Original Article

Efficacy of EMG-Guided Biofeedback and Modified Robbery Exercises for Scapular Dyskinesia: Impact on Muscle Function, Disability, and Quality of Life

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Article Info

Abstract

Aims & Objective: Scapular dyskinesia affects shoulder function, with significant implications for individuals suffering from this. Rehabilitation approaches, including modified robbery exercises, aim to address this by improving scapular kinematics and muscle function. This study evaluates the effectiveness of modified robbery exercises supplemented with electromyography (EMG) biofeedback on muscle activation patterns and functional outcomes in individuals with scapular dyskinesia. **Methodology:** A randomized trial was performed with 40 participants split into two groups: the control group receiving modified robbery exercises and ergonomic training, and the experimental group receiving modified robbery exercises with EMG biofeedback. They received treatment three times weekly for six weeks, and the effectiveness was measured by pain, muscle activation, disability, and quality of life scores, using statistical tests to compare group differences before and after the interventions. **Results:** The experimental group showed significantly better muscle activation in the Serratus Anterior and both Upper and Lower Trapezius muscles, alongside greater reductions in pain and functional disability, and higher quality of life scores. **Conclusions:** This study suggests that EMG biofeedback-enhanced robbery exercises outperform traditional methods in improving muscle function, decreasing disability, and boosting quality of life for scapular dyskinesia patients, advocating for their inclusion in therapeutic regimens.

Keywords: Scapular Dyskinesia, Modified Robbery Exercises, Electromyography (EMG) Biofeedback, Muscle Activation, Functional Disability, Quality of Life

Introduction

Scapular dyskinesia is not merely a symptomatic manifestation but a biomechanical dysfunction that often coexists with shoulder injuries, such as rotator cuff pathologies and glenohumeral joint disorders. Its prevalence is notably high among athletes, particularly those involved in overhead sports, but it is also observed in the general population, reflecting its significance as a common yet complex clinical challenge (Burn, McCulloch, Lintner, Liberman, & Harris, 2016; Kibler & Sciascia, 2016). Scapular dyskinesia refers to abnormal movement patterns of the scapula, which is the triangular bone situated on the posterior aspect of the shoulder. The scapula's role as a pivotal element in shoulder movement underscores the necessity for precise evaluation and targeted interventions to address dyskinesia effectively. The serratus anterior and lower trapezius muscles are critical for scapular stabilization and movement. Dysfunction or weakness in these muscles can lead to altered scapular kinematics, contributing to conditions such as subacromial impingement syndrome by decreasing the subacromial space and affecting the rotator cuff's functionality (Leong, Tsui, Ng, & Fu, 2016). Dysfunctional scapular movement can manifest in various forms, including winging (where the medial border of the scapula protrudes excessively from the thoracic wall), tilting (where the superior angle of the scapula elevates or depresses excessively during arm movement), and protraction/retraction (Kibler & Sciascia, 2016). This biomechanical perspective is crucial for understanding the pathophysiology of scapular dyskinesia and its potential impact on shoulder health. It affects up to 67% of individuals with shoulder complaints and is particularly prevalent among athletes in overhead sports, where rates can exceed 70% (Lin et al., 2018). This high prevalence underscores scapular dyskinesia's importance as a pervasive and multifaceted clinical issue in both athletic and general populations.

Several factors contribute to the development of scapular dyskinesia. These may include muscle weakness or imbalance within the shoulder complex, alterations in neuromuscular control, anatomical variations, trauma, repetitive overhead activities, poor posture, and underlying shoulder pathologies. The effects of scapular dyskinesia on activities of daily living (ADLs) can be profound (Hickey et al., 2018). Abnormal scapular mechanics can predispose individuals to shoulder pain, fatigue, and reduced endurance during physical activities. These impairments not only impact functional independence but also diminish overall quality of life (QoL) by limiting participation in recreational activities, work-related tasks, and social interactions.

Recent literature emphasizes the importance of specific rehabilitation exercises aimed at correcting scapular dyskinesia. The modified robbery exercise, among others, has been proposed as an effective method for engaging the scapular stabilizers in a manner that mimics functional movement patterns. This approach is based on the premise that exercises tailored to replicate daily and sports-related activities can potentially offer more meaningful improvements in scapular positioning and muscle activation patterns (Ellenbecker & Cools, 2010; Tsuruike & Ellenbecker, 2015). These exercises are tailored to engage scapular stabilizers through functional movement patterns, potentially offering significant improvements in scapular positioning and muscle activation.

The use of electromyography (EMG) in evaluating the effectiveness of these exercises provides an objective measure of muscle activation, offering insights into the neuromuscular adaptations that occur with targeted interventions. By quantifying the engagement of specific muscles during the execution of rehabilitation exercises, EMG analysis allows for a nuanced assessment of exercise efficacy, informing the development of optimized rehabilitation protocols (Cools et al., 2007; De Mey et al., 2014).

Despite the advancements in understanding and treating scapular dyskinesia, there remains a significant gap in the literature regarding the comprehensive evaluation of rehabilitation exercises, particularly in their capacity to alter muscle activation patterns and improve scapular kinematics. The need for research that not only assesses the effectiveness of such interventions but also explores the underlying mechanisms of action is evident. This gap highlights the potential for studies that employ a detailed EMG analysis to contribute significantly to the body of knowledge on scapular dyskinesia rehabilitation (Welbeck et al., 2019). This approach allows for a nuanced assessment of neuromuscular adaptations, guiding the optimization of rehabilitation protocols. Despite this, a comprehensive evaluation of these exercises, particularly their impact on muscle activation patterns and scapular kinematics, remains sparse.

This study seeks to comprehensively assess and compare the impact of modified robbery exercises on individuals with scapular dyskinesia, with a particular focus on muscle activation patterns with biofeedback, scapular

kinematics, quality of life, and pain reduction. By utilizing detailed electromyography (EMG) analysis, our research aims to provide evidence-based insights into the efficacy of these rehabilitation exercises, not only in terms of biomechanical outcomes but also in their ability to enhance the overall well-being and reduce pain among affected individuals.

