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Comparative Electromyographic Study of Scapular Muscle Activity During Scaption in Individuals With Type I AND II Scapular Dyskinesis

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ABSTRACT

Aims: Scapular Dyskinesis (SD) in individuals with shoulder pathologies may result from inadequate muscle performance. Variations in muscle activity across different types of SD could offer valuable insights into the development of appropriate training programs. Nonetheless, a separate analysis of muscle activities between type I and type II SD has not yet been conducted.

Method and Materials: Twenty-four volunteers with SD were randomly allocated to type I (n=12) and type II (n=12) groups in this cross-sectional study. Electromyographic (EMG) activities of the Serratus Anterior (SA), Upper Trapezius (UT), Middle Trapezius (MT), and Lower Trapezius (LT) muscles were recorded during 60° and 110° scaption tasks. Muscle activity, including Maximum Voluntary Isometric Contraction (MVIC) and Root Mean Square (RMS), was assessed.

Findings: According to the results, SA showed significantly higher activity in Group I than in Group II at both 60° (P=0.039) and 110° (P=0.037) of scaption. MT activity was higher in group I at 110° (P=0.035) of scaption but showed no difference at 60° (P=0.054). UT activity was significantly higher in subjects with type II SD at both 60° (P=0.046) and 110° (P=0.023), while LT showed no significant difference at either 60° (P=0.505) or 110° (P=0.156) in both types.

Conclusion: Exercise prescriptions for type II SD should emphasize enhancing SA and MT activation more than type I SD. Additionally, more caution should be taken to avoid excessive UT activity in Type II SD. The activity of LT should be similarly prioritized in exercise prescriptions for both types.

Keywords: Electromyography (EMG), Scapular Dyskinesia, Anterior

Introduction

Scapular Dyskinesis (SD) is characterized by alterations in both the static positioning and dynamic movement patterns of the scapula [(1)]. Effective shoulder positioning, motion, stability, muscle performance, and motor control are significantly dependent on scapular performance [(2)].

Scapular Dyskinesis is prevalent within the general population and is not confined to individuals experiencing shoulder pain [(3)]. Approximately 60% of symptomatic individuals and 48% of asymptomatic individuals exhibit SD [(4)]. Kibler's visually-based classification of SD delineates three distinct types: I- Prominence of the inferior angle. II- Prominence of the medial border. III- Superior translation of the scapula [(1)]. Furthermore, the Lateral Scapular Slide Test (LSST) is also a clinical evaluation method used to confirm the presence of SD. The LSST demonstrates a good-to-high level of Intra-Rater Reliability (ICC > 0.87) and a poor-to-good level of Inter-Rater Reliability (ICCs ranging from 0.63 to 0.86). The test exhibits high sensitivity (100%) and low specificity (4%) [(5)].

Scapular Dyskinesis can arise from various causes, including bony abnormalities like clavicular fractures, neurological issues such as long thoracic or accessory nerve palsy, and muscular dysfunctions, including soft tissue inflexibility and deficits in muscle control and strength [(6)].

Therefore, the scapular muscles play a crucial role in ensuring correct scapular positioning, both at rest and during shoulder movements[7]. It has been proposed that abnormal scapular motion may be associated with either decreased [8] or increased [9] activity of the periscapular muscles. Increased activity of the Upper Trapezius (UT), combined with inhibition of the Lower Trapezius (LT) and Serratus Anterior (SA), has been linked to alterations in scapular positioning, notably reductions in upward rotation, posterior tilt, and external rotation [10]. Furthermore, the Middle Trapezius (MT) is reported to contribute to the upward rotation, retraction, and external rotation of the scapula [11, 12].

Among the muscles connected to the scapula, it seems that SA plays a substantial role due to its attachment along the entire length of the medial border and inferior angle of the scapula, ensuring the scapula is correctly positioned on the rib cage [13]. The activity of this muscle is involved in all components of scapular movement during shoulder elevation, including upward rotation, protraction, and external rotation [14]. Muscle weakness, fatigue, and abnormal firing patterns of SA, as well as long thoracic nerve injury, can lead to scapular winging and anterior tilting [7].

Huang et al. studied differences in muscle activity patterns between type I and type II SD in overhead athletes [12]. In another study, muscle activity in SD was examined during the lowering phase of elevation within the general population. The study did not compare the activities of LT and UT separately in type I and II SD, nor did it examine the activity of MT. Only the activity of SA was compared between type I and II during elevation [7]. Therefore, this study aimed to compare the activity of the scapular muscles between type I and type II SD.

Method and Materials

This cross-sectional, single-blinded study was conducted in the laboratory of movement disorders at Tarbiat Modares University between May 2023 and July 2024. Written informed consent was obtained from all study participants.

