Differences in Athletic Performance Between Sportsmen With Symptomatic Femoroacetabular Impingement and Healthy Controls

Karen Mullins, BSc,* Michael Hanlon, PhD,* and Patrick Carton, MD FRCS (Tr & Orth)*†

Abstract

Objective: Femoroacetabular impingement (FAI) is a commonly recognized condition in athletes characterized by activity-related hip pain and stiffness, which if left untreated can progress to hip osteoarthritis. The aim of the study was to determine the effect of symptomatic FAI on performance in young athletes based on the hypothesis that athletes with FAI would show deficits in performance compared with healthy controls. **Design:** The functional performance of a cohort of preoperative, competitive sportsmen with symptomatic FAI (FAI group, n = 54), was compared with that of a group of age, sex and activity-level matched controls (n = 66). **Outcome Measures:** Participants performed functional tests including a 10-m sprint, a modified agility T-test, a maximal deep squat test and a single-leg drop jump (reactive strength index). Hip range of motion was assessed by measuring maximal hip flexion, abduction, and internal rotation (at 90 degree hip flexion). **Results:** The FAI group was significantly slower during the 10-m sprint (3%, $P = 0.002$) and agility T-test (8%, $P < 0.001$); flexion, abduction, and internal rotation values for the FAI group were reduced compared with controls ($P < 0.001$). No significant differences between groups were identified for squat depth or reactive strength index. The FAI group also reported higher levels of anterior groin pain during the 10-m sprint, modified agility T-test, and while squatting. **Conclusions:** Many sportsmen with confirmed FAI continue sports participation up to and after diagnosis, despite issues with activity-related pain and stiffness. This study highlights the functional limitations in speed, agility, and flexibility that are likely to be present in this group of FAI patients.

Key Words: femoroacetabular impingement, performance, athletes

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INTRODUCTION

Femoroacetabular impingement (FAI) is a chronic condition of the hip caused by repetitive abnormal contact between the femoral head and the acetabulum of the pelvis and has been found to be highly prevalent in young athletes.[1–5] Two types of impingement exist; cam impingement arises due to excessive bone growth on the femoral head/neck region, resulting in progressive loss of femoral head sphericity and diminishing the concave nature of the proximal femoral neck, obstructing the fluid movement of the femoral head into the acetabulum.[6,7] Pincer impingement is defined as focal or global overcoverage of the femoral head by a prominent acetabular rim, resulting in the restriction of hip movement from the abnormal impact of the rim against the femoral neck.[8] Although 2 distinct types of impingement have been defined, it is common for patients to present with a combination of both.[9,10] Repetitive movements, mainly involving extreme flexion, adduction, and internal rotation lead to intra-articular damage including labral tearing and articular cartilage delamination. If left untreated, symptomatic FAI could progress to osteoarthritis (OA) of the hip.[11–13] Typical symptoms of FAI include deep anterior groin pain[14] and progressive hip stiffness which are often exacerbated during sporting activity[3,15] and without appropriate intervention may lead to a deterioration in athletic performance.

Research examining functional deficits in this population is emerging. Lamontagne et al[16] reported that patients with FAI could not squat as low as healthy controls. This was supported in research by Bagwell et al[17] who also found patients displayed increased anterior pelvic tilt and decreased peak hip internal rotation while squatting. These findings are important as squatting is an integral component in the assessment of overall functional mobility but is also widely used in athletic training.[18,19] More recently Brunner et al[20] examined the differences in functional performance among elite adolescent ice hockey players and found no significant differences in speed, acceleration, and agility among players with symptomatic FAI, asymptomatic FAI, and those with no indication of a bony abnormality. The authors suggested that little difference was found because of the age of the athletes and that the condition may not have progressed sufficiently to identify deficits in performance. Sprinting, changing direction, and jumping are important performance-related components of field sports; the aim of this study was to identify areas of athletic performance which are most likely to be negatively affected by FAI and to identify the magnitude of any such

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*From the *Department of Health Sport and Exercise Science, Waterford Institute of Technology, Co Waterford, Ireland; and †The Hip and Groin Clinic, Whitfield Clinic, Co Waterford, Ireland.*

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Corresponding Author: Karen Mullins, BSc, Department of Health Sport and Exercise Science, Waterford Institute of Technology, Cork Rd, Waterford, Ireland (kmullins@wit.ie).