Materials & Methods

For our study we selected individuals between 20- 50 years of age, presenting with winging of the scapula and postural abnormalities as rounded shoulder. To be eligible, participants needed to exhibit a positive Scapular Assistance Test (SAT) and effective performance in wall push-ups. The SAT is crucial for identifying the need to stabilize the scapula by manually assisting its rotation during arm movements, pinpointing the serratus anterior and lower trapezius muscles as key areas for rehabilitation focus. The scapular assistance test (SAT) demonstrated acceptable interrater reliability for clinical use, with a kappa coefficient of .62 and 91% percent agreement when performed in the sagittal plane (Rabin, Irrgang, Fitzgerald, & Eubanks, 2006) . Wall push-ups serve as a practical method for assessing the strength of the serratus anterior, with abnormalities typically emerging after 5-10 repetitions. The patients were included if they get any pain after the wall push-ups around scapula or not able to do same (Warner & Navarro, 1998). Additionally, participants were required to report pain and tenderness around the scapula area. Exclusion criteria were set to disqualify individuals with symptoms of shoulder impingement as indicated by a positive Neer's impingement test, those with a history of rotator cuff injuries, any prior shoulder surgery or trauma, and patients exhibiting neurological symptoms. This comprehensive approach ensured a targeted participant selection, aiming to evaluate the intervention's efficacy accurately. The data was collected from the physiotherapy OPD of Manav Rachna International of Research and Studies.

Sample size calculation

The sample size was determined utilizing a paired t-test approach to evaluate the effectiveness of the intervention across both control and experimental groups, with assessments conducted before and after the intervention. The formula employed for this calculation is

$$n = \frac{\left(z_{\alpha/2} + z_\beta\right)^2 \cdot 2 \cdot \sigma^2}{d^2}$$

where n signifies the sample size required for each group; $Z_{\alpha/2}$- is the critical value from the standard normal distribution for a two-tailed significance level α of 0.05, to ensure a 5% risk of Type I error. $Z_{\beta}2$- represents the critical value associated with the study's power, which is aimed at 80% (1 – β), with β at 0.20), to effectively minimize the risk of Type II error and enhance the probability of detecting a true effect (Faul, Erdfelder, Lang, & Buchner, 2007). $\sigma2$ is the variance of the paired differences, assumed to be 1 based on insights from comparable studies. 'd' is the expected effect size, established at 0.5 (medium effect size) that is expected to demonstrate a clinically meaningful difference between pre- and post-intervention measurements, as corroborated by existing literature (Cohen, 1988). Employing these parameters, the requisite sample size to attain the specified power for uncovering a medium effect size was calculated to be approximately 31 participants for 2 groups. Considering the drop out, the sample size was estimated to be 40, with 20 participants in each group.

Study Design and Sampling Technique

The study employed a randomized controlled trial (RCT) design to assess the effectiveness of modified robbery exercises on individuals diagnosed with scapular dyskinesia. The study followed a structured clinical research process beginning with the eligibility phase, where participants were screened against predefined criteria. The study began with the recruitment of 62 individuals screened for scapular dyskinesia. After obtaining informed consent from all potential participants, 18 were excluded for not meeting the study's stringent inclusion criteria. This left 44 participants who were then randomized into two groups: the control group, which received modified robbery exercises combined with ergonomic training, and the experimental group, which was provided with modified robbery exercises and EMG biofeedback. As the study progressed, attrition due to loss to follow-up and discontinuation of the exercises resulted in a reduction of numbers. Ultimately, both the control and the experimental groups continued with an equal number of 20 participants each, ensuring a balanced comparative analysis for the intervention's effectiveness (Figure 1).

Randomization and Blinding

Randomization was conducted using a computer-generated sequence, with allocation concealment achieved through sealed opaque envelopes. To minimize bias, participants were blinded to their group assignments, and outcome assessors were blinded to the treatments received by participants. Both the participants and the

researchers conducting the assessments are blinded to group assignments. This approach minimizes performance and assessment bias, ensuring that the outcomes are not influenced by participants' or researchers' expectations. 1:1 Allocation participants are