Among 33 individuals evaluated for study eligibility, 24 individuals, including type I (n=12) and type II (n=12) SD groups, were selected according to Kibler's classification [1] and a positive result on the Lateral Scapular Slide Test (LSST) [15]. Participants were aged between 20 and 40 years, with a Body Mass Index (BMI) ranging from 18.5 to 24.9, and reported pain levels of 3 to 5 on the Visual Analogue Scale (VAS). Individuals were excluded if they had rheumatoid arthritis, neurological disorders, a history of shoulder girdle surgery or traumatic events within the past 6 months, or had received treatment related to the shoulder girdle in the past 6 months.

Based on findings from our pilot study, with a significance level of 0.05, power of 80%, and effect size of 1.2, the total sample size was calculated to be 24 using G*Power 3.1.

To record the electrical activity of muscles, a 16-channel wireless electromyography system (Aktos; Mayon, Inc., Switzerland) and Nexus software (Vicon Nexus 2.8.1; Oxford, UK) were utilized. The electrode placement method in this study followed the SENIAM protocol. We recorded the activity of the UT, MT, LT, and SA muscles of the dominant upper extremity. Muscle activity was recorded with a 20–400 Hz bandpass and a sampling frequency of 100 Hz [16]. Maximum Voluntary Isometric Contraction (MVIC) was employed to normalize the electromyography signals. Each MVIC was held for three seconds, with each muscle tested twice and a rest interval of 1–2 minutes between tests.

For UT, electrodes were placed at the midpoint of the hypothetical line connecting the acromion to the C7 vertebra. For MT, the electrodes were placed at 50% of the distance between the medial border of the scapula and the spine, at the level of T3. For LT, electrodes were placed at the junction between the medial and medial thirds of the hypothetical line connecting the trigonum spinae to the T8 vertebra. For SA, electrodes were placed beneath the axilla, anterior to the latissimus dorsi and posterior to the pectoralis major, at the 6th-8th intercostal space and at the level of the xiphoid process [17]. Following skin preparation and electrode placement, the MVIC and rest activity of each muscle were recorded.

To measure the MVIC of UT, the patient was seated on the edge of the bed with hands placed beside the body. The patient was instructed to raise the shoulder, and resistance was applied to the shoulder in a downward direction. For MT, the patient was placed in a prone position with the shoulder abducted to 90° and the elbow flexed. The patient was asked to raise the arm while resistance was applied to the distal part of the arm in a downward direction. For the LT muscle, the patient was positioned prone, with the shoulder abducted to 145° and the elbow straight. The patient was instructed to raise the arm, and resistance was applied to the distal part of the arm in a downward direction. For SA, the patient was seated on the edge of the bed and instructed to raise the arm to 130° of flexion, with resistance applied to the distal part of the arm in a downward direction [18]. Each MVIC was taken twice, with each test lasting three seconds, and the highest value was selected.

To record the EMG activity of the muscles in the 60° scaption, the upper limb was initially placed next to the body for 3 seconds. The limb was then moved to a 60° angle and held in this position for 3 seconds before returning to the body's side, where recording continued for another 3 seconds. This task was performed twice. For the 110° scaption, the upper limb was also initially placed next to the body for 3 seconds. The limb was then moved to a 110° angle and maintained in this position for 3 seconds before returning to the body's side, with recording continuing for another 3 seconds. This task was also performed twice.

All EMG data were processed using custom code written in MATLAB (R2023b; MathWorks, Inc., Natick, MA). The raw EMG signals were filtered with a second-order Butterworth filter, rectified, and normalized to the muscle's MVIC. The Root mean Square (RMS) value was calculated in 100-millisecond windows [16].

Statistical analysis was performed using IBM SPSS Statistics 27. The normality of the data was assessed using the Shapiro-Wilk test, which confirmed normality. A two-sample independent t-test was employed to compare the mean values between groups, with a significance level of $P < 0.05$ considered statistically significant.

Findings

At 60° scaption, SA activity was significantly higher in group I compared to group II (P=0.039). Similarly, at 110° scaption, SA activity was considerably higher in group I compared to group II (P=0.037). UT activity was significantly higher in group II compared to group I at both 60° (P=0.046) and 110° scaption (P=0.023). For MT, no significant difference in activity was observed between groups I and II at 60° scaption (P=0.054). Still, at 110° scaption, MT activity was significantly higher in group I compared to group II (P=0.035). Lastly, there were no significant differences in the LT activity between groups I and II at both 60° scaption (P=0.505) and 110° scaption (P=0.156), as shown in Tables 2 and 3 .

