DOI: 10.48305/jrrs.2026.46070.1131 Published by Vesnu Publications

The Effect of Eight Weeks of Core Stability Training on Stable and Unstable Surfaces on Range of Motion, Proprioception, and Muscle Strength in Individuals with Rotator Cuff Tendinopathy; Randomized Controlled Trial

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Original Article

Abstract

Introduction: Rotator cuff tendinopathy is one of the most common musculoskeletal injuries. The aim of this study was to investigate the effects of eight weeks of core stability training on stable and unstable surfaces on range of motion, proprioception, and muscle strength in individuals with rotator cuff tendinopathy.

Materials and Methods: The study sample consisted of 36 participants from Kharazmi University, Karaj branch, who met the inclusion criteria. They were randomly assigned to three groups of 12: stable training, unstable training, and control. Range of motion, muscle strength, and proprioception were measured using a goniometer and an isokinetic device. Participants in the training groups performed core stability exercises on stable and unstable surfaces for eight weeks. After the training period, post-test measurements were recorded. Data were analyzed using SPSS with ANCOVA followed by Bonferroni post hoc tests at a significance level of 0.05.

Results: Eight weeks of training led to statistically significant improvements in shoulder rotator muscle strength and proprioception in both internal and external rotation ($P < 0.05$); however, range of motion showed no significant changes ($P > 0.05$). The unstable training group demonstrated greater improvements in proprioception and muscle strength compared to the stable training group.

Conclusion: Core stability training on both stable and unstable surfaces can be considered an effective intervention in rehabilitation programs to enhance shoulder function in individuals with rotator cuff tendinopathy.

Keywords: Range of Motion; Muscle Strength; Proprioception; Rotator cuff tendinopathy

Citation: Abbasi A, Shojaedin SS. **The Effect of Eight Weeks of Core Stability Training on Stable and Unstable Surfaces on Range of Motion, Proprioception, and Muscle Strength in Individuals with Rotator Cuff Tendinopathy; Randomized Controlled Trial.** J Res Rehabil Sci 2025; 21.

Received date: 31.12.2024 Accept date: 04.02.2025 Published: 03.04.2025

Introduction

The shoulder joint, as one of the most mobile joints in the human body, is highly susceptible to injury in various sports, particularly volleyball, handball, and tennis, due to its complex anatomical structure and extensive range of motion (1). Shoulder injuries account for up to 40% of all sports-related injuries, a considerable proportion of which result from overuse and excessive muscular loading (2). Optimal shoulder function requires precise coordination among multiple muscle groups, and neuromuscular control of this region is primarily ensured through activation of the rotator cuff muscles and integration of the nervous system (3).

The rotator cuff consists of the subscapularis (internal rotator) and the supraspinatus, infraspinatus, and teres minor (external rotators), which collectively provide functional stability of the glenohumeral joint (4). Among these muscles, the supraspinatus tendon is particularly vulnerable to injury, as repetitive overhead activities may compromise its vascular supply at the tendon-bone interface, increasing susceptibility to

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degeneration and damage (5).

Rotator cuff tendinopathy, commonly referred to as subacromial impingement syndrome, is characterized by pain and functional impairment and has a high prevalence in the general population (4, 6). In this condition, the subacromial space between the humeral head and the inferior surface of the acromion is reduced, which is essential for normal shoulder biomechanics and stability (7). This pathology may result from tendinopathy, partial or complete tendon tears, or age-related degeneration, ultimately leading to superior migration of the humeral head and secondary impingement (8).

Patients with this condition typically present with reduced external rotator strength relative to internal rotators, muscular imbalance, decreased range of motion, and impaired proprioception (6, 7). A reduction in shoulder internal rotation range of motion, known as glenohumeral internal rotation deficit (GIRD), is frequently observed in overhead athletes (4). Dysfunction of the rotator cuff muscles and subacromial impingement alter shoulder kinematics, scapulothoracic rhythm, joint stability, and postural alignment (9).

