ORIGINAL RESEARCH PAPER

Medical Science

EFFECTIVENESS OF A SCAPULOTHORACIC AND GLENOHUMERAL STABILIZATION EXERCISE PROTOCOL IN BOULDERERS: A RANDOMIZED CLINICAL TRIAL.

KEY WORDS: Shoulder, Climber, Glenohumeral Stability, Scapulothoracic Stability, Athletic Performance, Randomized Clinical Trial.

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ABSTRACT

Background: Athletic performance of bouldering climbers largely depends on shoulder stability, the climber's speed of movement and the number of grips using the upper limbs. The objective was to assess the effectiveness of two shoulder stabilization exercise programs in climbers. 40 climbers were randomized to two groups: Experimental Group undergoing a glenohumeral and scapulothoracic stability exercise program, and Control Group performing glenohumeral stabilization exercises. Assessments were performed by a blinded physiotherapist at baseline, at 4 weeks, and after a 4-week follow-up period. The primary variable was shoulder stability (Closed Kinetic Chain Upper Extremity Stability Test). Athletic performance was also measured, this being the time required to complete a climb and number of grips needed (Climbing test). Shoulder stability increased significantly from baseline to following the intervention and follow-up. Shoulder stability in the control group improved significantly from the pretreatment evaluation to after the intervention. There were intra-subject differences in shoulder stability ($F = 14.63$; $p < .001$), time needed to complete a given climbing route ($F = 14.98$; $p < .001$) and number of grips required ($F = 10.08$; $p < .01$). There were significant differences between treatment groups at any time measured in joint stability ($F = 7.41$; $p < .01$), time needed to complete a given climb ($F = 8.17$; $p < .01$) and the number of grips made ($F = 5.13$; $p = .02$). A glenohumeral and scapulothoracic stability exercise intervention achieved significant differences in shoulder stability and athletic performance in boulderers.

INTRODUCTION

Mountaineering and rock climbing have acquired great relevance in recent years. One of the aspects to be evaluated in climbing competitions is an athlete's performance fluency and climbing skills for a given route. Harmonious movement of the limbs, and the ability to generate effective grips on the various climbing holds reduce energy expenditure and increase athletic performance (1,2).

The climbing technique involves a series of repetitive movements of the shoulder above the level of the head, to enable reaching the holds and accomplishing the climb. These movements imply overuse of the rotator cuff muscles, which can alter the normal biomechanics of the shoulder joint, increasing the risk of injury of the periarticular structures (3,4). Van Middelkoop et al. (5) described the incidence, prevalence and risk of injuries of the upper extremity in climbers. The incidence of injuries, after one-year follow-up, reached 42.4%, with a rate of 13 injuries per 1,000 hours of climbing. Most of the injuries were in the fingers (36%), while the shoulder ranked fourth with 18.7% of the injuries. The most common injuries reported related to this joint include tearing of the labrum, external impingement, dislocations, bursitis, and tendinopathies of the biceps and rotator cuff (6,7).

Therapeutic exercise has shown to be effective for the treatment of shoulder pain through the activation of the rotator cuff and scapular stabilizers (7,8). Exercises focused on motor control have shown to be effective for reducing the incidence of acute injuries and those due to overuse, thus becoming a treatment technique and an approach to injury prevention by improving joint stability (9).

The efficacy of exercise programs for the improvement of shoulder stability has been evidenced by changes noted in the electromyographic activity, scapular kinematics or different types of scores (10-13). However, given that the body operates as a dynamic unit in sports, the assessment of these variables fails to suitably provide the required information to evaluate the functional abilities or the performance of an athlete. The Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) was designed with the aim to assess the dynamic stability of the upper limbs. This test is efficient for the detection of execution, mobility and stability deficiencies, being used to identify potential risks of injury of the upper limb (14,15).

Although therapeutic exercise approaches vary greatly, the overall level of evidence is low. Single-plane open-chain upper limb exercises below 90 degrees of shoulder elevation and closed-chain upper limb exercises have provided the largest amount of evidence for improved functionality and injury prevention in athletes with shoulder pathology (16). Understanding the role of the kinetic chain in improving performance and preventing injuries for overhead athletes is essential to help with their everyday training (17).

