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Comparison of Electromyographic Activity of Scapular Stabilizer Muscles in Different Arm Movement Planes Between Males With Upper Crossed Syndrome and Healthy Individuals

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ABSTRACT

The present study aimed to compare the electromyographic (EMG) activity of scapular stabilizer muscles (upper trapezius, middle trapezius, lower trapezius, and serratus anterior) across different arm movement planes (abduction, flexion, and scaption) in males with upper crossed syndrome and healthy individuals. This causal-comparative (ex post facto) study was conducted on non-athlete male students aged 18 to 28 from the University of Tehran. A total of 22 participants with upper crossed syndrome and 22 healthy individuals (without upper crossed syndrome) were purposefully selected based on the inclusion criteria. Following initial assessments and screening, the electrical activity of the upper, middle, and lower trapezius muscles, as well as the serratus anterior muscle, was measured using an electromyography device during three arm movements: shoulder abduction, arm elevation in the scapular plane (30 degrees anterior to the frontal plane), and shoulder flexion, all performed without resistance and across three phases (concentric, isometric, and eccentric), with each phase lasting 3 seconds. Each participant repeated the movement 5 times, with a 3-second rest interval between repetitions. After assessing normality and homogeneity of variances, data were analyzed using an independent t-test in SPSS version 26. The results of the present study indicated that in the abduction, flexion, and scaption planes, participants with upper crossed syndrome exhibited significantly higher muscle activity in the upper trapezius during concentric, isometric, and eccentric phases compared to healthy participants ($p < .05$). In contrast, participants with upper crossed syndrome showed significantly lower muscle activity in the middle trapezius, lower trapezius, and serratus anterior muscles across all movement phases (concentric, isometric, and eccentric) compared to the healthy group ($p < .05$). These findings suggest that individuals with upper crossed syndrome experience altered muscle activation patterns, characterized by overactivity of the upper trapezius and underactivity of the middle trapezius, lower trapezius, and serratus anterior.

Keywords: Upper crossed syndrome, muscular imbalance, arm movements.

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Introduction

Upper Crossed Syndrome (UCS) is a postural imbalance pattern first introduced by Vladimir Janda, characterized by a constellation of musculoskeletal deviations including forward head posture, protracted shoulders, and hyperkyphosis of the thoracic spine (1, 2). These changes are typically accompanied by muscular imbalances, notably overactivity and shortening of the upper trapezius, levator scapulae, and pectoral muscles, in conjunction with underactivity and lengthening of the deep cervical flexors, lower trapezius, and serratus anterior (3, 4). Such maladaptive neuromuscular patterns contribute significantly to scapular dyskinesis, impaired shoulder kinematics, and increased risk for chronic musculoskeletal dysfunction (5, 6).

Given the scapula's central role in upper limb biomechanics, alterations in scapular position and muscle activation—collectively referred to as scapular dyskinesis—can have substantial implications on movement efficiency, joint stability, and susceptibility to shoulder injuries (7, 8). Specifically, dysfunctional recruitment of the scapular stabilizers—namely the upper, middle, and lower trapezius, along with the serratus anterior—disrupts the scapulohumeral rhythm and has been associated with conditions such as subacromial impingement and adhesive capsulitis (9-11).

The functional complexity of the scapulothoracic joint demands coordinated activity across various movement planes. During shoulder abduction, flexion, and scapular plane elevation (scaption), the scapula must rotate, tilt, and protract with precision to ensure optimal glenohumeral articulation. Any imbalance in the activation timing or intensity of key stabilizers can lead to compensatory strategies and overload of adjacent structures (12, 13). Numerous studies have identified that patients with UCS display hyperactivity of the upper trapezius alongside hypoactivity of the middle and lower trapezius and serratus anterior during both static and dynamic tasks (14, 15).

Electromyography (EMG) has been extensively utilized to quantify the magnitude and timing of muscular activation during movement. Studies employing EMG have provided evidence for altered neuromuscular control in individuals with UCS, particularly during shoulder movement patterns involving arm elevation (16, 17). These findings support the hypothesis that UCS not only disrupts static postural alignment but also impairs dynamic motor control. For example, De Mey and colleagues (2012) reported that athletes with shoulder impingement exhibit reduced activation of the lower trapezius and serratus anterior during rehabilitation exercises, highlighting the need for targeted corrective protocols (18).