allocated to the intervention and control groups in equal numbers. This balanced allocation ensures that both groups are equally sized, maximizing the study's statistical power to detect differences between groups.
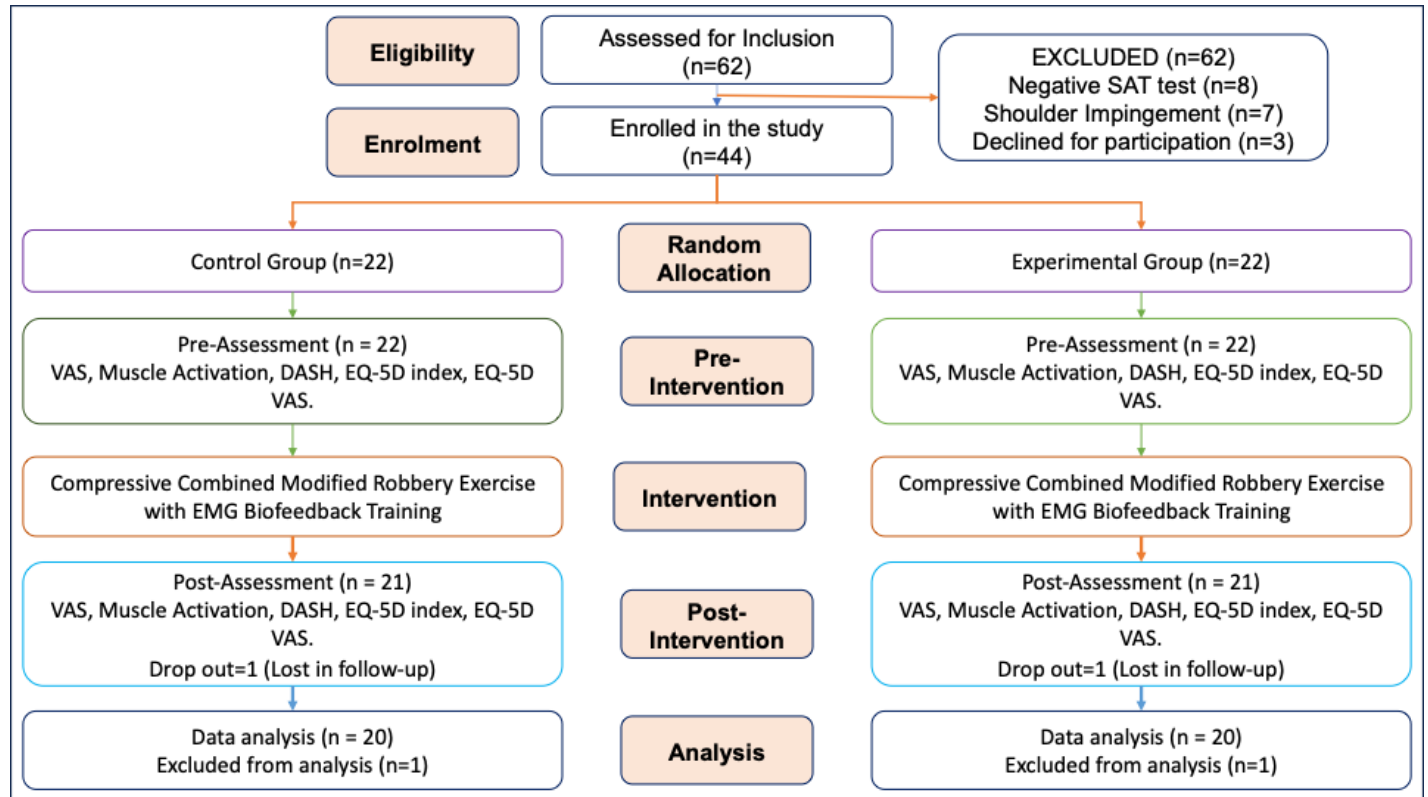

Figure 1: Flow chart of the study design

Ethical Consideration

The study's protocol received approval from the Department Ethical Committee at Faculty of Allied Health Sciences (Ref No. MRIIRS/FAHS/DEC-2023 – BPT-009). Participants were fully briefed on the study's aims, procedures, potential risks, and benefits before giving their written informed consent. Throughout the study, participant confidentiality was upheld, with all data anonymized and securely stored.

Selection criteria

The inclusion criteria were meticulously defined to recruit individuals aged 20 to 50 years, both male and female, presenting with symptoms of scapular winging and postural abnormalities indicative of scapular dyskinesia. Eligibility required a positive Scapular Assistance Test (SAT), indicating the necessity for enhanced scapular stabilization, and effective performance in wall push-ups to assess the functional capacity of the serratus anterior muscle, with deficits typically becoming apparent after 5

to 10 repetitions. Additionally, candidates were required to report experiencing pain and tenderness around the scapula area, further suggesting the presence of scapular dyskinesia. The exclusion criteria were established to ensure the study's focus remained on scapular dyskinesia unaccompanied by other complicating shoulder conditions. Therefore, individuals displaying symptoms of shoulder impingement as evidenced by a positive Neer's impingement test, those with a history of rotator cuff injuries, any previous shoulder surgeries or trauma, and patients with neurological symptoms affecting shoulder function were disqualified from participation.

Intervention

Two distinct groups were formed for the study to assess the effectiveness of modified robbery exercises in treating scapular dyskinesia, each comprising 20 participants. The control group participated in a parallel 6-week program that also centered around modified robbery exercises (3 sessions per week) but was supplemented with ergonomic training (Table 1) instead of EMG biofeedback.

Conversely, the Experimental group engaged in a comprehensive 6-week treatment program (3 sessions per week) that combined modified robbery exercises with EMG biofeedback training. This intervention aimed to improve muscle activation and scapular control through real-time feedback, with sessions scheduled three times a week. This approach focused on promoting better posture and adapting workplace ergonomics to alleviate stress on the scapular region, without leveraging biofeedback technology. Both groups aimed to enhance shoulder stability, function, and pain relief through their respective interventions.

Participants in the control group underwent a program consisting of modified robbery exercises (table 1) designed to address scapular dyskinesia by strengthening the scapular stabilizer muscles and improving scapular alignment. In addition to these exercises, the control group received ergonomic training, which was tailored to each participant's daily activities and work environment. The ergonomic training included workplace setup, recommendations for adjustments in workstation design, seating arrangements, and equipment used to reduce strain on the shoulder and scapular region.

Table 1: Modified robbery exercises protocol (3 sessions/week for 6 weeks)

Phase	Exercise Type	Description	Purpose
Warm-up (5-10 mins)	Cardiovascular	Gentle walking or cycling on a stationary bike.	Increase heart rate and blood flow to muscles, preparing the body for physical activity.
	Dynamic Stretching	Dynamic stretches focusing on the upper body, such as arm circles and shoulder rolls.	Improve range of motion and flexibility in the upper body, specifically targeting the shoulder and scapular muscles.
Main Exercise (30-40 mins) (3 sets of 10-15 repetitions)	Scapular Retraction	Focuses on squeezing the shoulder blades together, typically performed in a seated or standing position, to strengthen the rhomboids and middle trapezius muscles.	Enhance scapular stability by strengthening key stabilizers, vital for proper scapula motion and upper limb function.
	Prone Y	Performed face down, arms lifted overhead in a Y formation to target and strengthen the lower trapezius muscles, crucial for upward rotation and stabilization of the scapula.	Target the lower trapezius for improved scapular rotation and stability, essential for functional overhead activities.
	Prone T	Involves extending arms to the sides and lifting, while face down, to engage and strengthen the mid-back muscles, including the middle trapezius and rhomboids, facilitating scapular retraction and depression.	Strengthen mid-back muscles for enhanced scapular control and posture, promoting optimal shoulder function.
	Wall Angels	Executed with the back against a wall and arms in a 'goalpost' position, moving the arms up and down against the wall to improve posture and scapular mobility by challenging the scapular stabilizers.	Improve scapular mobility and posture through active engagement of scapular stabilizers in a controlled, movement-oriented exercise.
Cool Down (5-10 mins)	Static Stretching	Stretches focusing on the pectoral muscles, upper trapezius, and posterior shoulder to promote muscle relaxation, reduce post-exercise stiffness, and increase flexibility.	Facilitate muscle recovery, enhance flexibility, and reduce the risk of muscle imbalances.

