI, and no FAI). In case of a significant main group effect, Tukey post hoc procedures were used. Statistical analyses were performed with Statistica 7.0 (StatSoft Inc). The level of significance was set at $P < .05$.

TABLE 1
Participant Characteristics by Group[a]

	sFAI Group (n = 16)	aFAI Group (n = 34)	No FAI Group (n = 24)	All (N = 74)
Age, y	16.7 ± 1.6	15.9 ± 1.9	16.4 ± 1.9	16.3 ± 1.8
Height, m	1.77 ± 0.05	1.73 ± 0.11	1.75 ± 0.09	1.75 ± 0.09
Body mass, kg	69.8 ± 8.4	63.8 ± 12.9	66.7 ± 11.3	66.9 ± 11.8
Experience, y	11.2 ± 2.9	9.9 ± 2.3	11.6 ± 1.9	10.8 ± 2.4
FAI deformity, n (%)				
Cam	9 (56)	11 (32)	—	20 (27)
Pincer	2 (13)	15 (44)	—	17 (23)
Combined	5 (31)	8 (24)	—	13 (18)
Cam deformity grade[b]	2.0 ± 0.9[c]	1.6 ± 1.0[c]	0.5 ± 0.5	1.3 ± 1.0
Alpha angle, deg	63.8 ± 12.5[c]	58.4 ± 8.5[c]	53.1 ± 4.2	57.8 ± 9.3
Acetabular depth, mm	6.6 ± 2.1	6.1 ± 3.0	6.4 ± 2.0	6.3 ± 2.5
Acetabular version, deg	–0.9 ± 4.4[d]	–0.9 ± 4.7[d]	3.5 ± 2.9	0.5 ± 4.6
Femoral antetorsion, deg	13.2 ± 6.5	14.2 ± 8.1	11.8 ± 8.0	13.2 ± 7.7

[a]Values are reported as mean ± SD unless otherwise indicated. aFAI, asymptomatic femoroacetabular impingement; FAI, femoroacetabular impingement; sFAI, symptomatic femoroacetabular impingement.
[b]0 = no cam deformity; 1 = possible mild cam deformity; 2 = definite cam deformity; 3 = severe cam deformity.
[c]Statistically significantly higher than no FAI group ($P < .001$).
[d]Statistically significantly lower than no FAI group ($P < .01$).

TABLE 2
Hip Range of Motion Results by Group[a]

	sFAI Group (n = 16)	aFAI Group (n = 34)	No FAI Group (n = 24)
Adduction	22 ± 3	23 ± 4	22 ± 6
Abduction	35 ± 6	38 ± 7	35 ± 6
Internal rotation	36 ± 10	38 ± 11	36 ± 11
External rotation	53 ± 6	56 ± 8	56 ± 8
Flexion	113 ± 8	116 ± 7	114 ± 8
Extension	20 ± 6	18 ± 6	19 ± 7

[a]Values are reported in degrees as mean ± SD. aFAI, asymptomatic femoroacetabular impingement; FAI, femoroacetabular impingement; ROM, range of motion; sFAI, symptomatic femoroacetabular impingement.

TABLE 3
On-Ice Physical Performance Results by Group[a]

	sFAI Group (n = 16)	aFAI Group (n = 34)	No FAI Group (n = 24)
Agility	9.43 ± 0.68	9.52 ± 0.75	9.41 ± 0.74
Speed	6.63 ± 0.24	6.79 ± 0.44	6.67 ± 0.38
Acceleration	1.30 ± 0.05	1.31 ± 0.10	1.34 ± 0.09

[a]Values are reported in seconds as mean ± SD. aFAI, asymptomatic femoroacetabular impingement; FAI, femoroacetabular impingement; sFAI, symptomatic femoroacetabular impingement.

