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# INTRODUCING THE ARM TRACTION ABDUCTION (ATA) TEST: A NEW DIAGNOSTIC METHOD FOR SUBACROMIAL IMPINGEMENT SYNDROME

Mohammad Hassabi[1,2], Farzin Halabchi[3], Seyedeh Sara Shams[4], Behnaz Mahdaviani[2,5]

[1] Taleghani Hospital Research Development committee, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[2] Department of Sports and Exercise Medicine, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[3] Department of Sports and Exercise Medicine, Tehran University of Medical Sciences, Tehran, Iran
[4] School of Medicine, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[5] Sports Medicine Research Center, Neuroscience Institute, Tehran University of Medical Sciences, Tehran, Iran

**Corresponding author's e-mail:** behnazmahdaviani@gmail.com

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## ABSTRACT

*Background:* Differentiating Subacromial Impingement Syndrome (SIS) from other shoulder problems through physical examination remains challenging due to the limited sensitivity or specificity of the existing tests, and the difficulty of interpreting the results in patients with significant pain. This study aimed to examine if the Arm Traction Abduction (ATA) maneuver could be used as a non-provocative test for diagnosing SIS.

*Methods:* One hundred patients with shoulder pain lasting less than three months were enrolled. Fifty patients were diagnosed with SIS (Group 1) and the remaining fifty did not have SIS (Group 2). The diagnosis was based on a cut-off point of three positive results out of five impingement tests including Neer, Hawkins- Kennedy, Painful arc, Jobe, and external rotation resistance. Both groups underwent active and passive painless shoulder abduction measurements and the ATA test. ROC curve analysis was used to determine the optimal cut-off value.

*Results:* The ATA test characteristics were calculated as follows: Sensitivity= 55. 5% (CI95%: 0.45-0.65), specificity= 79.8% (CI95%: 0.71-0.87), positive predictive value= 73.7% (CI95%: 0.65-0.81), negative predictive value= 63.7% (CI95%: 0.58-0.69), accuracy= 67.5% (CI95%:0.60-0.75), positive likelihood ratio= 2.74 (CI95%: 1.79-4.21), and negative likelihood ratio = 0.56 (CI95%: 0.44-0.71). A Receiver Operative Characteristics (ROC) curve analysis recommended using a 20-degree improvement in passive abduction as the best cut-off value.

*Conclusions:* We suggest that the ATA test as a new non-provocative test among patients suffering from shoulder pain for differentiating SIS from other problems. This test showed high specificity and patients' compliance because it did not trigger pain.

## KEYWORDS

Physical examination, Sensitivity, Shoulder, Specificity, Subacromial Impingement Syndrome

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## INTRODUCTION

Shoulder pain is one of the most common causes of musculoskeletal problems and disability, imposing heavy costs to health care systems[1,2]. Its prevalence has been reported to be between 7 to 34 percent[3,4], with an upward trend, especially among women and the elderly[4,5]. Common causes of shoulder pain include impingements, rotator cuff disease, biceps tendinopathy, acromioclavicular osteoarthritis, and calcified tendonitis[6,7]. Subacromial Impingement Syndrome (SIS) is one of the most common reasons of shoulder pain[8-10], responsible for 44% to 64% of such cases[1].

SIS is caused by the compression of the upper structure of the humerus head against the anterior inferior surface of the acromion and the coracoacromial ligament. During shoulde flexion and abduction, the rotator cuff muscles and the long head of biceps may become entrapped between these structures. The main reasons consist of tendinosis or partial tearing of rotator cuff muscles as well as subacromial bursitis, bony spur, acromioclavicular osteoarthritis, and coracoacromial ligament thickening[11]. Arthroscopy[12,13], Magnetic Resonance Imaging (MRI)[12,14], sonography[15,16], and lidocaine local injection[17-19], along with specific physical examination tests, help establish the diagnosis of SIS. Generally, MRI with a sensitivity of 84-98% and a specificity of 36.8- 87%, and ultrasound with a sensitivity of 79% and a specificity of 94%, are used for diagnosis[3,14,20-22].

