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Title: The Effect of a Six-Week Corrective Exercise Program on Shoulder Stability in Male Crossfit Athletes with Scapular Movement Dysfunction

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Abstract

Objective: Shoulder injuries are common in CrossFit athletes, with scapular dysfunction playing a key role. Given the importance of the scapula in force transmission and shoulder stability, this study aims to investigate the effect of a corrective exercise program on improving shoulder stability in CrossFit athletes.

Methodology: This quasi-experimental study initially enrolled 26 male CrossFit athletes (25–30 years) recruited via purposive sampling from local clubs based on predefined eligibility criteria. An a priori power analysis (G*Power 3.1; effect size = 0.54, $\alpha = 0.05$, power = 0.80) indicated a minimum of 24 participants; to accommodate ~10% attrition, 26 were enrolled and equally allocated to intervention and control groups (13/13). Scapular stability was assessed with the Davis Test pre- and post-intervention. Data normality was examined with the Shapiro–Wilk test; within-group changes were analyzed using paired t-tests, and between-group effects with ANCOVA (adjusting for pre-test values). Two control participants were lost to follow-up; analyses were completed on 24 athletes. All analyses were performed in SPSS v26 ($\alpha = 0.05$).

Findings: The intervention group showed significant improvements in scapular stability, with Davis Test record increasing by 8.4% and Power Output increasing by 8.4% ($P < 0.01$), while the control group showed no significant changes ($P > 0.05$). ANCOVA confirmed significant between-group differences in both Davis Test record (Adjusted Means ± SD: 13.42 ± 1.20 vs. 12.67 ± 1.65; Partial $\eta^2 = 0.205$) and Power Output (Adjusted Means ± SD: 1138.23 ± 98.67 vs. 1050.76 ± 134.55;Partial $\eta^2 = 0.241$; $P < 0.05$), demonstrating the effectiveness of the corrective exercise program.

Conclusion: The present study demonstrated that the selected corrective exercises can improve scapular function and enhance shoulder stability. This improvement contributes to increased shoulder strength and power, ultimately leading to the correction of movement dysfunctions.

Keywords: CrossFit, scapular movement dysfunction, scapular stability, corrective exercises

Highlight:

Selected corrective exercises can enhance scapular function and improve shoulder stability, leading to increased strength and power in the shoulder region. Consequently, these positive changes can contribute to the improvement of movement dysfunctions and the overall quality of life in athletes.

Plain language summary:

This study looked at how targeted corrective exercises can improve shoulder function and stability in people with abnormal shoulder movement. These exercises focus on strengthening key muscles like the deltoid, rotator cuff, and upper back, which are essential for proper shoulder motion. Regularly doing such exercises can reduce pain, enhance movement control, and lower the risk of injury—benefits that help individuals feel more comfortable in both daily life and sports. By improving shoulder strength and coordination, these exercises not only boost athletic performance but also make everyday activities easier and safer.

Introduction:

CrossFit, first introduced in the early 2000s, is a type of high-intensity functional training that combines aerobic workouts, gymnastics, and Olympic weightlifting to enhance overall physical performance (1, 2). It is designed to improve various domains of fitness including aerobic capacity, muscular strength and endurance, flexibility, coordination, agility, speed, and balance. CrossFit workouts are typically performed in a high-intensity circuit format, characterized by short durations, minimal rest, and high repetitions, aiming to simultaneously develop strength and endurance (3-5).

The increasing popularity of high-intensity training modalities like CrossFit reflects a broader trend in sports science favoring such approaches over traditional methods, due to their greater time-efficiency and effectiveness in improving health and fitness(6, 7). Due to its adaptability to different fitness levels, motivational nature, and group-based execution, CrossFit has gained global popularity since its inception(8, 9).