Given the increasing prevalence of sedentary lifestyles and prolonged screen time, UCS has become a common clinical observation among young adults, particularly university students and office workers (4, 19). This underscores the importance of early identification and rehabilitation strategies to restore neuromuscular balance. The current literature suggests that corrective exercise programs focusing on posture re-education, muscular activation retraining, and mobility enhancement are effective in ameliorating the symptoms of UCS and normalizing EMG patterns (16, 20). Nevertheless, most existing studies have assessed general posture or a limited set of movements, lacking a comprehensive examination across all key movement planes.

Furthermore, studies have shown that abnormal activation patterns in UCS are not limited to symptomatic populations. For instance, Silva et al. (2022) demonstrated that even asymptomatic CrossFit practitioners with UCS displayed altered muscle activation patterns compared to those without postural deviations, emphasizing the silent progression of motor dysfunction (17). Kang et al. (2023) similarly found significant differences in the serratus anterior activation ratio between individuals with and without impingement syndrome during closed-chain exercises (21). These results point to the importance of early detection even in seemingly healthy populations.

Considering the anatomical and functional roles of the scapular stabilizers, it is essential to understand their behavior across different contraction types—concentric, isometric, and eccentric phases of motion. Camargo and Neumann (2019) emphasized that the upper trapezius tends to dominate scapular elevation tasks unless counterbalanced by appropriate activation of the middle and lower trapezius (22). Moreover, Andersen et al. (2012) noted that low-intensity resistance exercises may insufficiently activate the lower trapezius and serratus anterior, which are often under-recruited in UCS (23).

In light of these findings, researchers and clinicians have emphasized the need for EMG-based assessments during specific motor tasks to provide a clearer picture of muscle recruitment strategies in individuals with UCS (5, 8). While various postural assessments such as the Kibler lateral scapular slide test and McClure's scapular dyskinesis grading system are useful, they are limited by their qualitative nature and examiner subjectivity (5, 20). EMG, in contrast, offers an objective method to evaluate timing and intensity of muscle activation during functional tasks, providing more precise data to inform targeted interventions.

The present study aims to fill this gap by investigating the electromyographic activity of the scapular stabilizers (upper trapezius, middle trapezius, lower trapezius, and serratus anterior) in different movement planes (abduction, flexion, and scaption) and across all contraction phases in men with and without UCS. By adopting a comprehensive, phase-specific, and plane-specific EMG protocol, this study seeks to advance our understanding of how UCS alters muscle behavior in functional shoulder movements. Such insights can guide clinicians in designing more effective corrective exercise strategies.

Furthermore, this study builds upon the foundational concepts introduced by Janda's muscular imbalance theory and contributes to the growing body of evidence suggesting that motor re-education and neuromuscular retraining are indispensable components of UCS management (1, 3, 11). Notably, Valli (2004) highlighted that even in chronic cases involving comorbidities like adhesive capsulitis and diabetes, postural correction and muscle retraining resulted in functional improvements, reinforcing the broad relevance of addressing UCS (24). Hemant et al. (2013) further confirmed the benefits of restoring trapezius and levator scapulae length in resolving shoulder dysfunction (25).

In conclusion, identifying the alterations in scapular stabilizer muscle activation in UCS is critical not only for clinical diagnosis but also for the development of targeted therapeutic interventions. By integrating EMG data with established postural assessment techniques, clinicians can better quantify the dysfunction and monitor progress during rehabilitation. The current study endeavors to provide a detailed analysis of muscle activity across movement planes, offering nuanced insights into the neurophysiological disruptions associated with upper crossed syndrome.

Methods and Materials

Study Design and Participants

The present study, based on its stated objectives, was classified as an ex post facto (causal-comparative) investigation and, considering the time span of implementation, as a cross-sectional study. Furthermore, in terms of aim, the research was categorized as applied research and was conducted in the field. Research ethics were fully observed in this study. Participants were assured of the confidentiality of their information and participated voluntarily and anonymously. This research adhered to the standards of the National Research Committee and the Declaration of Helsinki (1964). Additionally, ethical codes commonly applied in medical research—codes 2, 13, and 14 (benefits derived from findings contributing to human knowledge advancement), code 20 (research conformity with religious and cultural norms), and codes 1, 3, and 24 (participant and legal representative consent)—were all respected.

