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# Effect of adding high-intensity strengthening exercises to conventional physiotherapy in athletes with shoulder impingement syndrome: A randomized controlled trial

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## ABSTRACT

This study aimed to investigate the effect of adding high-intensity strengthening exercises (HISE) to the conventional physiotherapy program in athletes with shoulder impingement syndrome (SIS). Thirty-two athletes with SIS were randomly and equally assigned into two groups; HISE group (n=16) and conventional physiotherapy group (n=16). The HISE group received both HISE and conventional physiotherapy programs, while the conventional physiotherapy group received only the conventional physiotherapy program. Both groups received a total of 18 sessions at a rate of 3 sessions/week for six weeks. Outcome measures included shoulder function and performance, muscle strength of the external and internal rotators and supraspinatus, acromio-humeral distance at 0° and 90° abduction, and supraspinatus tendon thickness. There was a significant improvement in shoulder performance (p=0.029), shoulder muscle strength of external rotators at 0 abduction (p<0.001) and at 90-90 abduction/external rotation (p<0.001), internal rotators at 0 abduction (p=0.001) and at 90-90 abduction/external rotation (p=0.001), and supraspinatus muscle (p<0.001), acromio-humeral distance at 0 (p=0.031) and 90 degrees of active abduction (p<0.001), and supraspinatus tendon thickness (p=0.009) in the HISE group compared to the conventional physiotherapy group post-treatment. However, no significant difference was observed in shoulder function (p=0.259). It could be concluded that the addition of supervised progressive HISE to the conventional physiotherapy in SIS in athletes improves shoulder performance, muscle strength, acromio-humeral distance, and supraspinatus tendon thickness.

**KEYWORDS**

High-Intensity Strengthening Exercises; Physiotherapy; Shoulder Impingement Syndrome; Throwing; Overhead Athlete

## 1. INTRODUCTION

The condition known as shoulder impingement syndrome (SIS) was initially identified by Neer, who defined it as a mechanical compression of the tendons of the rotator cuff and the subacromial bursa against the coracoacromial ligament and the undersurface of the acromion, especially when the arm is elevated (Neer, 1972). It has also been defined in more recent research as a collection of symptoms rather than a particular diagnosis (Cools et al., 2007). The prevalence of shoulder impingement is as high as 16 to 40% of shoulder complaints, which is frequently observed in certain sports such as swimmers, Basketball players, and Handball players. Repetitive shoulder elevation at or above 60 degrees in any of the three plans of freedom of movement has been reported with higher incidence rates of shoulder tendinitis or nonspecific shoulder pain (Hagberg & Wegman, 1987; Ludewig & Cook, 2000).

The scapular position is an important factor for the proper function of the upper limb specifically the shoulder. This position is retraction and external rotation, which facilitates proper and maximal activation of the scapular muscles (Kibler et al., 2001). Also, this allows the synergistic muscle activation of the hip and trunk to affect the shoulder through scapulothoracic articulation. As well, by activating the muscles in this particular order, the retracted scapular position provides a stable foundation for the origin of all rotator cuff muscles, resulting in ideal concavity compression (Lippitt et al., 1993; Sciascia & Cromwell, 2012).

Altered anatomical alignment of the scapula has been found to affect its kinematics which results in dysfunction in the normal kinetic chain and hence predisposes it to injury and malfunction (Cools et al., 2014). Furthermore, overhead athletes complaining of impingement syndromes were observed to have an abnormal recruitment pattern of all parts of the trapezius muscle; upper, middle and lower parts. Therefore, rehabilitation of those athletes with impingement syndromes or scapular dyskinesis was initiated with single-plane intervention in an attempt to obtain efficient and independent activation of only the middle and lower parts of the trapezius muscle in addition to the serratus anterior and reduction of the activity of the upper part of the trapezius (Cools et al., 2003).

The rotator cuff muscles also play a vital role in the normal arthrokinematics of the shoulder joint which optimize its function in overhead athletes. Rotator cuff power and control must be sufficient to maintain an adequate amount of glenohumeral joint congruency to allow proper function (Sharkey & Marder, 1995).

Most research advocates that the majority of shoulder impingement syndrome cases usually recover with non-surgical interventions. In the conservative track of treatment, the aim was to control pain and return to normal function while maintaining a normal passive shoulder range of motion. Strengthening of the rotator cuff muscles was a cornerstone in the rehabilitation program for shoulder impingement; aiming to restore its capability to control humeral head movement and to prevent further progressive degeneration of those tendons (Ardıç et al., 2006).