In spite of its benefits, research reports a broad range of injury rates in CrossFit, from 3.3% to 73.5%, with approximately 9.18 cases occurring per 1,000 training hours (10). Approximately 67% of injuries occur among beginner to intermediate athletes (11). The most common injury sites in CrossFit athletes are the shoulder (26%), spine (24%), and knee (18%) (12). Shoulder injuries are particularly frequent, mainly linked to overhead activities that decrease the subacromial space (13) and to gymnastic movements, which represent about 41% of such injuries (14, 15). In Iran, the incidence has been estimated at 4.421 cases per 1,000 training hours, with the shoulder and knee reported as the most vulnerable areas. Overall, men experience higher injury rates than women, likely because of less supervision and fewer consultations with professional coaches(14, 16).

One of the major biomechanical contributors to shoulder injuries in CrossFit is scapular dyskinesis, which refers to non-functional or altered scapular motion patterns(17, 18).

Scapular dyskinesis is defined as an alteration in the normal position or motion of the scapula during coordinated scapulohumeral movements(19). It is commonly observed among overhead athletes and individuals with shoulder pathologies, with prevalence rates reported between 61% to 100% depending on the population and assessment methods(20, 21). Kibler et al. categorized scapular dyskinesis into three main types: Type I (prominence of the inferomedial border), Type II (prominence of the entire medial border), and Type III (excessive elevation and shrugging during arm elevation), each reflecting specific muscular imbalances such as serratus anterior weakness or upper trapezius overactivity (22) .The etiology of scapular dyskinesis is multifactorial, including neuromuscular imbalance, poor posture, nerve injury (e.g., long thoracic nerve palsy), and repetitive overhead movements(23). These alterations disrupt scapulohumeral rhythm and glenohumeral joint mechanics, increasing the risk of subacromial impingement, labral injuries, and rotator cuff pathology (24). Clinically, it can be identified using tests such as the Scapular Dyskinesis Test (SDT), Scapular Assistance Test (SAT), and Lateral Scapular Slide Test (LSST), which are reliable tools for detection and functional evaluation(25) . Treatment typically focuses on neuromuscular re-education, strengthening of stabilizing muscles (particularly lower trapezius and serratus anterior), and postural correction strategies(26) . Consequently, early recognition and correction of scapular dyskinesis are crucial in restoring optimal shoulder biomechanics and preventing secondary injuries (27).

The scapula plays a crucial role in maintaining glenohumeral stability and ensuring the efficient transmission of kinetic energy from the lower extremities to the upper limbs(28, 29). Dyskinesis is associated with disrupted scapulohumeral rhythm, leading to compromised shoulder mechanics and increased injury risk (30). It is typically characterized by abrupt or exaggerated protraction and elevation during arm lifting, as well as accelerated downward rotation when the arm is lowered (25, 31).

Contributing factors include abnormal recruitment patterns in stabilizing muscles, skeletal malalignment, structural joint instability, and altered soft tissue or neural input (30, 31). Scapular dysfunction may result in a winged scapula, seen as the prominence of the medial border or inferior angle detaching from the thoracic wall, often due to delayed activation or weakness in the serratus anterior and lower trapezius muscles (25, 31-33). Furthermore, limited flexibility of the pectoralis minor and the short head of the biceps brachii has been associated with excessive anterior tilting and forward movement of the scapula (34).

Muscle imbalance frequently observed in overhead athletes with overuse pain syndromes can inhibit proper scapular stabilizer activation, further contributing to dysfunctional scapular motion (24, 35-37). These neuromuscular and biomechanical disturbances may lead to increased stress on the anterior shoulder capsule, rotator cuff compression, and reduced functional performance .Imbalances among key muscles such as the serratus anterior, trapezius, pectoralis minor, rhomboids, and levator scapulae negatively affect scapulohumeral rhythm and shoulder joint function (38).

Considering the high prevalence of shoulder and scapular dysfunction in CrossFit athletes and the lack of sufficient research on corrective interventions in this population, this study aims to evaluate the effects of a six-week corrective exercise program on shoulder stability in male CrossFit athletes with scapular dyskinesis, in order to improve movement mechanics, musculoskeletal alignment, and reduce the risk of injury.

