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ORIGINAL RESEARCH ARTICLE

Efficacy of Proprioceptive Exercises in Patients with Subacromial Impingement Syndrome

A Single-Blinded Randomized Controlled Study

ABSTRACT

Dilek B, Gulbahar S, Gundogdu M, Ergin B, Manisali M, Ozkan M, Akalin E: Efficacy of proprioceptive exercises in patients with subacromial impingement syndrome: a single-blinded randomized controlled study. Am J Phys Med Rehabil 2016;95:169–182.

Objective: The objective of this study was to evaluate the effectiveness of proprioceptive exercises on shoulder proprioception, range of motion, pain, muscle strength, and function in patients with subacromial impingement syndrome.

Design: Sixty-one patients with subacromial impingement syndrome participated in this prospective, single-blind randomized controlled trial. All patients were randomly divided into two groups: control group (conventional physiotherapy, $n = 30$) and intervention group (proprioceptive exercise and conventional physiotherapy, $n = 31$). The primary outcome measures were sense of kinesthesia and active and passive repositioning for proprioception at 0 degrees and 10 degrees external rotation at 12 wks. The secondary outcome measures were pain at rest, at night, and during activities of daily living with the visual analog scale (0–10 cm), the Western Ontario Rotator Cuff index, the American Shoulder and Elbow Surgeons index, range of motion, and isometric muscle strength at both 6 and 12 wks.

Results: After treatment, significant improvement was found in range of motion, pain, isometric muscle strength, kinesthesia at 0 degrees external rotation, and functional tests in both groups. The intervention group showed a significant improvement in kinesthesia at 10 degrees external rotation and active and passive repositioning at 10 degrees external rotation. When groups were compared, there were no statistically significant differences in any of the parameters at 12 wks.

Conclusions: Although proprioceptive exercises may provide better proprioceptive acuity, no additional positive effect on other clinical parameters was observed.

Key Words: Proprioception, Exercise, Shoulder Pain, Physiotherapy

Subacromial impingement syndrome (SIS) is the most common cause of shoulder pain and it affects shoulder sensory-motor control and maximal shoulder muscle strength.[1] After shoulder injuries or pathologies, disruption of mechanoreceptors results in partial deafferentation of the joint. This has been shown to inhibit normal neuromuscular reflex stabilization and it contributes to repetitive injuries and the progressive decline of the joint.[2] In histologic studies, the periarticular mechanoreceptors, which play an important role in proprioception, were shown to exist in the capsule, bursae, and coracoacromial ligament.[2,3] Numerous studies demonstrated that damage in the capsule, ligaments, glenoid labrum, or the pericapsular muscles was associated with a proprioceptive deficit in the shoulder joint.[4–6] The proprioceptive impairment was demonstrated in patients with rotator cuff pathology and also with shoulder instability.[5–8] It is suggested that proprioception should be improved to ensure the synergic contractions and normal functioning of the muscles in the shoulder, thereby providing protection from future injuries. Research in the field of sports clearly shows how specific proprioceptive exercise programs improve neuromuscular coordination.[3,6,9–12] Trials investigating the effectiveness of specific proprioceptive exercise programs for SIS is limited in the literature.[4,13] An uncontrolled study showed that a sensory-motoric exercise program improved proprioception in patients with subacromial pathology.[4] A recent randomized controlled study found that neurocognitive rehabilitation using proprioceptive exercises was effective in reducing pain and improving function in patients with SIS.[12] However, there is no randomized controlled research on the effectiveness of these exercises in patients with SIS on proprioceptive measurements.

The goal of this study is to determine the effectiveness of proprioceptive exercises in patients with SIS on proprioception, pain, range of motion (ROM), muscle strength, and functional tests.

