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The FADIR test accuracy for screening cam and pincer morphology in youth ice hockey players

Nicola C. Casartelli[a,b,*], Romana Brunner[a], Nicola A. Maffiuletti[a], Mario Bizzini[a], Michael Leunig[c], Christian W. Pfirrmann[d,e], Reto Sutter[d,e]

[a] Human Performance Lab, Schulthess Clinic, Switzerland
[b] Laboratory of Exercise and Health, Department of Health Sciences and Technology, ETH Zurich, Switzerland
[c] Department of Orthopaedic Surgery, Schulthess Clinic, Switzerland
[d] Department of Radiology, Orthopaedic University Hospital Balgrist, Switzerland
[e] Faculty of Medicine, University of Zurich, Switzerland

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ABSTRACT

Objectives: Aim of this study was to evaluate the flexion-adduction-internal rotation (FADIR) test accuracy for screening cam and pincer morphology in youth male ice hockey players without diagnosed hip disorders.
Design: Cross-sectional study.
Methods: Seventy-four ice hockey players with a mean age of 16 years (range: 13–20 years) were assessed unilaterally. The presence of cam and pincer morphology was evaluated using the FADIR test and magnetic resonance imaging (MRI) (reference standard). Positive FADIR test consisted of groin pain during the maneuver, while positive MRI findings consisted of (1) pure cam, pure pincer or combined morphology and acetabular labral alterations, or (2) pure cam or combined morphology and acetabular labral alterations. Sensitivity, specificity, positive and negative likelihood ratios, and positive and negative predictive values were calculated.
Results: For pure cam, pure pincer or combined morphology as positive MRI findings, the FADIR test demonstrated a sensitivity of 41%, specificity of 47%, positive likelihood ratio of 0.78, negative likelihood ratio of 1.24, positive predictive value of 19% and negative predictive value of 73%. For pure cam or combined morphology as positive MRI findings, the FADIR test showed a sensitivity of 60%, specificity of 52%, positive likelihood ratio of 1.24, negative likelihood ratio of 0.78, positive predictive value of 16% and negative predictive value of 89%.
Conclusions: The FADIR test is inadequate for screening cam and pincer morphology in youth ice hockey players without diagnosed hip disorders because of the large number of false positive test outcomes.

1. Introduction

Femoroacetabular impingement (FAI) is a hip pathomechanism mainly induced by bony deformities at the proximal femur (cam morphology) and/or acetabulum (pincer morphology) at end range of hip flexion and internal rotation.[1] This pathomechanism may lead to acetabular labral tears, hip pain and sports disability, therefore to development of FAI syndrome. In addition, the presence of cam morphology has been associated with an increased risk of developing hip osteoarthritis.[2] Ice hockey players are athletes at high risk for developing FAI syndrome and potentially hip osteoarthritis.[3,4] Indeed, they present with a high prevalence of cam morphology[5–7] and perform hip motions during skating that may repetitively induce FAI and cause intra-articular hip damage.[4,8]

Whilst the prevalence of cam morphology is around 23% in asymptomatic subjects,[9] it was reported to range between 45% and 75% in ice hockey players.[5–7] The high prevalence of cam morphology in ice hockey players might result from bone adaptation in response to sport-specific vigorous hip loading during skeletal growth, as shown in youth soccer players.[10] Indeed, high and specific mechanical loading on the femoral growth plate may influence bone modelling and lead to abnormal bone formation.[11] In addition, repeated hip movements performed by ice hockey players while skating, such as hip flexion and internal rotation at the end of the recovery phase of the hockey stride, may promote the occurrence of the FAI pathomechanism.[4]

* Corresponding author.
E-mail address: nicola.casartelli@kws.ch (N.C. Casartelli).

