JRSR 5 (2018) 99-105

Journal of Rehabilitation Sciences and Research

Journal Home Page: jrsr.sums.ac.ir

Original Article

Patients with Subacromial Impingement Syndrome Exhibit Altered Shoulder Rotator Muscles Eccentric and Concentric Peak Torque

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ARTICLE INFO

Article History:
Received: 03/05/2018
Revised: 15/ 05/2018
Accepted: 20/11/2018

Keywords:
Subacromial impingement
Peak torque
Shoulder rotation
Isokinetic

ABSTRACT

Background: Current conservative management of subacromial impingement syndrome (SIS) involves generic strengthening exercises, especially for internal (IR) and external (ER) shoulder rotators. So far, no study has directly investigated the difference in muscle strength between patients with SIS and normal subjects. Accordingly, the purpose of the current study was to compare the shoulder rotator muscles eccentric and concentric peak torque in patients with SIS and normal subjects.

Methods: This study was a cross sectional research. Twenty-four patients with SIS (23.33±2.47 Years) and 24 normal subjects (22.83±2.15 Years), matched for hand dominance and physical activity level, completed isokinetic shoulder IR and ER testing. Within the SIS group, 18 patients had the symptoms in their dominant and 6 patients in their non-dominant side. The IR and ER strengths of both sides were measured separately using continuous reciprocal concentric and eccentric contraction cycles at speeds of 60 and 120 degrees per second, respectively. The values of peak torque were compared using independent t-tests between the SIS and normal groups.

Results: Significantly lower concentric ER peak torque at 120 °/second ($p = 0.016$), eccentric ER peak torque at 60 °/second ($p = 0.022$), eccentric ER peak torque at 120 °/second ($p = 0.043$), and eccentric IR peak torque at 60 °/second ($p = 0.036$) and 120 °/second ($p = 0.040$) were identified in the symptomatic SIS group dominant shoulder compared to the control group dominant shoulder.

Conclusion: Changes in eccentric and concentric peak torque in SIS group may be related to the limb dominancy, which may have clinical implications for strengthening regimes. Therefore, clinicians' and therapeutic exercise expertise may benefit from eccentric isokinetic exercises for shoulder IR and ER rotators in order to design a treatment plan for patients with SIS.

Introduction

The shoulder complex relies on its surrounding muscles to provide dynamic stability during its large range of mobility. Proper flexibility and strength balance in the agonistic and antagonist muscles surrounding the shoulder complex is necessary for preventing musculoskeletal dysfunction [1]. Among shoulder-related dysfunctions, subacromial impingement syndrome (SIS) is a common condition characterized by anterolateral catching pain or aching of the shoulder, without a history of trauma. Pain originates from the tissues within the subacromial space including the rotator cuff [2, 3]. SIS can be classified into extrinsic and intrinsic [4]. Extrinsic SIS occurs as a result of mechanical compressive force applied via an external structure to the tendon. However, the reason

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behind the intrinsic SIS is associated with overuse and tension overload affecting the tendons intrinsically [5, 6]. It is reported that during shoulder elevation, patients with SIS have significantly less subacromial space width compared to their asymptomatic side [7], even though their subacromial space is not significantly different from healthy shoulders in the resting anatomical position [8]. Compared to normal subjects, patients with SIS demonstrate more proximal translation of the humeral head during abduction, thus reducing the subacromial space width [9].

Clinical tests should be used in the assessment of SIS [10]. Internal and external rotation are consistently used to assess the rotator cuff function [11]. Bilateral comparison of concentric peak torque has been shown to be the most appropriate parameter for comparison rotator cuff muscles strength among subjects with and without pain [12]. Researchers investigated comparison of eccentric and concentric exercise interventions in adult with SIS. They reported that both eccentric and concentric progressive resistance exercise resulted in improved function, active range of motion, and strength in the patients with SIS. However, no changes were observed between the two exercise modes, suggesting that therapists may use exercises that utilize both eccentric and concentric modes in the treatment of SIS [13].