Relaxation	Deep breathing or mindfulness exercises to promote overall relaxation and stress reduction, enhancing recovery and well-being.	Support mental recovery and well-being by calming the nervous system and reducing stress levels post-exercise.

The experimental group participated in a similar regimen of modified robbery exercises. However, this group's program was enhanced with EMG (Electromyography) biofeedback training, focusing on improving muscle activation patterns and scapular control. Participants performed exercises (table 1) while receiving immediate visual or auditory feedback on muscle activation levels, using EMG sensors placed on key scapular muscles. Based on biofeedback, exercises were adjusted in real-time to ensure optimal muscle engagement and correct movement patterns, facilitating better scapular positioning and function. Regular assessments using EMG biofeedback to monitor improvements in muscle activation patterns and adapt the exercise program accordingly.

Outcome Measures

Pain Levels (Visual Analog Scale, VAS): In the study assessing the impact of modified robbery exercises on patients with scapular dyskinesia, pain levels around the shoulder and peri-scapular region were quantitatively measured using the Visual Analog Scale (VAS), a reliable tool for self-reporting pain intensity on a continuum from "no pain" to "worst imaginable pain|. Participants marked their perceived pain level on this 10-cm line at two junctures: pre-intervention and post-intervention. This methodology aligns with established practices in pain assessment, as documented in the literature (Hawker, Mian, Kendzerska, & French, 2011), ensuring that the study's findings are grounded in a validated approach to measuring pain outcomes.

Muscle Activation (Electromyography, EMG): This involved recording the muscle activation patterns of key scapular muscles (serratus anterior, lower trapezius, upper trapezius, and rhomboid muscles) during exercise. The aim was to quantify changes in muscle engagement that occurred because of the intervention. EMG data collection points were at baseline and 6 weeks into the program.

EMG Placement and Procedure

Serratus Anterior (SA): Participants were seated comfortably with their trunk areas exposed for electrode placement. Electrodes were positioned on both sides of the trunk at the seventh intercostal space and at the xiphoid process level at the fifth intercostal space. With arms flexed at 90 degrees, participants underwent submaximal isometric contractions for 10 seconds, interspersed with 7-second relaxation periods over seven repetitions, to gather average muscle work data.

Upper Trapezius (UT): Following the SA measurements, electrodes were repositioned parallel to the muscle fibers of the upper trapezius, at the midpoint of the spine at C7, and 2.5 cm from the shoulder at the lateral point of the acromion. Participants were asked to elevate their shoulders against resistance, with data collected over similar contraction and relaxation cycles.

Lower Trapezius (LT): Electrodes were moved to T1 and T4 along the spine for measurements of the lower trapezius. Participants engaged in retraction movements against resistance, following the established protocol for contraction, relaxation, and repetitions to collect average work data.

Rhomboid Muscles: After completing the LT measurements, the focus shifted to the rhomboid muscles, crucial for scapular stabilization and retraction. Electrodes were carefully placed to accurately capture the activity of the rhomboid major and minor. One electrode was situated at the level of the spine between the scapula and the vertebral column, specifically between the third and fourth thoracic vertebrae (T3 and T4), which corresponds to the primary location of these muscles. Participants were then instructed to perform scapular retraction exercises, where they were asked to draw their shoulder blades toward each other as if squeezing an object between them. This action was performed against a resistance applied by the therapist to maximize engagement of the rhomboids. The protocol of 10 seconds of contraction followed by 7 seconds of relaxation was repeated seven times to ensure a comprehensive assessment. This procedure allowed for the collection of detailed data on the average work output of the rhomboid muscles, complementing the study's overall assessment of muscle activity changes resulting from the intervention programs.

Functional Disability (DASH Questionnaire)

The Disabilities of the Arm, Shoulder, and Hand (DASH) Questionnaire was used in this study as a primary outcome measure to assess the self-reported function and symptomatology of patients with scapular dyskinesia undergoing modified robbery exercises. The DASH is a validated instrument that quantifies the impact of upper limb disorders on both physical function and symptoms, making it an ideal tool for evaluating the subjective outcomes of therapeutic interventions. . It consists of 30 items that cover physical function, symptoms, and social/psychological aspects, offering a comprehensive view of how scapular dyskinesia affects daily life and activities. Scores range from 0 (no disability) to 100 (most severe disability), allowing for the quantification of functional improvements or declines (Hudak et al., 1996).

Health related Quality of life management

EQ-5D Index: This component evaluates five critical dimensions of health, including mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. Participants' responses in each dimension were converted into utility scores using the Danish time trade-off values. This conversion facilitates the quantification of health states on a scale where -0.6 represents the worst possible health state and 1.0 signifies the best possible health state. The adoption of Danish utility scores enables the transformation of the EQ-5D index into health utility scores, reflecting the comprehensive assessment of participants' health status.

EQ-5D Visual Analog Scale (EQ-VAS): Complementing the index, the EQ-VAS provides a direct subjective measure of the participant's current health state on a scale from 0 (worst imaginable health state) to 100 (best imaginable health state). This scale allows participants to express their overall health perception, offering an invaluable subjective counterpart to the objective utility scores derived from the EQ-5D index.