The main objective of this study is to evaluate the effectiveness of a scapulothoracic and glenohumeral stabilization exercise program for the improvement of joint stability and athletic performance in boulderers aged between 18 and 40 years.

MATERIAL AND METHOD

Study design

A randomized controlled trial comparing two training programs, namely, scapulothoracic and glenohumeral stabilization exercises (experimental group) and glenohumeral stabilization training alone (control group). All participants underwent an informed consent process before taking part in the study.

Ethical considerations

The study was recorded in the International Clinical Trials Registry (ClinicalTrials.gov identifier: NCT03847805). This study has been approved by the Research Committee of the European University of Madrid (registration no.: CIPI/18/086).

Screening and recruitment

The subjects were recruited from the climbing gym, Boulder Madrid, located in the city of Madrid (Spain). After presenting the research project to the managers, the objectives of the study were explained to the potential participants. Fortyeight climbers were invited to participate.

The study included those subjects: being climbers, between the ages of 18 and 40 years, belonging to the Boulder Madrid Climbing Gym; who climbed at least twice a week; and having at least 6 months of experience. On the other hand, excluded subjects were those who: were participating in competitions at the time; presented pathologies of the upper limb; used any type of ergogenic aid; and had not signed the informed consent document.

Randomization

Participants were randomized to either the experimental or control group by drawing sealed opaque envelopes. For randomization purposes, 40 envelopes were prepared: 20 contained an allocation card to the experimental group and 20 contained an allocation card to the control group. The cards were shuffled by a blinded research physiotherapist, placed into opaque sealed envelopes, and shuffled again.

Interventions

The experimental group followed a program that included three scapulothoracic stabilization exercises and three glenohumeral stability exercises, while subjects in the control group only performed the latter set of exercises. Two weekly sessions were carried out over a period of 6 weeks, and each session lasted 30 minutes. The intervention was conducted before the climbing session, to avoid muscle fatigue.

The six exercises in question have been previously used by Yin et al. (18) and described in a literature review conducted by Cricchio et al. (11) The program comprises three sets, including 10 repetitions of each exercise, and one-minute rest between sets (Table 1).

Table: 1 Intervention Protocol Through Stability Exercise To Scapulothoracic And Shoulder Joint Used In This Study.

Type of exercise	Exercise	Starting position	Action
	Full can	Standing, holding elastic band with thumbs pointing up.	30° abduction in the scapular plane.
Shoulder stabilization	Sidelying external rotation	Lateral decubitus, 90° flexion elbow and shoulder in slight internal rotation.	External rotation against resistance.
	Diagonal exercise	Start with 90° shoulder abduction and slight elbow flexion.	Adduction and internal rotation of the shoulder against resistance.
	Push-up plus	Elbows in extension, and hands under the shoulders.	Protraction and controlled scapular retraction.
Scapulothoracic stabilization	Lawn mower	Column flexion and rotation to the opposite side.	Extension and rotation of the spine, with retraction of the scapula.
	Wall slide	Standing in front of the wall, with ulnar edge of forearms stabbed in the wall.	Slide forearms up and down, in a controlled manner, with scapular retraction.

Assessments

Participants were assessed prospectively by a blinded physiotherapist who was not involved in the intervention. These assessments were conducted at baseline, posttreatment (6 weeks), and at follow-up (4 weeks). The primary outcome was shoulder stability. The secondary outcomes were time need to complete a given climbing route and number of grips needed.

To assess shoulder stability, we used the CKCUEST test, according to the protocol described by Goldbeck et al. (15) This scale evaluates the number of upper limb movements the subject is able to make in 15 seconds. A higher score represents better shoulder stability.

For assessment of the other two dependent variables (time need to complete a given climbing route and number of grips needed), we performed a bouldering test, replicating the demands of a competition, based on those used by Donath et al. (19) and Wall et al. (20). The test was carried out on a 4-meter-high wall having a 20-degree inclination, comprising a route with 15 climbing holds: 3 small, 7 medium and 5 large. A start hold and a finish hold were clearly identified. The climber had 5 minutes to visualize the route, in a familiarization process often used in competitions (21). Before the test, participants were instructed to be as efficient as possible in their movements. The time taken by the climber to complete the route was recorded, and the number of grips used for the route.