The current conservative management of SIS involves generic resistance band strengthening exercises for the rotator cuff, particularly shoulder external rotators (ER) [11, 12]. Although comparison of dominant and non-dominant limbs has been reported in patients with SIS, to the best of our knowledge, there is no study matching for dominant side in the recruitment of symptomatic and asymptomatic participants. Greater strength in the dominant upper limb compared to the non-dominant upper limb of the asymptomatic group is expected; however, this may or may not be the case in an SIS population. Lack of matching for upper limb dominance limits the opportunity to understand specific variations in the strength which may be present due to usual physical activities. Therefore, it seems that matching the limb dominance should be an essential component to understand upper limb isokinetic testing results [10]. Indeed, isokinetic testing, performed through an active range at a constant velocity, has proved to be a reliable measure of shoulder strength [13].

The purpose of the current study was comparing the shoulder rotator muscles eccentric and concentric isokinetic peak torque between patients with SIS and normal subjects. The authors hypothesized that patients with SIS exhibit altered shoulder rotator muscles eccentric and concentric peak torque as compared to the healthy subjects.

Methods

This study was a cross-sectional research, using matched pairs, conducted to compare rotator cuff muscle strength in patients with SIS, of gradual onset and without trauma, with an asymptomatic control group matched for age, gender, hand dominance, and physical activity level. All testing was performed by an experienced physical therapist with over 20 years of clinical experience. Note that both shoulders were evaluated and tested in all participants.

Participants

Twenty-four patients with SIS and 24 matched normal subjects were recruited from X university students. Table 1 presents the demographic characteristics of the subjects.

Inclusion and Exclusion Criteria

Subjects in the control group had no history of shoulder, neck or upper back pain 12 months prior to participation. For the patient group, a physical assessment was conducted in order to rule out other shoulder diagnoses and focus only on the SIS. The patient group had:

- A minimum of three positive orthopedic special tests [14, 15]. Hawkins-Kennedy [16] must have been positive along with two of the following: ER rotation resistance test [14], tendon palpation [3], horizontal (cross-body) adduction [15], painful arc [17], drop arm test [15], and speed test [15].
- Catching or aching pain without appreciable joint stiffness [18]
- A painful arc elicited with pain easing on lowering the arm [3]
- Pain localized to the anterior or antero-lateral-superior shoulder [2]
- Insidious onset of symptoms with a possible history of gradual progression over time but without history of trauma
- X-ray or ultrasound scans revealing osteophytes within the subacromial region, calcification of tendons or large rotator cuff tears. Alterations in acromial shape and bursal thickening were noted but did not prevent inclusion.
- The subjects were excluded from the study if they had recent (within previous two years) or current pregnancy
- Previously undergone shoulder surgery or suffered a fracture of the shoulder girdle

Table 1: Demographic characteristics of the participants

Variable	SIS group (n=24)	Control group (n=24)
Age (year)	23.33±2.47	22.83±2.15
Height (cm)	176.79±4.05	2.49±178.07
BMI (kg/m^2)	22.88±3.34	3.54±23.32
Dominant hand		
Right	22	22
Left	2	2

- Glenohumeral instability identified by a grade 2 or 3 anterior, posterior or inferior load and shift test (assessed objectively) or a history of shoulder dislocation [15]
- Scoliosis (observed visually)
- Participated in an intense shoulder strength training at least two or more times per week during the 6 months prior to the study
- Had severe cervical or thoracic pain in the previous six months
- Shoulder corticosteroid injection at any time in the past.

Procedure

The shoulder pain and disability index questionnaire (SPADI) was completed to further describe the SIS group. This outcome measures pain and disability associated with shoulder impairment [19] and is frequently used for assessment of SIS syndrome [20]. The visual analogue scale (VAS) was used to measure pain at rest and during activity [21]. Physical activity level was established by completing the short form of the International Physical Activity Questionnaire (IPAQ). The IPAQ assesses three specific types of activity: [1] walking, [2] moderate-intensity activities such as cycling for transport and yard work, and [3] vigorous intensity activities such as running and boxing. A rating of low, medium or high physical activity is given for the duration (in minutes) and frequency (days) of activity.