Several studies have examined the sensitivity and specificity of the specific tests for finding SIS[10] and have shown that a single test usually does not have the required sensitivity and specificity to confirm the diagnosis[23]. Thus, a combination of tests is usually recommended[18,21,23]. Michener et al. investigated diagnostic values of each and combinations of five tests comprising Neer, Hawkins-Kennedy, painful arc, empty can, and external rotation resistance test. They proposed the result of at least three positive tests out of five for making a diagnosis of SIS with a sensitivity of 75% and specificity of 74%[4]. However, these tests sometime cannot be performed accurately due to severe pain and limited shoulder movement. During these tests, the examiner tries to provoke the patient's pain by stressing the injured structure or narrowing the space.

Passive axial traction of the humerus may increase the subacromial space by moving the head of the humerus away from the acromion. Maintaining traction during shoulder abduction may improve the limited motion of an impinged shoulder by reducing the pressure on injured or inflamed structures. With this logic, we aimed to examine whether the increased range of shoulder abduction following this maneuver could be considered a non-provocative test for diagnosing SIS. Therefore, we designed a test, provisionally named the arm traction-abduction (ATA) test, through which the examiner compares passive shoulder abduction range without and with passive axial traction of the humerus. This study set out to estimate the power and validity of this test.

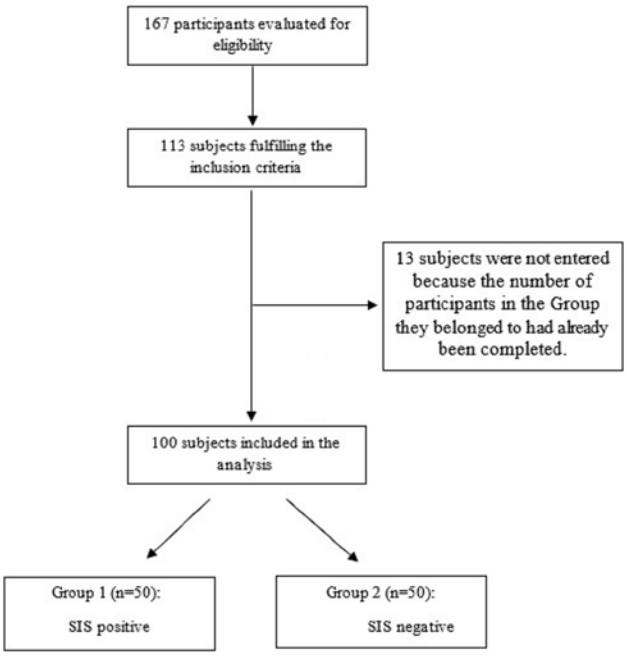



**Figure 1.** *The flowchart of recruitment.*

## METHOD

After April 2021, all patients presenting to the Sports Medicine Clinic at Taleghani hospital with a chief complaint of shoulder pain lasting less than three months were enrolled if they consented to participate in this study. They were divided into two groups according to the results of the five clinical tests comprising Neer, Hawkins-Kennedy, painful arc, empty can, and external rotation resistance test. A cut-off point of three positive results out of five was considered to diagnose SIS[4]. Those with at least three positive tests were put into group 1 (shoulder pain with probable SIS); the rest with less than three positive tests were placed in group 2 (shoulder pain with no probable SIS). Sampling continued until we had 50 participants in each group *(Figure 1)*. The ATA test was performed for both groups, and the non-painful range of shoulder abduction was measured with a goniometer after each part of the test.

Inclusion criteria were defined as follows: shoulder pain lasting less than three months, age between 20 and 70 years, no history of severe trauma to the neck or shoulder in the previous three months, no history of surgical treatment of the painful shoulder, no history of localized shoulder lesions or injuries such as infection, tumor, or infection, no history of congenital impairments leading to limited range of motion, and no systemic arthropathies.

What the participants were required to perform was thoroughly explained to them, written consent was obtained, and their information was kept confidential. Every participant could choose to leave the study if they were reluctant to participate. The management of shoulder pain for all patients was the same regardless of their participation. This study was performed under the supervision of the Department of Sports and Exercise Medicine of Shahid Beheshti University of Medical

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***Figure 2.*** *The five impingement tests used for diagnosis. A) Neer. B) Hawkins-Kennedy. C) Painful arc. D) Empty can (Jobe). E) External rotation resistance.*

Sciences, and also was approved by the ethics committee of Shahid Beheshti University of Medical Sciences (code: IR.SBMU.RETECH.REC.1399.1370).