Data analysis

Statistical analysis was performed with SPSS software, version 19.0, for Windows. Using a descriptive statistical analysis, quantitative data of the independent variables were expressed in terms of mean and standard deviation.

Homogeneity in sample distribution between the two groups was calculated using the Kolmogorov-Smirnov test. Changes between the various evaluations were observed using the parametric paired samples t-test.

The repeated measures ANOVA provided the intra-subject effect and group interaction. The error rate of the significance level was controlled by the Bonferroni correction. When the Mauchly sphericity test was significant, the Greenhouse-Geisser correction coefficient was used. The partial eta-squared value was calculated as an indicator of effect size (classified as small 0.01, medium 0.06 and large 0.14) (22).

An intent-to-treat analysis has been performed in this study. The differences between groups were considered statistically significant for $p<.05$.

RESULTS

In total, 48 subjects were screened (Fig. 1). Forty boulderers were recruited and randomized. The flow of participants through the study is represented in Fig. 1.

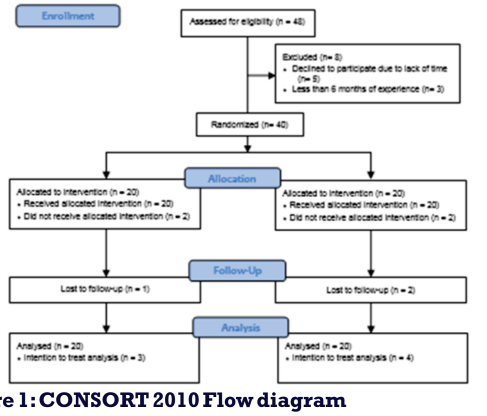

Figure 1: CONSORT 2010 Flow diagram

Baseline data for the groups were similar in all independent variables, except in experience in climbing and weekly hours of training ($p < .01$) (Table 2).

Table – 2 descriptive Analysis Of All Sample And In Each Group.

Anthropometric variables	Experimental group		Control group		P-value
	M (SD)		M (SD)		
Height (cm.)	171 (11.0)		172 (9.0)		0.85 [a]
Weight (kg.)	65.75 (14.47)		66.45 (11.20)		0.76 [a]
Body mass index (kg /m^2)	22.13 (2.79)		22.23 (2.00)		0.81 [a]
Experience in climbing (years)*	13.25 (10.87)		12.10 (8.29)		0.00 [a]
Hours of week training (hours)*	4.30 (1.89)		3.95 (1.39)		0.00 [a]
Clinical variables	n	%	n	%	
Gender (Male / Female)	15 / 5	75 / 25	14 / 6	70 / 30	0.08 [b]
Previous injuries (Yes / No)	9 / 11	45 / 55	9 / 11	45 / 55	1.00 [b]

n: number of subjects; M: mean; SD: standard deviation; %: percentage.
[a] Kolmogorov–Smirnov test.
[b] Fisher exact test.
*** Significant difference ($p < .05$).**

Shoulder stability

At 4 weeks, the mean of shoulder stability in the experimental group had increased from 20.08 (95% confidence interval [CI], 18-34-21.81) to 23.63 (95% CI, 21.80-25.46; $p < .0001$, paired t test). The mean improvement in the shoulder stability was -3.55 (95% CI, -4.81--2.29). After follow-up, the mean of shoulder stability in the experimental group was 23.07 (95% CI, 21.26-24.87). This was significantly different from baseline ($p < .0001$, paired t test). The mean improvement was -2.99 (95% CI, -4.21--1.76).

Following intervention, the mean joint stability in the control group had increased from 21.05 (95% CI, 19.38-22.71) to 21.99 (95% CI, 20.32-23.66; $p < .002$, paired t test). The mean improvement in the shoulder stability was -0.94 (95% CI, -1.50- -0.38). After follow-up, the mean shoulder stability in the control group was 21.04 (95% CI, 18.20-23.88). This was not significantly different from baseline ($p = .99$, paired t test). The mean improvement was 0.01 (95% CI, -1.50- -0.38) (Tables 3 and 4).