Research Methodology

A total of 24 male CrossFit athletes, aged between 25 and 30 years, who had a minimum of two years of continuous training experience and a clinical diagnosis of scapular movement dysfunction, participated in this study. The sample size determination was carried out with G*Power 3.1, drawing on earlier clinical trials that examined scapular stabilization programs. The calculation was performed using the following parameters: effect size = 0.54, $\alpha = 0.05$, and statistical power = 80% ($1-\beta = 0.80$), which yielded a minimum of 24 participants (12 per group). To allow for a potential 10% dropout, the final sample size was increased to 26.

To clarify the recruitment and allocation process, a CONSORT-style flow diagram was provided (Figure 1). Initially, 26 CrossFit athletes were assessed for eligibility, all of whom met the inclusion criteria and were randomized into intervention (n = 13) and control (n = 13) groups. During the study, two participants from the control group were lost to follow-up due to absence in the post-test phase. Therefore, the final analysis included 24 participants (intervention = 13, control = 11).

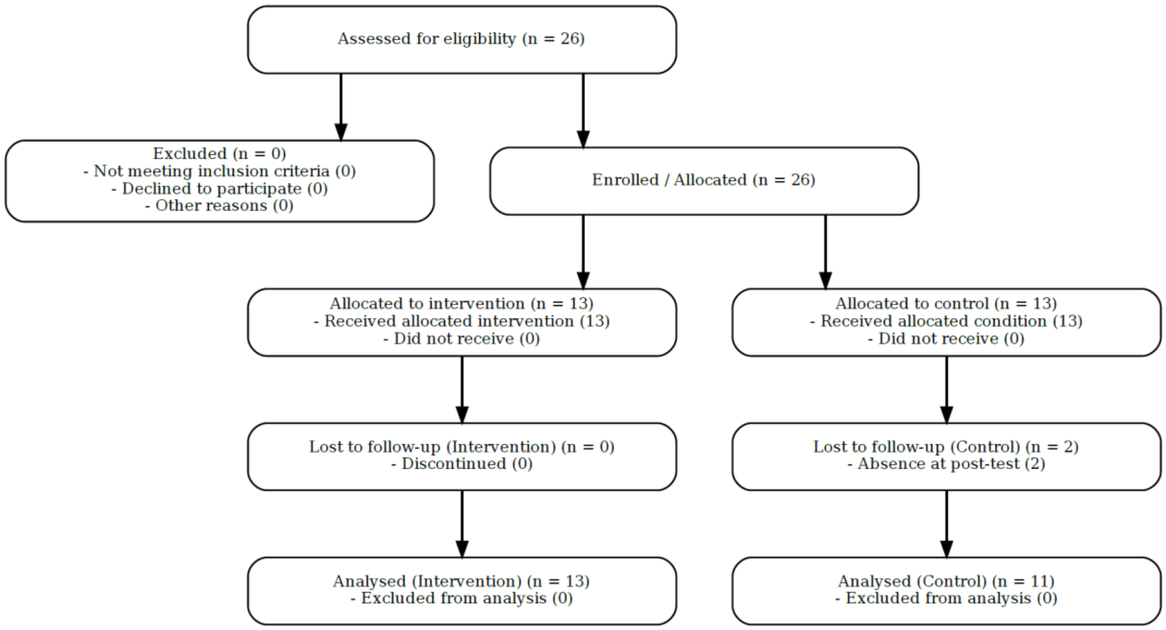

Figure 1 *CONSORT flow diagram: assessed (n=26); allocated—intervention (n=13), control (n=13); lost to follow-up—control (n=2); analysed—intervention (n=13), control (n=11).*

The chosen sample size aligns with earlier intervention-based research. For instance, Turgut et al. (2017) performed a randomized controlled study on scapular stabilization exercises in people with subacromial pain syndrome, involving 30 subjects divided equally into two groups of 15 (39). Similarly, Buttagat et al. (2023) investigated posture correction and mobility improvements using scapular based interventions with 48 participants (24 per group)(40).

