VIDEO

Two Novel Clinical Tests for the Diagnosis of Hip Labral Tears

Farshad Adib,* MD, Jacob Hartline,† MD, J. Skye Donovan,‡ PT, PhD, Kourosh Kalachi,† BS, Pegah Dehghan,§ MD, and Derek Ochiai,*‖ MD
Investigation performed at Nirschl Orthopaedic Center, Arlington, Virginia, USA

Background: There are few well-studied clinical tests for the diagnosis of hip labral tears. As the differential diagnosis for hip pain is broad, accurate clinical examination is important in guiding advanced imaging and identifying patients who may benefit from surgical management.

Purpose: To determine the diagnostic accuracy of 2 novel clinical tests for the diagnosis of hip labral tears.

Study Design: Cohort study (diagnosis); Level of evidence, 2.

Methods: Clinical examination findings including the Arlington, twist, and flexion-adduction-internal rotation (FADIR)/impingement tests as performed by a fellowship-trained orthopaedic surgeon specializing in hip arthroscopy were obtained from retrospective chart review. The Arlington test ranges the hip from flexion-abduction-external rotation to FADIR while applying subtle internal rotation and external rotation motion. The twist test involves internal rotation and external rotation of the hip while weightbearing. Diagnostic accuracy statistics for each of the tests were calculated using magnetic resonance arthrography as the reference standard.

Results: A total of 283 patients were included in the study with a mean age of 40.7 years (range, 13-77 years) and 66.4% were women. The Arlington test was found to have a sensitivity of 0.94 (95% CI, 0.90-0.96), specificity of 0.33 (95% CI, 0.16-0.56), positive predictive value (PPV) of 0.95 (95% CI, 0.92-0.97), and negative predictive value (NPV) of 0.26 (95% CI, 0.13-0.46). The twist test was found to have a sensitivity of 0.68 (95% CI, 0.62-0.73), specificity of 0.72 (95% CI, 0.49-0.88), PPV of 0.97 (95% CI, 0.94-0.99), and NPV of 0.13 (95% CI, 0.08-0.21). The FADIR/impingement test was found to have a sensitivity of 0.43 (95% CI, 0.37-0.49), specificity of 0.56 (95% CI, 0.34-0.75), PPV of 0.93 (95% CI, 0.87-0.97), and NPV of 0.06 (95% CI, 0.03-0.11). The Arlington test was significantly more sensitive than both the twist and FADIR/impingement tests ($P < .05$), while the twist test was significantly more specific than the Arlington test ($P < .05$).

Conclusion: The Arlington test is more sensitive than the traditional FADIR/impingement test, while the twist test is more specific than the FADIR/impingement test in diagnosing hip labral tears in the hands of an experienced orthopaedic surgeon.

Keywords: hip; femoroacetabular impingement; hip arthroscopy; clinical assessment/grading scale; groin pain

The field of hip preservation has seen immense growth over the past few decades, as evidenced by a 600% increase in hip arthroscopy cases and a 500% increase in published literature in the late 2000s.[4,7] This growth has been primarily driven by the recent attention to femoroacetabular impingement (FAI) and associated labral tears. While advancements in the surgical management of FAI and labral tears have headlined much of this work, it is equally vital to refine our understanding of the presentation of these pathologies and develop accurate and cost-effective diagnostic approaches.

The differential for hip pain is enormous and includes radicular pain, hip flexor tendinitis, pelvic floor dysfunction, greater trochanter pain syndrome, hamstring tendinitis, and hip arthritis. In addition, multiple processes from acute dislocations to chronic, degenerative changes may lead to labral tearing.[18,24] Labral tears may present with acute or insidious pain in multiple locations and will only present with mechanical symptoms about half of the time.[8] However, the presence of labral pathology on

‖Address correspondence to Derek Ochiai, MD, Nirschl Orthopaedic Center, Arlington, VA, USA (email: teamsurgeon@gmail.com).
*Nirschl Orthopaedic Center, Arlington, Virginia, USA.
†University of Maryland, Department of Orthopaedics, Baltimore, Maryland, USA.
‡Marymount University, School of Health Sciences, Arlington, Virginia, USA.
§Johns Hopkins School of Medicine, Department of Physical Medicine and Rehabilitation, Baltimore, Maryland, USA.

Submitted February 8, 2022; accepted November 18, 2022.

One or more of the authors has declared the following potential conflict of interest or source of funding: F.A. has received hospitality payments from Zimmer Biomet Holdings and support for education from Supreme Orthopedics Systems. D.O. has received consulting fees and royalties from Linvatec Corporation, Arthrex Inc, and Conformis Inc and consulting fees from Bioventus. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

The American Journal of Sports Medicine
1–8
DOI: 10.1177/03635465221149748

magnetic resonance imaging (MRI) in asymptomatic patients is well-documented.[8-10,25,27] Given this discrepancy between MRI findings and symptoms, clinical examination of the patient with a suspected labral tear is essential. Magnetic resonance arthrography (MRA) is remarkably sensitive and specific in detecting hip labral tears, but it is a costly and invasive diagnostic study and should be reserved only for those with high clinical suspicion.