RESULTS

The prevalence of FAI-related bony deformities was 68% (50/74 players); 16 players (22%) were categorized as sFAI and 34 (46%) as aFAI. Of these, 17 players had a pincer deformity, of whom 2 were sFAI and 15 were aFAI. A total of 20 players had a cam deformity, of whom 9 were sFAI and 11 were aFAI. Of the 20 players with a cam deformity, 14 were classified as having a definite deformity; the 6 remaining players had a severe deformity. A total of 13 players had a combined FAI, of whom 5 were sFAI and 8 aFAI. Age ($F = 1.10$, $P = .34$), height ($F = 1.17$, $P = .32$), body mass ($F = 0.68$, $P = .51$), and ice hockey experience ($F = 3.07$, $P = .053$) did not differ significantly between the 3 groups of subjects (Table 1). The degree of cam deformity and the alpha angle were significantly higher in both sFAI and aFAI groups compared with the no FAI group (both $P < .001$). Acetabular depth ($F = 0.24$, $P = .79$) did not differ significantly between the 3 groups of players. Acetabular version was significantly lower in both sFAI and aFAI groups compared with the no FAI group ($P = .002$ and $P < .001$, respectively). Femoral antetorsion did not differ significantly between the 3 groups of players ($F = 0.71$, $P = .50$).

For all movements, passive hip ROM did not differ significantly between the 3 groups of players (adduction, $F = 0.19$, $P = .82$; abduction, $F = 1.77$, $P = .18$; internal rotation, $F = 0.24$, $P = .79$; external rotation, $F = 0.88$, $P = .42$; flexion, $F = 1.07$, $P = .35$; extension, $F = 0.53$, $P = .59$) (Table 2).

For all hip muscle groups, isometric MVC strength did not differ significantly between the 3 groups of players (adductors, $F = 0.98$, $P = .38$; abductors, $F = 1.78$, $P = .18$; internal rotators, $F = 0.48$, $P = .62$; external rotators, $F = 1.24$, $P = .30$; flexors, $F = 1.22$, $P = .30$; extensors, $F = 0.17$, $P = .84$) (Figure 3).

Skating agility, speed, and acceleration did not differ significantly between the 3 groups of players (acceleration, $F = 1.27$, $P = .29$; speed, $F = 1.21$, $P = .31$; agility, $F = 0.19$, $P = .83$) (Table 3).

