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Original Research Article

Comparison of EMG Responses of Serratus Anterior and Lower Trapezius in Push up Plus Variation Exercises on Stable and Unstable Surface in Subjects with Scapular Dyskinesia.

Ganaie MI[1], Haque MK[2], Hussain S[3], Muzaffar J[4], Shagufta S[5], Muzaffar T[6]

[1]Clinical Investigator, United Healthcare Group, Delhi
[2]Senior Resident, Department of PMR, SKIMS, Soura.
[3]Jr Physiotherapist, Department of PMR, SKIMS, Soura
[4]Senior Resident, Department of PMR, SKIMS, Soura
[5]Jr Physiotherapist, Department of PMR, SKIMS, Soura
[6]Assistant Professor, Department of PMR SKIMS Soura

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Corresponding author: Muzaffar T
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Abstract:

Introduction: This research evaluates the activation of muscles in scapular dyskinesis subjects and normal individuals during the execution of Push-Up Plus (PUP) exercises on both stable and unstable platforms.

Methods: An EMG was used to examine the differences in muscular activation, with an emphasis on the serratus anterior and lower trapezius amidst the PUP exercises on the two distinct surfaces.

Results: The research discovered increased muscle activation in scapular dyskinesis subjects on stable surfaces when contrasted with normal participants. In contrast, exercises on unstable surfaces showed no discernable difference between the two groups. Additionally, it was observed that there was a reduction in the activation of the lower trapezius and no significant alteration in the serratus anterior activation during PUP exercises on an unstable surface compared to a stable surface.

Discussion: The study indicates that participating in unstable resistance training may lead to high muscle activation levels, causing less strain on the joint system and mimicking daily activities or sports demands. However, the degree of instability should be moderate to enable sufficient EMG levels to strengthen muscles. The study also speculates that scapular muscle activation may vary during similar exercises between subjects with shoulder dysfunction versus those with regular shoulder function.

Conclusion: The research recommends further investigation into the impact of irregular surfaces on muscle activation, especially the rotator cuff muscles, and subsequent studies involving athletes suffering from shoulder impingement syndrome. This information would be invaluable for fitness coaches and rehabilitation experts to construct effective exercise programs targeting specific upper body musculoskeletal muscles.

Keywords: Scapula, Dyskinesis, Pushup, EMG.

Introduction

The shoulder complex, due to its high mobility[1], relies heavily on balanced muscle strength for stability[2], and an imbalance can lead to shoulder problems, especially in athletes with overhead activities [3]. The role played by the trapezius and serratus anterior (SA) muscles in conditions such as shoulder impingement and scapular dyskinesia, as described in numerous studies, is pertinent [3,5-8]. Various treatments have focused on developing these muscles, incorporating a variety of closed kinetic chain (CKC) exercises like push-ups that target and strengthen the scapular stabiliser muscles[9-13]. Surface electromyography also quantifies the muscular demand during these exercises[12,14,15,16]. Different conditions like load increase, muscle fatigue, instability, and postural changes can alter the scapulohumeral rhythm. Some studies have suggested using unstable surfaces like slings, rotating devices, swiss balls, etc. for exercises like push-ups and push-ups plus, as they could promote joint proprioception and increase neuronal activity [1,17-22]. However, the impact of these surfaces on serratus anterior (SA) and trapezius muscle activity remains unclear. Some studies also showed contradictory results regarding the effectiveness of such exercises[19,20,21,23]. Others have demonstrated that push-up plus on a static, unstable surface can increase serratus anterior muscle activity compared to a stable surface[1,24,25,26]. Gender variations in skeletal muscle activations have been noted in the literature - women tend to rely more on muscle activation than men during dynamic movements [12, 23]. This particular study compares EMG responses of the serratus anterior and lower trapezius during push-up plus exercise variations on different surfaces in normal and scapular dyskinesis subjects. The hypothesis is that a sling-based push-up plus exercise could lead to higher SA EMG activity than the same exercise performed on a stable surface.

Methodology

Subjects

Eighteen young normal men and eighteen young men with scapular dyskinesis participated in this study. All subjects were right-handed and physically inactive (not involved in any sports activity or practicing any regular strength training). The other inclusion criteria were having received a positive diagnosis of scapular dyskinesia in the lateral scapular slide test applied, no history of surgery, fractures, instability or pain in the shoulder joint and absence of restrictions of movement in the shoulder joint. The exclusion criteria were being unable to perform push-up plus exercise for any reason. Ethical clearance was taken from the Institutional Ethical Committee of Jamia Millia Islamia, New Delhi, by giving details of the research and consent required for the study. Subjects who met the inclusion and exclusion criteria were selected for the study. Prior to the participation, all subjects were explained the procedure and the purpose of the study. Height and weight were measured with the stadiometer and the digital weighing machine, respectively.