A limited amount of research has been devoted to validating clinical examination tests for diagnosing hip labral tears, with the most promising findings seen with the anterior impingement or flexion-adduction-internal rotation (FADIR) test. While generally very good sensitivities are reported for this test, these studies are limited by small sample sizes, and specificity data are poor due to high pretest probabilities.[5,10,15,17,18,29] Few other clinical tests have been proposed for the diagnosis of hip labral tears, with significantly more variable results.[20]

The current study introduces 2 novel diagnostic tests to improve the clinical diagnosis of hip labral tears: the Arlington test and twist test. The Arlington test serves as a dynamic examination to evaluate the entire labrum rather than just the anterosuperior location. The twist test provides a functional weightbearing test akin to the Thessaly test in the meniscal knee examination. Both tests were developed by 2 of the authors of the study (F.A., D.O.). We propose that the addition of these 2 tests to the clinical examination of the patient with hip pain will improve diagnostic accuracy and serve as an important complement and guide to advanced imaging.

METHODS

Study Design

Exemption status was confirmed by our institutional review board. Patients indicated for hip MRA based on suspicion for hip labral tear by the study's lead surgeon (D.O.) between the years 2009 and 2011 were identified prospectively for inclusion into the study. The lead surgeon of this study is fellowship trained in sports medicine and specializes in hip arthroscopy, performing a high annual volume of procedures addressing hip labral pathology. Exclusion criteria included those who did not have hip symptoms as their primary complaint; did not have Arlington, twist, and impingement tests documented on the examination; and/or did not have MRA and plain radiographs of the hip, as well as those with severe osteoarthritis of the hip. The clinical tests were typically performed on all patients with a chief complaint of hip pain during the time of the study.

Clinical Test Descriptions

The Arlington test is performed with the patient supine on the examination table. The affected hip is brought from a neutral or slightly extended position into flexion, abduction, and external rotation and gradually ranged into adduction and internal rotation. Through this gradual range, with 1 hand on the ipsilateral posterior proximal lower leg and the other hand holding the ankle, the examiner provides a "bouncing" motion of subtle internal and external rotation of the hip. Reproduction of symptoms is considered a positive test (Figure 1).

Figure 1. Demonstration of the Arlington test. The patient is taken from a (A) neutral position into (B) flexion, abduction, and external rotation; then taken through a (C) range of motion into a (D) final position of flexion, adduction, and internal rotation. Throughout the range of motion, the hip is ''bounced'' with a small internal rotation and external rotation motion.

The twist test involves instructing the patient to stand with both knees slightly flexed while creating a "windshield wiper" motion with one's knees, effectively internally and externally rotating the hips while keeping the feet planted. Next, this same motion is repeated only on the affected leg, keeping the contralateral foot off the ground with the support of the examiner. This is also repeated on the nonaffected side. Reproduction of symptoms in the affected hip is considered a positive test (Figure 2).

The FADIR/impingement test as performed by the lead surgeon in this study consists of taking the supine patient's affected hip from neutral to flexion, adduction, and internal rotation (Figure 3). Reproduction of symptoms is considered a positive test. Video demonstration of the Arlington, twist, and FADIR/impingement tests can be found in the online version of this article.

Data Collection

The following patient characteristics and comorbidities were collected: age, sex, laterality, concomitant potential

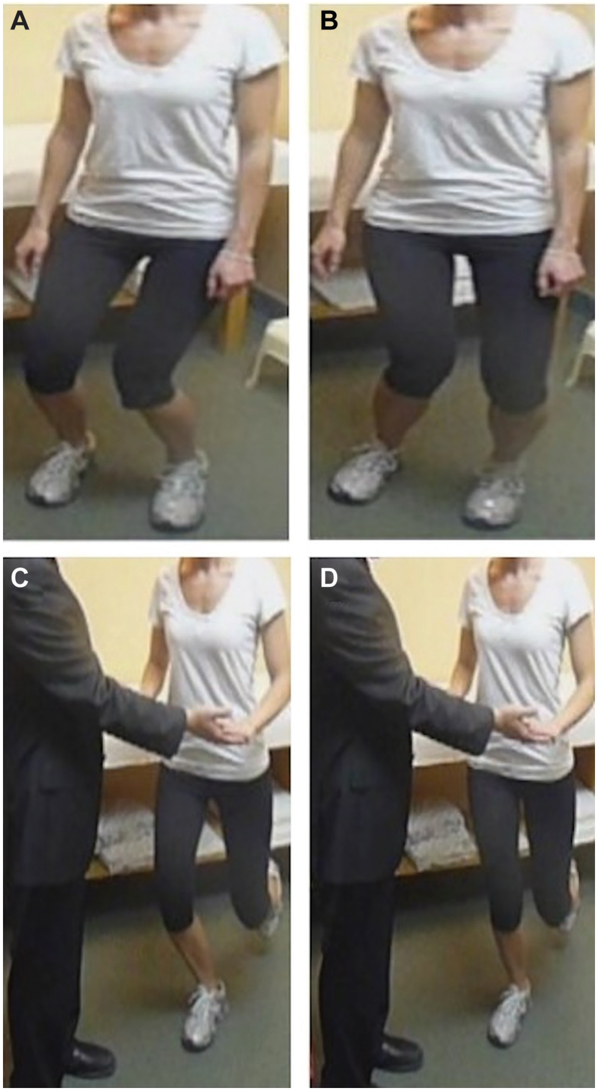

Figure 2. Demonstration of the twist test. (A, B) The patient is first asked to slightly flex the knees and move both knees back and forth in a ''windshield wiper'' motion while keeping the feet planted. (C, D) Next, the patient is asked to repeat this motion while standing only on the affected leg while supported by the examiner. This is repeated on the nonaffected leg as well.