Optimal upper-limb function requires both static and dynamic stability mechanisms, including symmetry in strength, endurance, flexibility, and neuromuscular control (10). Static stability is primarily provided by passive anatomical structures such as the joint capsule and ligaments, whereas dynamic stability is achieved through neuromuscular control and coordinated muscle activation during movement. From a kinetic chain perspective, shoulder stability is closely linked to core stability, as the core musculature provides a stable base for efficient force transfer from the lower extremities through the trunk to the upper limbs (11). Consequently, deficits in core stability may lead to compensatory movement patterns, early fatigue, and increased mechanical stress on upper-extremity structures (12).

Proprioception, including joint position sense, kinesthesia, and sense of effort, is a fundamental component of coordinated shoulder function (7). The core region—comprising the abdominal, paraspinal, diaphragm, and pelvic floor muscles—plays a crucial role in transmitting forces from the central axis to the upper extremities (4, 13, 14). Previous studies have shown that core stability training, particularly on unstable surfaces, enhances proprioceptive feedback and neuromuscular control by improving the timing of trunk muscle activation and reducing mechanical stress on the rotator cuff tendons (12). Accordingly, improved postural control may reduce compensatory shoulder activity and decrease the risk of overuse injuries (15).

Various treatment approaches for rotator cuff tendinopathy include taping, therapeutic exercise, and manual therapy techniques (7, 16, 17). Exercise therapy, as a non-invasive, low-risk intervention, has demonstrated favorable outcomes in managing this condition (17, 18). Strengthening of the internal and external rotator muscles has been shown to increase the subacromial space and improve pain and disability (15). Furthermore, Espinoza et al. reported that incorporating core stability exercises into physiotherapy programs enhances rotator cuff strength and functional outcomes by improving force transmission along the kinetic chain (19).

Despite growing evidence of the core's importance in force transmission and shoulder stability, most rehabilitation protocols for rotator cuff tendinopathy focus primarily on direct strengthening of the rotator cuff muscles. In contrast, the role of core stability exercises as an indirect intervention has received less attention. These exercises may improve scapular kinematics, reduce compensatory muscular tension, and consequently enhance shoulder range of motion (11). Additionally, by challenging the neuromuscular system along the kinetic chain, they may stimulate mechanoreceptors and improve sensorimotor integration, thereby enhancing proprioception and joint position sense (20). Clinical studies have also shown that this approach can significantly reduce symptoms of shoulder impingement syndrome (21).

Therefore, investigating the effects of these exercises on shoulder functional outcomes in individuals with rotator cuff tendinopathy appears necessary. Moreover, the comparative effects of stable versus unstable surface training on these parameters have not yet been comprehensively examined. The present study was designed to address this gap, with the hypothesis that unstable surface training, due to greater neuromuscular demand and increased activation of stabilizing muscles, would yield greater improvements in muscle strength, proprioception, and range of motion than stable surface training.

This study aimed to investigate and compare the effects of eight weeks of core stability training on stable and unstable surfaces on shoulder rotator muscle strength, proprioception, and range of motion in individuals with rotator cuff tendinopathy.

Materials and Methods

This study was a randomized controlled clinical trial with a pre-test/post-test design. The study population consisted of male physical education students at Kharazmi University, Karaj Campus. Initially, 36 participants aged 18–30 years were voluntarily recruited through advertisements posted at the university.

The sample size was determined using G*Power software (version 3.1), based on a statistical power of 0.80, an effect size of 0.60, and a significance level of 0.05, using proprioception as the primary outcome variable (23). Considering a 20% attrition rate, 12 participants were allocated to each group.

Following baseline assessments, participants were randomly allocated into three groups (two intervention groups and one control group) using block randomization generated via an online tool. Allocation concealment was ensured by a third party not involved in assessment or intervention delivery, who prepared sealed opaque envelopes. The principal investigator opened the envelopes after participant enrollment to assign groups, thereby minimizing selection bias.

Inclusion criteria were positive results on the Neer and Hawkins-Kennedy tests (24), deltoid region pain, and a painful arc sign. Exclusion criteria included missing two or more consecutive training sessions, history of severe shoulder injury (e.g., fractures or rotator cuff tears), previous shoulder surgery, participation in rehabilitation programs within the past six months, inability to continue participation, missing pre- or post-test assessments, cervical abnormalities, and inflammatory, rheumatic, or neurological disorders diagnosed by a specialist (25, 26).