The study population consisted of non-athlete male students aged 18 to 28 at the University of Tehran who exhibited upper crossed syndrome (UCS). A total sample of 44 individuals (22 per group) was selected using purposeful sampling based on inclusion criteria and calculated using G*Power version 3.1.9.2, with $\alpha = 0.05$, $\beta = 0.95$, and an effect size of 0.8 derived from prior studies. Inclusion criteria included non-athlete male students aged 18–28, observable abnormal scapular tilt or winging at rest, movement and rhythm disorders during dynamic scapular motion assessed via Kibler's lateral scapular slide test and McClure's grading system, forward head posture with an angle exceeding 44°, forward shoulder posture with an angle exceeding 49°, and thoracic hyperkyphosis with an angle exceeding 42°. Exclusion criteria included unwillingness to complete testing, presence of visible lower limb or pelvic abnormalities, or the researcher's determination of insufficient participant cooperation throughout the study.

Data Collection

An informed consent form was used to confirm participant agreement. A grid chart was employed to assess posture, and a flexible ruler was used to measure thoracic kyphosis angle while standing. A scoliometer ensured no vertebral rotation. A digital camera on a tripod facilitated photogrammetry to measure head and shoulder angles. Electromyographic activity and muscle timing were recorded using a ME-6000 surface electromyography system (MegaWin, Finland), a 16-channel wireless system connected to a laptop via electromagnetic signals. This enabled EMG recording during various motor tasks, including arm abduction, while the device was worn in a belt pouch by the participant.

Procedure

Participants were selected based on the inclusion and exclusion criteria. Informed consent and demographic information (age, height, weight, BMI, and medical history) were collected. Recruitment was initiated through a general call for voluntary participation, and interested individuals completed a demographic form. The full procedure was explained, and verbal and written consent was obtained. A general posture screening was conducted, and those suspected of having UCS were identified based on the predefined criteria. Of these, 22 individuals were selected for the UCS group. Another 22 healthy individuals were also selected.

Upon arriving at the lab, participants' height and weight were recorded. Scapular positioning and movement were assessed using the scapular dyskinesis test. Participants removed their upper clothing for accurate observation, and dumbbells were assigned based on weight: 1.5 kg for those under 68 kg and 2.5 kg for those over 68 kg. Each participant performed 5 bilateral abductions and 5 flexions at a rhythm of 3 seconds up and 3 seconds down. The elbow remained extended with the thumb pointing upward. A metronome was used for rhythm control. The examiner stood behind the participant and rated scapular movement on the dominant side using McClure et al.'s scale (obvious dyskinesis, subtle dyskinesis, normal).

For static posture assessment, the spinous processes of T1 and T12 were identified, and a flexible ruler was shaped along the spine and then traced onto paper to calculate the kyphosis angle. For head and shoulder angles, participants stood naturally while landmarks were placed on the tragus, acromion, and C7 spinous process. A lateral-view photograph was taken, and angle calculations were performed using photogrammetric software (Seidi et al., 2014).

After initial screening, EMG assessments were performed. Surface EMG of the selected muscles was recorded using the 16-channel ME-6000 system, with data analyzed using MegaWin software. Assessments were conducted on the dominant side. Electrode placements were based on validated scientific protocols using the SENIAM European guidelines, with the reference electrode placed on the ipsilateral clavicle (De Mey et al., 2012). Disposable surface electrodes (2 cm diameter, 2 cm inter-electrode distance) were used, with data recorded at a 1000 Hz frequency. Skin was prepared by shaving and cleaning with alcohol, and electrode sites were marked. For signal validation, isolated maximal voluntary isometric contractions (MVIC) were performed three times for 5 seconds each, with 5-second rest intervals. The peak MVIC was used to normalize EMG signals.

Participants then performed three non-resisted arm movements—abduction, scaption (30° anterior to the frontal plane), and flexion—each across concentric, isometric, and eccentric phases, each phase lasting 3 seconds. Movements were practiced beforehand to ensure accuracy. Each movement was repeated 5 times, with 3 seconds rest between repetitions. EMG data were RMS-processed and normalized to MVIC. To minimize fatigue and habituation effects, only the second, third, and fourth repetitions were used for analysis. Muscle onset timing was analyzed from the concentric phase only, referenced to the deltoid onset. Onset was defined as the point when muscle activity exceeded two standard deviations above baseline (De Mey et al., 2012).