Evaluation procedure

The assessment of the scapular dyskinesia was obtained through the Lateral Scapular Slide Test, which consists of measuring the distance between the inferior angle of the scapula and the corresponding spinous process. The measurement was made with the individual standing upright and the shoulder at 0^0, 45^0 and 90^0 of abduction. A positive test result occurs when the difference between the measurements of left and right exceeds 15 mm [26,13].

Surface EMG preparation

Before the experimental procedure, each subject was prepared for EMG recording. The skin was prepared by shaving excess hair and rubbing the skin with skin abrasive and alcohol swabs to reduce impedance (typically ≤ 10 kOhm). Disposable Ag/AgCl surface electrodes were attached parallel to the muscle fibre orientation. For serratus anterior shoulder abduction 90° and electrodes were positioned in line with the lower angle of the scapula, just anterior to the latissimus dorsi muscle [9]. For the lower trapezius muscle, the subject placed the arm in 90° flexion and the electrodes were positioned at an oblique and vertical angle of 5 cm from the base of the spine of the scapula parallel to the muscle fibres [9]. A reference electrode was placed over the ipsilateral clavicle to normalise background electrical activity. The inter electrode distance was kept around 20 mm.

Maximal voluntary isometric contraction (MVIC) assessment

The MVIC of the muscles were performed to develop readings for EMG signal amplitude normalisation. Two trials of each muscle for MVIC were performed by giving manual resistance and verbal cues to ensure maximal effort. Each trial was recorded for 5 seconds, and a 2-minute rest was given between the trials. The maximum activation of the serratus anterior was recorded with the subject sitting tested arm in 1350 flexion in the scapular plane and performing a maximal effort to flex the arm further while the investigator was applying manual resistance above the elbow to restrict motion [13]. For lower trapezius muscle MVIC recording, the arm was placed diagonally overhead in line with the lower fibres of the trapezius while the subject was in a prone position. Resistance was applied against further elevation[13]. The EMG data was collected for 3 seconds of the isometric phase, and the best among the two trials was considered for normalisation.

Exercise procedures

After an explanation of each exercise followed by a guided trial, the muscle activation of the exercises was recorded. The subjects executed two experimental exercises in a random sequence. The push-up plus exercise on the two surfaces (standard push-up plus exercise on the push-up bar; standard push-up plus exercise on the sling) were performed by subjects while the instructors provided feedback to ensure that the exercises were performed correctly. The height of the sling was adjusted according to the height of the push-up bar so that there is a similar distribution of percentage body weight on upper arms while performing push-up plus exercise on the sling and push-up bar. Three repetitions of push-up plus exercise were performed in 6 seconds on both the push-up bar and sling. A 2-3 minute rest time was given between exercises performed on push-up bar and sling.

Standard push-up plus exercise on push-up bar

The standard push-up plus exercise began with the subject in a prone position with the hands shoulder width apart forearm pronated, hands holding the push-up bar and chest near the ground [11]. The subject then extended his elbows to a standard push-up position and continued to rise up by protracting the scapula. The subject returned to the starting position by retracting the scapula and flexing the elbows.

Standard push-up plus exercise on sling

The standard push-up plus exercise began with the subject in a prone position with the hands shoulder width apart forearm pronated, hands holding the sling and chest near the ground [11]. The subject then extended his elbows to a standard push-up position and continued to rise up by protracting the scapula. The subject returned to the starting position by retracting the scapula and flexing the elbows.

Instrumentation

The raw surface EMG signals were band pass filtered between 10 and 500 Hz and amplified 1000 times. The sampling frequency was 1000Hz. The signals were stored in analogue/digital (AD) form on a personal computer.