Participants' standing height and weights were measured using a Seca 700 Mechanical Column Scale. Body Mass Index (BMI) was calculated by dividing weight (kg) to height squared ($m^2$). A sports medicine specialist performed specific impingement tests, while another colleague, who was unaware of previous test results conducted the ATA test. The researcher analyzing the recorded results was not engaged in the physical examinations.

### *Neer test*

The examiner fixes the scapula by pressing it down with one hand and raises the straightened arm forward with the other hand while the elbow is pronated. The test is considered positive if it triggers pain in the superior anterior aspect of the shoulder[4] *(Figure 2A)*.

### *Hawkins- Kennedy test*

The examiner places the patient's shoulder and elbow at 90 degrees flexion and then rotates the shoulder inward. The test is considered positive if it causes pain in the anterior upper part of the shoulder.[4] *(Figure 2B)*.

### *Painful arc test*

While the patient actively abducts the shoulder away from the body, the examiner asks about any pain during this movement. The test is considered positive if the patient feels pain in the superior anterior part of the shoulder between 60 to 120 degrees of abduction[4] *(Figure 2C)*.

### *Empty can test (Jobe test)*

The examiner places the patient's shoulders in 90 degrees abduction in the scapular plane, 30-40 degrees horizontal adduction, and internal axial rotation (thumbs down). The patient is then asked to resist the examiner's downward push on his wrists. The test is considered positive if there is pain or weakness compared to the contralateral side[4] *(Figure 2D)*.

### *External rotation resistance test*

The patient is asked to resist the force exerted by the examiner on the forearms to rotate the shoulder inward while keeping the arms at the sides of the body and the elbows bent at 90 degrees. Any weakness compared to the contralateral side is considered a positive result[4] *(Figure 2E)*.

Participants who had positive results in three or more of the tests mentioned above were placed in group 1 with a diagnosis of SIS (SIS positive). Group 2 comprised patients who had shoulder pain without SIS (SIS negative), with two or fewer positive results. The painless range of active shoulder abduction and the ATA test were measured for both groups.

### *Active shoulder abduction test*

Active shoulder movement assessments should be done prior to passive tests. Therefore, the painless range of shoulder abduction in the coronal plane is assessed before the ATA test. For this purpose, a goniometer is placed on the posterior surface of the glenohumeral joint. The examiner holds one arm of the goniometer in a vertical position and

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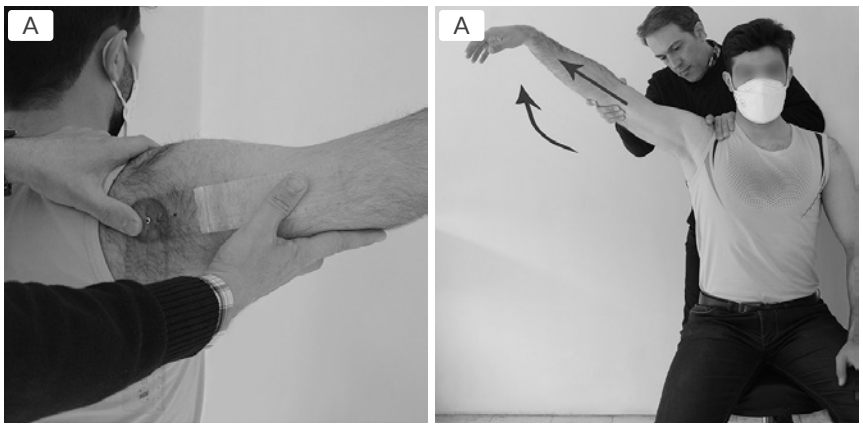



***Figure 3.*** *A) Passive abduction. B) Arm traction abduction (ATA) maneuver.*

allows the other arm move with the patient's arm during shoulder abduction, from the resting position to the point of pain onset or anatomical limitation.