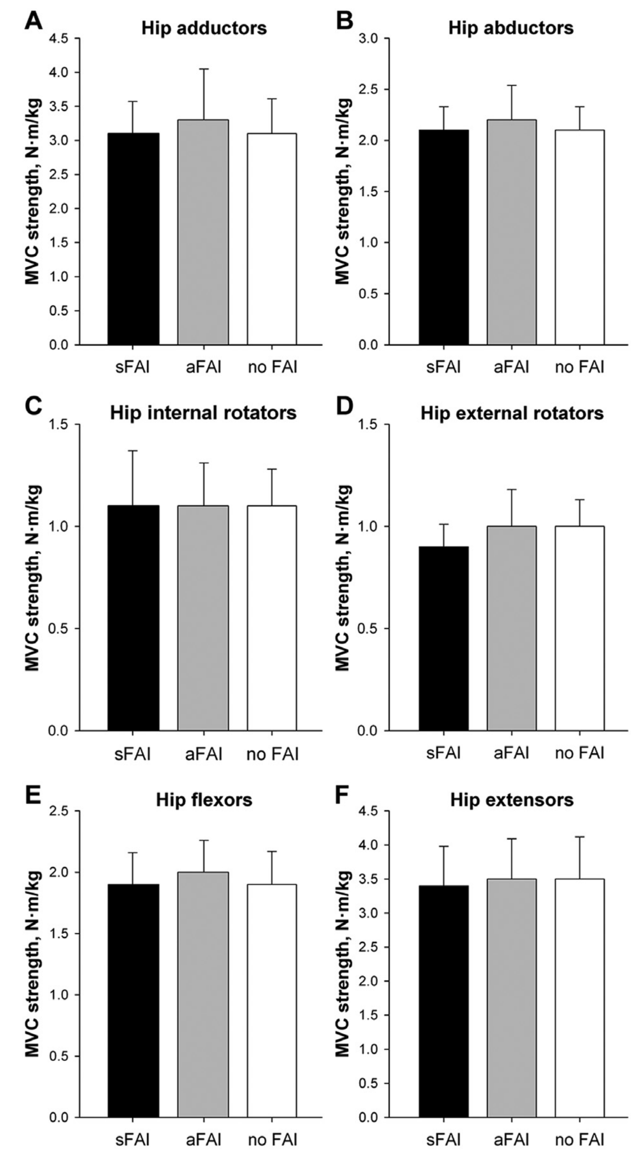

Figure 3. Mean and SD values for hip (A) adductor, (B) abductor, (C) internal rotator, (D) external rotator, (E) flexor, and (F) extensor muscle strength results by group. aFAI, asymptomatic femoroacetabular impingement; FAI, femoroacetabular impingement; MVC, maximal voluntary contraction; sFAI, symptomatic femoroacetabular impingement.

DISCUSSION

We observed FAI-related bony deformities in 2 out of 3 young male ice hockey players, of whom approximately one-third were clinically symptomatic and two-thirds were asymptomatic. No functional alterations in hip muscle strength, passive hip ROM, and ice hockey physical performance were observed between players with and without FAI or between players with asymptomatic MRI-positive FAI and symptomatic FAI.

The prevalence of pure pincer deformities was 23% and the prevalence of cam deformities was 45% (27% for pure cam and 18% for combined deformities) in our sample of youth ice hockey players. These numbers are (1) quite high compared with the 25% prevalence of cam FAI deformities observed in a population of Swiss male army recruits,[18] (2) comparable with the 56% prevalence of cam FAI deformities reported in ice hockey players with a mean age of 16 years,[21] but (3) quite low compared with the 79% prevalence of cam FAI deformities observed in asymptomatic ice hockey players aged between 10 and 18 years.[14] In the present study, the prevalence of symptoms was significantly higher in players with pure cam than pincer deformities (P = .028; Z test for 2 population proportions); however, the clinical significance of this finding remains to be elucidated. Contrary to our results, no significant difference in hip pain was previously observed between cam and pincer FAI in a nonathlete population.[16] Recent studies showed a high prevalence of cam FAI deformities in high-impact sports such as ice hockey and soccer, with the severity of these deformities increasing the most between the ages of 12 and 16 (from 2% to 18%) in young male soccer players (ie, before the closure of the proximal femoral growth plate), while no further increase was observed afterward.[1] This is likely caused by high physical stresses imposed on the growing skeleton during actual training and competition.[1] Stull et al[21] identified 2 at-risk positions for FAI during ice skating: (1) hip abduction combined with external rotation during the push-off phase of the skating cycle and (2) hip flexion combined with internal rotation during the recovery phase of the skating cycle, which may explain at least partly the relatively high prevalence of FAI in youth ice hockey players observed here and elsewhere.[14,20]

Hip muscle strength was not significantly reduced in players with FAI-related bony deformities (both symptomatic and asymptomatic) compared with players without structural FAI signs. In other words, FAI deformities did not result in hip muscle weakness. In contrast to our results, Casartelli et al[2] found decreased muscle strength for hip flexors, adductors, external rotators, and abductors in patients with symptomatic FAI compared with healthy controls. The present study did not look into patients but rather classified as symptomatic those players who reported hip pain during exercise and had a positive anterior impingement test. Additional reasons explaining the different findings between our current study and the study by Casartelli et al could also include (1) the age of the participants, (2) their physical activity level, and (3) the stage of FAI pathologic progression. In the study by Casartelli et al, the average age of the patients was 32 years, participants were recreationally active before the onset of symptoms, and were all scheduled for surgery. In contrast, in the present study participants were on average 16 years old, they were playing ice hockey at the highest national level, and those who reported hip pain and had a positive anterior impingement test were not scheduled for surgical treatment. Indeed, patients with FAI-related, symptomatic chondrolabral damage that requires surgical treatment are usually older than the players in the current study and are unable to exercise and engage in competitive sport.