Table – 3 Means (and Standard Deviations) Of Dependent Variables Evaluated In The Three Assessments.

Variables	Experimental group			Control group		
	T0	T1	T2	T0	T1	T2
Stability of the shoulder (number)	20.08 (3.71)	23.63 (3.91)	23.07 (3.85)	21.05 (3.56)	21.99 (3.57)	21.04 (6.07)
Time to climbing (seconds)	46 (9.78)	41 (9.16)	42.45 (8.85)	44.50 (14.95)	43.65 (13.05)	44.25 (13.36)
Grips during climbing (number)	18.55 (2.23)	17.60 (2.23)	18.20 (2.16)	18.60 (2.81)	18.45 (2.70)	18.60 (2.74)

Outcome measures at the baseline (T0), after the three-week period of experimental and control interventions (T1) and after further 4-weeks as follow-up (T2).

Table – 4 mean Differences (and Significance) Between Baseline And Posttreatment And Between Baseline And Follow-up Assessment.

Variables	Experimental group		Control group	
	T0 - T1	T0 - T2	T1 - T2	T0 - T2
Stability of the shoulder (number) †	-3.55 (.00) **	-2.99 (.00) **	-0.94 (.00) *	0.00 (.99)
Time to climbing (seconds) ‡	5.00 (.00) **	3.55 (.00) *	0.85 (.12)	0.25 (.63)
Grips during climbing (number) ‖	0.95 (.00) *	0.35 (.09)	0.15 (.37)	0.00 (1.00)

T0-T1: outcome measures between baseline to posttreatment assessments: T0-T2: outcome measures between baseline to follow-up assessments (T0).

† Higher number indicating greater joint stability; ‡ Lower time indicating greater athletic performance; ‖ Lower grips indicating athletic performance; * Significant difference ($p < .01$); ** Significant difference ($p < .001$).

There were intra-subject differences in shoulder stability ($F(1.60, 61.02) = 14.63$; $p < .001$; $\eta^2_p = 0.27$). We found differences between the groups in joint stability ($F = 7.41$; $p < .01$; $\eta^2_p = 0.16$) (Table 5).

Table – 5 Statistical Analysis Of Repeated Measures Of The Dependent Variables In The Three Study Assessments.

Variables	Mauchly sphericity test		Intra-subject effect			Interaction		
	W	Sig.	F	Sig.	η^2_p	F	Sig.	η^2_p
Stability of the shoulder (number) [a]	0.75	.00	14.63	0.00 **	0.27	7.41	.00 *	0.16
Time to climbing (seconds) [a]	0.27	.00	14.98	0.00 **	0.28	8.17	.00 *	0.17
Grips during climbing (number) [a]	0.46	.00	10.08	0.00 *	0.21	5.13	.02 *	0.11

W: Mauchly Sphericity test; Sig.: significance. η^2_p: eta squared partial (effect size); Interaction: interaction with the group.

[a] The df corresponds to Greenhouse–Geisser test.
*** Significant difference ($p < .05$).**
**** Significant difference ($p < .001$).**

In the pairwise comparison analysis, there was a significant improvement at posttreatment as compared to baseline values (MD: -2.25; $p < .001$). There was likewise a significant improvement at follow-up as compared to baseline (MD: -1.49; $p = .01$) (Table 6).

Table – 6 Pairwise Comparison Analysis, Means Difference And (significance), Between The Three Evaluations Carried Out In Each Study Group.