hip symptom generators noted on history, imaging, and location of labral tear where this was recorded. Arlington, twist, and impingement tests were documented as positive or negative. MRA was noted as positive or negative for a labral tear as interpreted by a musculoskeletal radiologist as well as independently by the lead surgeon. Ultimately, surgeon interpretation was used to define a patient's findings as positive or negative for labral tear. Note was also made of any concomitant potential hip symptom generators identified on MRA. Furthermore, operative reports, if surgery was performed, were reviewed and the presence of labral tear was recorded. The presence of cam and/or pincer lesions on plain film as well as evidence of chondromalacia

Figure 3. Demonstration of the FADIR/impingement test. While supine on the examination table, the patient's hip is first taken into (A) flexion and then (B) adduction and internal rotation. Reproduction of symptoms is considered a positive test. FADIR, flexion-adduction-internal rotation.

on MRA were recorded although not included in the concomitant pathology group, as these were considered to be a part of the spectrum of hip labral tear pathology.

Statistical Analysis

Analyses were performed using NCSS software (version 21.0.3). Sensitivity, specificity, positive (+LR) and negative (–LR) likelihood ratios, and positive (PPV) and negative (NPV) predictive values were calculated for each of the 3 clinical tests. Diagnostic statistics were also calculated for the combination of Arlington and twist tests in parallel (test considered positive if either one of the tests was positive) and in series (test only considered positive if both were positive). Patients found to have missing data were excluded from analysis. The 95% CIs were calculated using the Wilson score method. Comparison of sensitivities and specificities between the individual tests was performed using McNemar 2-sided hypothesis tests of the difference.[12] Patients were then separated into those with concomitant hip pathology, excluding chondromalacia, and those without. Each test's sensitivity and specificity were calculated in each subpopulation and compared using Pearson chi-square tests. Sensitivities calculated using MRA as the standard were also compared with those calculated using intraoperative findings as the standard using Pearson chi-square tests. Last, patients were divided into those diagnosed specifically with an anterosuperior tear and those diagnosed with a tear in another location. The sensitivities of each of the tests were calculated in each of these subgroups, and the tests' sensitivities in patients with anterosuperior tears were compared with sensitivities in nonanterosuperior tears using the chi-square test of independence.

RESULTS

A total of 292 patients were identified for the study (Figure 4). Nine of these patients were excluded due to missing

TABLE 1
Patient Characteristics and Concomitant Pathology[a]

	Value
Total No. of patients	283
Confirmed labral tears on MRA	265 (93.6)
Mean age, y	40.7
Sex	
Male	95 (33.6)
Female	188 (66.4)
FAI	233 (82.3)
Cam	90 (31.8)
Pincer	27 (9.5)
Both	116 (41)
Chondromalacia	154 (54.4)
Concomitant hip symptom generators	61 (21.6)
Iliopsoas tendinitis	21 (7.4)
Greater trochanteric bursitis	15 (5.3)
Loose bodies	7 (2.5)
Hip dysplasia	7 (2.5)
Sacroiliac pathology	6 (2.1)
Snapping hip/external impingement	3 (1.1)
Os acetabulum	2 (0.7)

[a]Data are presented as n (%) unless otherwise indicated. FAI, femoroacetabular impingement; MRA, magnetic resonance imaging.

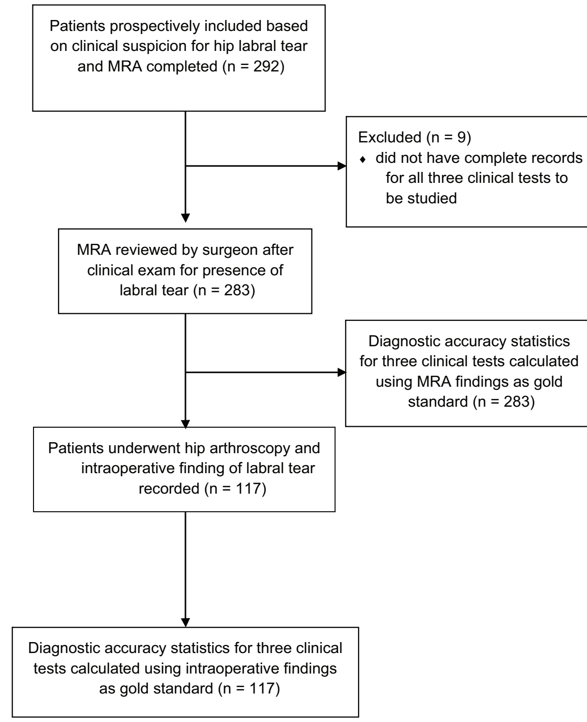

Figure 4. Flow diagram demonstrating patient selection and analysis. MRA, magnetic resonance arthrography.