According to the clinical guidelines, exercise therapy targeting the rotator cuff and scapular stabilizing muscles is recommended for the treatment of subacromial pain syndrome (SAPS). It was advised to follow a low-intensity, high-frequency training regimen within the tolerable pain limit, with an emphasis on eccentric loading (Dierckx et al., 2014). In addition, individuals suffering from SIS require roughly 50% greater shoulder strength to regain asymptomatic motion and reach the level of the unaffected shoulder (MacDermid et al., 2004; Clausen et al., 2017).

Although it is advised to incorporate shoulder muscle strengthening into the conservative therapy for subacromial impingement, the current method does not appear to sufficiently increase the shoulder muscular strength (Lombardi et al., 2008; Bennell et al., 2010; Clausen et al., 2018). This failure may be attributed to the dose of strengthening exercise which may be insufficient to improve muscle power. Consequently, patients with SIS, especially athletes, may require a larger dosage of exercises to enhance muscular power and manage shoulder impingement-related symptoms (Malliaras et al., 2020).

Therefore, this study aims to investigate the effect of adding high-intensity strengthening exercises (HISE) to the conventional physiotherapy program on shoulder function, shoulder performance, shoulder muscle strength, acromiohumeral distance, and supraspinatus tendon thickness.

## 2. METHODS

### 2.1. Design and Participants

This study was a two-group pretest-post-test double blinded randomized controlled trial (RCT). The study was approved by the institutional review board of the Faculty of Physical Therapy, Cairo University (P.T.REC/012/004361), and the trial was registered (ClinicalTrials.gov: NCT05950880). All participants provided written consent forms. This study was conducted between January and

December 2023 in the outpatient clinic of the Faculty of Physical Therapy, Modern University for Technology and Information (MTI) University, Cairo, Egypt. We followed the Consolidated Standards of Reporting Trials (CONSORT) when reporting this RCT (Schulz et al., 2010).

Thirty-two athletic patients with SIS were recruited using the following inclusion criteria: 18–35 years of age, presence of unilateral shoulder pain more than 3 months, presence of pain at night or incapable of lying on the affected shoulder, presence of a positive Hawkins-Kennedy, and Empty or Full Can tests, presence of pain with active shoulder elevation in the scapular plane, presence of history of pain in the C5-C6 dermatome, presence of pain with palpation of the rotator cuff tendons, and presence of history of pain with resisted isometric abduction (Michener et al., 2009).

Participants were excluded if any of the following exclusion criteria existed: presence of history of shoulder instability (positive Sulcus sign, positive apprehension test, and history of shoulder dislocation), presence of labral lesions, capsular or ligamentous tears or avulsions, or cartilage lesions, presence of clinical signs of cervical radiculopathy, presence of acromioclavicular pain, presence of rheumatoid arthritis, presence of adhesive capsulitis, and presence of tumors (Michener et al., 2009).

### 2.2. Randomization and Blinding

The patients were randomly and equally assigned by a random sequence generator website (www.randomization.com) into two groups with an allocation ratio of 1:1. Allocation was calculated using sequentially numbered sealed opaque envelopes. All patients were blinded to group allocation by ensuring that they were unaware of the exercises performed by the other group. The outcome assessor was also blinded. Furthermore, the statistician who analyzed the current results was blinded to the aim of the current study and the treatments delivered.

### 2.3. Interventions

Patients were allocated into either the conventional physiotherapy group or the high-intensity strengthening exercises group. Both groups received 18 sessions of exercise training for 6 weeks, at a rate of 3 times per week.

#### 2.3.1. Conventional physiotherapy group

Patients in this group received the conventional physical therapy program for SIS that consisted of supervised progressive scapular muscle-strengthening exercises (Cools et al., 2007), Rotator cuff strengthening exercises (Ellenbecker & Cools, 2010; Ha et al., 2013), and posterior capsule stretch (Cools et al., 2012). Every exercise was done in three sets of ten repetitions, with a sixty-second rest in between (Bang & Deyle, 2000). Scapular muscle-strengthening exercises included prone extension, forward flexion in side-lying and the affected shoulder is the uppermost, external rotation in side lying, and prone horizontal abduction with external rotation as reported by Cools et al. (2007a) & Cools et al. (2007b). Scapular muscle-strengthening exercises were performed using dumbbells with concentration on quality of movement and neuromuscular control. Rotator cuff strengthening exercises included external rotation strengthening exercises from side lying using dumbbells (Ha et al., 2013) and from standing using TheraBand (Ellenbecker & Cools, 2010). Posterior capsular stretch was performed from the side-lying position either by the therapist or by the patient for 30 seconds maintenance and repeated four times as reported by Ellenbecker et al. (2012).

