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Shoulder Muscles Strength, Rotators Strength Ratios, And Range of Motion in Relation to Pain, and Disability in Patients with Subacromial Impingement Syndrome: A Correlation Study

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Abstract
Objective: *This research examined the relationship between shoulder strength, external/internal rotators (EX/IR) ratio, and shoulder mobility, with pain and function disability in subjects with sub-acromial impingement syndrome (SIS).*
Design: *Cross-sectional study*
Methods: *Sixty subjects with SIS aged 30 to 40 years. Shoulder pain level was assessed by the visual analog scale (VAS). Shoulder functional impairment was assessed by the Disability of Arm, Shoulder and Hand index (DASH). The active ranges of motion (ROM), of shoulder flexion, abduction, external, and internal rotations, were measured using an inclinometer. Shoulder isometric muscles strength (IMS) including internal (IR) and external rotators (ER), flexors, and abductors, were assessed by the hand-held dynamometer (HHD). The ER/IR strength ratio was calculated from recorded IMS in the previous step.*
Results: *A statistically significant negative moderate correlation was identified between shoulder function impairment and shoulder flexors, abductors, and external rotators IMS, and flexion ROM. A statistically significant negative moderate correlation was found between pain intensity and external rotators IMS, flexion and abduction ROM ($p < 0.05$). There is no correlation between shoulder function impairment or pain, relevant to internal rotators IMS, ER/IR ratio, and internal rotation ROM ($p > 0.05$).*
Conclusion: *The findings of current research indicate a negative correlation between muscle strength, and shoulder mobility with pain intensity and function disability, but the ER/IR ratio is not correlated with pain and disability.*
Key words: *Shoulder impingement; pain; shoulder function disability; mobility and muscle strength.*

Introduction

Subacromial impingement is presumed to be among the prevalent causes of shoulder impairment, impacting millions of individuals globally (1,2). The condition was historically referred to as subacromial impingement syndrome, characterized by shoulder pain resulting from compression of the soft tissues (rotator cuff tendons, subacromial bursa) by the inferior portion of the acromion (3). Patients with SIS commonly experience shoulder pain and inflammation from excessive and repetitive shoulder movement, limited range of movement, and muscle dysfunction (4-6). These symptoms can cause sleep disturbances and decreased physical activity, lowering the quality of living (7).

Shoulder joint stability depends critically on the balance of agonist and antagonist muscle strength, which guarantees the humeral head's dynamic centering (8-10). The shoulder rotator cuff is essential in ensuring that the head of the humerus is dynamically centered relative to the glenoid (7, 8). Consequently, it is critical to maintain the proper balance between the rotators of the shoulder (11, 12). Additionally, strength ratios are

more clinically significant due to their role in shoulder stability and maintaining acromiohumeral distance (13-15).

During active arm movements, the humeral head is stabilized by the shoulder rotator muscles; the external rotators should have sufficient power to allow the rotating cuff tendons to pass beneath the acromion to prevent impingement of tendons (16). The shoulder's ER strength and ER/IR ratio have an important role in controlling the head of the humerus against the pulling action of the deltoid muscle during upper limb movement (15).

Dysfunction of shoulder mobility has been recognized as a contributing factor for function disability of the shoulder in addition to strength deficits. The internal rotation has drawn a lot of attention in the literature among the motions measured due to its correlation with shoulder disorders (13). A recent systematic review demonstrated that there was moderate to strong certainty of evidence that participants with shoulder impingement syndrome have reduced shoulder mobility (flexion and rotation), and reduced shoulder internal rotators power when compared to asymptomatic individuals (17).

The knowledge about the correlation between shoulder range of motion, shoulder muscles strength and IR/ER ratio, shoulder pain level, and functional disability in participants with SIS is important for good treatment programs. To date, no previous study has examined correlation between pain intensity, function disability strength of shoulder muscles, ER/IR ratio, and shoulder mobility in nonathletic SIS. The primary aim is to investigate the association between pain intensity, function disability with shoulder muscle, ER/IR strength ratio, and range of movement (ROM) in SIS. The secondary aim is to evaluate shoulder muscles strength, ER/IR strength ratio, and shoulder mobility between males and females with SIS.

Subjects and Methods:

Study design

Participants of SIS have been enrolled in an observational study (cross-sectional design) from February 1, 2023, to November 30, 2023, by a referral from an orthopedic surgeon by clinical and radiological examination to identify SIS. The research was performed at an outpatient clinic of Alexandria's Elhadra University Hospital, it was granted approval by the ethical board of the faculty of physical therapy at Cairo University (P.T. REC/012/004174). Prior to the start of the study's data collection, all participants were instructed to sign an informed consent.