data, leaving 283 eligible for analysis. Of these patients, the mean age was 40.7 years (range, 13-77 years) and 188 (66.4%) patients were women (Table 1). FAI was noted in 233 (82.3%) patients, with cam lesions in 90 (31.8%), pincer lesions in 27 (9.5%), both cam and pincer lesions in 116 (41%), and no radiographic evidence of FAI in 50 (17.7%). Evidence of any level of chondromalacia in the femoral head or acetabulum was noted on radiographs or MRA in 154 (54.4%) patients. A total of 61 (21.6%) patients were noted to have concomitant pathology that could cause hip symptoms. This included iliopsoas tendinitis in 21 (7.4%) patients, greater trochanteric bursitis in 15 (5.3%), loose bodies in 7 (2.5%), hip dysplasia in 7 (2.5%), sacroiliac pathology in 6 (2.1%), snapping hip/external impingement in 3 (1.1%), and os acetabulum in 2 (0.7%). Of the 283 patients with MRA performed, 117 went on to have surgery with documentation of labral tear status. All 117 of these patients were found to have a labral tear. In regard to differences in interpretation of the MRA by the radiologist and the surgeon, there were 8 (6.8%) cases in which the surgeon interpreted a labral tear when the radiologist did not read a tear. Other than these, there was agreement in interpretation of labral tear on MRA in all other cases.

Sensitivity, Specificity, +LR, –LR, PPV, and NPV With MRA as the Reference Standard

Use of the Arlington test with MRA as the reference standard yielded a sensitivity of 0.94 (95% CI, 0.90-0.96) and specificity of 0.33 (95% CI, CI 0.16-0.56) (Table 2). Use of the twist test yielded a sensitivity of 0.68 (95% CI, 0.62-0.73) and specificity of 0.72 (95% CI, 0.49-0.88) using MRA as the reference. Use of the FADIR/impingement test yielded a sensitivity of 0.43 (95% CI, 0.37-0.49) and specificity of 0.56 (95% CI, 0.34-0.75) using MRA as the reference. Combining Arlington and twist tests in parallel, where a positive on either test was considered a positive result, yielded a sensitivity of 0.95 (95% CI, 0.93-0.98) and specificity of 0.33 (95% CI, 0.12-0.55). Combining Arlington and twist tests in series, where a positive on both tests was required for a positive result yielded a sensitivity of 0.66 (95% CI, 0.60-0.72) and specificity of 0.72 (95% CI, 0.47-0.90). Positive and negative likelihood ratios as well as positive and negative predictive values are reported in Table 2.

When comparing sensitivities between tests, the Arlington test was found to have a significantly higher sensitivity than both the twist test ($P < .001$) and the FADIR/impingement test ($P < .001$). The twist test had a significantly higher sensitivity than the FADIR/impingement test ($P < .001$).

When comparing specificities between tests, there was no statistically significant difference between the Arlington and FADIR/impingement tests ($P = .21$) or twist and FADIR/impingement tests ($P = .18$). The twist test was found to have a significantly higher specificity than the Arlington test ($P = .008$).

As all surgical cases documented a labral tear, specificity data were unable to be calculated using surgical findings as the reference standard. Sensitivities using surgical findings as the reference standard were 0.93 (95% CI, 0.86-0.96), 0.57 (95% CI, 0.47-0.67), and 0.43 (95% CI, 0.34-0.54) for the Arlington test, twist test, and

TABLE 2
Diagnostic Statistics Using MRA as Reference Standard[a]

	Sensitivity	Specificity	+ LR	–LR	PPV	NPV
Arlington test	0.94 (0.90-0.96)[b]	0.33 (0.16-0.56)[d]	1.40 (1.01-1.95)	0.26 (0.13-0.46)	0.95 (0.92-0.97)	0.26 (0.13-0.45)
Twist test	0.68 (0.62-0.73)[b,c]	0.72 (0.49-0.88)[d]	2.44 (1.16-5.17)	0.44 (0.32-0.62)	0.97 (0.94-0.99)	0.13 (0.08-0.21)
FADIR/impingement test	0.43 (0.37-0.49)[b,c]	0.56 (0.34-0.75)	0.96 (0.56-1.64)	1.03 (0.67-1.58)	0.93 (0.87-0.97)	0.06 (0.03-0.11)
Arlington + twist in parallel	0.95 (0.93-0.98)	0.33 (0.12-0.55)	1.43 (1.03-1.99)	0.14 (0.06-0.32)	0.95 (0.94-0.97)	0.33 (0.18-0.54)
Arlington + twist in series	0.66 (0.60-0.72)	0.72 (0.47-0.90)	2.39 (1.13-5.06)	0.47 (0.33-0.65)	0.97 (0.94-0.99)	0.13 (0.09-0.17)

[a]Data are presented as sensitivities, specificities, likelihood ratios, and predictive values with 95% CIs. Diagnostic statistics were calculated using MRA findings as the reference standard. FADIR, flexion-adduction-internal rotation; + LR, positive likelihood ratio; –LR, negative likelihood ratio; MRA, magnetic resonance arthrography; NPV, negative predictive value; PPV, positive predictive value.
[b]The Arlington test had higher sensitivity than the twist and FADIR/impingement tests ($P < .001$).
[c]The twist test had higher sensitivity than the FADIR/impingement test ($P < .001$).
[d]The twist test had higher specificity than the Arlington test ($P = .008$).