The eligibility requirements for this study included: (1) being male; (2) an age range of 25–30 years; (3) a minimum of two years of prior CrossFit training; and (4) regular attendance in training sessions at least three times per week and (5) clinical diagnosis of scapular movement dysfunction. Exclusion criteria included: (1) unwillingness to participate in training or assessment; (2) absence from at least three consecutive sessions; (3) shoulder pain affecting functional task execution; (4) engagement in other professional sports; (5) history of cardiopulmonary, orthopedic, or neuromuscular disorders (based on informed consent, observation, and coach input); and (6) thoracic kyphosis greater than 45°.

Scapular movement dysfunction was assessed through a standardized clinical protocol involving bilateral shoulder flexion and abduction with 5 kg dumbbells. Each task was performed five times, with a 3-second duration per phase. Two independent kinesiologists evaluated scapular rhythm, symmetry, winging, and tilting. If abnormal movement was present in three or more of fiverepetitions, the result was recorded as positive (41, 42).

The test result was as follows: if a change in rhythm or scapular winging was observed, the test was "positive", and otherwise, it was "negative". In the case of a positive result, "Yes" was recorded, and in the case of a negative result, "No" was recorded (42).

Figure 2 *An example of study participants with scapular movement dysfunction.*

Scapular Dysfunction Diagnosis

Scapular dysfunction was diagnosed using the Scapular Dyskinesis Test (SDT). This test involved the assessment of scapular movement patterns during shoulder flexion and abduction exercises, each performed five times with a 3-second duration per phase. The scoring method was as follows: A. Normal movement: No observable abnormal scapular movement. B. Mildly abnormal movement: Slightly abnormal or suspicious scapular movement. C. Clearly abnormal movement: Evident abnormal scapular movement in at least 3 out of 5 repetitions.

The final score was determined based on a combination of the flexion and abduction tests: Normal: Both tests are normal, or one test is mildly abnormal. 1.Suspiciously abnormal: Both tests are mildly abnormal. 2.Clearly abnormal: One or both tests are clearly abnormal. 3.Of the participants, 25% showed "clearly abnormal" scapular movement patterns. This diagnostic method has demonstrated moderate to good levels of validity and reliability, with reported coefficients around 0.57(25, 33, 41).

Scapular Dyskinesis and Stability Assessment:
The Davis Test for scapular stability was employed to assess the effectiveness of the intervention. This test involves calculating power output using 68% of the participant's body weight, a method that has been validated in previous studies for shoulder stability assessments (43). It is widely accepted as it provides an accurate measure of relative power output, particularly when compared to other methods that use fixed loads.

In administering the test, participants adopted a push-up stance with their hands positioned 90 cm (36 inches) apart. Each trial lasted 15 seconds, during which they alternately touched one hand to the other, followed by a 45-second recovery. This procedure was carried out three times per participant. Results for performance and power output were calculated through established formulas. Previous studies have confirmed the Davis Test as a highly valid and reliable assessment, with reliability coefficients reported between 0.90 and 0.92 (44-48).

For scapular dyskinesis assessment, the Scapular Dyskinesis Test (SDT) was used to evaluate the severity of scapular dysfunction. This test assesses scapular movement patterns during shoulder flexion and abduction exercises. The scoring method involves categorizing movement as normal, mildly abnormal, or clearly abnormal, based on observable deviations in at least three out of five repetitions. Participants who demonstrated clearly abnormal movement in at least 3 out of 5 repetitions were diagnosed with scapular dyskinesis. In the current study, 25% of the participants showed "clearly abnormal" scapular movement patterns.(49, 50).

While the reliability coefficient for the SDT (κ = 0.57) is considered moderate, it suggests the potential for measurement error due to factors such as inter-rater variability and the subjective nature of scapular movement evaluations. To minimize these errors, future studies could benefit from incorporating more standardized protocols and more reliable methods. Despite this, the SDT remains a valuable tool for assessing scapular dyskinesis in both clinical and athletic settings(51) .