The evaluated muscles were upper, middle, and lower trapezius and serratus anterior. Electrode placement was as follows:

- Upper trapezius: 50% between the acromion and C7 spinous process.
- Middle trapezius: 50% between the medial scapular border and the spine at T3 level.
- Lower trapezius: 50% between the spine of the scapula and T8 spinous process.
- Anterior deltoid: one finger width below and anterior to the acromion.
- Middle deltoid: on the bulk of the muscle along a line from acromion to lateral epicondyle.
- Posterior deltoid: two finger widths behind the angle of the acromion.
- Serratus anterior: although not defined in SENIAM, the electrode was placed parallel to muscle fibers, anterior to the latissimus dorsi's anterior border, at ribs 6–8 (Basmajian, 1979).

Data Analysis

Means and standard deviations were used for descriptive statistics. The Shapiro–Wilk test assessed data normality. Independent t-tests were used to analyze the collected data in SPSS version 26, with the significance level set at $p < .05$.

Findings and Results

Table 1 presents the mean and standard deviation of the participants' age, height, and weight across groups. As shown in Table 1, there were no statistically significant differences between groups in the variables of age (p = .38), height (p = .65), and weight (p = .36). Therefore, the groups are homogeneous in these demographic variables.

Table 1. Mean and Standard Deviation of Age, Height, and Weight of Participants

Group	N	Age (years)	Height (cm)	Weight (kg)
Upper Crossed Syndrome	22	22.3 ± 3.95	175.3 ± 4.45	76.3 ± 13.62
Healthy	22	23.3 ± 3.86	176.4 ± 4.87	77.3 ± 13.53
Independent *t*-test	–	t = -0.87, p = .38	t = -0.45, p = .65	t = -0.92, p = .36

Table 2 shows the findings of the independent *t*-test comparing electromyographic activity of selected muscles (upper, middle, and lower trapezius, and serratus anterior) in individuals with upper crossed syndrome versus healthy individuals during the abduction movement plane.

Table 2. Independent *t*-Test Results for EMG Activity During Abduction Plane

Variable	UCS Group	Healthy Group	Mean Difference	*t*-value	*p*-value
Upper trapezius – concentric	23.6 ± 0.73	18.6 ± 0.59	4.40	2.36	.023
Upper trapezius – isometric	22.5 ± 0.77	16.6 ± 0.68	6.09	3.43	.001
Upper trapezius – eccentric	17.6 ± 0.02	11.6 ± 0.59	5.40	3.11	.003
Middle trapezius – concentric	16.6 ± 0.41	20.7 ± 0.68	-4.63	-2.28	.027
Middle trapezius – isometric	10.6 ± 0.68	16.6 ± 0.68	-6.00	-3.22	.002
Middle trapezius – eccentric	10.6 ± 0.67	15.6 ± 0.36	-5.00	-3.00	.005
Lower trapezius – concentric	21.6 ± 0.86	25.6 ± 0.95	-4.09	-2.20	.033
Lower trapezius – isometric	25.6 ± 0.54	30.5 ± 0.90	-5.36	-3.05	.004
Lower trapezius – eccentric	16.5 ± 0.31	22.5 ± 0.54	-6.22	-3.74	.001
Serratus anterior – concentric	22.6 ± 0.91	26.4 ± 0.82	-3.95	-2.20	.033
Serratus anterior – isometric	27.5 ± 0.77	31.5 ± 0.48	-3.45	-2.16	.036
Serratus anterior – eccentric	14.5 ± 0.47	19.5 ± 0.60	-5.13	-3.07	.004

As shown in Table 2, in the abduction plane, participants with upper crossed syndrome showed significantly higher EMG activity in the upper trapezius during concentric (MD = 4.40), isometric (MD = 6.09), and eccentric (MD = 5.40) phases compared to healthy participants (p < .05). However, EMG activity in the middle trapezius during concentric (MD = -4.63), isometric (MD = -6.00), and eccentric (MD = -5.00) phases was significantly lower in the UCS group (p < .05). Similarly, the lower trapezius and serratus anterior muscles showed significantly lower activity in all three contraction phases in participants with UCS (p < .05).