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Since the presence of cam and pincer morphology may result in the development of FAI syndrome and early hip osteoarthritis,[1,2] regular hip morphology screening in athletic populations such as youth ice hockey players is essential for identifying at-risk athletes, and providing them with timely preventive measures. These measures could consist of adjusting athletic activities during a period of skeletal growth[10] or implementing a physiotherapy-led rehabilitation program.[12] Hip physical examination tests may be more practical, convenient and cheaper than standard imaging evaluations for hip morphology screening purposes. The most commonly used hip examination test for FAI is the flexion-adduction-internal rotation (FADIR) test.[13] This test replicates the mechanical abutment of the femoral head against the anterosuperior portion of the acetabulum,[13] where also acetabular labral tears most often occur.[14] The FADIR test was recently shown to have a high sensitivity (94%) and a low specificity (9%) for the diagnosis of FAI syndrome in patients presenting with groin pain or symptoms highly suggestive of hip pathology.[15] The diagnostic accuracy of the FADIR test has only been investigated in patients with high suspicion of FAI syndrome and high likelihood of a positive test, thus providing sample-biased results.[15] The aim of this study was to evaluate the FADIR test accuracy for screening cam and pincer morphology in youth male ice hockey players without diagnosed hip disorders.

2. Methods

A total of 74 male youth ice hockey players belonging to the same professional club were evaluated. Data were collected in a previously published study, which investigated the prevalence of cam and pincer morphology in youth ice hockey players, and their association to hip muscle strength, range of motion and on-ice physical performance.[5] Mean (±SD) age and body mass index of the players were 16 ± 2 years (range: 13–20 years) and 22 ± 3 kg/m^2 (range: 17–27 kg/m^2), respectively. Twenty-four players were defenders, 19 forwards, 13 wings, 10 centers and 8 goalies with a mean (±SD) playing experience of 11 ± 2 years (range: 4–16 years). Players were excluded if they already had a diagnosis of FAI syndrome and/or if they had previous hip surgery. The study was conducted according to the Declaration of Helsinki and the protocol was approved by the local ethics committee. All players and parents of minor players signed an informed consent before participating in the study. The accuracy of the FADIR test for screening cam and pincer morphology was evaluated by comparing FADIR test outcomes with magnetic resonance imaging (MRI) findings (reference standard). Only unilateral MRI assessments were performed to reduce costs. Since the prevalence of cam morphology seems to increase with decreasing hip internal rotation range of motion (ROM),[16] only the hip that demonstrated less internal rotation ROM on a hip examination chair[17] was further evaluated. If the side-to-side difference in hip internal rotation ROM was <1°, the evaluated hip was randomized using a computer random number generator. In addition, self-reported hip pain and function was assessed using the Hip Outcome Score (HOS).[18,19]

All the FADIR tests were performed by a single investigator with 5 years of experience as a sports physical therapist in the clinical evaluation and treatment of hip patients and athletes. The investigator was blinded to MRI findings. With the athlete lying supine on a treatment table, the investigator passively moved the hip in a combination of flexion, adduction and internal rotation until end of ROM was achieved.[20] A positive FADIR test was determined by groin pain experienced by the athlete during the test maneuver.

The presence of cam and pincer deformities, as well as the presence of acetabular labrum alterations, was assessed with non-contrast MRI. A 1.5 Tesla high-field system (Magnetom Avanto, Siemens Medical Solutions, Erlangen, Germany) was used 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 sequence, and a transverse oblique water-excitation true fast imaging with steady-state precession 3D sequence. After MRI examination, additional radial reformations of the transverse oblique true fast imaging with steady-state precession 3D sequence were reconstructed to assess the osseous contour of the femoral head-neck junction. MRI examinations were analysed by two experienced radiologists, who were blinded to FADIR test outcomes. The presence of cam morphology was determined by means of the alpha angle. The alpha angle was measured on radial oblique MRI at the anterosuperior segment as the angle between the axis of the femoral neck and the line from the center of the femoral head to the point where the distance from the center of the femoral head to the peripheral contour of the femoral head exceed the radius of the femoral head (Fig. 1A).[21] An alpha angle >60° was considered positive for the presence of cam morphology.[21,22] The presence of pincer morphology was determined by means of acetabular version and depth. Acetabular version was measured on the oblique transverse MRI at the level of 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 borders of the acetabulum (Fig. 1B).[23] A positive angle indicated acetabular anteversion and a negative angle indicated acetabular retroversion.[24] 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 (Fig. 1C).[25] Acetabular retroversion and/or acetabular depth ≤3 mm were considered positive for pincer morphology.[25] The presence of acetabular labral alterations was evaluated on radial MRI as a linear band of high signal intensity detected in the labrum (Fig. 1D).[25] Since the presence of cam, but not pincer, morphology has been recently associated with an increased risk of developing hip osteoarthritis,[2] the accuracy of the FADIR test for screening cam and pincer morphology was evaluated by using two different combinations of morphology types as positive MRI findings: (1) the presence of pure cam, pure pincer or combined morphology together with the presence of acetabular labral alterations, and (2) the presence of pure cam or combined morphology (without pure pincer) together with the presence of acetabular labral alterations.