Variables	T0 - T1	T1 - T2	T0 – T2
Stability of the shoulder (number)	-2.25 (.00) **	0.75 (.21)	-1.49 (.01) *
Time to climbing (seconds)	2.92 (.00) **	-1.02 (.00) **	1.90 (.01) *
Grips during climbing (number)	0.55 (.00) *	-0.37 (.00) **	0.17 (.47)

T0 - T1: outcome measures between baseline to posttreatment assessments; T1 – T2: outcome measures between posttreatment to follow-up assessments: T0 - T2: outcome measures between baseline to follow-up assessments (T0); MD, mean difference.
*** Significant difference ($p < .05$).**
**** Significant difference ($p < .001$).**

Time need to complete a given climbing route

At 4 weeks, the mean time required to complete a given climbing route in the experimental group had improved from 46 (95% CI, 41.42-50.58) to 41 (95% CI, 36.71-45.29; $p < .001$, paired t test). The mean improvement in shoulder stability was 5 (95% CI, 2.56-7.43). At follow-up, the mean time needed to complete a given climbing route in the experimental group was 42.45 (95% CI, 38.30-46.6). This was significantly different from baseline values ($p < .01$, paired t test). The mean improvement was 3.55 (95% CI, 1.03- 6.07).

Following intervention, the mean time needed to complete a given climbing route in the control group had improved from 44.50 (95% CI, 37.50-51.50) to 43.65 (95% CI, 37.54-49.76; $p = .12$, paired t test). The mean improvement was 0.85 (95% CI, -0.25- 1.95). At follow-up, the mean time needed to complete a given climbing route was 44.25 (95% CI, 38-50.50). This was not significantly different from baseline values ($p = .63$, paired t test). The mean improvement was 0.25 (95% CI, -0.83-1.33).

There were intra-subject differences in the time needed to complete a given climbing route ($F(1.16, 44.14) = 14.98$; $p < .001$; $\eta^2_p = 0.28$). We found differences between the groups in time needed to complete a given climbing route ($F = 8.17$; $p < .01$; $\eta^2_p = 0.17$). In the pairwise comparison analysis, there was a significant improvement at posttreatment as compared to baseline values (MD: 2.92; $p < .001$). There was a significant improvement at follow-up compared to baseline (MD: 1.90; $p = .01$).

Number of grips

At 4 weeks, the mean number of grips made in climbing in the experimental group had improved from 18.55 (95% CI, 17.5-19.6) to 17.60 (95% CI, 16.55-18.65; $p < .01$, paired t test). The mean improvement in the number of grips needed was 0.95 (95% CI, 0.37-1.52). At follow-up, the mean number of grips in the experimental group was 18.2 (95% CI, 17.19-19.21). This was not significantly different from baseline values ($p = .09$, paired t test). The mean improvement was 0.35 (95% CI, -0.60-0.76).

Following intervention, the mean number of grips in the control group had improved from 18.60 (95% CI, 17.28-19.92) to 18.45 (95% CI, 17.18-19.72; $p = .37$, paired t test). The mean improvement in the number of grips was 0.15 (95% CI, -0.19-0.49). At follow-up, the mean number of grips in the control group was 18.60 (95% CI, 17.32-19.88). This was not significantly different from baseline values ($p = 1.00$, paired t test). The mean improvement was 0.00 (95% CI, -0.30- 0.30).

There were intra-subject differences in the number of grips needed ($F(1.30, 49.42) = 10.08$; $p < .01$; $\eta^2_p = 0.21$). We found differences between the groups in number of grips needed ($F = 5.13$; $p = .02$; $\eta^2_p = 0.11$). In the pairwise comparison analysis, there was a significant improvement at posttreatment as compared to baseline values (MD: 0.55; $p < .01$). There was not a significant improvement at follow-up compared to baseline (MD: 0.17; $p = .47$).

DISCUSSION

This study mainly aims to identify the efficacy of a glenohumeral stabilization exercise program combined with scapulothoracic stabilization exercises for improving shoulder stability in boulderers. The secondary objective was to assess improvements in terms of a reduction in the time required to complete a given climbing route and the number of grips required for the climb. Subsequent to the intervention, climbers who performed the glenohumeral and scapulothoracic stabilization exercises significantly improved all the study variables, while effects remained after four weeks of follow-up. Such improvements were significant compared to athletes who performed glenohumeral stabilization exercises only.

Dynamic balance and stability are associated with performance and risk of injury (23) Yin et al. (18) evaluated changes in electromyographic activity during shoulder elevation of the open kinematic chain of the upper limb, following a 4-week neuromuscular control and strengthening protocol. Although rotator cuff strength increased, no improvement was recorded in muscle activation during movement. The movement evaluated involved a different effort than that evaluated by the CKCUEST test or the climbing movement, which develops in a closed kinetic chain.