FADIR/impingement test, respectively. There were no significant differences between these sensitivities and those calculated using MRA as the standard ($P > .05$).

Sensitivity and Specificity in Those With and Without Concomitant Pathology

When subdividing the patients by the presence of concomitant hip symptom generators noted on plain radiographs or MRA, the Arlington test had a sensitivity of 0.89 (95% CI, 0.78-0.95) and specificity of 0.33 (95% CI, 0.10-0.70), the twist test had a sensitivity of 0.71 (95% CI, 0.58-0.81) and specificity of 0.67 (95% CI, 0.30-0.90), and the FADIR/impingement test had a sensitivity of 0.53 (95% CI, 0.40-0.65) and specificity of 0.67 (95% CI, 0.30-0.90) in those with concomitant pathology. The Arlington test had a sensitivity of 0.95 (95% CI, 0.91-0.97) and specificity of 0.33 (95% CI, 0.14-0.61), the twist test had a sensitivity of 0.67 (95% CI, 0.60-0.73) and specificity of 0.75 (95% CI, 0.47-0.91), and the FADIR/impingement test had a sensitivity of 0.40 (95% CI, 0.34-0.47) and specificity of 0.50 (95% CI, 0.25-0.75) in those without concomitant pathology. There were no significant differences in sensitivity or specificity between groups for any of the 3 tests ($P < .05$).

Sensitivity by Location of Tear

The specific location of the labral tear was recorded in the documentation of 138 of the 283 (49%) patients. Of these, 82% were anterosuperior tears, 8% were anterior tears, 5% were superior tears, 3% were posterior tears, and 2% involved anterior and posterior tears. When dividing patients into those with anterosuperior tears and those with other tear locations, the Arlington test demonstrated sensitivities of 0.95 in the anterosuperior group and 1 in the other group (χ^2 [1, 138] = 0.03; $P = .86$). The twist test demonstrated sensitivities of 0.68 in the anterosuperior group and 0.60 in the other group (χ^2 [1, 138] = 0.10; $P = .75$). The FADIR/impingement test demonstrated sensitivities of 0.39 in the anterosuperior group and 0.44 in the other group (χ^2 [1, 138] = 0.094; $P = .759$).

DISCUSSION

The results of this study indicate a very high sensitivity of the Arlington test at detecting hip labral tears. While not as sensitive, the twist test showed overall good specificity for hip labral tears. Ultimately, both the Arlington and twist tests demonstrated higher sensitivity compared with the traditional FADIR/impingement test in the hands of a single orthopaedic surgeon specializing in hip pathology.

We propose that the Arlington test provides a more comprehensive examination than the traditional FADIR/impingement test by providing a greater range of motion and loading of the labrum. In the FADIR/impingement test, the examiner seeks to elicit symptoms by placing the hip into a single position of FADIR, while the Arlington test ranges the flexed hip from an externally rotated and abducted position to an endpoint in the more traditional internally rotated and adducted position while providing dynamic micromotion throughout the range. The traditional FADIR/impingement test places strain very specifically at the anterolateral aspect of the labrum.[13] Previous biomechanical studies support using this full range of motion as abduction and external rotation place higher strains in the posterior aspect of the labrum and slightly different anterior aspects than the impingement test.[13,23] A flexion-abduction-external rotation test has been described previously as a relatively sensitive test for the detection of general intra-articular pathology and FAI, although only 1 study looked specifically at its role in detecting labral tears, with a smaller sample showing 81% sensitivity.[22,29,30] A small study of 22 patients described an "impingement provocation test" that, similar to the Arlington test in this study, takes the hip through a range of positions and showed similarly high sensitivity.[20] Ultimately, this large study demonstrates the Arlington test to be a very sensitive clinical examination supported by a strong foundation in hip labral biomechanics.

While proving to be a less sensitive test than the Arlington test, the results of this study suggest that the twist test is relatively specific for the detection of labral tears. Calculating specificity for clinical tests in the diagnosis of hip labral tears has long been a problem, as labral tears are highly prevalent in the selected populations undergoing

MRA or surgery, ultimately leading to very few true-negative or false-positive results. A large majority of the previous studies either did not calculate specificity or acknowledged the limitation of the calculation.[5,8,14,16,19,28,29] Our patient sample included a larger number with negative MRA for which to calculate specificity compared with previous studies, although with only 18 such patients, we acknowledge that our study is not immune to this problem. The idea that a functional weightbearing test will have high specificity is not unique to the hip, as the Thessaly test has been shown to have reasonably high specificity in detecting meniscal tears in the knee.[1,15] To our knowledge, only 1 other weightbearing test has been described for diagnosing hip labral tears, the maximal squat test, which reported limited sensitivity and specificity.[3] Finally, this relatively simple test does not require the presence of a skilled examiner, making it particularly useful in the current state of health care in which telemedicine is becoming increasingly necessary.