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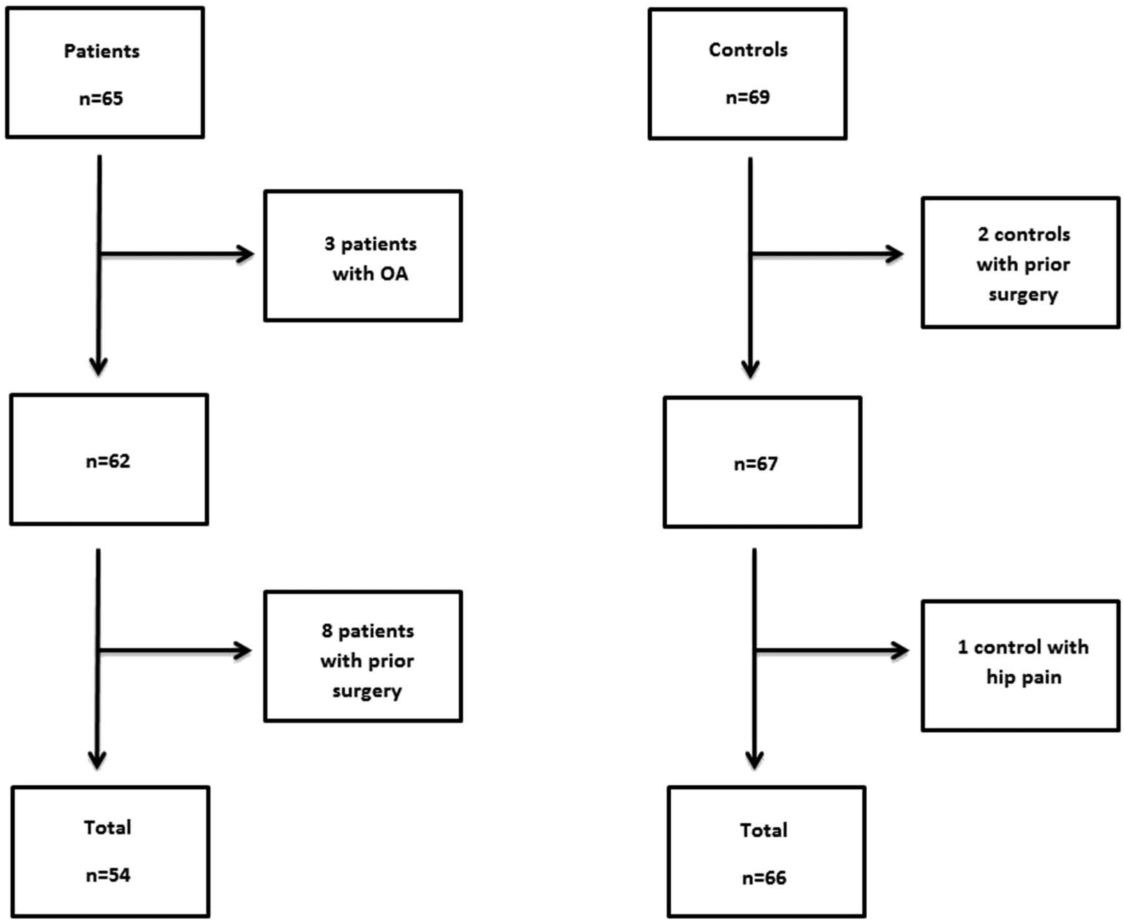

Figure 1. Recruitment of participants.

reductions in performance. This research also aims to educate clinical practitioners and coaching staff as to the potential decreases in athletic performance ability as a consequence of the condition.

METHODS

Participants

Two distinct groups, FAI group and control, were assessed using a cross-sectional study design. Based on a *P* value of 0.05 and an effect size of >0.60, a power test was performed using G*Power 3.0.10 software[21] to determine the sample size required. It was estimated that a sample group of at least 90 participants would be needed (minimum of 45 in each group); to allow appropriate control of the type II error rate and give a statistical study power of >0.80.