The HOS is a self-reported questionnaire specifically developed for assessing hip pain and function of young and active subjects.[18,19] Two independent scores were obtained: one for activities of daily living (HOS ADL: 19 items, 17 scored) and one for sport activities (HOS sport: 9 items, 9 scored). The scores range from 0 to 100, where 100 indicates the best possible score. The HOS has previously been shown to be reliable (i.e., intraclass correlation coefficients of 0.94 for HOS ADL and 0.89 for HOS sport) and valid when correlated with other self-reported measures.[19]

The number of true positive (positive FADIR and MRI), false positive (positive FADIR, negative MRI), false negative (negative FADIR, positive MRI) and true negative (negative FADIR and MRI) FADIR test outcomes was used for the calculation of sensitivity, specificity, positive and negative likelihood ratios, positive and negative predictive values, and disease prevalence.[26,27] Results are presented as mean and 95% confidence intervals (CI) or mean ± SD. One-way ANOVAs were used to compare age, alpha angle, HOS ADL and HOS sport between athletes with true positive, false positive, false negative and true negative FADIR test outcomes. Tukey's HSD tests were used for *post-hoc* pairwise comparisons of the means. Statistical analyses were performed using Microsoft Excel 14.6.0 (Microsoft

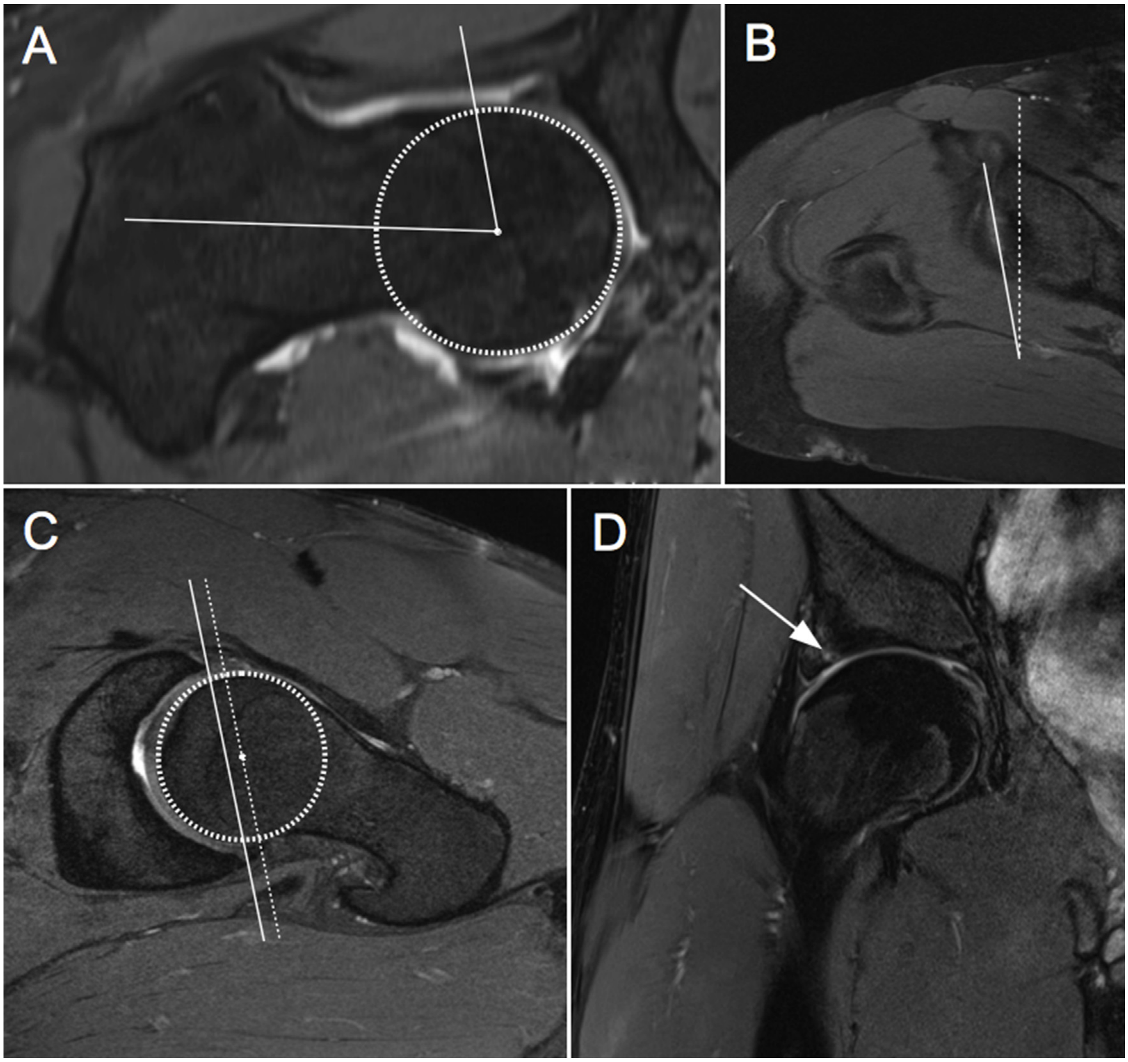

Fig. 1. The presence of cam morphology was determined by measuring the alpha angle (A, angle between the two solid lines), while the presence of pincer morphology was assessed by measuring the acetabular version (B, angle between the solid and dashed lines) and acetabular depth (C, distance between the solid and dashed lines). Acetabular labral alterations were determined by detecting the presence of a linear band of high signal intensity in the labrum (D, white arrow). Dashed circles indicate the contour of the femoral head, dashed lines indicate reference lines, and solid lines are drawn based on the bony morphology of the assessed subject.