Normalization of data

EMG data was collected during MVIC and push-up plus exercises. The root-mean-square (RMS) of EMG amplitude was calculated for a second period of the isometric phase of each exercise. The mean RMS of two MVIC trials for each muscle was used to provide the basis for EMG amplitude for the normalisation of data obtained during the experimental exercises (%MVIC). The static phase of the experimental exercise was analysed, using the best of two readings used to provide a basis for EMG amplitude normalisation of data obtained during the experimental exercises (%MVIC). The RMS of EMG amplitude was calculated for 2000ms muscle contraction of serratus anterior (during the protraction phase) and 2000ms muscle contraction of lower trapezius (during the retraction phase of push-up plus exercise). The mean of root-mean-square (RMS) for the three repetitions of push-up plus exercises after normalisation (%MVIC) was used for comparison.

Data analysis

The SPSS version 21.0 software program was used for data analysis. The Shapiro-Wilk test was used to verify the normality of variable distribution, and then the data was log-transformed. After that one way analysis of variance (ANOVA) with repeated measures was used to compare the difference in muscle activation of serratus anterior and lower trapezius during push-up plus exercises performed on two surfaces. Bonferroni correction was used for the analysis to determine the significant differences between the individual muscles in each exercise. The confidence interval used was 95%, with the level of significance set at $p<.05$

Results

Thirty six subjects were included in this study to determine the effect of surface on the muscle activation of the

lower trapezius and serratus anterior in normal (n=18) and scapular dyskinesic(n=18) subjects. To test for the difference between groups and across two assessments, a 2X2 split plot ANOVA with group (control, experimental), surface (stable and unstable) and interaction effect (Group X surface) was employed. A Bonferroni test was employed as a post hoc analysis to verify the significant difference. The significance level was set at $p< 0.05$.

The demographic data is shown in [Table 1]. There was no significant difference for the demographic characteristics between the groups. Both the groups were comparable in terms of age, height, weight and BMI.

Table 1:

	Group 1 Mean (SD)	Group 2 Mean (SD)	F-value	*p*-value
Age (years)	23.06 (2.66)	21.61 (2.09)	3.27	0.079
Weight (kg)	60.53 (7.27)	58.17 (5.56)	1.197	0.282
Height (cm)	168.72 (4.91)	170.38 (6.24)	0.79	0.38
BMI (kg/m^2)	21.27 (2.16)	20.12 (2.37)	2.20	0.14
Data are presented as Mean (SD), SD: Standard Deviation; significant difference = $p<0.05$; BMI: Body Mass Index; Kg: kilogram; m: meter; cm: centimeters				

Demographic data of participants

A comparison of baseline criterion measurements between the control and experimental group was done using an independent t-test to check the homogeneity between the groups ([Table 2]. No significant difference in % MVIC muscle activation of serratus anterior ($p = 0.617$) and lower trapezius ($p = 0.194$) during PUPS was found between the groups. However, there was a significant difference in %MVIC muscle activation of serratus anterior ($p = 0.005$) and lower trapezius ($p = 0.024$) during PUPB between the groups.

Table 2: ***Comparison of Baseline Measures Between Groups***

Variables	Muscles	Control Mean (SD)	Experimental Mean (SD)	Independent *t*-test (*p*-value)
PUPS	SA	52.87 (26.56)	45.97 (21.66)	0.617
	LT	42.38 (37.75)	35.63 (16.21)	0.194
PUPB	SA	44.93 (18.09)	57.15 (32.91)	0.005*
	LT	41.34 (22.93)	58.81 (35.90)	0.024*
%MVIC: percentage maximal voluntary isometric contraction; PUPS: push-up plus exercise on sling; PUPB: push-up plus exercise on bar; SA: serratus anterior; LT: lower trapezius				

Mean relative muscle activity (%MVIC) and standard deviation (SD) during push-up exercise on stable and unstable surface

Result of split plot ANOVA is given in [Table 3]. A 2X2 split plot ANOVA yielded a main effect for surface on lower trapezius, F (1, 34) =6.001, p = 0.020. The main effect of group was not significant, F (1, 34) = 0.557, p = 0.453. Also, the interaction effect was not significant, F (1, 34) = 3.260, p = 0.087, indicating that the surface effect was similar between the two groups.

A 2 X 2 split plot ANOVA effect for surface on serratus anterior was not significant, F (1, 34) =0.011, p = 0.918. The main effect of group was non significant, F (1, 34) = 0.012, p = 0.914. Also, the interaction effect was not significant, F (1, 34) = 2.460, p = 0.067, indicating that the surface effect was similar in both groups.