Statistical analysis: Data analysis was conducted using the Statistical Package for the Social Sciences (SPSS) version 22 (IBM, USA). Descriptive statistics, such as means and standard deviations, were computed to summarize the characteristics of the data. The paired t-tests were conducted to compare the pre- and post-intervention measurements within each group. On the other hand, the independent t-tests were performed to compare the differences between the control and experimental groups for various variables, such as pain perception and muscle activity. The significance level was set at $p<0.05$ to determine statistical significance.

Results

The study focused on evaluating the effectiveness of robbery strengthening exercises for scapular dyskinesis patients in two groups: a control group and an experimental group. The control group, which received only robbery-strengthening exercises while the experimental group received both robbery strengthening exercises and electromyography (EMG) biofeedback training.

Table 2: Demographic characteristics of the participants

Demographic characteristics	Control (n=22)	Experimental (n = 22)	t/χ²	p
Age	22.8±6.4	23.9±7.1	0.54	0.59
Gender (Male/Female)	15 (68%) /7 (32%	13 (59%)/9 (41%)	0.0006	0.98
Handedness (Left/Right)	4 (18%)/18 (82%)	3 (14%)/19 (86%)	0.17	0.68
Profession				
School Teacher	4 (18%)	5 (23%)		
Visual display terminal users (>6 hrs/day)	8 (36%)	9 (41%)	0.45	0.93
Painters	3 (14%)	2 (9%)		
Construction workers	7 (32%)	6 (27%)		
Education				
Undergraduates	12 (55%)	10 (45%)	0.37	0.83
Graduates	4 (18%)	5 (23%)		

| Postgraduate | 6 (27%) | 7 (32%) | | |

Note: t = statistical value for independent t test for nominal variables; χ2 is the statistical value for categorical variables

Table 2 shows the demographic characteristics of all the participant included in this study. In terms of age, the control group had an average age of 22.8 years, while the experimental group had a slightly higher average age of 23.1 years. The difference in average age between the two groups was minimal, suggesting that age was relatively comparable and should not significantly influence the observed outcomes.

An independent samples t-test was conducted to compare baseline characteristics between the control and experimental groups to ensure comparability before the intervention. The analysis revealed no significant differences in baseline measures of pain (VAS), muscle activation (EMG for SA, UT, LT, RM), functional disability (DASH), and health-related quality of life (EQ-5D and EQ-5D VAS), indicating that the two groups were comparable at the start of the study (Table 3).

Table 3: Comparison of pain, muscle activation, disability and quality of life group A and group B at baseline (pre-assessment), and after 6 weeks (post-assessment) using independent sample t-test

Variables		Control	Experimental	t	p
VAS	Pre	4.4±1.35	5.3±1.6	-1.34	0.2
	Post	1.6±0.84	1±0.94	1.5	0.15
EMG_SA	Pre	733.4±85.7	791.3±59.9	-1.75	0.1
	Post	762.4±84.8	908.9±78.2	-4.02	**p<0.001**
EMG_UT	Pre	612.1±98.2	581.7±41.3	0.9	0.38
	Post	706.4±97.9	671±32.6	1.09	0.29
EMG_LT	Pre	609.4±80.5	632.6±65.9	-0.7	0.49
	Post	686.4±81.0	737.5±61.6	-1.59	0.13
EMG RM	Pre	634.3±75.2	648.9±85.26	0.58	0.57
	Post	659.8±81.6	679.9±75.7	0.81	0.43
DASH	Pre	47.5±12.7	44.7±9.2	0.80	0.42
	Post	48.6±14.3	34.7±12.1	3.32	**0.002**
EQ-5D	Pre	0.64±0.23	0.63±0.22	0.14	0.89
	Post	0.59±0.16	0.81±0.31	0.008	0.82
EQ-5D VAS	Pre	62.8±19.1	64.2±20.16	0.23	0.82
	Post	66.6±21.5	73.9±18.1	1.16	0.25

Note: VAS- Visual Analog Scale; EMG- Electromyography; SA- Serratus Anterior; UT- Upper Trapezius; LT- Lower Trapezius; RM- Rhomboid Major; DASH- Disabilities of the Arm, Shoulder, and Hand; EQ-5D- EuroQol 5 Dimensions; EQ-5D VAS- EuroQol 5 Dimensions Visual Analog Scale; t - statistical value for independent t test; p - level of significance.

Post-intervention, an independent samples t-test showed no significant difference in pain reduction between the control and experimental groups, suggesting that both interventions were effective in pain management without a significant advantage of one over the other. Significant differences were found in post-intervention muscle activation levels for the Serratus Anterior (SA) between the groups. The experimental group, which received modified robbery exercises with EMG biofeedback, showed significantly higher SA muscle activation (M = 908.9, SD = 78.24) compared to the control group (M = 762.4, SD = 84.75); $t(38) = -4.02$, $p < .001$, indicating the effectiveness

of EMG biofeedback in enhancing muscle engagement. There was a significant difference in post-intervention DASH scores between the groups, with the experimental group showing greater improvement in functional disability (M = 34.71, SD = 12.1) compared to the control group (M = 48.61, SD = 14.3); t(38) = 3.32, p = .002. This finding suggests that the inclusion of EMG biofeedback in rehabilitation exercises significantly reduces functional disability in individuals with scapular dyskinesia. The EQ-5D index scores significantly improved in the experimental group compared to the control group post-intervention (M = 0.81, SD = 0.31 vs. M = 0.59, SD = 0.16); t(38) = 2.82, p = .008, demonstrating the positive impact of the intervention on quality of life. However, changes in the EQ-5D VAS scores did not show a significant difference between the groups, indicating similar perceptions of overall health status despite the objective improvements in quality-of-life metrics.

Paired t-tests were calculated in this study to evaluate the effectiveness of modified robbery exercises on various outcome measures in patients with scapular dyskinesia, comparing pre-intervention and post-intervention values. This statistical approach allows for the assessment of the intervention's impact on each variable by analyzing the changes within the same group of participants (Table 4).