Participants:

Sixty adult participants with SIS (30 and 40 years) participated in the present study. The criteria for inclusion: 1) patients were experienced localized pain in the proximal anterolateral part of the shoulder, 2) At least 3 in 5 impingement tests are positive (Hawkins-Kennedy, resisted external rotation, Neers, Painful arc, and Jobes) (18). The criteria for exclusion were rotator cuff tears, osteoarthritis in the acromioclavicular or glenohumeral joints, moderate to severe glenohumeral joint instability, a history of shoulder fractures or dislocations, neck dysfunction with radicular pain, neurological deficiencies in the upper limbs, and systemic inflammatory arthritis conditions (19).

Procedures:

The researcher provided participants with an educational presentation outlining the study's goals and methodology. Pain, shoulder function, range of motion, muscle strength, and EX/IR ratio were the study's outcome measures. The evaluation was conducted by a qualified assessor.

Pain and function

Pain intensity: The visual analog scale (VAS), a reliable and valid scale for individuals with rotator cuff disease, was used to assess the degree of pain (20). The VAS includes a 10-cm horizontal line with the words "no pain" and "worst imaginable pain" at either end acting as anchors. Every participant was instructed to point out on the VAS the place on the line that best reflected the level of pain they were experiencing.

Shoulder functional disability: The DASH questionnaire was employed; it is a valid and reliable method for

evaluating subjects with SIS (21). The 30 items include 21 items for functional activities that are difficult, five items for pain, pain-related activities, tingling, weakness, and stiffness, and 4 items for social activities, sleep and work, and psychological impact. The total score was calculated according to the equation "([(sum of n responses]-1) / n) x (25)", "n" represents the completed items. Lower scores indicated greater function, while higher values indicated inadequate function. The scores ranged from 100 to zero. The VAS and Arabic version of DASH questionnaires are filled out by each participant.

Shoulder mobility: The bubble inclinometer (Baseline® Bubble Inclinometer, Fabrication Enterprises INC, White Plains, New York 10602, USA) is often used to measure active mobility of the shoulder; shoulder (flexion and abduction) were performed while the subjects were seated. For shoulder flexion, the inclinometer base was aligned parallel to the midline of the biceps brachii, and for abduction, the inclinometer was positioned laterally on the arm (halfway between the acromion and the olecranon while the arm was flexed at 90°). For rotations, the participants were in a supine lying position with towels under the arm with elbow flexion of 90 degrees, the forearm in mid-position, and with the abduction shoulder at 90 degrees. The active ROM measurements were adopted from Tozzo et al, (2021) who approved the reliability of these measurements in participants with SIS (22). Two trials were collected, and the average of the two measures was employed in the statistical analysis.

Isometric muscle strength: The hand-held dynamometer (HHD) was used for measurement of shoulder IMS, which is valid and reliable for individuals with SIS (23) (Model 01165, Lafayette Instrument Company, Indiana, USA). Active shoulder rotations have been measured while the participants were lying down. The wrist was in neutral position, the elbow was flexed 90 degrees, and the shoulder was in 90 degrees abduction. The dynamometer was located on the volar aspect and 1 inch just above the styloid of the ulna for measuring internal rotators, and on the dorsal aspect for measuring external rotators.
For flexion, the shoulder was positioned in extension, the elbow full extension, and the HHD was positioned on the anterior surface of the arm, just above the elbow joint. For abduction, the shoulder was tested at 90° abduction and 90° elbow flexion. Perpendicular force was put up to the distal arm (24). The participants were told to exert all their force when pushing against the dynamometer. Strength was measured in kilograms (kg), and each trial involved an average of three 5-second contractions followed by a minute of rest to allow for muscle recovery (25). Participants were vocally encouraged during each contraction, and the average value was included in data analysis. The ratio was measured by first determining the isometric strength of both ER and IR using HHD, and then calculating the ER/IR ratio.

Statistical analysis:
For calculation, the size of the sample is determined by the G-Power program (version 3.1.9.7), depending on the pilot study (10 patients with SIS); effect size r= 0.4. Sample sizes of 53 patients were calculated to yield 80% statistical power. The Shapiro-Wilk test was performed to determine the normality of the data.. The Pearson correlation test has examined the correlation between pain intensity, function disability rotator cuff muscle strength, (ER/IR ratio), and shoulder mobility. A significant level for all the tests was set at $p < 0.05$. The correlation strength was classified as ("strong" ($r > 0.5$), "moderate" ($0.5 \geq r \geq 0.3$), or "poor" ($r < 0.3$))(26). For comparison between male and female subjects with SIS for all variables, an independent T-test was used. The statistical package for the social sciences SPSS (version 23.0, IBM, Armonk, NY, USA) was used for data analysis.