Corp., Redmond, WA, USA) and Statistica 7.0 (StatSoft Inc., Tulsa, OK, USA). Significance level was set at $p < 0.05$.

3. Results

The FADIR test accuracy outcomes are presented in Table 1. The characteristics of athletes are reported in Table 2 according to their FADIR test outcomes.

Table 1
FADIR test accuracy outcomes.

Test accuracy outcomes	Pure cam, pure pincer or combined morphology	Pure cam or combined morphology
	Mean (95% CI)	
Sensitivity (%)	41 (18–67)	60 (26–88)
Specificity (%)	47 (34–61)	52 (39–64)
Positive likelihood ratio	0.78 (0.42–1.45)	1.24 (0.70–2.18)
Negative likelihood ratio	1.24 (0.77–2.01)	0.78 (0.35–1.72)
Positive predictive value (%)	19 (8–35)	16 (10–25)
Negative predictive value (%)	73 (56–86)	89 (79–95)
Disease prevalence (%)	23 (14–34)	13 (7–23)

CI, confidence interval.

Considering pure cam, pure pincer or combined morphology as positive MRI findings, no group effect was observed for age. For the alpha angle, a group effect was found ($p = 0.046$), with true positive athletes demonstrating 11° (95% CI: 1–20°) larger angles than false positive athletes ($p = 0.028$). For HOS ADL, a group effect was observed ($p = 0.049$), with false positive players reporting 6 points (95% CI: 1–12 points) less than true negative players ($p = 0.043$). For HOS sport, a group effect was found ($p = 0.005$), with true positive athletes reporting 14 points (95% CI: 1–28 points) less than true negative athletes ($p = 0.047$), and false positive players reporting 10 points (95% CI: 1–18 points) less than true negative players ($p = 0.015$).