Visual Analog Scale (VAS) for Pain

The significant decrease in pain levels observed in both groups, with the control group moving from 4.4±1.35 to 1.6±0.84 (t=11.23, p<0.001) and the experimental group from 5.3±1.64 to 1±0.94 (t=10.17, p<0.001), suggests a substantial alleviation of pain due to the intervention. This indicates that the modified robbery exercises were effective in reducing pain associated with scapular dyskinesia, improving patient comfort, and potentially facilitating better engagement with physical therapy and daily activities.

Muscle activation

Electromyography (EMG) assessments were conducted to evaluate the effects of modified robbery exercises on muscle activation in patients with scapular dyskinesia. The focus was on two key muscles critical for scapular movement and shoulder stability: the Serratus Anterior (SA) and the Upper Trapezius (UT)

For the Serratus Anterior (SA) muscle, the study's findings reveal a contrast in outcomes between the control and experimental groups. In the control group, the SA muscle activation levels showed a slight but not statistically significant increase from pre-intervention measurements of 733.40±85.65 to post-intervention measurements of 762.4±84.75 (t = -1.71, p = 0.14). This change suggests that without targeted intervention, the SA muscle activation experienced minimal alterations, not enough to be considered significant. Conversely, the experimental group demonstrated a substantial and statistically significant increase in SA muscle activation, moving from a pre-intervention average of 791.3±59.96 to a post-intervention average of 908.9±78.24 (t = -7.67, p<0.001). This underscores the effectiveness of the intervention tailored to the SA muscle. This significant improvement suggests that the modified exercises specifically targeted and successfully enhanced the activation of the SA muscle, which is crucial for scapular protraction and upward rotation, playing a vital role in maintaining shoulder stability and function.

For the Upper Trapezius (UT) muscle, the control group showed no significant change in muscle activation levels, with measurements moving from a pre-intervention average of 612.1±98.24 to a post-intervention average of 706.4±97.87 (t = -1.40, p = 0.20). This suggests that without targeted interventions, UT muscle activation remained relatively stable. In contrast, the experimental group experienced a significant increase in UT muscle activation following the intervention, with initial measurements at 581.7±41.3 increasing to 671±32.57 post-intervention (t= -9.55, p<0.001), highlighting the effectiveness of the targeted intervention in enhancing UT muscle activation.

Regarding the Lower Trapezius (LT) muscle, the control group also exhibited a significant improvement, with muscle activation levels increasing from an average of 609.4±80.51 before the intervention to 686.4±81.02 afterward (t =-7.02, p<0.001). This increase suggests some level of general improvement in LT muscle activation with robbery exercises alone. The experimental group saw a more pronounced significant increase in LT muscle activation, with pre-intervention levels at 632.6±65.97 rising to 737.5±61.57 post-intervention (t = -9.37, p<0.001) confirming the intervention's success in specifically enhancing LT muscle activation, important for scapular stabilization and movement.

For the Rhomboid (RM) muscle, neither the control nor the experimental group showed a significant change in muscle activation as a result of the intervention. The control group's pre-intervention measurements were 634.28±75.23, slightly increasing to 659.84±81.57 post-intervention (t = 1.03, p = 0.31), indicating no significant improvement. Similarly, the experimental group's pre-

intervention measurements of 648.89±85.26 and post-intervention measurements of 679.91±75.68 (t= 1.22, p = 0.23), also suggest that the targeted exercises did not significantly affect Rhomboid muscle activation.

These findings highlight the added effectiveness of EMG biofeedback training when combined with modified robbery exercises in enhancing muscle activation for treating scapular dyskinesia, particularly in the Serratus Anterior, Upper Trapezius, and Lower Trapezius muscles, compared to exercises supplemented with ergonomic training alone.

Table 4: Comparison of the pre- and post-test effects of general exercises and robbery exercises on pain, muscle activation, functional disability, and quality of life

Variables	Group	Pre	Post	t	p
VAS	Control	4.4±1.35	1.6±0.84	11.23	p<0.001
	Experimental	5.3±1.64	1±0.94	10.17	p<0.001
EMG SA	Control	733.40±85.65	762.4±84.75	-1.40	0.20
	Experimental	791.3±59.96	908.9±78.24	-7.67	p<0.001
EMG UT	Control	612.1±98.24	706.4±97.87	-1.40	0.20
	Experimental	581.7±41.3	671±32.57	-9.55	p<0.001
EMG LT	Control	609.4±80.51	686.4±81.02	-7.02	p<0.001
	Experimental	632.6±65.97	737.5±61.57	-9.37	p<0.001
EMG RM	Control	634.28±75.23	659.84±81.57	1.03	0.31
	Experimental	648.89±85.26	679.91±75.68	1.22	0.23
DASH	Control	47.5±12.7	48.6±14.3	0.26	0.80
	Experimental	44.7±9.2	34.71±12.1	2.94	**0.001**
EQ-5D	Control	0.64±0.23	0.59±0.16	-0.80	0.43
	Experimental	0.63±0.22	0.81±0.31	2.12	**0.04**
EQ-5D VAS	Control	62.8±19.05	66.57±21.54	0.59	0.56
	Experimental	64.24±20.16	73.85±18.07	-9.16	0.12

VAS- Visual Analog Scale; EMG- Electromyography; SA- Serratus Anterior; UT- Upper Trapezius; LT- Lower Trapezius; RM-Rhomboid Major; DASH- Disabilities of the Arm, Shoulder, and Hand; EQ-5D- EuroQol 5 Dimensions; EQ-5D VAS- EuroQol 5 Dimensions Visual Analog Scale

Disabilities of the Arm, Shoulder, and Hand (DASH) Questionnaire

For DASH questionnaire outcomes, the data presents a distinct comparison between the control and experimental groups' responses to their respective interventions. In the control group, there was a slight alteration in DASH scores from a pre-intervention mean of 47.5±12.7 to a post-intervention mean of 48.6±14.3 (t=0.26, p =0.80). This change indicates that the intervention administered to this group did not lead to a statistically significant improvement in upper limb function, as measured by the DASH questionnaire. Conversely, the experimental group exhibited a significant improvement in their DASH scores, which decreased from a pre-intervention average of 44.7±9.2 to a post-intervention average of 34.71±12.1 (t= 2.94, p =0.001) signifying a substantial reduction in disability and symptoms related to the arm, shoulder, and hand. This demonstrates the effectiveness of the intervention implemented with the experimental group in enhancing upper limb functionality and reducing associated disabilities.