Ethical approval was obtained from the Ethics Committee of Kharazmi University. The study was also registered in the University Hospital Medical Information Network Clinical Trials Registry (UMIN000058541). All participants provided written informed consent and were free to withdraw at any time.

Baseline assessments included demographic data (height and weight), followed by measurements of muscle strength, proprioception, and range of motion. Post-tests were conducted 48 hours after completion of the eight-week intervention. All assessments were performed by an experienced physiotherapist who was blinded to group allocation.

Proprioception was assessed using a Biodex isokinetic dynamometer (Model 3, USA), with reported validity and reliability of 0.99 (27). A familiarization session was conducted 48 hours before baseline testing to minimize learning effects. Joint position sense was assessed at 45° of internal and external rotation in the scapular plane at a velocity of 5°/s, starting from 90° of shoulder position (28). The 45° position was selected for its functional relevance and to reduce the confounding effects of pain associated with higher degrees of abduction and impingement (29).

For testing, the target angle was passively positioned and held for 10 seconds before returning to the starting position. Participants, blindfolded, were then asked to actively reproduce the target angle. Each condition was repeated three times, and the mean absolute error was recorded.

Muscle strength was also measured using the Biodex isokinetic dynamometer (Model 3, USA) with validated reliability (0.99) (27). Participants were seated and stabilized with straps to minimize compensatory movements. Testing was performed in the scapular plane with standardized positioning. The range of motion was set from 40° external rotation to 30° internal rotation (30). Participants performed 5 maximal repetitions at 60°/s in both internal and external rotation (31), and peak torque, normalized to body weight, was recorded.

Range of motion was assessed using a universal goniometer with reliability ranging from 0.85 to 0.99 (32). Shoulder flexion, abduction, internal rotation, and external rotation were measured using standardized supine positioning protocols (33, 34).

Following baseline testing, both intervention groups completed an eight-week progressive training program consisting of three sessions per week, each lasting 30–50 minutes (Table 1). All sessions were conducted in groups under the direct supervision of the researchers to ensure correct execution. Training volume was limited to a maximum of three sets per exercise. A 3-kg medicine ball was used for selected exercises to provide neuromuscular stimulation without inducing significant hypertrophy or strength adaptation (35).

The unstable-surface group performed exercises on a rehabilitation trampoline (90 cm diameter, medium stiffness, 25 cm height), while the stable group performed identical exercises on a firm surface (36). The control group received no intervention. Participants were instructed not to use analgesic medication during the study and were monitored for compliance. Post-intervention assessments were conducted under identical conditions to baseline testing.

Data analysis was performed using SPSS version 27 (IBM). Normality was assessed using the Shapiro-Wilk test, and homogeneity of variance was evaluated using Levene's test. Between-group differences were analyzed using ANCOVA with baseline values as covariates, followed by Bonferroni post hoc tests. Within-group changes were assessed using paired-sample t-tests. Statistical significance was set at $P < 0.05$.

Table 1. Eight-week steady-state and unstable-level training protocol

Exercise	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Plank	2 × 10s holds	3 × 10s holds	3 × 15s holds	3 × 15s holds	2 × 20s holds	3 × 20s holds	2 × 25s holds	3 × 25s holds
Russian Twist	2 × 10 reps	3 × 10 reps	3 × 15 reps	3 × 15 reps	2 × 20 reps	3 × 20 reps	2 × 25 reps	3 × 25 reps
Slide Board Mountain	2 × 10 reps	3 × 10 reps	3 × 15 reps	3 × 15 reps	2 × 20 reps	3 × 20 reps	2 × 25 reps	3 × 25 reps
Medicine Ball Rotation	2 × 10 reps	3 × 10 reps	3 × 15 reps	3 × 15 reps	2 × 20 reps	3 × 20 reps	2 × 25 reps	3 × 25 reps
Dumbbell Side Bend	2 × 10 reps	3 × 10 reps	3 × 15 reps	3 × 15 reps	2 × 20 reps	3 × 20 reps	2 × 25 reps	3 × 25 reps
Oblique Twist	2 × 10 reps	3 × 10 reps	3 × 15 reps	3 × 15 reps	2 × 20 reps	3 × 20 reps	2 × 25 reps	3 × 25 reps
Overhead Weighted Split Squat		2 × 10 reps	3 × 10 reps	2 × 10 reps	3 × 15 reps	2 × 20 reps	3 × 20 reps	2 × 25 reps
Medicine Ball Rotational Lunge Walk			2 × 10 reps	3 × 10 reps	2 × 15 reps	3 × 15 reps	2 × 20 reps	3 × 20 reps
Medicine Ball Throw			2 × 10 reps	3 × 10 reps	2 × 15 reps	3 × 15 reps	2 × 20 reps	3 × 20 reps