### 2.3.2. High-intensity strengthening exercises (HISE) group

Patients in this group received supervised progressive HISE in addition to the conventional physiotherapy program. The HISE included external rotation exercises from 0° and 90° abduction and full cane exercise. These exercises were performed at a resistance of 90% of 1 repetition maximum (1 RM) with slow dynamic contraction and a 5-second isometric contraction at the end range. Patients performed each exercise for three to five repetitions for three sets with a 2-minutes rest interval period between sets (National Strength and Conditioning Association, 2021; Schoenfeld et al., 2021). The 1 RM was determined using a hand-held dynamometer, then the adjustable free weight was set at 90% of the 1 RM. At any session, if the patient was able to perform more than 5 repetitions per set, 1 RM was reassessed, and the adjustable weight was reset again at 90% of the 1 RM.

## 2.4. Outcome Measures

They included shoulder pain and function, shoulder performance, shoulder muscle strength, supraspinatus muscle thickness, and acromiohumeral distance (AHD). They were obtained at baseline before intervention and post-intervention (six weeks after baseline) by a blind assessor.

### 2.4.1. Shoulder pain and function

Shoulder pain and function were measured using the valid and reliable shoulder pain and disability index (SPADI) (Roddey et al., 2000; MacDermid et al., 2006; Kromer et al., 2014). We used the Arabic version of SPADI (Alsanawi et al., 2015). It has a strong interrater agreement (ICC = 0.96) and a Cronbach alpha coefficient of 0.911. SPADI has 12 items assessing 2 domains, 5 for pain and 7 for function. Each item is assessed on a scale of 10 then the percentage of the total score is calculated. SPADI has a total score ranging from 0 to 100% with the higher scores indicating significant disability, and a minimal clinically important difference (MCID) of 12 points (Roy et al., 2009).

### 2.4.2. Shoulder performance

Shoulder performance was measured using the timed push-up test. The participants started with their elbows completely extended in the "up" position and they were asked to flex their elbows as they descended towards the ground, bringing their upper arms parallel to the testing surface. Push-ups were performed throughout the full range of motion and as quickly as possible. Three maximal trials were preceded by a warm-up trial. The three trials of maximum effort were conducted for 15 seconds for each, with a 45-second rest in between. The number of push-ups performed in each of the three trials was counted and the average of the three trials was used for analysis. All patients received verbal encouragement regularly to guarantee a maximum effort during all assessment procedures. Psychometric Properties for this test revealed that the minimal detectable change (MDC) is 2 repetitions and the test-retest reliability is 0.96 (Negrete et al., 2010).

### 2.4.3. Shoulder muscle strength

A hand-held dynamometer (HHD) was used for the assessment of the strength of the shoulder's external and internal rotators and supraspinatus muscle. The peak isometric strength of the external and internal rotators was obtained at 0 abduction and 90-90 abduction and external rotation from sitting position (Cools et al., 2014). The peak isometric strength of the supraspinatus muscle was obtained while the patient was standing and the shoulder elevated for 90 degrees in the scapular plane (45° from the frontal plane), midway between internal and external rotation with the thumb up (Full can position) (Cools et al., 2014). Three measurements of peak isometric strength of each group were taken and the average force value (N) of the three measurements was used and normalized to body weight (N/kg) (Morin et al., 2022). Patients were asked to do maximal isometric contraction for 5 seconds and rest for one minute between measurements. All patients received verbal encouragement regularly to guarantee maximal effort.

### 2.4.4. Acromiohumeral distance (AHD) and supraspinatus tendon thickness

Aixplorer diagnostic ultrasound machine was used in conjunction with an 8-12 Hz linear transducer (SuperSonic Imagine, Aix-en-Provence, France) for the measurement of acromiohumeral distance (AHD) and supraspinatus muscle thickness. AHD at 0 degrees and 90 degrees of active abduction was measured by positioning the transducer on the lateral surface of the shoulder along the longitudinal axis of the humerus (Desmeules et al., 2004) as shown in Figure 1 (A and B). To measure the supraspinatus tendon thickness, patients were asked to place their hands in their back pockets (Cholewinski et al., 2008). A short-axis view was taken as near as feasible to the greater tuberosity's supraspinatus tendon footprint to determine the maximal thickness as shown in Figure 1 (C). The measurements were made from the subdeltoid bursa's undersurface to the articular cartilage (Malanga et al., 2012). Test-retest reliability of the AHD and the supraspinatus tendon thickness has been reported to be excellent (ICC=0.922, and ICC=0.933 respectively) (Leong et al., 2012).