Isokinetic testing was performed using Biodex® isokinetic Dynamometer (Biodex® Medical System, Inc. Shirley, NY). The testing method proven to be reliable when testing a group experiencing SIS and also asymptomatic group [22], and had been used in similar studies [23-25].

IR and ER peak torques were measured separately using continuous reciprocal concentric and eccentric contraction cycles at a speed of 60º/second and again at 120º/second. Testing was performed through a total range of 60º from neutral rotation (30º IR and ER). The participants did four to five minutes of sub-maximal and maximal familiarization repetitions and performed five maximal-effort repetitions for IR and ER shoulder rotators, respectively. Visual feedback with Biodex monitor and verbal encouragement were provided to all participants to promote maximal effort and performance during all trials. Gravity correction was not applied as the range of motion tested in the seated position resulted in gravity equally affecting both IR and ER movements. The test position has been shown in Figure 1. During assessments, the assessor was blinded to the group allocation.

Data Analysis

All statistical analyses were performed using the IBM® SPSS statistics 22 software program (IBM®, Chicago, IL, USA). Descriptive statistics (mean, standard deviation) were calculated for each variable. All variables presented normal distribution using the Shapiro-Wilk normality test. The measurement included in analyses was the isokinetic concentric and eccentric peak torque of ER and IR measured in "newton-meters".

Figure 1: The isokinetic testing

Comparisons between matched patients with SIS and normal subjects were completed using independent samples t-tests, with significance level at $p \leq 0.05$. When the dominant shoulder was painful in the SIS group, it was compared to the dominant shoulder in the control group. In the same way, the non-dominant shoulder was compared to each other for both groups.

Results

Recruitment and assessment of patients with SIS and normal subjects were conducted at the same time. Twenty-four patients with SIS and 24 normal subjects matched for hand dominance, physical activity level, and age completed isokinetic testing. SIS cases reported symptoms being present between 4 weeks and 12 months. In the SIS group, 18 dominant limbs and 6 non-dominant limbs were symptomatic.

The statistical analysis revealed significantly less concentric ER peak torque at 120º/second, eccentric ER peak torque at 60º /second and 120º/second, eccentric IR peak torque at 60º/second and 120º/second in the symptomatic dominant shoulder of patients compared to the dominant shoulder of healthy subjects (Table 2). While no other statistical differences were identified, it was noted that all measures of the dominant shoulder in patients with SIS were lower than those of the dominant shoulder of healthy subjects.

The results indicated no significant difference in isokinetic strength between the symptomatic non-dominant shoulder of patients and the non-dominant shoulder of healthy subjects (Table 2, Figure 2).

Further, no significant differences were identified either when the asymptomatic shoulder of the patients with SIS was compared with the matched shoulder of the control group (Table 3, Figure 3).

Table 2. Peak torque values for symptomatic shoulder in SIS group and the matched shoulder in control group

Outcome measures D (N=18) ND (N=6)	D/ND shoulder	SIS group Mean±SD	Control group Mean±SD	T	P value
ER concentric peak torque					
60º s	D	15.31±4.63	16.73±4.86	0.335	0.740
	ND	17.43±3.36	16.66±3.91	0.576	0.569
120º s	D	11.36±3.36	15.81±5.45	-2.554	0.016*
	ND	12.76±3.32	14.25±3.25	221.1-	232.0
ER eccentric peak torque					
60º s	D	20.53±6.15	26.86±8.05	421.2-	*0220.
	ND	21.60±6.60	23.06±8.97	509.0-	614.0
120º s	D	22.20±7.01	29.21±8.26	-2.118	0.043*
	ND	27.86±9.31	24.93±11.01	788.0	437.0
IR concentric peak torque					
60º s	D	34.33±8.90	36.21±11.41	498.0-	622.0
	ND	30.73±9.06	33.40±10.76	734.0-	469.0
120º s	D	29.26±11.74	33.36±10.45	780.0	442.0
	ND	36.60±13.72	30.33±10.63	398.1	173.0
IR eccentric peak torque					
60º s	D	43.13±13.98	54.80±15.81	209.2-	*036.0
	ND	49.13±10.68	44.26±11.08	291.1	207.0
120º s	D	40.33±9.24	48.82±12.07	156.2-	*040.0
	ND	46.41±16.52	49.66±11.43	630.0-	534.0