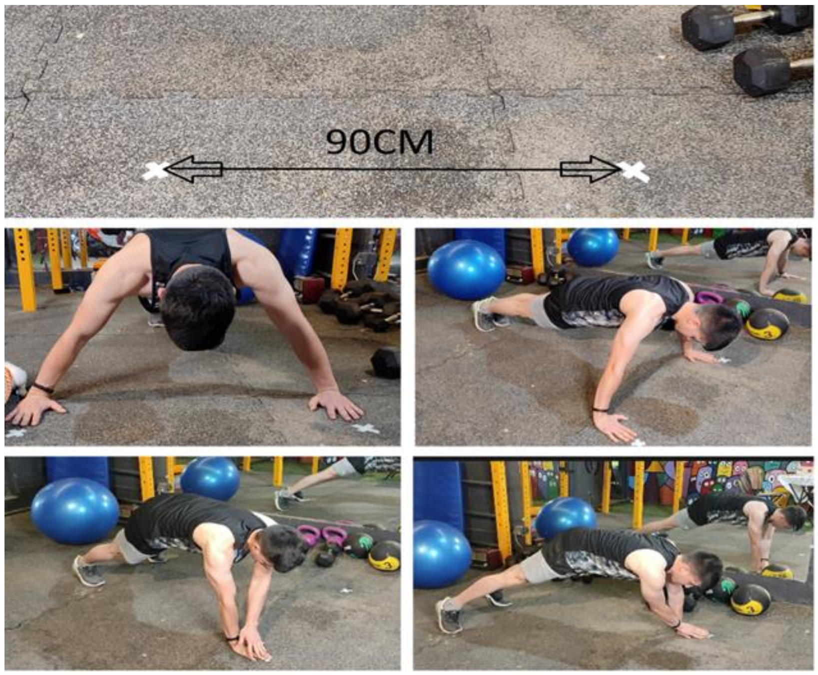

Figure 3 *Davis Test*

Record = Average number of touches / Height (m)

Power = 68% of body weight (kg) × Average number of touches

Training Protocol

The selected training program was adapted from Mora et al.(52, 53) and modified for participants with movement dysfunction. It included three phases: (1) exercises to increase range of motion and teach scapular control, (2) exercises targeting scapular muscles, and (3) advanced sensorimotor exercises emphasizing scapular stability and alignment(24, 41, 54). All exercises were performed in three sets of 15 repetitions, while stretching exercises were held for 20–30 seconds in three sets. The intervention was conducted over a six-week period, during which the experimental group trained three times each week.

Table 1 *Corrective Exercise Protocol*

Phase 1	Seated / Arms in a neutral position / Pull the shoulders back and down	Posterior capsule stretching of the shoulder	1. Punch: Performed in a supine or 90-degree position with shoulder flexion, elbows extended, focusing on scapular protraction and retraction. 2.Push-up: Movement of the scapula into protraction and retraction; modifications using knees are allowed if necessary. 3.Modified Prone Cobra: Hands in a neutral position, elbows extended, with external rotation of the arms.
Phase 2		Stretch for the posterior shoulder capsule	1. Punch with Dumbbell: Scapular protraction/retraction with shoulder flexion. 2. Modified Push-up: One-handed or standard push-up focusing on scapular motion. 3.Modified Prone Cobra with Dumbbell: Elbows extended, arms externally rotated. 4. Prone Horizontal Abduction: 90° shoulder abduction, arms externally rotated, using a dumbbell. 5. Prone Arm Elevation: 120° shoulder abduction with dumbbell. 6. Prone Shoulder Extension: Elbows flexed at 90°, extend shoulders. 7. Rotator Cuff Exercise: 45° abduction with a roller; perform internal and external rotation.
Phase 3		1. Lower stretch exercise (shoulder in a neutral rotated position / extend the upper arm / keep the elbow extended against resistance) 2. Rotator cuff exercise (internal/external rotation of the arm)	1. Punch exercise with Swiss ball 2. Standard push-up with Swiss ball 3. Modified prone cobra exercise with dumbbells on Swiss ball 4. Prone horizontal abduction exercise with dumbbells on Swiss ball 5. Prone V-raise exercise with dumbbells on Swiss ball

The intervention protocol was designed to progressively improve scapular stability through targeted corrective exercises. Intensity was regulated using the Borg Rating of Perceived Exertion (RPE) scale, with a targeted range of 12–15 on the scale (55). This range was chosen to ensure that participants experienced moderate to vigorous intensity without overexertion.