Table 3. Independent *t*-Test Results for EMG Activity During Flexion Plane

Variable	UCS Group (M ± SD)	Healthy Group (M ± SD)	Mean Difference	*t*	*p*
Upper trapezius – concentric	23.6 ± 6.68	17.5 ± 5.72	5.95	3.25	.002
Upper trapezius – isometric	19.5 ± 5.36	13.4 ± 5.40	5.95	3.70	.001
Upper trapezius – eccentric	14.6 ± 6.08	10.4 ± 6.25	4.50	2.41	.020
Middle trapezius – concentric	17.6 ± 6.04	21.7 ± 7.11	-4.54	-2.28	.027
Middle trapezius – isometric	14.6 ± 6.29	19.5 ± 5.92	-4.68	-2.54	.015
Middle trapezius – eccentric	10.5 ± 5.88	15.3 ± 5.37	-4.90	-2.88	.006
Lower trapezius – concentric	14.6 ± 6.68	18.9 ± 4.60	-4.63	-2.67	.011
Lower trapezius – isometric	17.6 ± 6.08	23.6 ± 5.86	-6.45	-3.58	.001
Lower trapezius – eccentric	11.5 ± 5.73	16.0 ± 5.08	-5.00	-3.05	.004
Serratus anterior – concentric	15.9 ± 5.90	19.6 ± 5.09	-4.00	-2.29	.027
Serratus anterior – isometric	18.6 ± 5.63	22.2 ± 5.59	-3.95	-2.37	.022
Serratus anterior – eccentric	10.5 ± 5.63	16.0 ± 6.77	-6.31	-3.36	.002

The same pattern was observed in Table 3 for the flexion movement. Participants with UCS had significantly higher upper trapezius activation during concentric (MD = 5.95), isometric (MD = 5.95), and eccentric (MD = 4.50) phases ($p < .05$), while middle and lower trapezius and serratus anterior muscles showed significantly reduced activation in all phases.

Table 4. Independent *t*-Test Results for EMG Activity During Scaption Plane

Variable	UCS Group (M ± SD)	Healthy Group (M ± SD)	Mean Difference	*t*	*p*
Upper trapezius – concentric	24.4 ± 4.31	18.2 ± 5.27	6.13	4.09	.001
Upper trapezius – isometric	20.4 ± 4.21	14.6 ± 7.59	5.86	3.20	.003
Upper trapezius – eccentric	16.6 ± 6.67	10.7 ± 7.27	5.27	2.50	.016
Middle trapezius – concentric	19.6 ± 5.16	23.3 ± 6.31	-3.72	-2.00	.049
Middle trapezius – isometric	16.0 ± 5.37	21.0 ± 5.00	-4.90	-2.87	.006
Middle trapezius – eccentric	13.7 ± 5.96	17.7 ± 5.70	-4.00	-2.27	.028
Lower trapezius – concentric	19.6 ± 6.34	24.9 ± 7.86	-5.36	-2.64	.012
Lower trapezius – isometric	21.6 ± 6.40	27.5 ± 5.57	-5.81	-3.21	.003
Lower trapezius – eccentric	14.1 ± 4.09	19.0 ± 5.04	-4.95	-3.21	.003
Serratus anterior – concentric	19.6 ± 6.61	24.0 ± 6.71	-4.90	-2.44	.019
Serratus anterior – isometric	22.0 ± 5.73	26.9 ± 6.32	-4.86	-2.67	.011
Serratus anterior – eccentric	12.7 ± 5.23	17.6 ± 6.59	-4.86	-2.71	.010

Table 4 illustrates that during scaption, the UCS group demonstrated significantly increased upper trapezius activation during concentric (MD = 6.13), isometric (MD = 5.86), and eccentric (MD = 5.27) phases ($p < .05$), alongside significantly decreased activation in the middle trapezius (MD = -3.72 to -4.90), lower trapezius (MD = -4.95 to -5.81), and serratus anterior (MD = -4.86 to -4.90) in all phases ($p < .05$).