Interestingly, combining the Arlington and twist tests did not substantially improve diagnostic accuracy. Instead, the combination in parallel reflected the sensitivity of the Arlington test, while the series combination represented the twist test's specificity. An overview of the data demonstrates that of those with MRA-confirmed labral tears, only a few patients tested positive on the twist test while testing negative on Arlington. Similarly, of those without a labral tear on MRA, no patient tested negative on the Arlington test while testing positive on the twist test. This reflects the seemingly complementary nature of these 2 tests. Ultimately, as with any diagnostic test, the clinician must determine whether a more specific or sensitive test or combination of tests is more desirable based on their population and a patient-by-patient basis. It may be noted that the PPVs for all the tests are very high, while the NPVs are all relatively low. This is explained by the overall high prevalence of labral tears in the population studied, with 93.6% of the sample found to have tears on MRA.

As there are multiple pathologies that can cause hip symptoms and may ultimately present concomitantly with FAI and labral tears, we assessed the sensitivity and specificity of the 3 tests in the presence and absence of these. About 20% of the patients were found to have concomitant pathology, and there were no significant differences in the tests' performances in these patients, supporting their diagnostic value in the patient with general hip symptoms.

We do acknowledge that the FADIR/impingement test in our study demonstrated a relatively low sensitivity compared with previous literature. This cannot be attributed to an inexperienced examiner, as all the physical examinations recorded in our study were performed by an experienced, sports medicine–trained orthopaedic surgeon specializing in hip pathology. While a majority of previous studies cite a higher sensitivity, there is significant variability, with some studies reporting sensitivities similar to those found in the present study.[5,14,16,17,28] This variability and disagreement between surgeons has been demonstrated in a previous study demonstrating low interobserver agreement in hip clinical examination.[21] Furthermore, many of the studies demonstrating high sensitivities either only include patients with positive impingement tests, analyze the diagnostic accuracy of an imaging study rather than the clinical examination itself, or look at a population with a higher pretest probability than that of our population (ie, all patients underwent, or were at least offered, surgery).[2,8,16,17,19,28,29,31] All these may potentially inflate the reported sensitivity. This is not to say that the FADIR/impingement test is not useful, but rather that incorporating these tests alongside the traditional FADIR/impingement test will provide more data points on which the clinician may base decision making.

As referenced previously, one limitation of this study is the relatively small percentage of the patients studied with MRA negative for labral tear. This issue plagues the previous literature on hip labral tear clinical examinations, and the present study includes a higher total number of patients with confirmed negative findings relative to those previous studies. Nevertheless, evaluation of the specificity of the tests presented remains limited, as evidenced by the associated broad confidence intervals. The inclusion of more patients with MRA negative for labral tears would be required to better assess this; however, this is difficult practically, as it is unethical to perform an invasive diagnostic test on patients with low suspicion for labral tear. Along these lines, it should be noted that the diagnostic accuracy of the reported tests in this study was calculated in a population with a high clinical suspicion for labral tear and may not be applicable to the patient with a lower initial clinical suspicion, that is, patients evaluated by a general practitioner.

The results in this study are based on physical examinations performed by a single surgeon who was one of the developers of the tests, limiting generalizability to other providers. These issues are seen throughout the literature on clinical hip examination. Ultimately, future studies, including larger patient samples with a varied pool of examiners, would help address these limitations and validate these tests.

We acknowledge a limitation in reporting the specific location of labral tears in this study. Because of the retrospective chart review nature of the study, extensive review only confirmed radiologist and surgeon notation of location in about half of the patients. With that being said, a majority of these patients were noted to have anterosuperior tears, consistent with previous literature.[17,26] Furthermore, a comparison of the sensitivity of each test between the group with anterosuperior tears and those with less common tear patterns did not show any significant differences. However, the relatively small sample size limits these analyses to the group with less common tears. While the results do not suggest that these tests perform differently based on the location of the tear, this interaction should be studied further, as each test theoretically preferentially loads different regions of the labrum.[13,23]

It should be noted that the ability of these tests to distinguish between FAI and labral tears was not assessed. Labral tears are strongly associated with underlying FAI, and it is commonly believed that impingement causes many labral tears.[6,32] Viewing labral tears as a part of the FAI spectrum of disease, it seems unlikely that clinical examination would be able to clearly distinguish between the 2. Furthermore, as both pathologies are usually addressed concomitantly with hip arthroscopy, there is questionable clinical utility in distinguishing between them on examination.

Finally, while this paper focuses on the most commonly used FADIR/impingement test, there are multiple other clinical tests that have been studied for the diagnosis of hip labral tears. These include the flexion-abduction-external rotation test, the Fitzgerald test, and the flexion-adduction-axial compression test, among others.[19,22,28-30] Although we did not show improved sensitivity or specificity with the combination of tests in this study, each test serves as another data point upon which the clinician may base their decision making. Future work to further investigate the diagnostic accuracy of these other tests and their combination alongside the tests in this study will be useful in further refining the optimal clinical examination for diagnosing hip labral tears.