SIS, subacromial impingement syndrome; ER, external rotation; IR, internal rotation; D, dominant; ND, non-dominant. *significant differences

Table 3. Peak torque values for asymptomatic shoulders in SIS group and matched shoulders in the control group

Outcome measures D (N=6) ND (N=18)	D/ND shoulder	SIS group Mean±SD	Control Mean±SD	T	P value
ER concentric peak torque					
60º s	D	16.66±5.96	15.73±6.88	397.0	694.0
	ND	14.40±5.32	15.33±5.38	576.0	569.0
120º s	D	12.53±4.40	14.33±4.63	090.1-	285.0
	ND	13.40±4.82	12.46±4.01	576.0	569.0
ER eccentric peak torque					
60º s	D	22.66±8.64	23.46±6.47	287.0-	776.0
	ND	25.06±8.85	23.26±5.24	677.0	504.0
120º s	D	84.10±10.28	26.53±10.77	372.0	713.0
	ND	26.27±8.26	21.66±5.20	824.1	079.0
IR concentric peak torque					
60º s	D	32.66±11.73	33.60±12.94	207.0-	838.0
	ND	36.27±14.57	34.06±12.03	396.0	695.0
120º s	D	29.80±10.40	01.11±11.31	716.0	480.0
	ND	31.80±11.05	30.06±10.87	932.0	359.0
IR eccentric peak torque					
60º s	D	53.53±17.88	56.06±13.47	454.0-	653.0
	ND	45.61±11.40	44.93±12.78	151.0	881.0
120º s	D	48.44±14.24	46.66±14.90	322.0	750.0
	ND	46.13±12.26	43.33±15.92	540.0	594.0

SIS, subacromial impingement syndrome; ER, external rotation; IR, internal rotation; D, dominant; ND, non-dominant

Discussion

The purpose of this study was to compare the shoulder rotator muscles eccentric and concentric peak torque in the patients with SIS and normal subjects. The results indicated that differences in eccentric strength were only present when the dominant shoulder was the affected shoulder in the SIS group. Significantly less concentric ER peak torque at 120 º/second, eccentric ER peak torque at 60 º/second and 120 º/second, eccentric IR peak torque at 60 º/second and 120 º/second were found when compared to the matched control shoulders. When the non-dominant shoulder was the affected shoulder in the patients with SIS, no significant differences were identified compared to the matched non-dominant shoulder in the control group. Mean values for all measurements of the dominant shoulder in the SIS were consistently lower compared to the matched dominant shoulder in the control group. However, when the non-dominant shoulder was the affected shoulder in the SIS group, the values were very similar or slightly higher compared to the control group. The changes in the muscle strength in the SIS group seem to be related to the dominance of the symptomatic shoulder, which may

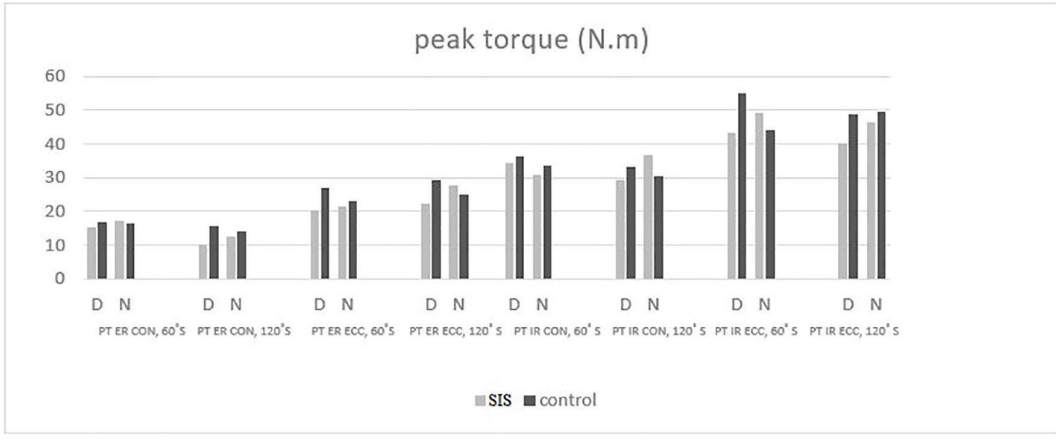

Figure 2: Peak torque of symptomatic shoulder in SIS group and the matched shoulder in the control group. PT, peak torque; ER, external rotation; IR, internal rotation; CON, concentric; ECC, eccentric; D, dominant; N, non-dominant.