Across all three movement planes—abduction, flexion, and scaption—the individuals with upper crossed syndrome consistently exhibited hyperactivation of the upper trapezius and hypoactivation of the middle trapezius, lower trapezius, and serratus anterior muscles across concentric, isometric, and eccentric phases, as demonstrated by statistically significant differences compared to healthy controls ($p < .05$). These findings support the presence of muscular imbalance associated with upper crossed syndrome, marked by overactivity of the upper trapezius and underactivity of scapular stabilizers such as the middle and lower trapezius and serratus anterior.

Discussion and Conclusion

The present study aimed to compare the electromyographic activity of scapular stabilizer muscles—namely the upper trapezius, middle trapezius, lower trapezius, and serratus anterior—across different movement planes (abduction, flexion, and scaption) and contraction phases (concentric, isometric, eccentric) between individuals with upper crossed syndrome (UCS) and healthy controls. The results indicated a consistent pattern across all three movement planes: individuals with UCS exhibited significantly increased activation of the upper trapezius and significantly reduced activation of the middle trapezius, lower trapezius, and serratus anterior muscles during all phases of movement. These findings corroborate the muscular imbalance model proposed in UCS pathology and align with earlier studies suggesting overactivation of superficial mobilizers and underactivation of deep stabilizers in individuals with postural syndromes (1, 2, 4).

In the abduction plane, UCS participants demonstrated statistically higher EMG amplitudes in the upper trapezius during concentric, isometric, and eccentric phases compared to the control group. Conversely, the middle trapezius, lower trapezius, and serratus anterior showed reduced activation in the same phases. These results confirm the functional dominance of the upper trapezius in individuals with UCS and impaired recruitment of the muscles responsible for scapular stabilization and posterior tilt. Such patterns reflect the faulty motor control mechanisms discussed in biomechanical models of shoulder dysfunction (9, 10). Similar findings have been observed in prior EMG-based investigations. For instance, Cools et al. (2003) reported delayed and reduced activity of the middle and lower trapezius during arm elevation tasks in overhead athletes with scapular dyskinesis, highlighting the altered neuromuscular sequencing (8). Additionally, De Mey et al. (2012) demonstrated that even in subclinical cases of scapular dysfunction, the lower trapezius and serratus anterior failed to activate adequately during functional movements (18).

Flexion plane results further emphasized this imbalance. Upper trapezius activation remained significantly elevated across all contraction phases in the UCS group, while the other stabilizers were under-recruited. These patterns suggest that individuals with UCS rely heavily on the upper trapezius to elevate the scapula during forward flexion, compensating for weak or inactive synergists. Camargo and Neumann (2019) argue that upper trapezius overreliance can result in excessive scapular elevation and anterior tilt, disrupting scapulohumeral rhythm and contributing to impingement syndromes (22). The current findings extend this theory by showing that such compensatory patterns are consistent across multiple dynamic movements, not limited to overhead tasks. Smith et al. (2009) also identified increased upper trapezius and decreased lower trapezius activity in patients with subacromial impingement, underscoring the clinical implications of muscular imbalance (15).

In the scaption plane—recognized as biomechanically optimal for shoulder elevation—the same neuromuscular profile was observed: hyperactivation of the upper trapezius and hypoactivation of the middle trapezius, lower trapezius, and serratus anterior. This suggests that even in a mechanically favorable position, individuals with UCS fail to normalize their scapular muscle recruitment, pointing to deep-rooted motor control deficiencies. Lear and Gross (1998) reported that serratus anterior and lower trapezius work synergistically during push-up plus movements to stabilize the scapula; the underactivation of these muscles in UCS disrupts this synergy (12). This finding also aligns with the comprehensive EMG analysis by Arshadi et al. (2019), who observed significant reductions in scapular stabilizer activation during functional tasks in individuals with UCS (16).

The persistence of this muscle imbalance across all three planes highlights the global nature of neuromuscular dysfunction in UCS. While previous research has often focused on static postural alignment or isolated movements, the present study reveals that UCS alters muscle activity throughout dynamic tasks, regardless of movement direction. This supports the notion that UCS is not merely a postural anomaly but a dynamic motor control disorder (4, 21). Importantly, the reduced serratus anterior activation observed in this study echoes findings from Silva et al. (2022), who demonstrated impaired function in this key scapular protractor even among asymptomatic individuals with faulty postures (17). The serratus anterior plays a critical role in scapular upward rotation and posterior tilt; its inhibition may contribute to dysfunctional movement patterns and increased joint stress (5, 23).