METHODS

Patients with SIS were recruited consecutively from the outpatient clinic of the Department of Physical Medicine and Rehabilitation at the Dokuz Eylul University in Izmir, Turkey. The study was planned and conducted over a 15-mo period. There was no suitable comparable study in the literature to use in the calculation of the sample size. The study was conducted from May 2008 to August 2009. The study protocol was approved by the ethics committee at the same institution. Patients who met the inclusion and exclusion criteria and submitted written informed consent were included in the trial. The inclusion criteria were as follows: being between the ages of 25 and 65 yrs and a diagnosis of SIS by way of magnetic resonance imaging and physical examination. Patients had demonstrated both positive Neer impingement sign and Hawkins test for the diagnosis of SIS in physical examination. Exclusion criteria were previous shoulder surgery and subacromial or intra-articular injections, bilateral shoulder disease, pregnancy, shoulder instability and joint hypermobility syndrome, diabetes, hypothyroidism, vitamin B_{12} deficiency, and neurologic and inflammatory joint diseases. In addition, patients who had received physiotherapy within the last 3 mos or could not adapt to the tests conditions or therapy because of cardiac problems, cardiac pacemakers, and visible shortness of breath or epilepsy were also excluded.

Research Design

The study was designed as a prospective, single-blinded randomized controlled trial. Before the start of this randomized controlled trial, an independent researcher (MO) provided a randomization scheme from a random number table by using block randomization with four patients in a block. The eligible patients who had submitted a written informed consent were then referred to another researcher (EA) who was not involved in the selection and consent process. This researcher used the randomization scheme to assign patients into intervention or control groups. This process thus ensured allocation concealment.

Setting and Intervention

Demographic data including age, sex, education, occupation, dominant extremity, affected extremity, symptom duration, and trauma history for both groups were assessed by a researcher (MG) blind to group allocation at the outpatient clinic of the Department of Physical Medicine and Rehabilitation. Another researcher (BU) provided written and verbal information about the study to both groups. The control group ($n = 30$) was treated with the conventional physiotherapy program (transcutaneous electrical nerve stimulation, hot pack, and specific exercise). The intervention group ($n = 31$) was additionally assigned to proprioceptive shoulder exercises. A researcher (MG) in the Department of Physical Medicine and Rehabilitation in the

FIGURE 1 *Balance with both hands on the floor. The patient positions his or her upper extremity on the floor and holds an isometric contraction.*

University Hospital conducted these treatments 3 days/wk for a period of 6 wks. Nonsteroid anti-inflammatory drug intake was permitted during the study, and the patients were asked to keep a drug and exercise diary.

The Rehabilitation Program

For a period of 6 wks, the patients were under supervision 3 days/wk as they underwent a physiotherapy (transcutaneous electrical nerve stimulation and hot pack) and exercise schedule. A conventional exercise program consisting of three phases was applied to both groups.[14] Phase 1 was a maximum protection phase consisting of active rest, ROM exercises (pendulum exercises, passive and active assisted ROM with a stick), posterior capsular stretches, and patient education for activity modification. The criteria to advance to the second phase were pain-free full ROM. At the second phase of the exercise program, strengthening exercises of the rotator cuff, scapular stabilizers, and deltoid muscles were given. For strengthening rotator cuff muscles, isometric exercises, therabands, and free weights were used. For the advanced strengthening of scapular stabilizers, the shoulder shrugs, press-ups, and push-up exercises were added later at this phase. The criteria to advance to the third phase were pain-free full ROM during activities and ability to perform second-phase exercises without pain. At the last phase of the program, the goal was for the patient to carry out unrestricted symptom-free activities of daily living (ADL), occupation, recreational activities, and sports. At this phase, the activities progressively increased to prepare the patient for full functional return. Patients performed the exercises both at the hospital and at home.

The intervention group was also assigned to an additional proprioceptive exercise program with three phases (Figs. 1–7; Supplemental Digital Content 1, http://links.lww.com/PHM/A128).

The patients were asked to do the exercises once at home as well. At the completion of the 6 wks, both groups were asked to continue exercises at home twice a day for an additional 6 wks and to keep an exercise diary during the study.