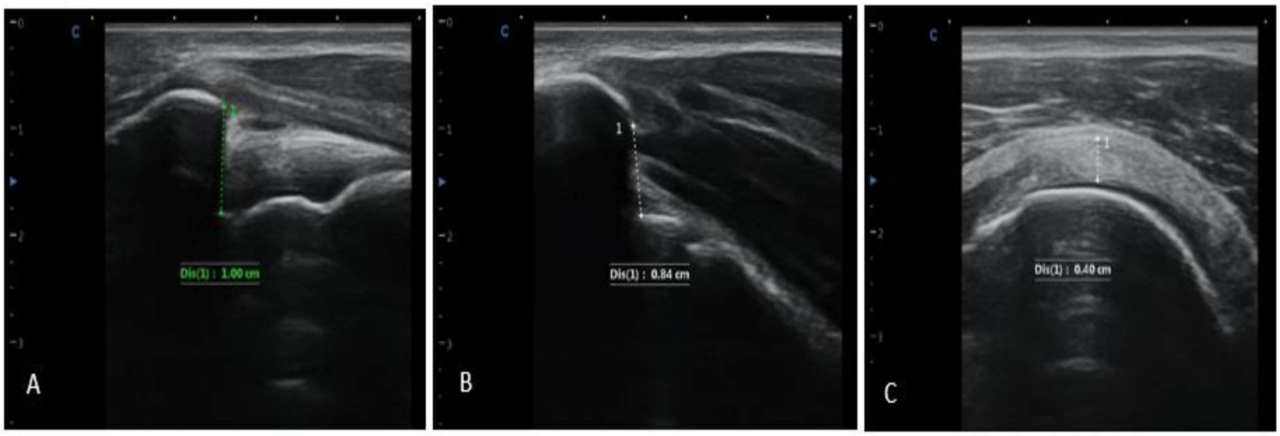


**Figure 1.** A) Acromiohumeral distance at 0 degrees. B) Acromiohumeral distance at 90 degrees. C) Supraspinatus tendon thickness

### 2.5. Sample Size Calculation

The sample size was calculated using GPower software (GPower 3.1.9.7). Based on the minimum clinically important difference (MCID) of 12% on the SPADI (Roy et al., 2009), a standard deviation for the SPADI = 10.32 (Sharma et al., 2021), a two-tailed α: .05, and a power of 80%, an estimated 13 patients were required in each of the intervention groups. The number increased by 20% to overcome the expected dropouts. The total number was 16 for each group.

### 2.6. Statistical Analyses

The version 26 of SPSS for Windows was used to do statistical analysis (SPSS, Inc., Chicago, IL). Before final analysis, data were screened for normality assumption, homogeneity of variance, and presence of extreme scores and the p-value was set at $< 0.05$. This analysis was done before the parametric testing of the analysis of differences. Comparison between mean values of the different parameters in the two groups was performed using repeated measure MANOVA test to determine the significant differences between both groups at the two times testing intervals (pre and post).

## 3. RESULTS

A total of 59 patients were evaluated in the clinic for potential inclusion in this study. A flow diagram of the study is shown in Figure 2. Thirty-two participants were randomized to the HISE group and conventional physiotherapy group. The two groups were similar at the baseline for all characteristics except for age and body mass index (BMI).