Considering pure cam or combined morphology as positive MRI findings, no group effect was observed for age. For the alpha angle, a group effect was found ($p = 0.001$), with true positive athletes showing 12° (95% CI: 2–22°) larger angles than false positive and true negative athletes ($p = 0.012$ and $p = 0.010$, respectively). In addition, false negative athletes demonstrated 13° (95% CI: 1–25°) larger angles than false positive and true negative athletes ($p = 0.028$ and $p = 0.025$, respectively). For HOS ADL, a group effect was observed ($p = 0.048$), with false positive players reporting 6 points (95% CI: 1–11 points) less than true negative players

Table 2
Athletes' characteristics.

Athletes' characteristics	FADIR test outcomes vs. MRI findings			
	True positive	False negative	False positive	True negative
Pure cam, pure pincer or combined morphology				
N	7	10	30	27
Type of morphology	• 5 cam • 1 combined (retroversion) • 1 pincer (retroversion)	• 2 cam • 2 combined (retroversion) • 5 pincer (retroversion) • 1 pincer (coxa profunda)		
Age (years)	17 ± 2	16 ± 2	16 ± 2	16 ± 2
Alpha angle (°)	67 ± 10	59 ± 10	56 ± 6	57 ± 11
HOS ADL (0–100)	94 ± 7	99 ± 2	94 ± 12	100 ± 0
HOS sport (0–100)	86 ± 24	98 ± 3	90 ± 15	100 ± 1
Pure cam or combined morphology				
N	6	4	31	33
Type of morphology	• 5 cam • 1 combined (retroversion)	• 2 cam • 2 combined (retroversion)		
Age (years)	17 ± 2	17 ± 2	16 ± 2	16 ± 2
Alpha angle (°)	68 ± 10	69 ± 5	56 ± 5	56 ± 10
HOS ADL (0–100)	94 ± 8	98 ± 3	94 ± 12	100 ± 1
HOS sport (0–100)	83 ± 25	98 ± 3	91 ± 14	100 ± 2

HOS, Hip Outcome Score; ADL, activities of daily living.

($p = 0.041$). For HOS sport, a group effect was found ($p = 0.003$), with true positive athletes reporting 17 points (95% CI: 2–31 points) less than true negative athletes ($p = 0.020$), and false positive players reporting 9 points (95% CI: 1–17 points) less than true negative players ($p = 0.014$).

4. Discussion

The FADIR test demonstrated low sensitivity and specificity, insufficient positive and negative likelihood ratios, as well as low positive predictive values and low to moderate negative predictive values. This suggests that the FADIR test is not a useful examination test for detecting cam and pincer morphology in youth ice hockey players without diagnosed hip disorders, regardless of whether pure pincer morphology is considered as a positive finding.

The sensitivity and specificity demonstrated by the FADIR test in the present study indicate that it has neither the ability to rule in nor to rule out cam and/or pincer morphologies in young ice hockey players without diagnosed hip disorders. These results are in contrast with those previously observed in patients with high suspicion of FAI syndrome.[15] Indeed, earlier studies showed that the FADIR test has on average a sensitivity of 94% and a specificity of 9% for detecting FAI morphology/labral tears in patients with symptomatic hip disease, as shown in a meta-analysis by Reiman et al.[15] Accordingly, FAI syndrome can be ruled out with high probability in patients with FAI morphology/labral tears suspicion if the FADIR test outcome is negative but cannot be confirmed if the outcome is positive. The differences in FADIR test sensitivity and specificity observed between our athletes and patients with suspected FAI syndrome may be explained by the larger prevalence of cam and/or pincer morphology presented by patients compared with our athletes (84% vs. 13–23%, respectively). Whereas in earlier studies the subjects were patients scheduled for hip preservation surgery or patients with groin pain and/or symptoms highly suggestive of hip pathology,[15] our athletes had no particular symptoms that required medical consultation at the time of hip examination.