An FAI group (n = 65), consisting of 18- to 35-year-old competitive sportsmen with diagnosed symptomatic FAI, was recruited from the Whitfield clinic (Figure 1). Participants were excluded from the FAI group if they had previous hip surgery, evidence of OA on radiographs, a secondary lower limb injury other than FAI, or if they were not involved in competitive sport (Table 2). Subsequently, 3 athletes were excluded because of the presence of OA, whereas a further 8 were excluded because of previous hip surgery, yielding an FAI group of n = 54. Control participants were recruited from various local sporting teams and were excluded from the study if they had previous hip surgery, prolonged hip/groin pain or stiffness or a secondary lower limb injury at the time of testing. Sixty-nine control participants were recruited, with 2 being excluded because of previous surgery and one for persistent groin pain which required treatment; leading to 66 control participants. The FAI group and controls were well matched

TABLE 1. Characteristics of FAI and Control Groups

Participant Type	Age, Yrs	Height, cm	Body Mass, kg	Weekly Training Hours
Patient (n = 54)	25.28 ± 4.7	179.09 ± 5.8	80.91 ± 8.60	5.5 ± 3.4
Control (n = 66)	24.08 ± 6.5	180.20 ± 6.5	83.10 ± 7.50	6.4 ± 2.3

Values are expressed as mean ± SD.

TABLE 2. Types of Sports Played by FAI Group and Controls

Sport Type	Patient, %	Control, %
Gaelic games*	95	97
Rugby	5	3

*The Gaelic games of Hurling and Gaelic Football are both multidirectional, high-intensity field sports native to Ireland.[22]

with no significant differences detected between the age, height, body mass, or training hours of each group (Table 1). Both groups were matched as closely as possible for sporting type and were predominantly made up of Gaelic games and rugby athletes. The Gaelic games of Hurling and Gaelic football are both multidirectional, high-intensity field sports played over 70 minutes for elite players and 60 minutes for subelite players.[22]

The testing protocol consisted of a timed 10-m sprint from a standing start, a timed modified agility T-test[23] (Figure 2), a single leg drop jump for the calculation of reactive strength index, a deep squat, and a measurement of passive hip mobility all of which were preceded by a standardized 10-minute dynamic warm up. All participants were asked to report any groin pain or stiffness during the tests.

Diagnosis

The FAI group presented with a classical history and clinical examination in keeping with symptomatic FAI (activity-related groin pain and hip stiffness, reduction in adduction/internal rotation of the flexed hip with a positive impingement sign, in the absence of other pathology). A standardized AP Pelvis, Dunn view, and false-profile x-rays of all participants in the FAI group were taken at the clinic and confirmed the clinical diagnosis of FAI. Athletes were diagnosed with cam impingement if they presented with an alpha angle >55 degree on Dunn view or >65 degree on AP view x-rays. Pincer lesions were identified if athletes had a lateral center edge angle >35 degree, a clear "cross-over sign" on AP pelvic view, or a clear anterolateral rim deformity was evident on the false profile view. For diagnosis of combined impingement, a cam lesion on either AP or Dunn view, in conjunction with a pincer lesion on either AP or false profile view was necessary.[24–26] The presence and extent of chondrolabral pathology in supporting the diagnosis was assessed using magnetic resonance angiogram magnetic scanning.

Functional Assessments

Ten-Meter Sprint and Modified Agility T-Test

A rubber nonslip sprinting track was used for both the 10-m sprint and T-test to ensure that all participants completed the tests on the same surface. Dual-beam timing gates (Witty Wireless timing gates; Microgate, Bolzano, Italy) were used to record time (s) for both tests. For the 10-m sprint, all participants were required to start with one foot on the start pad and one foot behind, without any cue, participants sprinted forward, passing through the timing gates located 10 m from the start pad (see **Video, Supplemental Digital Content 1**, http://links.lww.com/JSM/A140). Three trials of the sprint were performed with 45-second seated recovery between trials.