### *ATA test*

A height-adjustable chair without a backrest is suitable for this test. The patient is asked to sit on the chair with bare shoulders. The examiner stands behind the patient and raises the patient's shoulder passively in the coronal plane while trying to fix the scapula with the other hand. The maximum painless range of passive shoulder abduction is measured with a goniometer *(Figure 3A)*. Next, the examiner repeats the measurement of passive shoulder abduction after inducing axial traction on the humerus *(Figure 3B)*. This traction is exerted by the examiner's hand on the patient's distal humeral condyles from the beginning of the movement. The examiner should maintain the force of traction at about grade 2 of the Kaltenborn scale during the entire range. This means the traction must effectively remove the humeral head off the glenoid surface by taking up the slack of the shoulder joint capsule[24]. A significant improvement in painless shoulder abduction after inducing the traction is a positive result for the test.

### *Statistical analysis*

Statistical Package for Social Sciences (SPSS) 21.0 software for Windows was used for all statistical analyses. Quantitative and categorical variables were presented as mean (standard deviation) and frequency (percentage), respectively. Independent T- and Chi square tests were used for between-group comparisons. ROC curve analysis was used to determine the best cut-off value to provide a higher Youden index (sensitivity + specificity -1).

Sensitivity, specificity, Positive Predictive Value (PPV) and Negative Predictive Values (NPV), accuracy, Positive Likelihood Ratio (LR+=sensitivity/1-specificity) and Negative Likelihood Ratio (LR-= 1-sensitivity/specificity) of our proposed maneuver to detect SIS were calculated using a 2*2 table with a method proposed by Staquet, et al for assessment of new dichotomous diagnostic tests[25]. These analyses were performed to determine the diagnostic validity and efficacy of the ATA test as a new clinical tool.

## RESULTS

A total of 100 patients with shoulder pain were recruited for the study *(Figure 1)*. According to the cut-off point of three positive tests out of five, patients were grouped into SIS positive (Group 1=50 patients) and SIS negative (Group 2=50 patients). *Table 1* shows the characteristics of the participants. There was no significant statistical difference between the two groups in terms of mean age, sex ratio, height, weight, and right- or left-sided involvement *(Table 1)*. There was no significant difference between groups regarding shoulder abduction during active or passive movements. However, the average of maximum painless passive shoulder abduction among group 1 participants was significantly (p = 0.003) more in group 2 after inducing passive axial traction to the humerus *(Table 2)*.

ROC curve analysis recommends using 20-degree improvement of passive abduction as the best cut-off value.

| Characteristics | Group 1 (n=50) | Group 2 (n=50) | Total (n=100) | P Value |
|---|---|---|---|---|
| Age (Mean ±SD*) | 52.72±12.74 | 52.22±11.74 | 52.47±12.19 | 0.84 |
| Gender (Male/Female) | 26/24 | 27/23 | 53/47 | 0.84 |
| Height (Cm) | 169.68±9.49 | 169.42±9.18 | 169.55±9.29 | 0.89 |
| Weight (Kg) | 72.42±12.73 | 70.84±11.71 | 71.63±12.19 | 0.52 |
| Involved side (Left/Right) | 22/28 | 23/27 | 45/55 | 0.84 |

***Table 1.*** *Characteristics of participants.*
*SD: Standard Deviation, Cm: Centimeter, Kg: Kilogram.*

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| Painless abduction ROM (Degrees) | Group 1 (N=50) | Group 2 (N=50) | P Value |
|---|---|---|---|
| Active | 86.6±20.27 | 94.30±24.74 | 0.09 |
| Passive | 90.6±20.55 | 95.8±24.25 | 0.25 |
| Passive with traction | 112.8±25.48 | 97.4±24.89 | 0.003* |

***Table 2.*** *Range of shoulder abduction (Mean ±SD).*
*N: Number, * Statistically significant.*

| | SIS positive | SIS negative | Total |
|---|---|---|---|
| ATA test positive (≥20° increase) | 32 | 1 | 33 |
| ATA test negative | 18 | 49 | 67 |
| Total | 50 | 50 | 100 |

***Table 3.*** *Results of the ATA test among participants.*
*SIS: Subacromial Impingement Syndrome*

Accordingly, the area under the curve (AUC) was 0.84 (CI 95%: 0.76- 0.93) (P<0.001), and abduction improvement of ≥20° was calculated to provide the highest Youden index (equal to 0.62) *(Figure 4)*.