The importance of clinical examination in diagnosing and managing hip labral tears cannot be overstated. While MRA is very sensitive at detecting labral tears, the high rate of asymptomatic labral tears is well-documented.[9,10,25,27] There are also many other hip pain generators outside of the labrum that may complicate diagnosis, as best outlined by Dr. Bryan Kelly's layer concept.[11] MRA results must be interpreted in the context of the clinical examination to accurately identify patients who may benefit from intervention directed at labral pathology. Furthermore, the clinical examination should precede any advanced imaging, as MRA is expensive and invasive and should be reserved only for those with high clinical suspicion based on the examination.

CONCLUSION

This study reports the diagnostic accuracy of 2 novel clinical tests for hip labral tears in a large sample of patients. The Arlington test is based on sound biomechanical principles and demonstrates a very high clinical sensitivity in detecting hip labral tears. While limited by a high prevalence of labral tears in those indicated for MRA, the twist test in this study demonstrates promising specificity when a paucity of data exists. These tests can serve as complements to the traditional FADIR/impingement tests to guide the appropriate use and interpretation of advanced imaging, ultimately providing more sound indications for surgical management.

A Video Supplement for this article is available online.

REFERENCES

1. Alexanders J, Anderson A, Henderson S, Clausen U. Comparison of the Thessaly test and McMurray test: a systematic review of comparative diagnostic studies. *Physiother Rehabil*. 2016;1:104. doi:10.4172/2573-0312.100010
2. Aprato A, Massè A, Faletti C, et al. Magnetic resonance arthrography for femoroacetabular impingement surgery: is it reliable? *J Orthop Traumatol*. 2013;14(3):201-206. doi:10.1007/s10195-013-0227-1
3. Ayeni O, Chu R, Hetaimish B, et al. A painful squat test provides limited diagnostic utility in CAM-type femoroacetabular impingement. *Knee Surg Sports Traumatol Arthrosc*. 2014;22:806-811. doi:10.1007/s00167-013-2668-8
4. Ayeni OR, Chan K, Al-Asiri J, et al. Sources and quality of literature addressing femoroacetabular impingement. *Knee Surg Sports Traumatol Arthrosc*. 2013;21(2):415-419. doi:10.1007/s00167-012-2236-7
5. Beaulé PE, Zaragoza E, Motamedi K, Copelan N, Dorey FJ. Three-dimensional computed tomography of the hip in the assessment of femoroacetabular impingement. *J Orthop Res*. 2005;23(6):1286-1292. doi:10.1016/j.orthres.2005.03.011.1100230608
6. Bedi A, Kelly BT. Femoroacetabular impingement. *J Bone Joint Surg Am*. 2013;95(1):82-92. doi:10.2106/JBJS.K.01219
7. Bozic KJ, Chan V, Valone FH III, Feeley BT, Vail TP. Trends in hip arthroscopy utilization in the United States. *J Arthroplasty*. 2013;28(8)(suppl):140-143. doi:10.1016/j.arth.2013.02.039
8. Burnett RS, Della Rocca GJ, Prather H, Curry M, Maloney WJ, Clohisy JC. Clinical presentation of patients with tears of the acetabular labrum. *J Bone Joint Surg Am*. 2006;88(7):1448-1457. doi:10.2106/JBJS.D.02806
9. Crespo Rodríguez AM, de Lucas Villarrubia JC, Pastrana Ledesma MA, Millán Santos I, Padrón M. Diagnosis of lesions of the acetabular labrum, of the labral-chondral transition zone, and of the cartilage in femoroacetabular impingement: correlation between direct magnetic resonance arthrography and hip arthroscopy. *Radiologia*. 2015;57(2):131-141. doi:10.1016/j.rx.2013.11.002
10. Czerny C, Hofmann S, Neuhold A, et al. Lesions of the acetabular labrum: accuracy of MR imaging and MR arthrography in detection and staging. *Radiology*. 1996;200(1):225-230. doi:10.1148/radiology.200.1.8657916
11. Draovitch P, Edelstein J, Kelly BT. The layer concept: utilization in determining the pain generators, pathology and how structure determines treatment. *Curr Rev Musculoskelet Med*. 2012;5(1):1-8. doi:10.1007/s12178-011-9105-8
12. Dwyer AJ. Matchmaking and McNemar in the comparison of diagnostic modalities. *Radiology*. 1991;178:328-330. doi:10.1148/radiology.178.2.1987587
13. Dy CJ, Thompson MT, Crawford MJ, Alexander JW, McCarthy JC, Noble PC. Tensile strain in the anterior part of the acetabular labrum during provocative maneuvering of the normal hip. *J Bone Joint Surg Am*. 2008;90(7):1464-1472. doi:10.2106/JBJS.G.00467
14. Hananouchi T, Yasui Y, Yamamoto K, Toritsuka Y, Ohzono K. Anterior impingement test for labral lesions has high positive predictive value. *Clin Orthop Relat Res*. 2012;470(12):3524-3529. doi:10.1007/s11999-012-2450-0
15. Karachalios T, Hantes M, Zibis AH, Zachos V, Karantanas AH, Malizos KN. Diagnostic accuracy of a new clinical test (the Thessaly test) for early detection of meniscal tears. *J Bone Joint Surg Am*. 2005;87(5):955-962. doi:10.2106/JBJS.D.02338
16. Kassarjian A, Yoon LS, Belzile E, Connolly SA, Millis MB, Palmer WE. Triad of MR arthrographic findings in patients with cam-type femoroacetabular impingement. *Radiology*. 2005;236(2):588-592. doi:10.1148/radiol.2362041987
17. Keeney JA, Peelle MW, Jackson J, Rubin D, Maloney WJ, Clohisy JC. Magnetic resonance arthrography versus arthroscopy in the evaluation of articular hip pathology. *Clin Orthop Relat Res*. 2004;429:163-169. doi:10.1097/01.blo.0000150125.34906.7d
18. Kelly BT, Weiland DE, Schenker ML, Philippon MJ. Arthroscopic labral repair in the hip: surgical technique and review of the literature. *Arthroscopy*. 2005;21(12):1496-1504. doi:10.1016/j.arthro.2005.08.013
19. Leibold MR, Huijbregts PA, Jensen R. Concurrent criterion-related validity of physical examination tests for hip labral lesions: a systematic review. *J Man Manip Ther*. 2008;16(2):e24-e41. doi:10.1179/jmt.2008.16.2.24E
20. Leunig M, Werlen S, Ungersböck A, Ito K, Ganz R. Evaluation of the acetabular labrum by MR arthrography. *J Bone Joint Surg Br*. 1997;79(2):230-234. doi:10.1302/0301-620x.79b2.7288