The modified agility T-test was performed in the same manner although no start pad was used. The timing gates were placed at the beginning of the course and participants stood immediately behind. Without any cue, participants passed through the gates sprinting forward for 5 m, they side-shuffled 2.5 m to touch a cone located at the edge of the course and then side-shuffled to touch the cone on the opposite side; participants side-shuffled back to the center and concluded with a backward sprint passing through the gates for a second

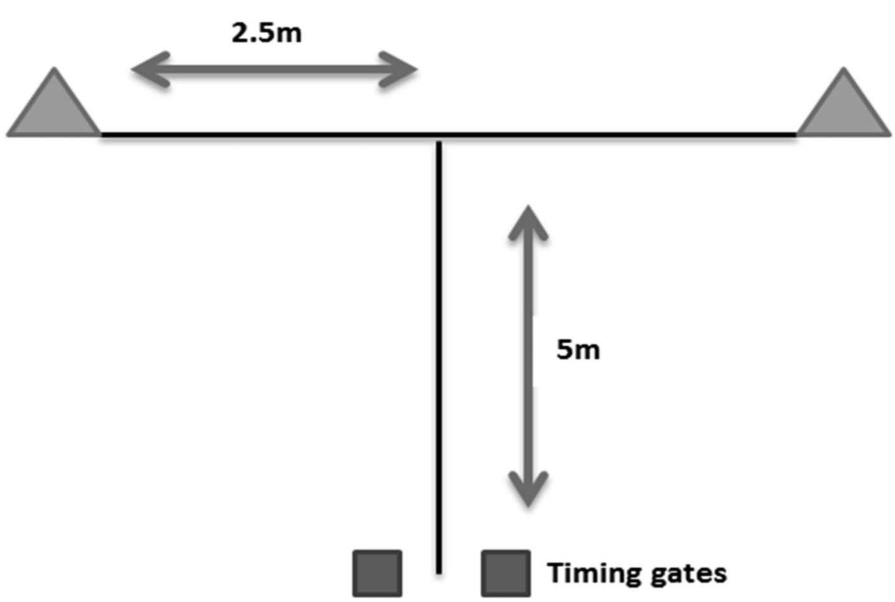

Figure 2. Modified agility T-test.

time to end the test (as seen in **Video, Supplemental Digital Content 2,** http://links.lww.com/JSM/A141). Three trials were performed with 45-seconds seated recovery in between. For both tests, an average of the fastest 2 times was taken as the overall result.

Squat Test

Based on Lamontagne's recommendations, a customized height-adjustable measure was made for the purpose of this test; it was set at 1/3 of the individual tibial height of each athlete and was placed to the rear of the athlete to act as a target for the squat.[16] A visible scale, 1 m in length marked on a stadiometer was also paced to the rear of the participant in the same plane of motion as the squat to facilitate analysis of the squat depth (Figure 3). Five trials of the squat were performed and a video camera (Nikon Coolpix S6500, Tokyo, Japan) recording at 30 frames per second was used to record the entire squat; the camera was located perpendicular to the plane of motion at a minimum distance of 4 m. The peak depth of the squat was determined using Dartfish 7 (ConnectPlus) software.

Single-Leg Drop Jump

A single-leg drop jump (see **Video, Supplemental Digital Content 3,** http://links.lww.com/JSM/A142) was used to calculate the reactive strength index (RSI) of each leg for both the FAI and control groups.[27] Both contact time (s) and flight time (s), used to calculate the RSI, were recorded using the Optojump Next system (Microgate) which has been found to be accurate and reliable in the assessment of vertical jump height (Figure 4).[28] Five practice trials were allowed for each leg to minimize any learning effect that may be associated with a test that participants may not be familiar with. Three actual trials were recorded for each leg and the average of the 2 highest RSI values was recorded, 10 s of recovery time was allowed between trials.