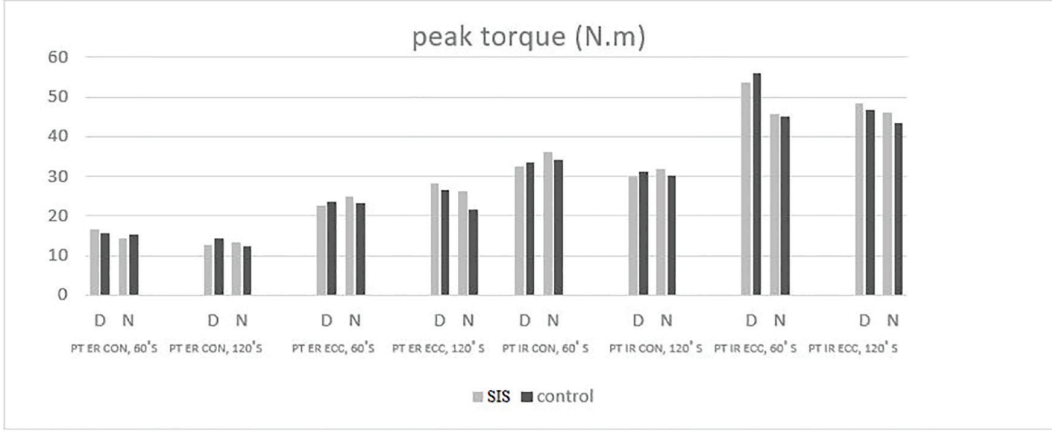

Figure 3: Peak torque of asymptomatic shoulders in SIS group and matched shoulders in the control group. PT, peak torque; ER, external rotation; IR, internal rotation; CON, concentric; ECC, eccentric; D, dominant; N, non-dominant.

have implications for strengthening regimes.

The results of this study are consistent with Dulgeroglu et al. and [24] Akyul et al. [26] studies, but inconsistent with Erol et al. [23], Moraes et al. [27], and Tyler et al. [25] studies. Dulgeroglu et al. showed that in patients who involved side internal and external rotation peak torque at angular velocities of 90 °/second and 180 °/second, the values were significantly lower than the respective averages of the dominant side of the healthy subjects [24]. The findings of the current study are consistent with Dulgeroglu et al. [24] in lower shoulder peak torques in the patients with SIS compared to healthy subjects. Akyul et al. measured the shoulder internal and external rotators torque at velocity of 60 °/second and 180 °/second using isokinetic dynamometer. They demonstrated that the peak torque values seem to be different between the patients' symptomatic and asymptomatic sides. Also, the muscle strength of the shoulders with SIS was significantly lower than that of the healthy side [26]. The main results of Erol et al. study suggested that peak torque values did not seem to be different between either groups or the patients' symptomatic and asymptomatic sides. Additionally, shoulder pain and disability scores were significantly higher in the patient group, and a moderate and negative correlation was found between the rotator muscle strength and pain scores [23]. Moraes et al. indicated that subjects with light to moderate impingement syndrome had late recruitment of the scapular muscles during arm elevation. However, muscular performance of the shoulder rotator muscles was not affected [27]. Tyler et al. measured the shoulder rotator strength with isokinetic system at 60 °/second and 180 °/second and manually with a handheld dynamometer in both the scapular plane and in 90º shoulder abduction. Comparing dominant-non-dominant side deficits of the healthy subjects with the symptomatic-asymptomatic side deficits of the SIS patients showed no significant difference between the isokinetic testing. However, the handheld dynamometer quantified an external rotation deficit in the patient group at 90º shoulder abduction position, and an internal rotation deficit in the control group, at both the scapular plane and 90 º shoulder abduction. Failure of the isokinetic tests to detect the strength deficit was explained by measuring the peak torque value at the middle range of the motion. However, the handheld dynamometer measured the strength at the end-range, where the deficit might be more significant. The lack of proper matching between the groups for age and gender and neglecting the dominancy of the symptomatic side were the major limitations of Tyler et al. study [25].