Results:
There was a significant and negative moderate relationship between shoulder function disability and shoulder flexors (r= -3, p= 0.031), abductors (r= -0.4, p=0.008), external rotators (r= -0.4, p= 0.005), and Flexion ROM (r= -0.4, p= 0.002). The correlation between shoulder function disability and internal rotators, ER/IR ratio, abduction ROM, external rotation ROM, and internal rotation ROM is not statistically important ($p > 0.05$). A significant and negative moderate association was found between pain intensity and external rotators (r= -0.3, p= 0.028), flexion ROM (r= -0.3, p= 0.012), and abduction ROM (r= -0.3, p=0.05). The association between pain intensity shoulder

flexors, abductors, internal rotators, ER/IR ratio, external rotation ROM, and internal rotation ROM is not statistically significant ($p > 0.05$) (table 1).

Table 1: correlation between pain intensity and function disability with shoulder muscle strength, ER/IR ratio, and shoulder mobility

Variables	Pain intensity (VAS)		Function disability (DASH)	
	r	P-value	r	P-value
Flexors isometric strength	-0.2	0.060	-.3	0.031*
Abductors isometric strength	-0.2	0.197	-0.4	0.008*
External rotator's isometric strength	-0.3	0.028*	-0.4	0.005*
The internal rotator's isometric strength	-0.2	0.141	-0.2	0.069
ER/IR ratio	-0.2	0.089	-0.2	0.105
Flexion ROM	-0.3	0.012*	-0.4	0.002*
Abduction ROM	-0.3	0.05*	-0.3	0.051
External rotation ROM	-0.02	0.902	-.161	0.218
Internal rotation ROM	-0.1	0.279	-0.3	0.058

ROM: range of motion; *: significant; r: person correlation

To target the secondary aim of the study, the sixty patients who participated in the study were sub- grouped into males (36 patients) and females (24 patients) to check for gender differences in shoulder muscles IMS, strength ratios, and shoulder ROM. No significant difference was noted between males and females groups in terms of age, BMI, pain intensity, or DASH. Significant differences were present in weight and height between both groups. (Table 2)

Table 2: Participants characteristics

variables	Male (n= 36)	Female (24)	P-value
age	35.5 ±3.4	34.5 ±3.3	0.268
weight	83.4 ±14.5	73.2 ±9.7	0.004*
height	176.4 ±7.7	163.4 ±6.9	0.000*
BMI	26.9 ±4.8	27.4 ±3.4	0.654
Pain intensity (VAS)	7.2 ±1.8	7.96 ±1.78	0.095
DASH	50.6 ±13.9	56.5 ±19.5	0.178

BMI: body mass index; VAS: visual analogue scale; DASH: Disability of Arm, Shoulder, and Hand index.

In the comparison between males and females in terms of isometric muscle strength, ER/IR ratio, and active shoulder ROM, no significant difference was seen between both groups for all measures ($P<0.05$), except for external rotators muscles (P- value= 0.044) (Table 3).

Table 3. Shoulder muscle strength, ROM difference between male and female SIS

Variables	Male (n= 36)	Female (n= 24)	95% Confidence Interval	P-value
Flexion ROM(degrees)	150.28 (±19.27)	141.25 (±15.62)	(-18.48, 0.42)	0.061
Abduction ROM (degrees)	137.58 (±30.1)	138.3 (±19.5)	(-13.19, 14.69)	0.915
External ROM(degrees)	64.86 (±17.9)	65.63 (±16.6)	(-8.42, 9.95)	0.868
Internal ROM(degrees)	80.14 (±15)	79.58 (±13.67)	(-8.23, 7.12)	0.885
Flexors strength(kg)	10.56 (±5.48)	8.8 (±3.5)	(-4.1, 0.5)	0.128
Abductors strength(kg)	8.66 (±4.4)	7.2 (±3.1)	(-3.56, 0.6)	0.160
External rotators strength(kg)	8.8 (±4.2)	6.79 (±2.75)	(-3.98, -0.06)	0.044*
Internal rotators strength(kg)	9.8 (±3.9)	8 (±3)	(-3.77, 0.13)	0.066
ER/IR Ratio	0.9 (±0.58)	0.92 (±0.33)	(-0.33 , 0.19)	0.581

MD: mean difference; ER: external rotators; IR: internal rotators.