The ATA test characteristics were initially determined using a 2*2 table, assuming a comparison with a well-established diagnostic method (3 0f 5 clinical tests) *(Table 3)*. With this assumption, the test's sensitivity and specificity were calculated to be 64% (CI95%: 0.49-0.77) and 98% (CI95%: 0.89-1), respectively. The other features were also computed including, a PPV of 97% (CI95%: 0.82-1), NPV of 73.13% (CI95%: 0.65-0.80), accuracy of 81% (CI95%: 0.73-0.90), LR+ of 32 (CI95%: 4.55-225.23), and LR- of 0.37 (CI95%: 0.25-0.53).

Next, these calculations were adjusted considering the five combined tests' overall sensitivity (75%) and specificity (74%) based on the method proposed by Staquet et al.[24] *(Table 4)*. In this way, the ATA test characteristics were calculated as follows: Sensitivity=55.45% [=56/101] (CI95%: 0.452-0.653), specificity=79.8% [=79/99] (CI95%: 0.71-0.87), PPV= 73.7% [=79/99] (CI95%: 0.65-0.81), NPV= 63.7% [=56/101] (CI95%: 0.58-0.69), accuracy= 67.5% [=56+79/200] (CI95%:0.60-0.75), LR+ = 2.74 [=0.64/1-0.737] (CI95%: 1.79-4.21), and LR- = 0.56 [=(1-0.64)/0.737] (CI95%: 0.44-0.71) *(Table 4)*.

## DISCUSSION

We introduce the ATA test to differentiate problems caused by SIS from other underlying issues for shoulder pain. Shoulder pain is a common musculoskeletal complaint, and SIS is one of its main reasons. The problems causing shoulder pain usually show similar clinical features, making precise diagnosis challenging. Adhesive capsulitis, calcific tendinopathy, and myofascial pains may be misdiagnosed as SIS[14,22]. Although Physical examination plays a vital role in identifying the underlying problem, due to patients' pain, limited range of movement, and the provocative nature of the tests, sometimes physicians prefer to rely more on imaging techniques. Regardless of the value of these procedures, there are some drawbacks to overusing them. Sonography is highly operator-dependent[26,27], and MRI is expensive, not available everywhere, and has relatively low specificity despite high sensitivity. Arthroscopy is an invasive method and only has proper sensitivity and specificity in severe cases[27,28]. A 2021 systematic review conducted by Lorusso et al. also confirmed that using conventional tests and imaging modalities in the diagnosis of SIS is challenging.[29] All of these highlight the importance of a non-provocative test with acceptable diagnostic properties.

SIS is secondary to the narrowing of the subacromial space due to anatomical or biomechanical impairments[14]. Although this definition of SIS has recently become a matter of debate, as rotator cuff injuries are now thought to result from more complex pathophysiology involving intrinsic factors rather than only extrinsic ones,[30] SIS is still considered a clinical concept encompassing both structural and functional alterations that can contribute to shoulder pain.[29] We hypothesized that by placing axial traction to the humerus prior to the passive abduction of the shoulder, the humeral head would move away from the acromion,

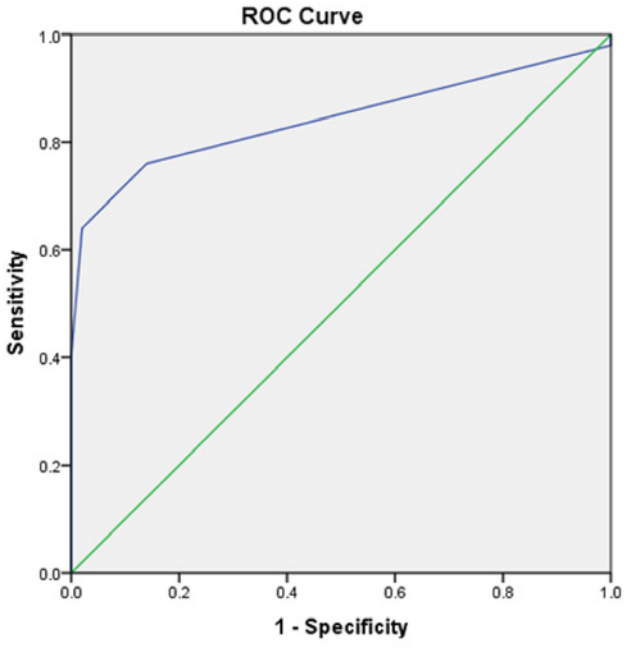



***Figure 4.*** *Cut-off 20-degree difference.*

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| | | Reference method | | |
|---|---|---|---|---|
| | | Positive | Negative | Total |
| New test (ATA test) | Positive | 55+1 | 18+2 | 76 |
| | Negative | 20+25 | 7+72 | 124 |
| | Total | 75+26 | 25+74 | 200 |