Clinically, these findings validate the corrective exercise protocols emphasizing selective activation of hypoactive muscles and inhibition of hyperactive ones. The chronic overuse of the upper trapezius and underuse of the middle/lower trapezius and serratus anterior suggest a need for neuromuscular re-education strategies rather than simple strengthening exercises (3, 14). Seidi et al. (2020) demonstrated that a targeted corrective exercise program significantly improved muscle activation and postural alignment in UCS patients over eight weeks, supporting the use of movement-specific interventions over generalized fitness routines (4). Similarly, Hemant et al. (2013) found that restoring muscle length and activation timing in the trapezius improved function and range of motion in individuals with shoulder dysfunction (25).

The present study also affirms the utility of EMG analysis for diagnosing and monitoring neuromuscular patterns in UCS. While clinical tests such as the lateral scapular slide test and visual assessments provide initial screening data, they lack the precision needed to capture real-time muscle dynamics (5, 13). EMG offers a more objective lens into neuromuscular performance, enabling clinicians to quantify baseline deficits and evaluate the effectiveness of intervention programs. In this regard, the study contributes to a growing body of evidence advocating for the integration of electromyographic assessment in physiotherapy protocols for postural syndromes.

Another important implication of this study is its relevance to both symptomatic and asymptomatic populations. While many individuals with UCS remain clinically silent, the altered muscle activation patterns identified here suggest that compensatory strategies may be in place long before the onset of pain or injury. This is consistent with Chu and Butler (2021), who noted that UCS-related biomechanical dysfunction could lead to a range of systemic symptoms, including gastrointestinal issues, due to altered thoracic mechanics (6). Thus, early detection and intervention may not only prevent musculoskeletal deterioration but also reduce the risk of secondary complications.

Finally, this study reinforces the conceptual framework introduced by Janda, who described postural syndromes as interconnected neuromuscular loops requiring integrated assessment and treatment (2). By quantifying the electromyographic signatures of UCS across multiple functional planes, the current research validates the foundational principle that muscle imbalances affect not only static alignment but also dynamic motor performance.

Despite the robust design and valuable insights, this study is not without limitations. First, the sample consisted only of young adult male university students, which restricts the generalizability of findings to other populations, including females, older adults, or athletes. Second, although EMG offers precise data, it is sensitive to factors such as electrode placement, skin impedance, and inter-individual variability, which may have influenced signal fidelity. Third, this study did not evaluate functional outcomes such as shoulder mobility, pain, or performance, which limits the ability to correlate EMG patterns with real-world impairments or improvements. Lastly, the cross-sectional nature of the design precludes causal inferences about the effects of UCS on muscle activation; longitudinal studies are needed to explore how these patterns evolve over time or in response to intervention.

Future studies should consider a more diverse participant pool, incorporating various age groups, female subjects, and individuals from athletic and non-athletic populations. Investigations could also explore the relationship between EMG patterns and clinical symptoms such as pain, joint stiffness, or range of motion to better understand the functional consequences of UCS. In addition, implementing longitudinal designs would allow researchers to evaluate how corrective exercise programs influence muscle recruitment over time. The use of high-density EMG and motion capture technologies may further enhance the spatial and temporal resolution of muscle activation patterns. Finally, exploring neural correlates of motor control through functional imaging or transcranial stimulation could open new avenues for understanding the central mechanisms driving these peripheral imbalances.

Clinicians should prioritize comprehensive assessment protocols that include EMG analysis when managing individuals with suspected UCS. Interventions should target both the inhibition of overactive muscles and the facilitation of underactive stabilizers through specific motor control exercises rather than generalized strengthening. Educational strategies aimed at increasing postural awareness and promoting ergonomic modifications in daily activities are also essential. Early screening in asymptomatic individuals, especially those in sedentary occupations, can help detect neuromuscular deficits before they develop into symptomatic conditions. Integration of phase- and plane-specific muscle activation retraining should be standard in rehabilitation programs for UCS to ensure dynamic motor control is restored, not just static alignment.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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