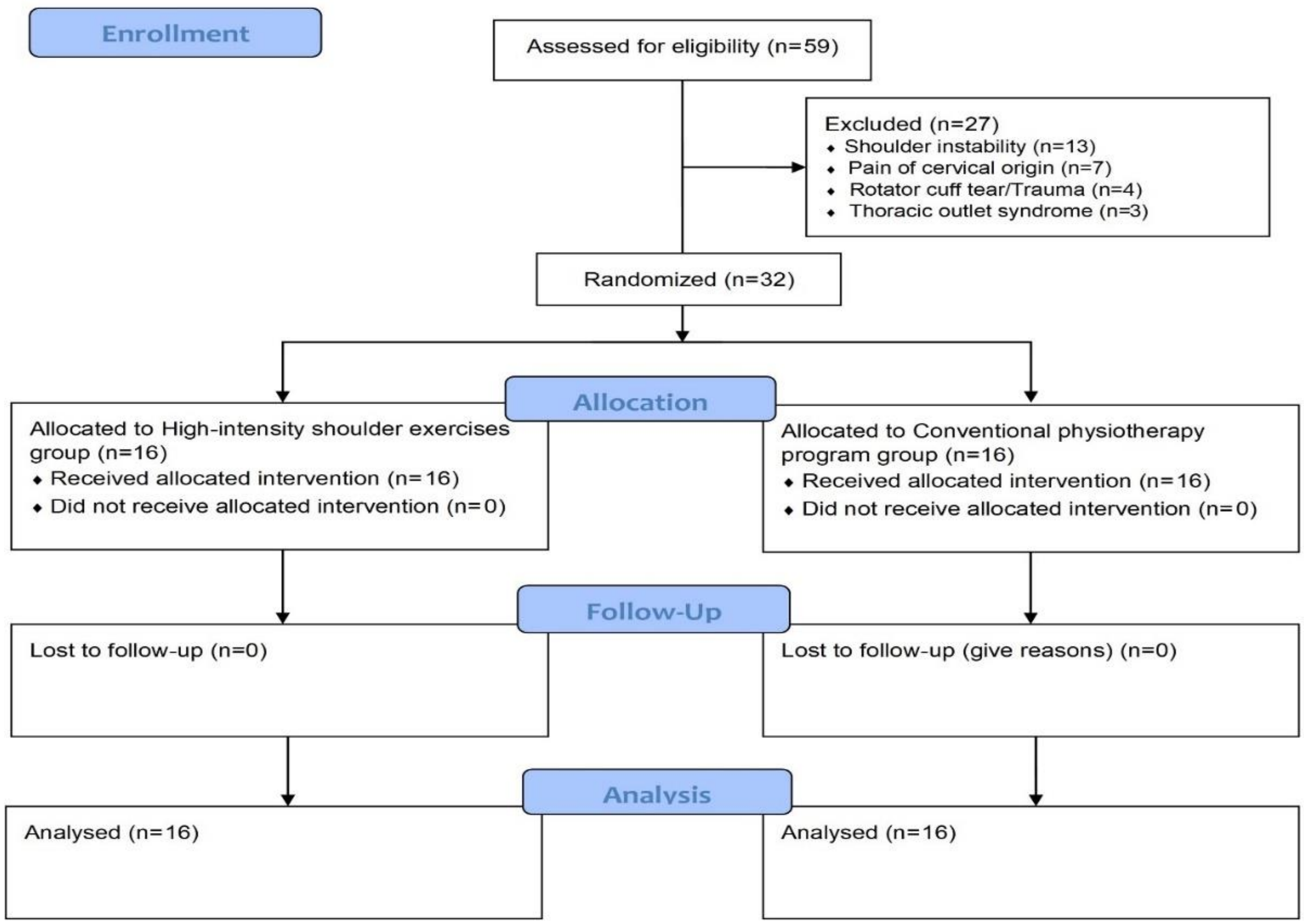


**Figure 2.** Study flow diagram

The characteristics of the participants are shown in Table 1. At baseline, there were significant differences between the groups in age (p=0.033) and BMI (p=0.023), with the conventional physiotherapy group being slightly older and having a higher BMI. No significant differences were found in weight (p=0.906), height (p=0.054), gender (p=1), or type of sport (p=0.66), indicating that the groups were generally similar in these characteristics (Table 1).

**Table 1.** Participants' characteristics at baseline

| Variable | High-intensity exercise group (n=16) | Conventional Physiotherapy group (n=16) | p-value |
|---|---|---|---|
| **Age (years)** | 23.13±4.241 | 26.44±4.163 | 0.033* |
| **Weight (kg)** | 71.94±8.33 | 71.56±9.423 | 0.906 |
| **Height (cm)** | 179.13±8.057 | 173.63±7.464 | 0.054 |
| **BMI (kg/m²)** | 22.331±0.997 | 23.631±1.926 | 0.023* |
| **Gender, n (%)** | | | |
| **Male** | 13 (81.25%) | 13 (81.25%) | 1 |
| **Female** | 3 (18.75%) | 3 (18.75%) | |
| **Type of sport** | | | |
| **Basketball** | 2 (12.5 %) | 3 (18.75%) | 0.66 |
| **Volleyball** | 1 (6.25%) | 2 (12.5 %) | |
| **Swimming** | 3 (18.75%) | 4 (25%) | |
| **Climbing** | 2 (12.5 %) | 2 (12.5 %) | |
| **Judo** | 1 (6.25%) | 1 (6.25%) | |
| **Boxing** | 3 (18.75%) | 2 (12.5 %) | |
| **Handball** | 3 (18.75%) | 1 (6.25%) | |
| **Pentathlon** | 1 (6.25%) | 1 (6.25%) | |

***Note.*** *BMI; Body mass index; Continuous values are expressed in mean ± standard deviation; *; significant*

In the following, Table 2 demonstrates the effect of the intervention on the measured outcomes by presenting the changes observed from baseline to post-intervention.