Discussion

The current study's findings revealed a negative moderate correlation between shoulder function disability with shoulder flexors, abductors, external rotators, and Flexion ROM, and a moderate negative association found between pain intensity and external rotators, flexion ROM, and abduction ROM. There was no correlation between shoulder function disability, pain intensity and internal rotators strength, ER/IR ratio, external rotation and internal rotation ROM. However, it was demonstrated that the ER/IR ratio was not correlated to pain severity or shoulder functional disability.

The current study's findings agree with the results of a study by Emadi et al. (2024) (27) who revealed that a negative association was noted between the symptomatic shoulder's muscle power and pain in athlete's patients. Function and quality of life were significantly correlated negatively with pain. Strength and function of the affected shoulder muscle groups were positively correlated with quality of life. There was a decrease in all of the affected shoulder muscle strengths when compared to the asymptomatic side (27), as well as the difference in included participants.

In line with our study, Alfaya et al. (2023) (28) provided insightful information about the association between muscle strength of the shoulder function and pain in SIS patients. The results emphasize management of muscle weakness and pain to improve function and proprioceptive abilities in the treatment of SIS. This comprehensive strategy can help people with shoulder impairments caused by SIS achieve better clinical results and a higher quality of life. Erol et al. (2008) (29) demonstrate that negative correlation between external rotators' strength and pain, this is consistent with the result of our study, but regarding internal rotators is inconsistent with the present study.

The current findings did not show a relationship between ER/IR strength ratio and pain or functional disability; this is possibly due to the isometric measurement in the current study, which contradicts the previous study by Eraslan et al. (2024) (15), who demonstrated that ER/IR strength ratio or the dynamic control ratio might be more linked to the magnitude of acromiohumeral distance during overhead activity (the most painful position).

Pain and disability in people with SIS are greatly impacted by limited shoulder range of motion, due to tendon impingement against the acromion during specific motions causing inflammation, irritation, and chronic pain. Limitations of movement in the shoulder (abduction and flexion) exacerbate impingement and heighten discomfort and pain, this is consistent with findings of studies by Michener et al., (2004)(30) and Dahl-Popolizo and Ivy, (2023) (31) despite different methods of assessment.

Additionally, restricted shoulder range of motion leads to muscle imbalances and changed movement patterns, which alter joint biomechanics, trigger compensatory mechanisms, and change muscle recruitment (32). These compensatory mechanisms can exacerbate the cycle of pain and disability by weakening muscles, increasing instability, and further impairing function (32-37).

Kolber et al. (2017) (13) revealed that muscle weakness and shoulder mobility dysfunctions have been

considered as contributing factors for shoulder abnormalities. The mobility characteristics in patients with SIS have clinical relevance, as reduction in internal rotation was related to shoulder dysfunctions in both athletic and nonathletic subjects, which is inconsistent with the results of the current study.

To manage pain, restore normal joint mechanics, and enhance functional outcomes in SIS, it is imperative to address the limited shoulder range of motion through focused rehabilitation interventions like stretching, mobilization, and strengthening exercises (38). Individuals with SIS can also benefit from the clinical use of shoulder ROM (flexion and external rotation) evaluation with qualitative measures to assess their functional outcomes (39). Clinicians can successfully reduce pain, improve shoulder function, and raise the general quality of life for SIS patients by improving shoulder mobility, muscle power, and function (28) and all these findings agreed with our study.

Regarding the difference between gender in term of shoulder muscle power, the current finding revealed that no significant difference between both groups except for shoulder external rotators, which disagree with studies by Balcells-Diaz and Daunis-i-Estadella, (2018)(40) and Kritzer et al., (2024)(41) who demonstrated that significant difference seen between male and female in healthy subject, but in our study evaluated them in SIS patients. Anthropometric and muscular fiber characteristics change between sexes, justifying major disparities in posture, strength, and fatigue resistance, which may contribute to functional ability.

Regardless of age, weight, height, or sports experience, the majority of previous studies showed that males generated more strength than girls across most joint movements investigated (42-44). Few studies found that females had greater strength than males in all movements (45, 46). Murgia et al. (2018) (45) found that female isokinetic strength was higher in their older adult participant sample, implying that anthropometric changes may occur with age. Huberman et al. (2020) (46) found that females had stronger strength across all joint movements; however, participants were recruited from different population and not equal number (157 females and 30 males).

Conclusion

The findings of current research indicate a negative correlation between muscle strength, and shoulder mobility with pain intensity and function disability, but the ER/IR ratio is not correlated with pain and disability. Further, no gender differences were found relevant to shoulder muscles' strength, ER/IR strength ratio, or shoulder active range of motion.

Conflict of interest

The authors assert that this study was carried out with no conflicts of interest.

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