Results

Analysis of demographic characteristics showed no statistically significant differences among groups in mean height, weight, age, or BMI (Table 2). The Shapiro–Wilk test indicated a normal distribution of data, and homogeneity of variance was confirmed. One-way ANOVA revealed no significant differences among the groups at baseline.

The results of analysis of covariance (ANCOVA), with pre-test values as covariates, indicated no significant differences in range of motion (ROM) across all four movement directions at post-test ($P > 0.05$). Within-group analyses demonstrated changes in the stable-surface training group from pre-test to post-test in flexion, abduction, and internal rotation. In the unstable-surface training group, improvements were observed in abduction and external rotation.

After controlling for baseline values, statistically significant differences were observed in internal and external rotator muscle strength at post-test ($P = 0.002$, $F = 7.68$, $\eta^2 = 0.32$; $P = 0.002$, $F = 7.43$, $\eta^2 = 0.31$, respectively). Bonferroni post hoc analysis revealed significant differences between the control group and the unstable training group for both variables. However, no significant differences were found between the stable and unstable groups or between the stable and control groups ($P > 0.05$). Within-group comparisons indicated significant improvements in both variables, with the unstable group demonstrating a greater effect size.

Statistical analysis also showed significant differences in proprioception at post-test in both internal and external rotation ($P = 0.001$, $F = 23.24$, $\eta^2 = 0.59$; $P = 0.007$, $F = 5.75$, $\eta^2 = 0.26$, respectively). Bonferroni post hoc tests indicated that, for 45° internal-rotation proprioception, significant differences existed between the control group and both intervention groups. For 45° of external rotation, significant differences were observed only between the control and unstable groups. No significant differences were found between stable and unstable groups. Within-group results demonstrated significant improvements in proprioception in both directions, with the unstable group showing larger effect sizes.

Discussion

The present study aimed to investigate the effects of eight weeks of core stability training on stable and unstable surfaces on muscle strength, proprioception, and range of motion in individuals with rotator cuff tendinopathy.

Table 2. Demographic characteristics of the subjects participating in the three stable, unstable, and control groups

Variable	Control group (N=12)	Stable group (N=12)	Unstable group (N=12)
Height (cm)	176.46± 4.43	174.50 ± 3.25	172.80 ± 4.22
Weight (kg)	72.21± 5.65	70.25 ± 4.39	74.14 ± 6.80
Age (years)	24.84± 2.71	23.31 ± 3.77	23.31 ± 4.17
BMI (m2/kg)	23.21± 1.62	22.81 ± 0.90	21.64 ± 2.12

Table 3. Results of mean and standard deviation in pre- and post-test, covariance, and paired t-test in stable, unstable, and control groups