**Table 2**. Changes in outcome measures from baseline to post-intervention

| Outcome measure | High-intensity exercises Group (n=16) (mean±SD) | Conventional Physiotherapy Group (n=16) (mean±SD) | p-value | Between-group MD (95% CI) |
|---|---|---|---|---|
| **SPADI (0-100%)** | | | | |
| **Pre-treatment** | 26.1±9.18 | 27.83±9.78 | 0.609 | -1.73 (-8.58; 5.11) |
| **Post-treatment** | 3.79±3.06 | 5.19±3.78 | 0.259 | -1.4 (-3.88; 1.08) |
| **P-value** | <0.001* | <0.001* | | |
| **Within-group MD (95% CI)** | -22.31(-26.41; -18.22) | -22.64 (-26.4; -18.9) | | |
| **Timed push-up test** | | | | |
| **Pre-treatment** | 9.94±2.63 | 9.85±2.84 | 0.928 | 0.09 (-1.89; 2.06) |
| **Post-treatment** | 16.61±3.13 | 14.13±2.99 | 0.029* | 2.48 (0.28; 4.7) |
| **P-value** | <0.001* | <0.001* | | |
| **Within-group MD (95% CI)** | 6.67 (5.56; 7.79) | 4.28 (3.12; 5.43) | | |
| **Peak isometric strength of shoulder external rotators at 0 abduction (N/kg)** | | | | |

| | | | | |
|---|---|---|---|---|
| **Pre-treatment** | 1.56±0.48 | 1.64±0.51 | 0.669 | -0.08 (-0.43; 0.28) |
| **Post-treatment** | 2.94±0.72 | 1.71±0.42 | <0.001* | 1.23 (0.81; 1.66) |
| **P-value** | <0.001* | 0.21 | | |
| **Within-group MD (95% CI)** | 1.38 (1.1; 1.66) | 0.07 (-0.05; 0.19) | | |
| **Peak isometric strength of shoulder external rotators at 90-90 abduction/ER (N/kg)** | | | | |
| **Pre-treatment** | 1.23±0.40 | 1.24±0.51 | 0.948 | -0.01 (-0.34; 0.32) |
| **Post-treatment** | 2.41±0.59 | 1.46±0.41 | <0.001* | 0.95 (0.59; 1.32) |
| **P-value** | <0.001* | 0.014* | | |
| **Within-group MD (95% CI)** | 1.18 (0.92; 1.43) | 0.22 (0.05; 0.38) | | |
| **Peak isometric strength of shoulder internal rotators at 0 abduction (N/kg)** | | | | |
| **Pre-treatment** | 2.22±0.69 | 2.38±0.72 | 0.513 | -0.17 (-0.67; 0.34) |
| **Post-treatment** | 3.36±0.77 | 2.49±0.56 | 0.001* | 0.87 (0.39; 1.36) |
| **P-value** | <0.001* | 0.334 | | |
| **Within-group MD (95% CI)** | 1.15 (0.87; 1.42) | 0.11 (-0.12; 0.34) | | |
| **Peak isometric strength of shoulder internal rotators at 90-90 abduction/ER (N/kg)** | | | | |
| **Pre-treatment** | 1.71±0.62 | 1.83±0.61 | 0.588 | -0.12 (-0.56; 0.33) |
| **Post-treatment** | 2.73±0.68 | 1.96±0.51 | 0.001* | 0.77 (0.33; 1.20) |
| **P-value** | <0.001* | 0.1 | | |
| **Within-group MD (95% CI)** | 1.02 (0.75; 1.29) | 0.13 (-0.03; 0.3) | | |
| **Peak isometric strength of supraspinatus muscle (N/kg)** | | | | |
| **Pre-treatment** | 1.41±0.42 | 1.45±0.47 | 0.81 | -0.04 (-0.36; 0.28) |
| **Post-treatment** | 2.31±0.39 | 1.59±0.41 | <0.001* | 0.72 (0.43; 1.01) |
| **P-value** | <0.001* | 0.021* | | |
| **Within-group MD (95% CI)** | 0.9 (0.73; 1.07) | 0.14 (0.03; 0.27) | | |
| **AHD at 0 degrees of active abduction (cm)** | | | | |
| **Pre-treatment** | 1.19±0.1 | 1.13±0.1 | 0.092 | 0.06 (-0.01; 0.14) |
| **Post-treatment** | 1.23±0.08 | 1.15±0.12 | 0.031* | 0.08 (0.01; 0.15) |
| **P-value** | 0.006* | 0.103 | | |
| **Within-group MD (95% CI)** | 0.04 (0.01; 0.07) | 0.03 (-0.01; 0.06) | | |
| **AHD at 90 degrees of active abduction (cm)** | | | | |
| **Pre-treatment** | 0.85±0.06 | 0.87±0.13 | 0.624 | -0.02 (-0.09; 0.06) |
| **Post-treatment** | 1.14±0.09 | 1±0.1 | <0.001* | 0.13 (0.06; 0.2) |
| **P-value** | <0.001* | <0.001* | | |
| **Within-group MD (95% CI)** | 0.29 (0.24; 0.33) | 0.13 (0.09; 0.18) | | |