Table 3: Summary of Split Plot ANOVA

Dependent variable	Source	Df	F	*p*-value	Partial eta squared
Lower trapezius activation	Surface	1	6.001	0.020*	0.150
	Group	1	0.577	0.453	0.017
	Surface X Group	1	3.260	0.080	0.087
Serratus anterior activation	Surface	1	0.011	0.918	<0.01
	Group	1	0.012	0.914	<0.01
	Surface X Group	1	2.460	0.126	0.067
*significant difference					

Lower trapezius

The activity of the lower trapezius was shown in two different types of push-up exercises [Figure 1]. Post hoc Bonferroni pairwise comparison showed a significant increase in activity during push-ups on a stable surface (M= 50.076, SD= 30.98) in relation to push-up plus exercise on an unstable surface (M= 39.006, SD= 28.83), p= 0.020. Normal subjects on unstable surfaces showed higher muscle activation (M= 42.37, SD= 37.74) in comparison to scapular dyskinesis subjects (M= 35.63, SD= 16.21). However, it was not statistically significant, with p= 0.453. Also, there was no significant difference in the interaction effect (Surface X Group) on the muscle activation of the lower trapezius (p= 0.453).

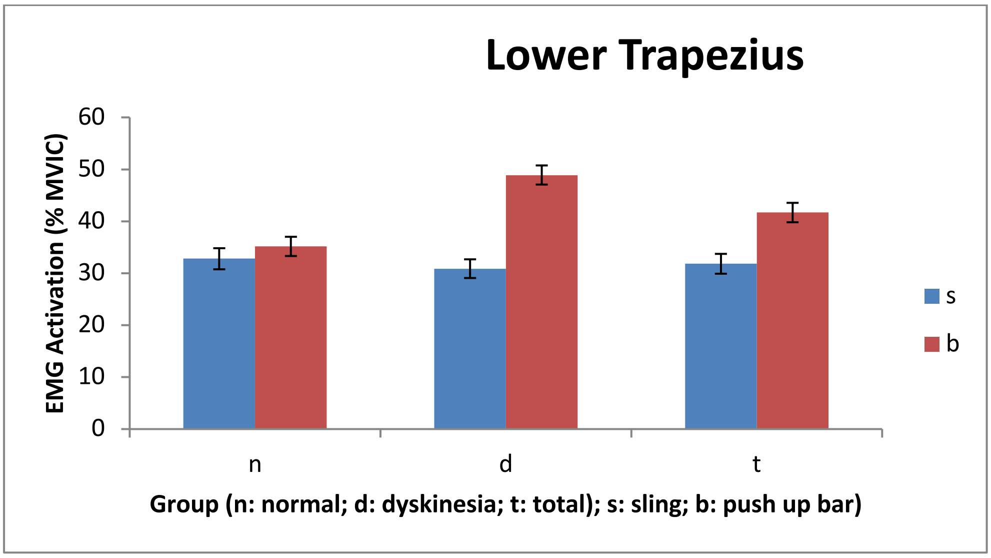

Figure 1:

EMG activity of lower trapezius during push up plus exercise on push up bar and sling in normal and dyskinesia group.

Serratus anterior

The activity of serratus anterior was shown in two different types of push-up exercises [Figure 2]: Post hoc Bonferroni pairwise comparison showed a slightly higher activation during push-up on a stable surface (M= 51.04, SD= 26.89) in relation to push-up plus exercise on an unstable surface (M= 49.42, SD= 24.14), but that was not statistically significant (p= 0.918). Normal subjects on the unstable surface showed higher muscle activation (M= 52.87, SD= 26.56) in comparison to scapular dyskinesic subjects (M= 45.97, SD= 21.66), however, it was not statistically significant, p= 0.914. Also, there was no significant difference in the interaction effect (Surface X Group) on the muscle activation of serratus anterior (p= 0.126).