21. Martin RL, Kelly BT, Leunig M, et al. Reliability of clinical diagnosis in intraarticular hip diseases. *Knee Surg Sports Traumatol Arthrosc*. 2010;18(5):685-690. doi:10.1007/s00167-009-1024-5
22. Maslowski E, Sullivan W, Forster Harwood J, et al. The diagnostic validity of hip provocation maneuvers to detect intra-articular hip pathology. *PM R*. 2010;2(3):174-181. doi:10.1016/j.pmrj.2010.01.014
23. Safran MR, Giordano G, Lindsey DP, et al. Strains across the acetabular labrum during hip motion: a cadaveric model. *Am J Sports Med*. 2011;39(suppl):92S-102S. doi:10.1177/0363546511414017
24. Schmerl M, Pollard H, Hoskins W. Labral injuries of the hip: a review of diagnosis and management. *J Manipulative Physiol Ther*. 2005;28(8):632. doi:10.1016/j.jmpt.2005.08.018
25. Schmitz MR, Campbell SE, Fajardo RS, et al. Identification of acetabular labral pathological changes in asymptomatic volunteers using optimized, noncontrast 1.5-T magnetic resonance imaging. *Am J Sports Med*. 2012;40:1337-1341. doi:10.1177/0363546512439991
26. Seldes RM, Tan V, Hunt J, Katz M, Winiarsky R, Fitzgerald RH Jr. Anatomy, histologic features, and vascularity of the adult acetabular labrum. *Clin Orthop Relat Res*. 2001;382:232-240. doi:10.1097/00003086-200101000-00031
27. Silvis ML, Mosher TJ, Smetana BS, et al. High prevalence of pelvic and hip magnetic resonance imaging findings in asymptomatic collegiate and professional hockey players. *Am J Sports Med*. 2011;39:715-721. doi:10.1177/0363546510388931
28. Thorborg K. Diagnostic accuracy of clinical tests for the diagnosis of hip femoroacetabular impingement/labral tear: a systematic review with meta-analysis. *Br J Sports Med*. 2015;49(12):811. doi:10.1136/bjsports-2014-094302
29. Tijssen M, van Cingel RE, de Visser E, Hölmich P, Nijhuis-van der Sanden MW. Hip joint pathology: relationship between patient history, physical tests, and arthroscopy findings in clinical practice. *Scand J Med Sci Sports*. 2017;27(3):342-350. doi:10.1111/sms.12651
30. Trindade CAC, Briggs KK, Fagotti L, Fukui K, Philippon MJ. Positive FABER distance test is associated with higher alpha angle in symptomatic patients. *Knee Surg Sports Traumatol Arthrosc*. 2019;27(10):3158-3161. doi:10.1007/s00167-018-5031-2
31. Troelsen A, Mechlenburg I, Gelineck J, Bolvig L, Jacobsen S, Søballe K. What is the role of clinical tests and ultrasound in acetabular labral tear diagnostics? *Acta Orthop*. 2009;80(3):314-318. doi:10.3109/17453670902988402
32. Wenger DE, Kendell KR, Miner MR, Trousdale RT. Acetabular labral tears rarely occur in the absence of bony abnormalities. *Clin Orthop Relat Res*. 2004;426:145-150. doi:10.1097/01.blo.0000136903 .01368.20