| | | | | |
|---|---|---|---|---|
| **Supraspinatus tendon thickness (cm)** | | | | |
| **Pre-treatment** | 0.76±0.08 | 0.67±0.08 | 0.002* | 0.0944 (0.04; 0.15) |
| **Post-treatment** | 0.55±0.07 | 0.62±0.07 | 0.009* | -0.07 (-0.12; -0.02) |
| **P-value** | <0.001* | <0.001* | | |
| **Within-group MD (95% CI)** | -0.21 (-0.24; -0.18) | -0.05 (-0.07; -0.03) | | |

***Note.*** *AHD; acromiohumeral distance, CI; confidence interval, ER; external rotation, MD; mean difference, SPADI; shoulder pain and disability index; *; significant*

No significant difference was observed in the SPADI of the HISE group compared to that of the conventional physiotherapy group at post-treatment (p = 0.259). There were significant differences in timed push-up test (p = 0.029), peak isometric strength of shoulder external rotators at 0 abduction (p < 0.001), peak isometric strength of shoulder external rotators at 90-90 abduction/ external rotation (p < 0.001), peak isometric strength of shoulder internal rotators at 0 abduction (p < 0.001), peak isometric strength of shoulder internal rotators at 90-90 abduction/ external rotation (p = 0.001), peak isometric strength of supraspinatus muscle (p < 0.001), AHD at 0 degrees (p = 0.031), AHD at 90 degrees (p < 0.001), and supraspinatus tendon thickness (p = 0.009) in HISE group compared to conventional physiotherapy group at post-treatment as shown in Table 2 above.

## 4. DISCUSSION

Our study investigated the effects of adding HISE to the conventional physiotherapy program compared to the conventional physiotherapy program alone in the rehabilitation program of athletes with SIS. Our results demonstrated that the addition of HISE resulted in greater improvement in performance, muscle strength, AHD, and supraspinatus tendon thickness suggesting that HISE may have a greater impact on tissue structure. However, those receiving HISE did not experience significantly greater improvement in function over conventional physiotherapy program in this population.

Strengthening exercises and motor control exercises are exercise approaches proposed in the literature for managing musculoskeletal conditions (Lafrance et al., 2021). While the concept behind motor control exercises is to perform specific muscle activation with focusing on the quality of movement to improve neuromuscular control (Lafrance et al., 2021), strengthening exercises depend on increasing the load on muscle to trigger neuromuscular adaptations (Hughes et al., 2018). Currently, there is no consensus on the best parameters for the prescription of strengthening exercises. Furthermore, the effectiveness of using lower loads to induce physiological changes of strengthening is still questionable (Bohm et al., 2015). Therefore, we performed HISE at 90% of 1 RM in our study to ensure that the physiological load applied to muscles is sufficient to produce the physiological changes of strengthening.

Notably, the concept of HISE has not been intensively studied in the literature. To the best of our knowledge, only one study has previously addressed the effect of HISE, performed at 90% of 1 RM, on SIS (Dubé et al., 2023). Dubé et al. (2023) compared the effects of three different interventions for SIS (HISE and education, motor control exercises and education, and education alone) on function, ultrasonographic measurements of AHD at rest and 60° of active abduction, and shoulder abductors and external rotators strength. Interestingly, they found that none of the three groups outperformed the other.