EuroQol five-dimension questionnaire (EQ-5D)

In control group, there was no significant change in EQ-5D scores pre- to post-intervention, with scores slightly decreasing from 0.64±0.23 to 0.59±0.16 (t=-0.80, p=0.43). This indicates that the intervention did not have a statistically significant impact on the quality of life as measured by EQ-5D in the control group. A significant improvement in EQ-5D scores was observed from 0.63±0.22 pre-intervention to 0.81±0.31 post-intervention (t=2.12, p=0.04) in the experimental group. This suggests that the modified robbery exercises had a positive effect on the quality of life among patients with scapular dyskinesia in the experimental group (Table 4).

EQ-5D Visual Analog Scale (VAS)

The EQ-5D VAS scores in the control group showed no significant change, moving from 62.8±19.05 pre-intervention to 66.57±21.54 post-intervention (t=0.59, p=0.56). This result indicates that the perceived overall health status as measured by the VAS did not significantly improve in the control group following the intervention. Despite an apparent improvement in the experimental group, the change in EQ-5D VAS scores from 64.24±20.16 pre-intervention to 73.85±18.07 post-intervention did not reach statistical significance (t=-9.16, p=0.12). Although there was a noticeable increase in the scores suggesting a trend towards improved self-perceived health status, the change was not statistically significant according to the p-value reported. In summary, the EQ-5D scores showed a significant improvement in the quality of life for the experimental group, highlighting the efficacy of the intervention. However, while there was an improvement in EQ-5D VAS scores for the experimental group, indicating a positive trend in perceived health status, this change did not achieve statistical significance. These results underline the importance of considering both objective measures of quality of life and subjective perceptions of health status in evaluating the impact of therapeutic interventions (Table 4).

Discussion

The objective of the study was to assess the efficacy of modified robbery exercises, augmented with EMG biofeedback training, on pain, muscular strength, and quality of life in patients with scapular dyskinesia. The introduction of EMG biofeedback training aimed to enhance the participants' awareness and control over muscle activation during the exercises, potentially amplifying the benefits observed from the modified robbery exercises alone. The reduction in pain levels for

participants performing robbery exercises highlights their potential for addressing the musculoskeletal imbalances associated with scapular dyskinesia. This is consistent with findings from (YESILYAPRAK, TÜRKSAN, & KARABAY, 2022) who noted improvements in shoulder stability and pain reduction following targeted rehabilitation exercises similar to the modified robbery exercises used in our study. The integration of modified robbery exercises into treatment plans for scapular dyskinesia could significantly enhance patient outcomes, as supported by findings of (Ouellet et al., 2021)2021, emphasizing targeted exercises are better than general exercises for modifying pain.

The employment of EMG equipment facilitated this process by providing immediate auditory and visual feedback on muscle activation patterns, particularly focusing on the Serratus Anterior (SA) and Upper Trapezius (UT) muscles, which are pivotal for scapular stability and function. Important results were obtained from the electromyography (EMG) evaluations of the activation of the Serratus Anterior (SA) and Upper Trapezius (UT) muscles in individuals with scapular dyskinesia in relation to the effects of modified robbery exercises. Examining these muscles is essential to comprehending the efficacy of the intervention since they are critical to scapular mobility and shoulder stability. The SA muscle, essential for scapular protraction and upward rotation, plays a critical role in maintaining shoulder stability and facilitating efficient upper limb movement (Kibler & Sciascia, 2016). The improvement in SA activation suggests that the exercises specifically bolster the scapular's ability to support dynamic shoulder actions, potentially reducing the risk of injury and improving functional outcomes for individuals with scapular dyskinesia (Miyasaka et al., 2017).

The UT is integral to scapular elevation and overall shoulder mechanics, with its proper function being crucial for overhead activities and arm elevation. The enhanced activation of the UT muscle suggests that the modified robbery exercises effectively address common deficits in scapular elevation and control, which are often observed in patients with scapular dyskinesia. Improved activation of the SA and UT muscles can lead to better shoulder mechanics, potentially reducing the risk of further injury and enhancing the quality of life for patients by enabling them to perform daily activities with less discomfort and more excellent stability (Jung, Hwang, Kim, Gwak, & Kwon, 2017).

The significant improvements observed in both control and experimental groups indicate a substantial enhancement in LT muscle activation, essential for scapular stabilization

and optimal shoulder function. The increase in the LT activation in control group is suggestive of efficacy of general physical therapy exercises in promoting shoulder health. The better benefit of robbery exercises for LT shows specific exercises are better for scapular positioning and movement. Incorporating LT activation is vital for a holistic shoulder rehabilitation strategy(Moeller, Bliven, & Valier, 2014)4, ensuring balanced scapular stabilization and function, also it reduces the chances of injury in patients with scapular dyskinesia (Zakharova-Luneva, Jull, Johnston, & O'Leary, 2012)2.