Variable	Group	Pre test	Post test	Between Group			Within-Group		
				F	P value	Effect size	T	P value	Effect size
Flexion range of motion (degrees)	Control	173.25 ± 3.13	4.49 ± 174.00	0.71	0.71	0.04	0.93	0.36	0.27
	Stable	172.41 ± 3.17	5.16 ± 174.50				2.33	0.03	0.67
	Unstable	2.80 ± 172.75	3.17 ± 174.33				2.04	0.06	0.59
Abduction range of motion (degrees)	Control	5.28 ± 168.50	5.44 ± 169.25	1.31	0.28	0.007	1.19	0.25	0.34
	Stable	6.66 ±164.25	5.60 ± 167.50				3.37	0.00	0.97
	Unstable	2.19 ± 167.50	3.69 ± 168.75				1.58	0.14	0.45
Internal rotation range of motion (degrees)	Control	4.60 ± 82.83	5.65 ± 81.83	2.77	0.07	0.14	1.86	0.08	0.53
	Stable	5.61 ± 81.08	5.51 ± 82.41				1.49	0.16	0.43
	Unstable	3.94 ± 81.38	4.77 ± 82.08				1.14	0.18	0.40
External rotation range of motion (degrees)	Control	4.48 ± 97.16	4.61 ± 97.25	1.69	0.20	0.09	0.23	0.82	0.06
	Stable	3.65 ± 97.50	2.90 ± 96.41				1.25	0.23	1.30
	Unstable	2.06 ± 99.08	1.91 ±97.25				3.65	0.00	1.04
Internal rotator strength (N/BW)	Control	6.23 ± 36.21	6.99 ± 36.24	7.68	0.002	0.32	0.08	0.93	
	Stable	8.49 ± 33.23	7.96 ± 36.97				3.82	*0.00	1.10
	Unstable	5.36 ± 34.52	6.28 ± 40.25				4.18	*0.00	1.20
Extrenal rotator strength (N/BW)	Control	5.56 ± 31.79	5.59 ± 31.29	7.43	0.002	0.31	1.03	0.32	0.30
	Stable	6.87 ± 27.81	5.73 ± 30.40				2.84	*0.01	0.82
	Unstable	4.98 ± 26.57	6.39 ± 31.40				4.88	*0.00	1.40
Proprioception 45 degrees internal (degrees)	Control	1.17 ± 4.17	0.93 ± 4.80	23.24	*0.001	0.59	1.13	0.09	0.76
	Stable	1.36 ± 4.56	1.07 ± 3.45				3.21	*0.00	0.91
	Unstable	1.61 ± 5.44	0.84 ± 2.91				6.11	*0.00	1.76
Proprioception 45 degrees External (degrees)	Control	1.18 ± 3.13	1.12 ± 3.16	5.75	0.007	0.26	0.18	0.85	0.05
	Stable	1.58 ± 3.50	1.04 ± 2.69				2.33	*0.04	0.58
	Unstable	1.31 ± 3.64	0.97 ± 2.06				3.27	*0.00	0.94

*Significant ($P<0.05$)

The findings indicated that both stable and unstable core stability training led to significant improvements in internal and external rotator muscle strength and proprioception compared with the control group. Additionally, significant within-group improvements in muscle strength were observed following the intervention period. One possible explanation for these improvements is enhanced force transfer from the trunk to the shoulder girdle and upper extremity. From a biomechanical perspective, complex movements require coordinated activation of multiple muscle groups to ensure efficient force production and transmission (37). Disruption in this kinetic chain may impair energy transfer and impose excessive mechanical stress on shoulder structures.

The core musculature plays a key role in maintaining spinal stability and balance. It acts as a central link for transferring forces generated in the lower extremities through the trunk to the upper limbs (38). Accordingly, core stability is essential for efficient upper-extremity function. These findings are consistent with previous research by Espinoza et al., who reported that incorporating core exercises into physiotherapy programs improves shoulder rotator strength in patients with subacromial impingement syndrome (19). Similarly, Ludewig et al. demonstrated that strengthening the core improves shoulder stability and movement control (21). Ebrahimi et al. also confirmed the positive effects of core stability training on shoulder muscle strength (39), supporting the present findings.

In contrast, no significant improvements in range of motion (ROM) were observed in either intervention group compared with the control group. However, the stable group showed significant within-group improvements in flexion and abduction. It appears that the implemented training protocol was not sufficient to produce meaningful changes in isolated glenohumeral and scapulothoracic mobility. These findings are consistent with those of Pashaki et al. (42). However, they are inconsistent with reports by Yazdani et al. (40) and El-Nashar et al. (41), who observed improvements in shoulder ROM following core stability training.