Although no differences in range of motion and shoulder strength have been found between overhead athletes with and without a history of shoulder joint injury, those who have suffered previous shoulder joint injuries exhibit poorer dynamic balance (23).

Our results are consistent with those disclosed by Illyés et al. (24) who reported how a stability and motor control exercise protocol followed by patients with shoulder instability greatly improved the electromyographic activity of the stabilizing shoulder muscles during the more demanding movements (dynamic movements and high speed dynamic movements). Overhead athletes present an adaptive mechanism that prevents disruption of the scapular movement pattern even when muscle fatigue is present.

We witnessed how climbing time and number of grips decreased subsequent to the glenohumeral and scapulothoracic stability exercise intervention, promoting more fluid movements to reach the climbing holds. These changes were not observed in subjects who performed glenohumeral stability exercises alone. Our results suggest that scapular stability has a major role in generating a proximal fixed point for efficient upper limb mobility.

Hence, climbers are able to generate points of support without constantly adjusting their position, which hinders free-flowing movements. Sibella et al. (25) reported how climbers using a movement strategy based on good balance control and smooth motion of their body center of mass exhibit enhanced athletic performance (26). It has also been reported (26) that climbers with heightened athletic performance exhibit shorter grip and hold times in climbing and a smoother movement of their center of mass. Although a number of physiotherapy techniques such as Kinesio taping (27) can cause significant changes in the scapular kinematics with muscle fatigue, these results are scarcely relevant.

After follow-up period, the improvements in shoulder stability, the reduced climbing time and the lower number of grips needed to complete the climb were sustained. The lower limbs, trunk, and scapular region play an important role in the development of optimal acceleration in the terminal motion segment of dynamic movements (17). Alterations affecting the kinetic chain can cause a higher incidence of shoulder and elbow joint injury in overhead athletes. Activation of the scapular stabilizing muscles and central muscles, coupled with concomitant activation of the rotator cuff, have been shown to improve functionality in overhead athletes.

Although the sample size was not very large, high values were obtained in the calculation of the effect size (partial eta-squared) for almost all the variables in the repeated measures analysis and group interaction. Thus, we are able to uphold the efficacy of an intervention using glenohumeral and scapulothoracic stability exercises for improving shoulder stability and athletic performance in boulderers.

Limitations of the study

One of the limitations of this study is that the climbing test used to assess athletic performance has not been validated. Validated measuring instruments for assessing climbing performance are based on the athlete's resistance and not on fluidity of movement. Tests designed to assess movement kinematics in climbing use costly devices that render them hardly available in clinical practice (1,19).

Another limitation of the study is the complexity of establishing a single starting position for the climbing test. More experienced climbers positioned the body such that reaching the second hold would be more efficient. In order to minimize this problem, two starting holds were clearly marked.

Finally, the number of subjects who withdrew from the study may also influence the results. With the aim of minimizing this limitation, an intention-to-treat analysis was carried out.

Relevance to clinical practice

Therapeutic exercise has shown to be efficient for the treatment of shoulder instability (12). At the same time, joint instability can be a risk factor of injury of periarticular structures (9). Therefore, the results of this study suggest that the proposed program for scapulothoracic and glenohumeral stabilization can be used by physical therapists or climbing coaches wishing to prevent injuries in their climbers.

On the other hand, climbers using a smoother movement of their center of mass (25) and a shorter contact time with the climbing holds (26), appear to have a more effective climbing strategy. The results of this study suggest that a shoulder stabilization program can help to improve these two parameters and increase athletic performance.

Recommendations for future research

Future research should focus on validating climbing tests such as that used in the present study, with the aim of assessing athletic performance quickly and without using expensive and sophisticated devices. Future research should assess whether shoulder stability and performance render better results with functional exercises, using larger muscle chains and more climbing specific.

CONCLUSIONS

A program of scapulothoracic and glenohumeral stabilization exercises can improve shoulder stability and fluidity of climbing movements. The improvement observed in the stability and climbing time can be maintained after a four-week follow-up period. Future studies should confirm the results obtained in this study.

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