Progression of resistance/loads was structured as follows: 1.Week 1–2: Participants performed exercises at low resistance (e.g., bodyweight or light resistance bands). 2.Week 3–4: Resistance was gradually increased by 10–15% each week based on participants' ability to complete the prescribed sets and repetitions with proper form. 3.Week 5–6: Resistance was further increased, with weekly adjustments based on individual progress, aiming for moderate to heavy resistance (e.g., dumbbells, resistance bands)(56).

The control group maintained their regular CrossFit training schedule throughout the study, which included their typical exercises (e.g., weightlifting, metabolic conditioning). The potential confounding effects of this were considered, and although both groups underwent similar training schedules, it was ensured that the intervention group received additional specific corrective exercises designed to target scapular stability. The impact of the control group's regular training was analyzed, and it was found that any changes observed in the intervention group were not attributable to CrossFit training alone but rather to the additional exercises.

Statistical Method

Data analysis was performed with SPSS version 26. To assess the distribution of the data, the Shapiro–Wilk test was applied. Since the results confirmed normality, between-group comparisons were carried out using Analysis of Covariance (ANCOVA), and within-group changes were evaluated with paired t-tests. Statistical significance was defined at the level of $p < 0.05$.

Ethical Considerations

All individuals participated in the study voluntarily and signed written informed consent forms. Before the research began, the procedures, testing protocols, and possible risks were fully explained to them. Participants were guaranteed complete confidentiality of their personal data, which was accessible only to the main investigator. The research protocol was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences, with the registration code IR.SBU.REC.1401.063.

Findings

A total of 26 male CrossFit athletes initially participated in the study (13 in each group). However, due to the absence of two participants from the control group in the post-test phase, the final analysis was conducted on 24 participants: 13 in the training group and 11 in the control group.

*Table 2 presents the anthropometric characteristics of the participants, including age, height, weight, and body mass index (BMI). Independent t-*tests *revealed no statistically significant differences between the groups in any of the measured variables (P > 0.05), confirming baseline homogeneity. Additionally, the participants' characteristics regarding weekly training volume and competitive level have been included in this table.*

Table 2. *Anthropometric Characteristics of Participants by Group*

Variable	Study group	Mean ± SD	P
Participant age (yrs)	Control	27.08 ± 1.71	0.710
	Training	27.08 ± 1.80	
Height (cm)	Control	174.08 ± 4.92	0.629
	Training	174.62 ± 4.86	
Weight (kg)	Control	70.20 ± 3.05	0.682
	Training	69.75 ± 3.05	
BMI (kg/m²)	Control	23.17 ± 0.45	0.673
	Training	22.87 ± 0.42	
Weekly Training Volume (hours/week)	Control	6–10 hours (3–5 days/week)	N/A
	Training	6–10 hours (3–5 days/week)	
Competitive Level	Control	Beginner-Intermediate	N/A
	Training	Beginner-Intermediate	

Normality of the dependent variables was examined through the Shapiro–Wilk test, which indicated that all variables were normally distributed (P > 0.05). This verified the assumptions required for applying parametric methods. To further check the appropriateness of these analyses, Levene's test was used to evaluate variance homogeneity between the intervention and control groups. The findings for both outcomes (Davis Test record and Power Output) showed non-significant results (P > 0.05), confirming equal variances and permitting the use of ANCOVA.

Following these assumptions, paired sample t-tests were used to analyze within-group differences, while ANCOVA was applied to compare between-group differences, adjusting for pre-test scores. This approach ensured that any observed differences between groups could be attributed to the intervention, rather than baseline differences or random variations.