The present study also demonstrated significant improvements in proprioception following both interventions. Reductions in proprioceptive error at 45° of internal and external rotation were observed in the post-test compared with the pre-test. These results are consistent with Moharrami et al., who reported that resistance training improves proprioception in patients with shoulder impingement syndrome (43). The observed improvements may be attributed to increased neuromuscular activation and heightened muscle spindle sensitivity induced by core stability exercises.

Individuals with subacromial impingement syndrome often exhibit reduced muscle spindle excitability (44), while joint pathology may impair afferent feedback from mechanoreceptors, disrupting neuromuscular control. This sensory deficit can lead to altered timing of rotator cuff muscle activation, reduced dynamic stability of the glenohumeral joint, and superior migration of the humeral head (20, 21). These biomechanical alterations increase subacromial pressure and contribute to tendon degeneration (45).

Proprioception is mediated by integrated input from articular, cutaneous, and muscular receptors (37). Injury may also lead to arthrogenic muscle inhibition and reduced muscle function, further impairing sensory feedback (46). Since core stability training actively engages stabilizing musculature, it may enhance receptor function and improve sensorimotor integration. Improved proprioception and ROM may also contribute to reduced subacromial pressure and improved shoulder stability, indirectly enhancing pain and functional outcomes (47).

Overall, the study hypothesis was partially confirmed. Unstable surface training resulted in greater improvements in muscle strength and proprioception compared with stable surface training; however, no significant differences were observed in range of motion. Therefore, core stability training may be considered an effective adjunctive approach in rehabilitation programs for individuals with rotator cuff tendinopathy. Although previous studies have reported positive effects of core training on shoulder function, further research is needed to clarify its broader clinical implications.

Limitations

This study had several limitations, including a relatively small sample size and a short intervention period. Additionally, participants' physical activity levels during the study could not be fully controlled. Another limitation was the absence of a follow-up assessment, which limited the evaluation of long-term effects.

Recommendations

Future studies are recommended to investigate the effects of core stability training on electromyographic activity and muscle activation timing in individuals with rotator cuff tendinopathy. Furthermore, although biomechanical variables improved in the present study, future research should focus on clinical outcomes, including pain reduction, functional capacity, and quality of life, to better assess clinical effectiveness.

Conclusion

Eight weeks of core stability training, particularly on unstable surfaces, significantly improved shoulder rotator muscle strength and proprioception in individuals with rotator cuff tendinopathy. However, no significant improvements in range of motion were observed. These findings suggest that core stability training may be an effective complementary intervention in rehabilitation programs for this population, although additional targeted interventions are likely needed to improve shoulder mobility.

Acknowledgments

We would like to thank all the participants who participated in the exercises and who patiently and sincerely cooperated in all stages of the research. We also thank all those who helped us in this way. This study has an ethics code number IR.KHU.REC.1403.137 from Kharazmi University and a clinical trial code number UMIN000058541 from the Japanese University Clinical Trials Registry.

Authors' Contribution

Project design and conceptualization: Alireza Abbasi, Seyed Sadredin Shojaedin
Attracting financial resources to carry out the project: Seyed Sadredin Shojaedin
Project support, scientific and executive services: Seyed Sadredin Shojaedin
Providing equipment and statical sample: Alireza Abbasi, Seyed Sadredin Shojaedin
Data collection: Alireza Abbasi, Seyed Sadredin Shojaedin
Analysis and interpretation of the results: Alireza Abbasi, Seyed Sadredin Shojaedin
Specialized statistics services: Alireza Abbasi
Manuscript preparation: Alireza Abbasi, Seyed Sadredin Shojaedin
Certical scientific evaluation of the manuscript: Seyed Sadredin Shojaedin
The final manuscript to be submitted to the journal: Alireza Abbasi, Seyed Sadredin Shojaedin
Maintaining the integrity of the study process from the beginning to the publication and responding to reviewers' comments: Alireza Abbasi, Seyed Sadredin Shojaedin

Funding

This study was supported by the Research Vice-Chancellorship of Kharazmi University. The article was extracted from a research project conducted under

the supervision of Dr. Seyed Sadredin Shojaedin at Kharazmi University, Tehran, and approved with the ethics code IR.Khu.Rec.1403.137.

Conflict of Interest

The authors did not have a conflict of interest.

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