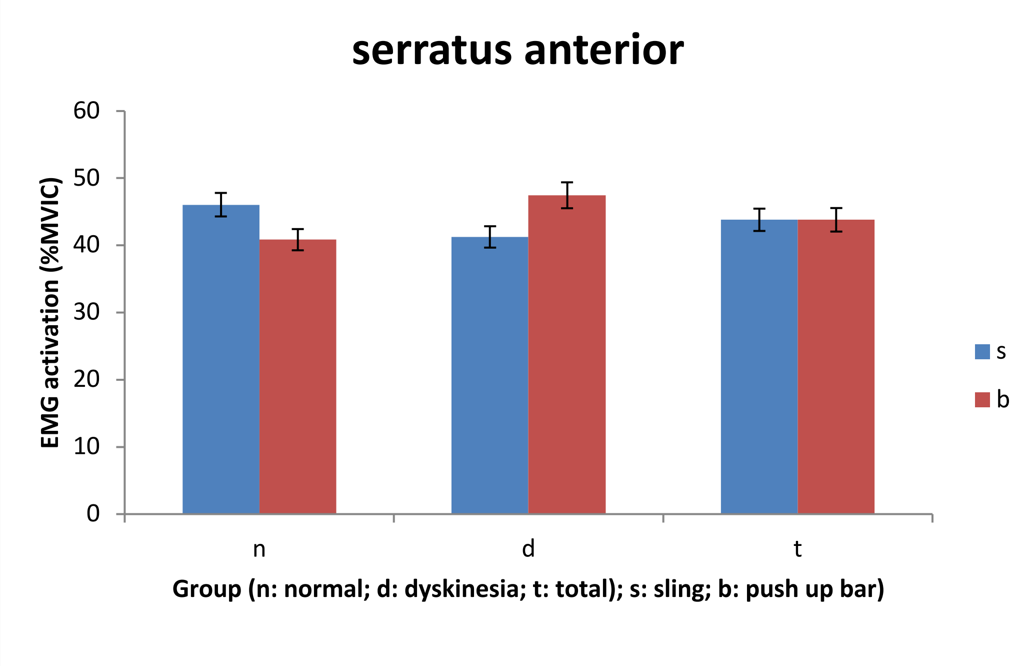

Figure 2:

EMG activity of serratus anterior during push up plus exercise on push up bar and sling in normal and dyskinesia group.

Discussion

Athletes involved in overhead activities are usually advised to perform scapular strengthening exercises in their training regime [23]. Exercises which preferentially demand serratus anterior and lower trapezius are recommended [27]. Push-up plus exercise is being advised to target these muscles, and adding unstable surfaces like a sling, wobble board, Swiss ball, etc. are frequently used to provoke increased activation levels in these muscles.

The present study examined the effect of surface-varied push-up plus exercise on muscle activation of scapular muscles (lower trapezius and serratus anterior) in normal and scapular dyskinesia subjects. According to the results of the present study, normal and scapular dyskinesis subjects showed only significant differences in the muscle activation of scapular stabilisers while performing push-up plus exercises on a stable surface. Scapular dyskinesic subjects showed higher activation of both muscles while performing PUP exercises on a stable surface when compared to normal subjects. This can be explained by the fact that when giving the same load (proportional to body weight on upper limbs) for the exercise, a dyskinesis shoulder requires higher muscle activation of scapular stabilisers than a normal shoulder. However, there was no significant difference in muscle activation between the two groups when the same exercise was performed on an unstable surface. This could be due to the complexity of exercise for both groups, as previous studies have noted that adding an unstable surface for push-up plus exercise increases EMG activity of other muscles like pectoralis major, latissimus dorsi, anterior deltoid, and core muscles [28]. So, adding an unstable surface for PUP exercise may be acting as a more demanding exercise for glenohumeral muscles rather than scapular stabiliser muscles and, thereby, increasing the favouring factor of PUP exercise for a dyskinesis shoulder.

While comparing the effect of two exercises on muscle activation regardless of groups, our study showed significantly lower activation of the lower trapezius and no significant difference for activation of the serratus anterior during unstable surface PUP exercise than stable surface PUP exercise. This result is contrary to other studies done by Periurra et al., (2014) , Yoo and Young, (2010), Kim et al., (2014) ,Sang yong lee (2013) [29.30,31,31]. However, our findings were in accordance with the findings of previous research showing that not all muscles increase or decrease their muscle activation levels in response to an unstable surface Tucker et al., (2008), Martins et al., (2008) Caroline et al., (2013) and Kristoff et al., (2014). Lear et al., (2008) also found no significant difference in the muscle activation of the serratus anterior while performing PUP exercise on stable and unstable surfaces, but there was significantly higher activation of the lower trapezius on unstable than on stable surface PUP exercise. Kristoff et al., (2014) observed a similar result as in our study for both the muscles, but the distribution of the percentage of body weight was not equal while comparing the effect of surface; however, we have set the height of the sling in such a way that distribution of body weight on upper limbs was equal for both exercises [21,22,33,34].