Similar to muscle strength, passive hip ROM did not differ between players with FAI-related bony deformities (symptomatic or not) and without structural MRI-positive signs of FAI. In contrast, Yuan et al[27] observed that asymptomatic adolescent athletes with reduced internal rotation ROM had a structural hip deformity (ie, increased alpha angle and/or crossover sign). Similarly, it was demonstrated that decreased hip internal rotation ROM was associated with cam deformity and hip pain in young, male ice hockey players.[20] Accordingly, it was expected that players with asymptomatic or symptomatic FAI-related bony deformities would demonstrate reduced hip ROM compared with subjects with no signs and symptoms of FAI, especially for those hip movements that directly induce bone-to-bone contacts (such as internal rotation and flexion). The lack of difference in passive ROM between the 3 groups is not clear but could be possibly related to the high pain tolerance of this athletic cohort. High pain tolerance in ice hockey players may have prevented a limited hip ROM in the sFAI group, although this speculation remains to be experimentally confirmed.

To our knowledge, this is the first study to evaluate on-ice performance of ice hockey players with FAI. Players with FAI (both symptomatic and asymptomatic) had similar agility, speed, and acceleration capabilities compared with players without structural signs of FAI, which again supports the notion that FAI-related signs and/or symptoms did not result in functional impairments—either hip specific or ice hockey specific—in our youth players. Taken as a whole, these results indicate that male, youth ice hockey players with a FAI-related bony deformity such as cam, pincer, or combined—whether associated with a painful hip or not—did not show functional alterations at this early stage of the FAI pathomechanical process. No functional differences were observed between players with cam, pincer, and combined FAI. Longitudinal studies are needed, however, to determine whether players with asymptomatic MRI-positive FAI will become symptomatic and whether players with symptomatic FAI will have functional impairments at a later stage because of the exacerbation of symptoms.

This cross-sectional study conducted on a relatively small cohort of young ice hockey players has some limitations. High-resolution MRI evaluations were conducted only unilaterally (on the hip with less internal rotation ROM) due to economic and practical reasons, and consequently FAI-related symptoms (FADIR test and pain history), hip muscle strength, and hip passive ROM were exclusively evaluated on one side (theoretically, the most affected hip). Thus, we cannot exclude that the contralateral hip also had FAI-related, MRI-positive signs and symptoms, and this could have affected ice hockey performance results, at least in part. In addition, although the methods we used to evaluate FAI-related symptoms (FADIR test), hip internal rotation ROM (hip examination chair), and hip muscle strength (dynamometry) are widely adopted for testing purposes,[2,6,17] their validity remains to be ascertained in young athletes.

In conclusion, two-thirds of young, male ice hockey players had FAI-related bony deformities, of whom approximately one-third were symptomatic. Despite this high prevalence of FAI-related structural signs, the young players we tested did not demonstrate functional impairments in hip muscle strength, hip ROM, or on-ice physical performance. Further research is needed to determine whether functional limitations will develop in later stages of the FAI pathomechanical process.

ACKNOWLEDGMENT

The authors thank Microgate for the loan of the photocells.