Table 1- The participants' demographic data

Variable	I (Mean ± SEM)	II (Mean ± SEM)	P-value
Age (Year)	28.33±1.50	34.25±1.69	0.409
Height (M)	1.79±0.01	1.77±0.01	0.310
Weight (Kg)	75.42±1.82	75.00±1.58	0.421
BMI (Kg/M^2)	23.44±0.20	23.72±0.37	0.122

BMI: Body Mass Index.

Table 2- Maximum Voluntary Isometric Contraction of muscles at 60° scaption.

Variable	I (Mean ± SEM)	II (Mean ± SEM)	P-value*	Effect-size (η^2)
SA	15.25±0.28	14.15±0.41	0.039*	0.89
UT	19.59±0.75	21.64±0.60	0.046*	0.86
MT	12.85±0.29	11.73±0.46	0.054	0.83
LT	10.81±0.37	10.44±0.40	0.505	0.27

SA: Serratus Anterior; UT: upper Trapezius; MT: Middle Trapezius; LT: Lower Trapezius. *p: pvalue < 0.05.

Table 3- Maximum Voluntary Isometric Contraction of muscles at 110° scaption.

Variable	I (Mean ± SEM)	II (Mean ± SEM)	P-value	Effect-size (η^2)
SA	24.47±0.31	22.66±0.74	0.037*	0.90
UT	28.24±1.01	31.81±1.06	0.023*	0.99
MT	17.45±0.46	15.84±0.54	0.035*	0.91
LT	16.70±0.65	15.24±0.74	0.156	0.60

SA: Serratus Anterior; UT: upper Trapezius; MT: Middle Trapezius; LT: Lower Trapezius. *p: pvalue < 0.05.

Discussion

This study investigated the activity of the scapular muscles, including SA, UT, MT, and LT, in individuals with type I and type II SD. The results revealed differences in muscle activities between the groups.

As observed in our study, the activity of SA in group I was significantly higher than in group II at both 60° and 110° of scaption (P<0.05), as shown in Tables 2 and 3. These findings contrast with those of Huang et al. [12], who reported no significant differences between the groups. Considering the biomechanical role of the SA in maintaining the medial border of the scapula adjacent to the thorax [10], our findings may explain the reduced distance of the medial border from the rib cage in individuals in group I compared to those in group II. Furthermore, according to the present data, strengthening SA appears to be more crucial in type II SD compared to type I SD.

The EMG activity of UT was significantly higher in subjects with type II SD at both 60° and 110° of scaption, as shown in Tables 2 and 3. These findings are consistent with those of Huang et al., who also reported increased UT activation in type II SD [7]. The elevated UT activity in group II may represent a functional adaptation to compensate for the reduced activity of SA in this group, thereby mitigating impaired scapular control during shoulder scaption [7].

The higher EMG activity of MT in group I compared with group II is consistent with a previous study indicating that MT plays a role in controlling the medial border of the scapula [19]. Strengthening of the MT should also be considered in SD training programs.

No significant differences in LT EMG activity at 60° and 110° of scaption (P=0.156) contradict previous studies, which have shown that LT weakness causes less posterior tilt of the scapula [20]. Although we had expected to observe lower LT activity in type I than in type II, our findings may be due to the medial border of the scapula becoming more prominent in type II SD, resulting in a degree of inferior angle prominence relative to the rib cage, similar to type I SD [1]. This similarity may lead to similar LT activation in both types.

Scapular Dyskinesis is a critical factor in shoulder girdle disorders, including pain and limitations in Range of Motion (ROM). The activity of associated muscles directly influences the kinematics of the scapula during shoulder girdle movements. Although several studies have examined muscle activity in individuals with SD, no study has yet compared muscle activity separately in type I and II SD within the general population. Investigating differences in muscle activity and the resulting data provides clinicians with the opportunity to design more specific therapeutic exercises for each type of SD. This approach helps to avoid prescribing a one-size-fits-all exercise regimen, ultimately enhancing clinical outcomes.

Conclusion

Based on our findings, exercise prescriptions for type II SD should emphasize enhancing SA and MT activation more than for type I SD. Additionally, more caution should be taken to avoid excessive UT activity in Type II SD. The activity of LT should be similarly prioritized in exercise prescriptions for both types.

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Authors' Contribution

All authors contributed to the conceptualization, methodology, project administration, resources, and formal analysis. All authors helped in the investigation, contributed to data curation, and approved the final version of the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Ethical Permission

The study was approved by the ethics committee of Tarbiat Modares University on 2023.4.29 (Ethical code: IR.MODARES.REC.1402.009).

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Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request

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