Rotator cuff weakness is reported to be associated with SIS [6, 14]. However, very few studies have investigated and compared the rotator cuff strength in patients with

SIS and asymptomatic subjects. Meanwhile, concentric testing has been shown to be more reliable than eccentric testing when comparing the patients with SIS and asymptomatic subjects [22]. A concentric contraction produces less force than an eccentric contraction, thereby reducing the influence of pain on the performance [28].

To the best of our knowledge, only one previous study has compared concentric isokinetic ER and IR peak torque in symptomatic shoulder of SIS patients with control group [24]. All peak torque values were found to be significantly lower for concentric IR and ER, at 90 °/second and 180 °/second, in the symptomatic shoulder of patients with SIS as compared to the dominant shoulder of the control group. However, of the 22 symptomatic shoulders assessed, only 14 of these were actually the dominant shoulder [24]. The remaining eight shoulders were non-dominant, while they were compared to the dominant shoulders of the control group. This analytical and methodological anomaly, together with the relatively small sample size of the study, may explain why the findings of the mentioned study [24] differed from the results reported in the current investigation.

Isokinetic testing in the patients with SIS and asymptomatic subjects using a similar age group, tested in the seated position, with the shoulder positioned in the scapular plane, has been reported in five previous studies [22-24, 29]. One of these studies reported within group differences of SIS group compared to within group differences of an asymptomatic group [23]. Only right-hand dominant participants were recruited in both groups and matched for age, sex, height, and body weight, with concentric testing performed at 60 °/second. No within group difference between dominant and non-dominant limbs in the SIS group was identified. However, a significant difference was found in the asymptomatic group. The other studies which used the same isokinetic testing position to compare SIS group with an asymptomatic group did not report dominant side of the recruited participants. They analyzed the within group differences for the painful versus non-painful shoulders in those with SIS and dominant versus non-dominant shoulder in the asymptomatic group, and then compared the values from these two analyses [22, 25, 29]. These statistical analyses are different from the analysis in the current study.

The findings of the previous studies are difficult and not appropriate to compare to the outcomes of the current investigation as limb dominance and the presence of pain both have important effects on the isokinetic performance.

The current study had some limitations. The participants were not familiar with the isokinetic dynamometer which is in line with other isokinetic studies. However, the instructions were clear and the subjects were reminded (both SIS and normal subjects) to apply their maximum effort throughout the test. Therefore, the measurement bias was likely to be the same in both groups. Further, only the participants aged 20-25 years were included in this study. Therefore, these findings should only be applied to this age group. The other limitation was that the impingement syndrome chronicity was not considered as an inclusion criterion for SIS group in the current study.

Conclusion

This study is the first to compare isokinetic rotator cuff testing at 60 °/second and 120 °/second through a total range of 60º in 20-25-year-old patients experiencing SIS and healthy subjects matched for age, gender, hand dominance, and physical activity level. Significant strength differences were found only when the dominant shoulder of the patients was the symptomatic one (concentric ER peak torque at 120 °/second, eccentric ER peak torque at 60 °/second and 120 °/second, eccentric IR peak torque at 60º /second and 120º /second). No strength differences were observed when comparing the non-dominant symptomatic shoulder of the patients with the non-dominant shoulder of the healthy subjects. These results can suggest that the muscle strength in the shoulder with SIS may be related to its dominance, which may have clinical implications for strengthening regimes. Therefore, clinicians and therapeutic exercise experts may benefit from eccentric isokinetic exercises for shoulder IR and ER rotators in order to design a treatment plan for patients with SIS.

Acknowledgement

We highly appreciate our colleagues who provided expertise which greatly assisted the research, although they may not agree with all of the interpretations provided in this paper. We are also grateful to our subjects for their assistance and participation in this study.

Conflict of interest: None declared.

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