The EMG results for the Rhomboid Major shows an observable increase in muscle activation in both control and experimental groups, the statistical analysis indicates that these changes are not significant. This suggests a more complex interaction between the exercises and Rhomboid Major muscle activation than initially hypothesized. The experienced marginal increases suggests that the modified robbery exercises, may not specifically target or sufficiently engage the Rhomboid Major muscle to a degree that significantly alters its activation pattern. The findings suggest that rehabilitation programs for scapular dyskinesia might need to include a broader or more targeted range of exercises to engage the Rhomboid Major muscle goes more effectively with findings of Moghadam et al. (Yuksel & Yesilyaprak, 2024) suggesting that scapular movement training does not significantly outperform standardized exercises, indicating that a one-size-fits-all approach may not be the most effective strategy for addressing scapular dyskinesis. The scapular movement training is beneficial for patients with chronic shoulder pain and scapular dyskinesia, it does not offer superior benefits over standardized exercises (Moghadam, Rahnama, Dehkordi, & Abdollahi, 2020).

The Disabilities of the Arm, Shoulder, and Hand (DASH) scores has significantly improved in the group who performed the modified robbery exercises, on functional disability related to upper limb disorders. The lack of significant change in the DASH scores within the control group contrasts sharply with the significant improvement noted in the experimental group, highlighting the effectiveness of the targeted exercises in enhancing upper limb function and reducing symptomatology. These findings advocate for the incorporation of specific, targeted exercises, such as those presumed to be modified robbery exercises then general exercises, into rehabilitation programs for patients with scapular dyskinesia also supported with the findings of (Willmore & Smith, 2016)6. A reduction in DASH scores often reflects improvements in the range of motion, strength, and overall

mobility of the arm, shoulder, and hand (Jester, Harth, Wind, Germann, & Sauerbier, 2005). This allows patients to perform daily tasks with greater ease and efficiency. Reduced DASH scores and assessments of scapular function provide valuable feedback on the effectiveness of rehabilitation strategies and optimizing the patient outcomes(Dos Santos, Jones, & Matias, 2021).

In this study, the EQ-5D questionnaire was administered at baseline and post-intervention phases, enabling the assessment of changes in the quality of life as a result of the modified robbery exercises. The analysis of EQ-5D scores before and after the intervention provided insights into the effectiveness of the exercise program in enhancing the overall well-being and health-related quality of life among patients with scapular dyskinesia. The significant improvement in EQ-5D underscores the positive effect of the modified robbery exercises on the quality of life. This enhancement reflects substantial benefits across all dimensions assessed by EQ-5D: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression except VAS. The lack of significant change in the control group suggests the specific efficacy of the intervention in improving overall quality of life metrics, emphasizing the value of targeted exercise regimens in therapeutic settings. The focused scapular exercises can improved the quality of life as supported by the findings of (Christensen et al., 2016). The supervised exercise program can improve the quality of life than home exercises also supported by (Robinson, Norris, & Roberts, 2017). The mechanism of action of modified robbery exercises in treating scapular dyskinesia encompasses several interconnected physiological and psychological pathways. These exercises improve muscle strength and coordination, optimize scapular positioning and movement, reduce biomechanical stress, and pain, and ultimately enhance functional ability and quality of life. The targeted strengthening of specific scapular stabilizers, combined with the promotion of optimal scapular kinematics, underlies the exercises' effectiveness. This comprehensive approach not only addresses the physical aspects of scapular dyskinesia but also positively impacts the psychological well-being of patients, highlighting the importance of integrated interventions in musculoskeletal rehabilitation. In conclusion, our study supports the integration of EMG biofeedback training with modified robbery exercises as an effective approach to improve functional disabilities, alleviate pain, and enhance the quality of life for patients with scapular dyskinesia. This combination leverages the benefits of targeted exercise to strengthen scapular stabilizers and optimize scapular

kinematics, with the added advantage of biofeedback for improved muscle activation and control.

Limitations

Acknowledging the detailed investigation into the effectiveness of modified robbery exercises for scapular dyskinesia, the study, while comprehensive, presents certain limitations that merit attention for future research. One significant limitation is the study's relatively short-term follow-up period, which spans only six weeks. This duration limits the ability to assess the long-term sustainability of the intervention's benefits, including any lasting improvements in muscle activation, functional disability, and quality of life, or the potential for regression after the cessation of the exercise program. Another notable limitation is the potential influence of external factors and concurrent therapeutic activities not accounted for within the study's design. Participants might have engaged in additional treatments or lifestyle changes outside of the prescribed exercise regimen, introducing confounding variables that could influence the measured outcomes. Lastly, although initially screening started with a larger cohort, the study does not fully explore the diversity of the participant pool, which could include variations in the severity of scapular dyskinesia, athletic status, or other health conditions, potentially affecting the intervention's applicability and effectiveness across different patient populations. Future studies addressing these limitations could offer more definitive insights into the long-term benefits and optimal application of modified robbery exercises for individuals with scapular dyskinesia.

Conclusion

The study conclusively demonstrates the effectiveness of modified robbery exercises in the management of scapular dyskinesia, highlighting significant improvements in pain reduction, muscle activation, functional disability, and quality of life among participants. Notably, the experimental group, which received electromyography (EMG) biofeedback in addition to the exercises, showed superior outcomes in serratus anterior muscle activation and reported greater improvements in functional disability and quality of life, as measured by the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire and the EuroQol five-dimension (EQ-5D) index, respectively. These findings suggest that incorporating EMG biofeedback into rehabilitation exercises for scapular dyskinesia can significantly enhance treatment efficacy, offering a promising approach for clinicians seeking to optimize recovery outcomes in this patient population. Despite these positive trends, changes in the EQ-5D Visual Analog Scale (VAS) did not achieve statistical significance, indicating the complexity of measuring perceived health status and highlighting the need for comprehensive assessment strategies in therapeutic interventions.

Practical applications and future scope

The clinical application of this study highlights the necessity for physical therapists to integrate specific exercises, like modified robbery exercises, into treatment plans for scapular dyskinesia to optimize pain management, muscle function, and quality of life. Future research should explore the long-term impacts of these exercises and investigate their applicability across a broader spectrum of shoulder disorders, further refining rehabilitation strategies and personalized care approaches.

Acknowledgement

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