Hip Range of Motion

All hip ROM testing (flexion, abduction, and internal rotation) was performed by one operator (K.M.) with the participant in the supine position on the floor using a goniometer. Care was taken to ensure that the hip was placed in a neutral position and that the contralateral limb was flat against the floor.[29] Two readings of each flexibility measure were taken on each side of the body, with a third reading made in cases of disagreement ($>$4 degree) between the first 2 measures. The average of the 2 closest unilateral readings was taken as the overall result for that side. Intra-rater reliability measurements were taken with a separate sample of athletes who regularly engage in competitive sport (n = 12). Measurements from both limbs were recorded using the methods provided above, on 2 separate occasions, 7 days apart. Intraclass correlation coefficients were used to determine reliability, all of which were $>$0.75.[30]

Figure 3. Deep squat test. Participants were asked to squat as low as possible at a self-selected pace, keeping both heels on the ground. Squat depth was measured as the change in distance from the greater trochanter to the floor at standing to the distance of the greater trochanter to the floor at the base of the squat. Squat depth as a percentage of total height was also determined.

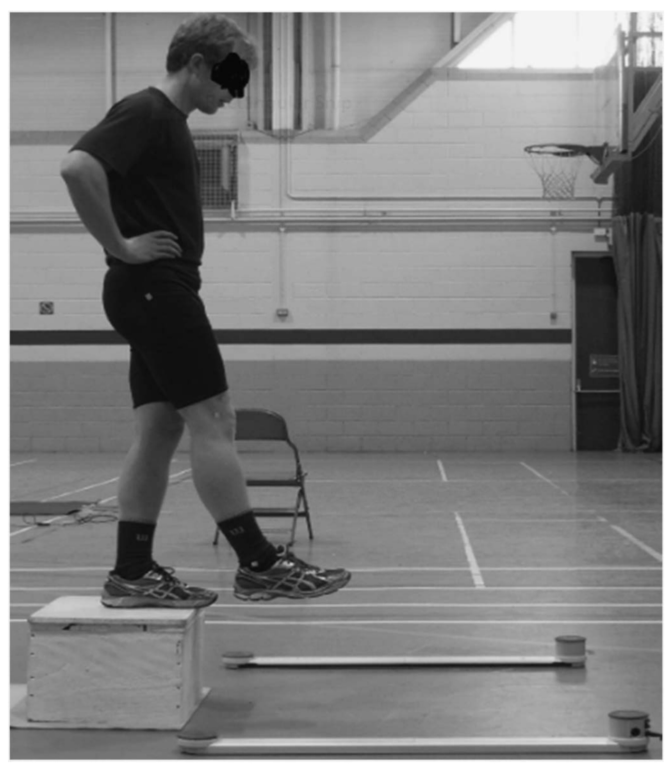

Figure 4. Single-leg drop jump. An audible cue was used to indicate the beginning of the test after which participants stepped off a 30-cm wooden box, and upon landing jumped as high as possible. Knee flexion was discouraged and participants were instructed to keep their hand on their hips throughout the jump. RSI was calculated as flight time/contact time.

TABLE 3. Center Edge and Alpha Angles for FAI Groups Affected Hips

	Hip Angles (n = 78)	Cutoff Hip Angles for Clinical Diagnosis
Center edge angle Dunn view, degree	36 ± 7	>35
Alpha angle Dunn view, degree	61 ± 13	>55
Alpha angle AP view, degree	63 ± 20	>65

Values are expressed as degrees, mean ± SD for FAI group with relative cutoff values used in clinical diagnosis.[24–26]

Statistical Analysis

SPSS 22 software was used for all statistical analysis. Initially data were tested for normality using the Shapiro–Wilk test; differences between the FAI group and controls for each variable were then assessed using an independent samples T-test or nonparametric equivalent, with a P value of <0.05 considered significant.

Participants within the FAI group with unilateral FAI were analyzed both as part of the main FAI group and as an independent subgroup where symptomatic versus nonsymptomatic limbs were assessed, using a paired samples T-test for reactive strength index and each hip ROM measurement. In addition, the unilateral FAI patient group scores were compared with matched unilateral control group scores (matched for age, sport, playing level, and leg dominance). An independent samples T-test was used for this comparison.

RESULTS

Fifty-four sportsmen were included in the FAI group, of which 24 were diagnosed with symptomatic bilateral impingement yielding 78 hips in total; 57 (73%) of these hips were diagnosed with combined impingement, 18 (23%) were identified as having an isolated pincer impingement, and 3 (4%) were diagnosed with pure cam impingement on x-ray (Table 3).