The FADIR test demonstrated insignificant value in altering the post-test with respect to the pre-test probability to detect cam and pincer morphology in our athletes, that is, 19% vs. 23%, respectively, if pure pincer morphology was included as positive finding, and 16% vs. 13%, respectively, if pure pincer morphology was excluded as positive finding. Indeed, positive likelihood ratios <2 and negative likelihood ratios >0.5 were found in the current investigation.[28] Similar results have been also observed in patients with symptomatic hip disease, where post-test vs. pre-test probability for detecting cam and pincer morphology was minimally altered (83% vs. 84%, respectively).[15] As already mentioned above it has to be considered that the prevalence of cam and pincer morphology, which corresponds to pre-test disease probability, significantly differed between our athletes and patients with suspected FAI syndrome tested in previous studies. The prevalence we observed was instead more similar to that reported in asymptomatic subjects (23%),[9] but relatively lower compared with that previously observed in ice hockey players (45–75%).[5–7] This difference among ice hockey players may be explained by the threshold for alpha angle >60° used in the present study for defining cam morphology, instead of the >55° threshold adopted in earlier studies.[6,7] We used a 60° alpha angle threshold to reduce the number of false positive MRI findings in this population of athletes without diagnosed hip disorders while maintaining similar test sensitivity.[21] In addition, an alpha angle of 60° was recently suggested as an optimal threshold for distinguishing between normal hips and hips with a cam morphology.[22]

The FADIR test showed low positive and negative predictive values in our study when pure pincer morphology was included as positive finding (19% and 73%, respectively), and low positive and moderate negative predictive values when pure pincer morphology was excluded as positive finding (16% and 89%, respectively). Almost opposite FADIR test predictive values were observed in earlier studies considering patients with suspected FAI.[15] Indeed, these studies demonstrated average positive predictive values of 83% and negative predictive values ranging between 13% and 25%. The low positive predictive value demonstrated by the FADIR test in our study was primarily caused by the large number of athletes without cam and/or pincer morphologies, who had a positive FADIR test (false positive). Based on our hip pain and function questionnaire outcomes, these athletes reported on average higher hip pain and lower hip function during ADL and sport compared with athletes without cam and/or pincer morphologies and with a negative FADIR test (true negative). In addition, athletes with a positive FADIR test reported on average similar hip pain and function during ADL and sport, regardless of the presence of cam and/or pincer morphologies. These results seem to indicate that a positive FADIR test outcome may be better associated with non-specific hip pain and impaired hip function than with the presence of cam and/or pincer morphologies. It can be speculated that the large number of positive

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FADIR tests in athletes without cam and/or pincer morphologies may be due to hip pain caused by extra-articular problems (e.g., muscle soreness, contractures or injuries), and by the inability of young athletes to differentiate between intra- and extra-articular hip pain.

Slightly higher FADIR test sensitivity and negative predictive value were observed when pure pincer morphology was excluded as positive finding. However, even if pure pincer morphology was excluded as positive finding, the FADIR test demonstrated no additional screening value in ruling out pure cam or combined morphology, since it could only minimally increase the post-test vs. pre-test probability to detect these morphologies (89% and 87%, respectively).

To the best of our knowledge, this is the first study that evaluated the accuracy of the FADIR test for screening cam and pincer morphology in a population of young athletes without diagnosed hip diseases but at high risk of developing FAI syndrome (i.e., ice hockey players). The FADIR test outcomes were compared with the best available reference standard for this sample of subjects (i.e., MRI findings). In addition, athletes underwent MRI evaluations even if the FADIR test was negative. A limitation of this study is that we did not assess the intra- or inter-rater agreement of the FADIR test. To our knowledge, no information is available about its intra-rater agreement. However, absolute inter-rater agreement of the FADIR test was reported to be about 95% in previous studies with asymptomatic subjects.[29,30] Accordingly, we do not expect our results to be negatively influenced by a significant rater-dependent variability in the FADIR test outcome.

5. Conclusion

The FADIR test is inadequate for screening cam and pincer morphology in youth ice hockey players without diagnosed hip disorders because of the large number of false positive test outcomes. Future studies should investigate the accuracy of other hip examination tests (e.g., hip internal rotation ROM) or a combination of several tests (e.g., FADIR test plus hip internal rotation ROM) for screening cam and pincer morphology in athletes.

Practical implications

- The FADIR test is inadequate for detecting cam and pincer morphology in youth male ice hockey players without diagnosed hip disorders.
- A positive FADIR test might be associated with non-specific hip pain and functional impairments rather than with the presence of cam and/or pincer morphologies.
- The FADIR test accuracy for screening cam and pincer morphology does not considerably improve when pure pincer morphology is excluded as positive finding.

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