***Table 4.*** *Assessment of the new test (ATA test) by a reference test with known sensitivity and specificity.*
*ATA: Arm Traction Abduction*

increasing the painless abduction range due to a larger space in patients with impingement syndrome. Meanwhile, we did not expect this to improve the abduction range in patients with other pathologies. Our study showed that this difference could be used as a diagnostic test to differentiate between shoulder pains due to subacromial impingement and shoulder pains related to other reasons. The ATA test showed acceptable diagnostic features with 55.5% sensitivity and 79.8% specificity. The measured sensitivity is similar to the painful arc test but lower than Hawkins-Kennedy and Neer tests; however, it has greater specificity.

It is essential to note that since we used the combination of results from five clinical tests instead of a gold-standard procedure as a reference test, the results are an estimate of the power of this test, not a completely accurate determination. Surprisingly, we did not find evidence regarding the diagnostic accuracy of lidocaine injection test despite its usual recommendation in diagnosing SIS. Arthrography brings the most accurate diagnosis, although its sensitivity in milder cases is debated. On the other hand, we ruled out SIS for half of our participants (Group 2); thus, it was not ethically proper to perform an invasive procedure just for our purpose. MRI could be the most appropriate reference test with high sensitivity, even though a wide range of specificity has been reported for its ability to diagnose SIS[21,22]. Regarding the relatively comparable specificity of the combination of the five tests (~%75)[4] to the mid-range of MRI specificity (~%80)[21,22], we significantly reduce the cost of our study by accepting about %15 sensitivity loss using the five tests. Therefore, the results were adjusted to consider the relative sensitivity and specificity of the chosen method based on the method proposed by Staquet et al.[25].

We found only one other test with a relatively similar approach in the literature, introduced by Corso et al. in 1995, titled of impingement relief test. In this test, the examiner evaluates the effects of a posterior or inferior-posterior humeral head glide on the patient's pain. However, the test properties, including sensitivity and specificity, are not available[31].

As a rule of thumb, a test is useful if it has a sum of sensitivity and specificity of at least 1.5, halfway between 1, which is useless, and 2, which is perfect[32]. Accordingly, our proposed maneuver's sum of sensitivity and specificity was calculated as 1.35 (0.554+0.798), meaning that it has a performance close to an acceptable value. Meanwhile, the most powerful tests for diagnosing SIS have shown similar performances regarding their sensitivity and specificity, including Hawkins- Kennedy (0.8+0.56=1.36), Neer (0.72+0.6=1.32), and painful arc (0.53+0.76=1.29)[9]. Therefore, ATA test can compete with these tests while having great specificity. Additionally, it is a safe test that does not require amplifying the patient's pain to distinguish the problem.

## LIMITATION

We acknowledge that potential biases exist in our investigation. Initially, we used the combination of five impingement tests for diagnosing SIS as a reference test instead of a more accurate method such as arthroscopy or MRI. Accordingly, the results of this study are estimations of the characteristics of this test rather than accurate determinations. Subsequently, as it was the first attempt to evaluate the diagnostic characteristics of the ATA test, we designed our single center study as a proof of concept, aiming to be non-invasive for participants and less expensive to see if we could find the primary evidence to justify future studies' ethical and financial issues. Therefore, we needed to know this initially to pursue further research with a higher power, requiring higher expenses and ethical considerations, as well as to encourage other centers to cooperate in multicenter studies.

Finally, we studied the new test regardless of the severity of SIS. Due to this, we could not discriminate its performance at different stages of the disease.

## CONCLUSION

We introduce the ATA test as a non-provocative method for shoulder pain designed to differentiate between problems caused by SIS and other underlying issues. The ATA test showed acceptable diagnostic features with at least 55.5% (CI: 45%-65%) sensitivity and 79.8% (CI:70%-87%) Specificity as a single test. We suggest further studies for more robust evidence by comparing the test with a gold-standard tool.

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