The FAI group were 3% slower than controls over 10 m ($P = 0.002$) (Table 4) and 8% slower on the modified agility T-test ($P < 0.001$). Fifty-four percent of the FAI group reported anterior groin pain while performing the 10-m sprint test, with a further 8% reporting stiffness. For the modified agility T-test, 62% of the group reported groin pain during the test, whereas 8% reported stiffness; no control participant reported either pain or stiffness for either test ($P < 0.001$).

The FAI group had 4%, 25%, and 38% lower values for flexion, abduction, and internal rotation, respectively, compared with the control group ($P = 0.001$). No significant differences were detected between the FAI cohort and controls with regard to absolute maximal squat depth (or when calculated as a percentage of total height) or average RSI. Dominant legs of both the FAI group and controls were also compared with respect to RSI and again no significant differences were detected, either within or between groups. Although no difference was detected between the maximal squat depth between the FAI group and controls, 56% of FAI athletes reported anterior groin pain while squatting, with a further 18% reporting stiffness; no control reported any such discomfort while performing the squat ($P < 0.001$).

Unilateral Patients

A sub category of the FAI group with unilateral impingement (n = 30, 21 right hip and 9 left hip) were assessed both independently, to determine the differences between symptomatic versus nonsymptomatic limb and to corresponding matched controls. Significantly, lower levels of flexion, abduction, and internal rotation were identified in the symptomatic side compared with the nonsymptomatic side (Table 5). There was a difference detected in RSI between symptomatic and nonsymptomatic limbs (1.13 ± 0.24 vs 1.17 ± 0.18) which showed a trend toward significance ($P = 0.080$). When assessed compared with controls, unilateral patients also showed significantly lower levels of flexion (112 degree ± 9 vs 117 degree ± 5) $P = 0.020$, abduction (34 degree ± 8 vs 45 degree ± 7) and internal rotation (32 degree ± 11 vs 51 degree ± 8) $P < 0.001$, with no significant difference in RSI ($P = 0.458$).

DISCUSSION

Athletes with symptomatic FAI typically experience increased anterior groin pain and/or stiffness during or after physical activity; FAI may also pose a significant threat to athletic performance.[5,16] The primary aim of this research was to compare functional performance measures in athletes with confirmed FAI, with an age, sex, and activity-matched control group to determine the extent of functional discrepancies between groups. This study also presents a new objective outcome test battery which may be beneficial for determining treatment outcomes among athletes with symptomatic FAI.

All participants were competing in field sports, which place a great importance on agility and sprinting over short distances[31] (eg, covering 10 m faster than an opponent is of great advantage when attempting to secure possession). Assessment of agility and speed demonstrated significant

TABLE 4. Differences Between Patients and Controls Across All Functional Measures

Measure	Patient Scoring	Control Scoring	P
10-m sprint, s	1.70 ± 0.11*	1.65 ± 0.07*	0.003
Modified agility T-test, s	7.86 ± 0.70*	7.27 ± 0.43*	<0.001
Squat depth, cm	48 ± 13	50 ± 13	0.426
RSI	1.15 ± 0.20	1.15 ± 0.22	0.963
Average maximal hip flexion, degree	112 ± 17*	117 ± 5*	0.004
Average maximal hip abduction, degree	33 ± 8*	44 ± 8*	<0.001
Average maximal hip internal rotation, degree	33 ± 10*	53 ± 10*	<0.001

Values are expressed as mean ± SD. RSI and ROM data are averages of each participant's left and right sides.
**Significant difference $P < 0.05$.*

TABLE 5. Differences Between Symptomatic and Nonsymptomatic Among the FAI Group

Measure	Symptomatic Limb	Nonsymptomatic Limb	*P*
RSI	1.13 ± 0.24	1.17 ± 0.18	0.080
Maximal hip flexion, degree	112 ± 9*	116 ± 7*	0.026
Maximal hip abduction, degree	34 ± 8*	37 ± 7*	0.032
Maximal hip internal rotation, degree	32 ± 11*	41 ± 9*	<0.001