In the present study, EMG activity of the serratus anterior during unstable surface PUP exercise did not increase than in the stable condition. This finding is supported by Korneki and Zschorlich (1994), Anderson and Bhem (2004), who showed similar results and concluded that the reason behind this was that a percentage of force output was diverted towards joint stabilisation [6,12,14,35]. Another reason behind the lack of increase in EMG activity of the serratus anterior can be because EMG activity of the serratus anterior was not inhibited during unstable surface. So, another muscle group may be activated to the same extent as with stable conditions to overcome the demand induced by percentage body weight during unstable PUP exercise. Therefore, it is possible that the muscle is maintaining EMG activity levels through a combination of force production and stabilising functions. A possible benefit of unstable resistance exercise training would be the ability to achieve high muscle activation (via movement and stabilising functions) with lower resultant joint torques from the reduced loads, resulting in less stress on the articular system. Furthermore, the need for greater stabilising responsibilities of the limb musculature may mimic more closely the typical requirements of daily activities or sports.

In the present study, there was significantly lower EMG activity of the lower trapezius in unstable surface PUP exercise than in stable conditions. The decrease in lower trapezius EMG activity may have been caused by the higher recruitment of other shoulder muscles. Another reason may be that the high level of instability caused by performing the exercise may have limited the individual's ability to activate and apply the force while maintaining balance. The synergetic participation of other shoulder muscles in scapular stabilisation may have been performed by the pectoralis major, levator scapulae, latissimus dorsi and anterior deltoid (kristoff et al 2014) (Sumiaki Maeo et al 2014) (Lehman et al 2006), which were not evaluated in the present study[12,28].

Instability recruits shoulder muscles in a more general way and thus promotes greater stability and proprioception. This makes exercises on an unstable surface less harmful to the joint and possibly more advantageous than those performed on a stable surface. This is because they allow for different levels of muscular contraction to be achieved with less force (Anderson & Behm, 2004)[2,6]. Nevertheless, the instability offered by exercises on an unstable surface must be moderate to generate EMG amplitude levels capable of strengthening those muscles and also preventing muscle action from being completely focused on joint stabilisation (Behm et el., 2002). Previous studies have observed difficulty in performing push-up plus exercises on the sling surface, especially when the rope attached to the sling was too thin or hung too high (Lee et al., 2013). Therefore, we used a strap instead of rope and connected it with a suspension apparatus so that it became easier for the subjects to perform the unstable surface exercise safely[6,37].

Previous studies have studied the effect of similar exercises on normal shoulder subjects Kim et al., 2013; Martins et al., 2008; Lee et al., 2013; Lear et al., 1998; Seo et al., 2013[34,36,37,38,39]. However, we propose that there may be a possibility of having variation in the activation of scapular muscles while performing the same exercises by subjects with shoulder dysfunction compared to normal shoulder subjects. Pirura et al (2014) reported higher activation of the lower trapezius and lower activation of the serratus anterior during unstable surface PUP exercise in subjects with scapular dyskinesis[29]. The reason for the difference in results may be because they have used a wobble board as an unstable surface for push-up plus exercise that would cause vertical axial force while performing unstable surface PUP exercise that would have led to higher activation of those muscles. Seo et al. (2013) evaluated 10 asymptomatic subjects and found that the execution of the push-up and knee push-up exercises with a Swiss ball (unstable surface) produced an increase in the EMG activity of the trapezius and serratus anterior muscles than stable surface PUP exercises[39]. On the other hand, the results described by Tucker et al. (2010) demonstrated that the use of an unstable surface for push-up exercises caused a decrease in EMG activity of the SA and increased EMG activity of the lower trapezius in athletes with shoulder impingent syndrome. Therefore, it is hypothesised that dyskinesic shoulder reduced the lower trapezius's reaction to an unstable surface by correlating these results with those from our study [33].

Conclusion

Further research options based on our initial findings are intriguing to consider. Primarily, the effects of irregular surfaces on the activation levels of different muscles, for example, the rotator cuff muscles, could be probed. These muscles are key stabilisers for the glenohumeral joint, and thus, examining their activation levels and understanding how different unstable situations during Closed Kinetic Chain exercises impact them could be important. A secondary proposal is to replicate the study with sportspeople suffering from shoulder impingement syndrome. Comparing the outcome of this study with our current findings could be significant as it might provide further clarity on how these factors affect muscle engagement during individual exercises. In summary, these findings should be taken into account by coaches and rehabilitation professionals when they aim to train or target specific upper body musculoskeletal muscles using push-ups.

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