In our study, improvement in function was observed in both groups as demonstrated by decreased SPADI scores after six weeks, which indicates better function. The improvement observed in both groups was similar. Therefore, there was no significant difference between groups. This finding is consistent with Dubé et al. (2023), who found no significant difference in function measured by Disability of Arm, Shoulder and Hand Questionnaire between the group received HISE and education and the group received education alone.

On the other hand, performance improvement measured by Timed pushup was greater in the HISE group than conventional physiotherapy group. This may be due to the improvement observed in muscle strength, which was greater in the HISE group compared to the conventional physiotherapy group. While muscle strength was observed in shoulder external rotators at 0 abduction and 90-90 abduction/external rotation, shoulder internal rotators at 0 abduction and 90-90 abduction/external rotation, and supraspinatus muscle in the HISE group, the conventional physiotherapy group showed improvement only in strength of shoulder external rotators at 90-90 abduction/external rotation and supraspinatus muscle. The slight improvement in muscle strength in the conventional physiotherapy group may be due to the reduction of muscle inhibition caused by pain (Sterling et al., 2001; Glover & Baker, 2020). However, in the HISE group, the improvement may be attributed to the increase in muscle strength in addition to the reduction of muscle inhibition. By comparing our study with previous literature, Dubé et al. (2023) found no significant difference in shoulder abductors and external rotators strength between the group received HISE and education and the group received education alone.

Furthermore, there was an increase in AHD at 0 degrees of active abduction in the HISE group with no increase in the conventional physiotherapy group. However, an increase in AHD at 90 degrees of active abduction was observed in both groups. The improvements in both groups may be due to increased neuromuscular control in glenohumeral and scapular muscles, which keeps the humeral head centralized with the glenoid. Of note, the improvement in both AHD at 0 and 90 degrees of active abduction was greater in the HISE group than in the conventional physiotherapy group, which may be due to higher muscle strength that may cause more increase in neuromuscular control on the humeral head during static and dynamic status. Additionally, a reduction in supraspinatus tendon thickness was observed in both groups, with a greater reduction in the HISE group. Exercise loading, especially in HISE, affects the mechanical properties of the tendon and the inflammatory process, which may lead to a decrease in its thickness (Docking & Cook, 2019). By comparing our study with previous literature, Dubé et al. (2023), found no significant difference in AHD at 0 degrees of active abduction and 90 degrees of active abduction between the group received HISE and education and the group received education alone.

Overall, Dubé et al. (2023) found that the group received HISE and education was not superior to the group received education alone, which contradicts the findings of our study that HISE improved muscle strength and biomechanics regarding AHD. The explanation for this may be due to differences in the type of participants. We included only young athletes and Dubé et al. (2023) included any participants with SIS. Additionally, we performed HISE, which was supervised in all sessions, at 90% of 1 repetition maximum from three up to five repetitions for three sets with two minute interval between sets. Participants in our study received three sessions per week for six weeks. However, In their study, HISE was performed for one set of the maximum number of repetitions until muscular fatigue. Only six sessions were delivered over a 12-week period, which may not exceed the minimum effective dose of exercises (Dubé et al., 2023).

Based on our results, adding HISE is recommended for shoulder rehabilitation programs as it increases muscle strength and decreases supraspinatus thickness, which may be associated with a decreased likelihood of future shoulder pain. Further research is recommended to assess the effect of HISE on the recurrence of shoulder pain and subacromial impingement.

Several strength points exist in our trial. Instead of the regular population, we included only young athlete patients, whose activities need a high level of strength. The intervention in our study was under the supervision of the primary investigator and was progressive with higher dose. Three sessions per week were delivered to those athletic patients to ensure the effective dose of exercises that matches their higher demand for power and performance in competition.

Additionally, the inclusion of both functional outcomes and structural changes allows for a comprehensive assessment of the study population. However, there was no longer follow-up of more than 6 weeks to assess maintenance of the efficacy and absence of recurrence. Further high-quality RCT with a longer time of follow-up and competition monitoring for recurrence may be recommended.

## 5. CONCLUSIONS

The addition of supervised progressive HISE to the conventional physiotherapy for athletes with SIS would improve their function, performance, muscle strength, and the structural properties of the shoulder as tendon thickness and AHD. The inclusion of HISE in the rehabilitation program of the athletic population with SIS is recommended.

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The authors declare no conflict of interest.


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