Values are expressed as mean ± SD.
**Significant difference $P < 0.05$.*

deficits in athletic performance along with a high occurrence of groin pain/stiffness in athletes with FAI, compared with the age and activity-matched controls. This is an important finding considering that it is common for athletes to continue with sports participation up to and often after diagnosis. If appropriate treatment is not administered, athletes are unlikely to improve because of persistent pain, irrespective of physical fitness. The findings indicate a distinct performance disadvantage for athletes with FAI over their asymptomatic counterparts, which is of relevance to both the athletes and related coaching staff. This is contrary to the findings described by Brunner et al[20] who reported no significant differences in sprint or agility performance between young ice hockey players with symptomatic FAI and those without. Differences in participant selection may account for these differences with Brunner's study using younger athletes (mean age 16.3 years), from ice hockey only, and whose FAI group were symptomatic, but not necessarily scheduled for corrective surgery. The FAI group size was also considerably smaller in the Brunner study (n = 16 vs n = 54).

Although functional differences between patients with FAI and controls have not been examined at length, Lamontagne et al[16] found that cam patients could not squat as low as healthy controls. In our study, no significant differences were found between the maximal squatting depths of both groups; however, the presence of anterior groin pain and/or stiffness during the squat was highly significant when differentiating the FAI group from the controls regardless of squat depth. This is an important consideration for athletes because of high levels of squatting used for muscle strengthening during preseason training. Tailored strength and conditioning programs should be considered by coaching staff to avoid exacerbating symptoms should an athlete wish to continue without intervention.

Reactive strength index is a valid measurement of the ability of an athlete to produce maximal eccentric and concentric force in the minimal amount of time, which is a prerequisite of many sports.[27,32] Athletes with FAI in this study showed no decrement in RSI compared with the matched controls, indicating minimal negative consequence of the condition on neuromuscular function during a simple vertical jump stretch-shortening activity. The similarity between controls and the athletes with FAI on this test highlights the effects of FAI on the more game-specific ambulatory tasks such as the 10-m sprint and agility test. Further research is required to understand the relative influences of anatomical defects/pain in possibly causing these deficits in athletic ambulatory performance.

In line with previous findings, hip ROM was diminished in the FAI group with a significantly lower range of flexion, abduction, and internal rotation[5,33,34] These restrictions in ROM may account for some of the deficits observed in the more functional tests. Speed decrements could result if, in conjunction with pain, an athlete does not have appropriate ROM within the joint, hindering a suitable body position to effectively produce force when accelerating the athlete forward.[35,36] Poorer abduction may restrict lateral motion involved in side stepping, whereas limitations in internal rotation may prevent an athlete from twisting and turning effectively, both of which are necessary for optimal agility; such restriction of motion may be a factor in the poorer agility scores for athletes with FAI observed during the T-test.

Some limitations to the study design have been identified: (1) control participants were not clinically examined for signs of impingement but were recruited on the basis that they had no symptoms of hip pain or stiffness at rest or with activity, and had no history of previous hip surgery, at the time of testing. Given the prevalence of FAI in young athletes, it is possible that some of the controls may have had abnormal hip morphology but were asymptomatic which could have led to an underestimation of functional differences between the 2 groups. (2) The absence of a frontal camera during the squat depth test may have allowed FAI group/controls to compensate during the squat and achieve a greater squat depth, although all participants were given identical instructions on how to carry out the squat and were closely supervised to optimize technique.

CONCLUSIONS

Athletic performance measures of speed, agility, and hip ROM are significantly reduced in the presence of underlying FAI. Such deficits in athletic ability in conjunction with activity-related groin pain and hip stiffness may greatly impact on individual and ultimately team performance. Poor athletic performance poses a major concern for athletes, clubs, and coaches as it is not uncommon for athletes with symptomatic FAI to continue playing for many years before diagnosis and treatment.

Not only does this research serve to identify areas of functional performance which are negatively affected by FAI but it also provides a quantitative functional outcome measuring tool which may be more suitable for this population than traditional qualitative self-reported measures. Future research should focus on changes in these functional performance measures after surgical intervention for FAI. This will give athletes a clearer indication of what functional outcomes may be expected from surgical intervention and allow them to make a more informed decision as to their treatment options.

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