REFERENCES

1. 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.
2. Casartelli NC, Maffiuletti NA, Item-Glatthorn JF, et al. Hip muscle weakness in patients with symptomatic femoroacetabular impingement. *Osteoarthritis Cartilage*. 2011;19(7):816-821.
3. Clapis PA, Davis SM, Davis RO. Reliability of inclinometer and goniometric measurements of hip extension flexibility using the modified Thomas test. *Physiother Theory Pract*. 2008;24(2):135-141.
4. Frost KL, Bertocci GE, Wassinger CA, Munin MC, Burdett RG, Fitzgerald SG. Isometric performance following total hip arthroplasty and rehabilitation. *J Rehabil Res Dev*. 2006;43(4):435.
5. Gilenstam KM, Thorsen K, Henriksson-Larsen KB. Physiological correlates of skating performance in women's and men's ice hockey. *J Strength Cond Res*. 2011;25(8):2133-2142.
6. Hase T, Ueo T. Acetabular labral tear: arthroscopic diagnosis and treatment. *Arthroscopy*. 1999;15(2):138-141.
7. Krause DA, Schlagel SJ, Stember BM, Zoetewey JE, Hollman JH. Influence of lever arm and stabilization on measures of hip abduction and adduction torque obtained by hand-held dynamometry. *Arch Phys Med Rehabil*. 2007;88(1):37-42.
8. Laborie LB, Lehmann TG, Engesaeter IO, Engesaeter LB, Rosendahl K. Is a positive femoroacetabular impingement test a common finding in healthy young adults? *Clin Orthop Relat Res*. 2013;471(7):2267-2277.
9. Laborie LB, Lehmann T, Engesaeter I, Eastwood D, Engesaeter L, Rosendahl K. Prevalence of radiographic findings thought to be associated with femoroacetabular impingement in a population-based cohort of 2081 healthy young adults. *Radiology*. 2011;260(2):494-502.
10. Leunig M, inventor and assignee. Device for measuring the internal rotation of a hip joint. United States patent US 8,216,157. July 10, 2012.
11. Leunig M, Juni P, Werlen S, et al. Prevalence of cam and pincer-type deformities on hip MRI in an asymptomatic young Swiss female population: a cross-sectional study. *Osteoarthritis Cartilage*. 2013;21(4):544-550.
12. Nötzli HP, Wyss TF, Stoecklin CH, Schmid MR, Treiber K, Hodler J. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. *J Bone Joint Surg Br*. 2002;84(4):556-560.
13. Nussbaumer S, Leunig M, Glatthorn JF, Stauffacher S, Gerber H, Maffiuletti NA. Validity and test-retest reliability of manual goniometers for measuring passive hip range of motion in femoroacetabular impingement patients. *BMC Musculoskelet Disord*. 2010;11:194.
14. 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.
15. 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.
16. Ranawat AS, Schulz B, Baumbach SF, Meftah M, Ganz R, Leunig M. Radiographic predictors of hip pain in femoroacetabular impingement. *Curr Rev Musculoskelet Med*. 2011;4(1):23-32.

17. Reichenbach S, Juni P, Nuesch E, Frey F, Ganz R, Leunig M. An examination chair to measure internal rotation of the hip in routine settings: a validation study. *Osteoarthritis Cartilage*. 2010;18(3):365-371.
18. Reichenbach S, Juni P, Werlen S, et al. Prevalence of cam-type deformity on hip magnetic resonance imaging in young males: a cross-sectional study. *Arthritis Care Res (Hoboken)*. 2010;62(9):1319-1327.
19. Reynolds D, Lucas J, Klaue K. Retroversion of the acetabulum. *J Bone Joint Surg Br*. 1999;81(2):281-288.
20. 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.
21. Stull JD, Philippon MJ, LaPrade RF. ''At-risk'' positioning and hip biomechanics of the Peewee ice hockey sprint start. *Am J Sports Med*. 2011;39(suppl):29S-35S.
22. Sutter R, Dietrich TJ, Zingg PO, Pfirrmann CWA. Femoral antetorsion: comparing asymptomatic volunteers and patients with femoroacetabular impingement. *Radiology*. 2012;263(2):475-483.
23. Sutter R, Dietrich TJ, Zingg PO, Pfirrmann CWA. How useful is the alpha angle for discriminating between symptomatic patients with cam-type femoroacetabular impingement and asymptomatic volunteers? *Radiology*. 2012;264(2):514-521.
24. Thorborg K, Bandholm T, Schick M, Jensen J, Holmich P. Hip strength assessment using handheld dynamometry is subject to intertester bias when testers are of different sex and strength. *Scand J Med Sci Sports*. 2011;23(4):487-493.
25. Tijssen M, van Cingel R, Willemsen L, de Visser E. Diagnostics of femoroacetabular impingement and labral pathology of the hip: a systematic review of the accuracy and validity of physical tests. *Arthroscopy*. 2012;28(6):860-871.
26. Whiteside D, Deneweth JM, Bedi A, Zernicke RF, Goulet GC. Femoroacetabular impingement in elite ice hockey goaltenders: etiological implications of on-ice hip mechanics. *Am J Sports Med*. 2015;43(7):1689-1697.
27. Yuan BJ, Bartelt RB, Levy BA, Bond JR, Trousdale RT, Sierra RJ. Decreased range of motion is associated with structural hip deformity in asymptomatic adolescent athletes. *Am J Sports Med*. 2013;41(7):1519-1525.