Paired sample t-test analyses demonstrated significant improvements in the training group across all scapular stability measures, such as test record and power output (P < 0.01). Conversely, the control group did not exhibit any meaningful differences between pre- and post-test assessments (P > 0.05), as presented in Table 3.

Table 3. *Paired Sample t-Test Results for Shoulder Stability by Group*

Variable	Group	Test Phase	t	df	P-value
Davis Test – Record	Training	Pre vs. Post	-4.085	12	0.002*
	Control	Pre vs. Post	-0.417	10	0.685
Davis Test – Power Output	Training	Pre vs. Post	-4.055	12	0.002*
	Control	Pre vs. Post	-0.463	10	0.635

** Statistically significant at P ≤ 0.05*

The paired sample t-test results revealed that the training group showed statistically significant improvements in both shoulder performance indicators — namely, test record and power output following the six-week corrective exercise program ($P = 0.002$ for both variables).

These findings indicate that the intervention effectively enhanced shoulder stability among male CrossFit athletes diagnosed with scapular movement dysfunction.

In contrast, the control group did not exhibit any significant changes in either metric ($P = 0.685$ for record; $P = 0.635$ for power output), suggesting that the observed improvements in the training group were attributable to the intervention rather than natural progression or external factors.

These findings support the first research hypothesis, demonstrating that targeted corrective exercises can meaningfully improve dynamic shoulder stability in athletes with scapular dyskinesis.Prior to conducting the ANCOVA, Levene's test was performed to assess the assumption of homogeneity of variances between the training and control groups. The results of Levene's test for both outcome variables Davis Test record ($P = 0.51$) and Power Output ($P = 0.54$) indicated that the assumption of equal variances was met ($P > 0.05$).

Therefore, it was appropriate to proceed with the ANCOVA analysis under the assumption of homogeneity of variances.

To assess the effectiveness of the corrective exercise program on shoulder stability between the two groups, an analysis of covariance (ANCOVA) was conducted. This test compared the post-test values of the Davis Test variables (record and power output) between the training and control groups while adjusting for pre-test scores as covariates. The results are shown in Table 3.

***Table 3**. ANCOVA Results Comparing Post-Test Scores Between Groups (Adjusted Means ± SD)*

Outcome Variable	Group (Adjusted Mean ± SD)	F(1,23)	P-value	Partial Eta²
Davis Test – Record	Control: 12.67 ± 1.65	**5.942**	**0.023***	**0.205**
	Training: 13.42 ± 1.20			
Davis Test – Power Output	Control: 1050.76 ± 134.55	**7.311**	**0.012***	**0.241**
	Training: 1138.23 ± 98.67			

**P ≤ 0.05*
**Note: Values represent adjusted post-test means (estimated marginal means) derived from ANCOVA controlling for pre-test scores.*

The ANCOVA results demonstrated statistically significant differences between the training and control groups for both key performance indicators. For Davis Test record, the adjusted mean scores differed significantly ($F(1,23) = 5.942$, $P = 0.023$), with a moderate effect size ($\eta^2 = 0.205$). For power output, the difference was even more pronounced ($F(1,23) = 7.311$, $P = 0.012$), reflecting a strong effect size ($\eta^2 = 0.241$).

These findings align with the within-group t-test results and confirm that the six-week corrective exercise program produced meaningful improvements in scapular stability among male CrossFit athletes with scapular dyskinesis. The combination of statistical significance and moderate-to-strong effect sizes indicates both clinical relevance and robustness of the intervention's impact.

Discussion

This study aimed to examine the effect of a six-week corrective exercise program on shoulder stability in male CrossFit athletes with scapular movement dysfunction. The findings demonstrated a statistically significant improvement in shoulder stability in the intervention group following the training period, indicating that the applied protocol effectively enhanced neuromuscular control and functional stabilization of the glenohumeral joint.

Shoulder stability, especially in overhead athletes, depends largely on the dynamic regulation of the scapulohumeral complex. Given the inherent structural mobility and shallow socket of the glenohumeral joint, its functional integrity is critically reliant on the coordinated activation of stabilizing muscles. Scapular dyskinesis, characterized by altered scapular positioning and motion, often disrupts this coordination, leading to abnormal loading patterns, increased posterior capsule stress, and compromised dynamic centralization of the humeral head(19, 57).

The exercise protocol used in this study specifically targeted key stabilizers of the scapula, including the serratus anterior and lower trapezius, while aiming to reduce the overactivity of the upper trapezius. By promoting balanced muscle activation patterns and enhancing proprioceptive feedback, the intervention contributed to restoring scapular control and shoulder joint stability. These outcomes are consistent with findings by Pashaei (2022), Eyvazi (2020), and Haji Hosseini (2019), who reported that targeted corrective training improved dynamic shoulder function in overhead athletes (58-60).

From a biomechanical perspective, improving the eccentric function of the rotator cuff muscles is essential to maintaining central humeral head alignment during deceleration and overhead movements. Ellenbecker and Cools (2010) highlighted that deficits in eccentric control can contribute to cumulative microtrauma and instability, and emphasized the importance of exercise-based rehabilitation for injury prevention (61)

Clinically, Owens et al. (2007) reported that over 85% of shoulder instability cases in overhead athletes stem from repetitive micro-subluxations caused by inadequate neuromuscular control (62) .This finding further supports the necessity of implementing structured corrective exercise protocols, particularly in high-demand sports such as CrossFit, which impose considerable mechanical stress on the shoulder complex. Thus, the present results validate the first hypothesis of the study and highlight the potential of functionally oriented exercise programs to improve shoulder stability and reduce injury risk in athletes with scapular dysfunction.

Conclusion

The findings of this study revealed that a six-week targeted corrective exercise program significantly improved shoulder stability in male CrossFit athletes exhibiting scapular movement dysfunction. These results suggest that incorporating corrective exercises can effectively enhance scapular control and reduce dysfunctional movement patterns. Strengthening both dynamic and static stabilizers of the shoulder joint appears to play a critical role in maintaining scapular stability under various loading conditions and across a range of motion and postural demands (29).

Research suggestions

Based on the findings of this study, it is recommended that sports therapists and rehabilitation specialists utilize these results to design targeted corrective and therapeutic programs aimed at improving scapular rhythm, positioning, and shoulder stability in athletes with scapular dyskinesis. Preventive training programs should also emphasize the correction of functional deficits and enhancement of proper movement patterns. Coaches are advised to evaluate and adjust technical execution in CrossFit athletes to reduce the risk of injury and improve performance. At the foundational level, proper movement education and early identification of dysfunctions—along with timely referral to specialists—are essential. Future research should expand the age range of participants and utilize more advanced biomechanical assessment tools. It is also suggested to investigate the effects of the corrective exercises on additional variables such as arm rotation and neuromuscular control indices. Moreover, given the prevalence of other injuries, such as knee disorders in CrossFit athletes, similar research should be conducted on other musculoskeletal issues. Finally, the effectiveness of the corrective exercises should also be examined in female CrossFit athletes to determine their broader applicability.

Research limitations

One of the main limitations of this study was the relatively small sample size, which may reduce the generalizability of the findings to broader athletic populations. Outcome assessments were not blinded, which may introduce potential observer bias. The study focused exclusively on male CrossFit athletes aged 25–30 years, limiting the extrapolation of results to female athletes or older participants. Additionally, the specific type of scapular dyskinesis was not classified according to established categories such as Kibler's types; only its presence or absence was assessed, which may limit analytical depth and comparability with previous studies. The assessment relied on visual observation, which, although widely used in clinical and field settings, may lack the precision of advanced tools such as 3D motion analysis or imaging systems. Furthermore, no long-term follow-up was conducted, restricting the ability to evaluate the sustainability of intervention effects. Compared to previous studies (Pashaei 2022; Eyvazi 2020), this study provides novel evidence regarding the effectiveness of targeted corrective exercises in improving scapular stability among male CrossFit athletes(63, 64).

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interests.

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