Outcome

Primary Outcome Measures

Primary outcome measures include the overall changes in the sense of kinesthesia, reproduction of

FIGURE 2 *Balance with one hand clockwise on the wall. Patients move the affected side's hand on the wall clockwise.*

FIGURE 3 *Double arm balance in kneeling push-up position on the balance board. Have the patient with both hands on the floor, a balance board. Both hands are moved in four directions: back, forward, left, and right on the board.*

FIGURE 4 *Rotation on the wall using a ball. Have the patient move his or her affected side's hand on the wall using a ball.*

active positioning (RAP), and reproduction of passive repositioning (RPP) at 12 wks.

Assessment of Shoulder Proprioception

Proprioceptive assessment was done by measuring joint position sensibility and kinesthesia (Fig. 8). Kinesthesia was measured by establishing the threshold to detection of passive motion. Joint position sensibility, which is perception of joint position, was measured by RPP and RAP. These proprioceptive assessments were done with an isokinetic dynamometer system (Cybex Norm, Ronkokoma, NC). Visual and auditory inputs were blocked by blindfold and headphones. Patients were familiarized with the testing through three practice attempts. Measurements were done with the patients in supine position and with the shoulder positioned at 90 degrees of abduction and 0 degrees and 10 degrees of external rotation (ER), and the elbow was immobilized at 90 degrees of flexion. The shoulder and arm were put into a pneumatic splint to reduce stimuli of the senses.

Reproduction of Passive Repositioning

From each reference angle (0 degrees and 10 degrees of ER), the shoulder was moved passively into ER direction at a speed of 5 degrees/sec. After 10 secs of static repositioning, the shoulder moved back passively from the presented angle to the reference angle. The patient was then asked to find the previously presented angle while the machine was passively moving. Angular displacements between the presented angle and repositioned angle were

FIGURE 5 *Double arm balance in kneeling push-up position on the foam. Have the patient with both hands on the floor, a foam. Both hands are moved in two directions: forward and back on the foam.*

recorded. Four trials were performed. In all joint position tests, the absolute difference between the presented angle and the repositioned angle was measured, and the mean absolute error score (noted in degrees) was calculated by averaging the absolute error scores of the four trials.

Reproduction of Active Repositioning

This time, the patient was asked to find the previously presented angle actively. Four trials were performed. In all joint position tests, the absolute difference between the presented angle and the repositioned angle was measured, and the mean absolute error score (noted in degrees) was calculated by averaging the absolute error scores of the four trials.

Sense of Kinesthesia

Sense of kinesthesia was also assessed from the reference positions (0 degrees and 10 degrees of ER). The machine passively moved the shoulder from the reference positions into the direction of ER at a speed of 1 degree/sec. When motion was first felt by the patient, the patient stopped the machine by pressing a handheld button. The angle the patient stopped the machine was recorded. Four trials were performed, and mean scores were calculated.

Secondary Outcome Measures

Secondary outcome measures were pain at rest, at night, and during ADL; ROM; isometric muscle strength; and American Shoulder and Elbow Surgeons (ASES) index and Western Ontario Rotator Cuff (WORC) index at both 6 and 12 wks.

FIGURE 6 *Scapular stabilization on the floor with one hand. Have the patient stand on the floor with the affected side's hand and hold an isometric contraction.*

FIGURE 7 *Dynamic stabilization exercise on a ball with one hand. Patients move up affected side's hand on the floor with a ball.*

Pain

Pain at rest, at night, and during ADL was assessed with the visual analog scale (0–10 cm) within the last 48 hrs time frame.

Range of Motion

All ROM measurements were done according to the shoulder index of the ASES.[15] Active-passive flexion, abduction, and active-passive ER were measured with a standard plastic goniometry. Internal rotation was measured as the vertebral level reached by the fully extended thumb and scored according to ASES.

Isometric Muscle Strength

An isokinetic dynamometer system (Cybex Norm) was used for measurement of isometric muscle strength. The abductor isometric muscle strength was measured at 20 degrees and 90 degrees abduction. The ER muscle strength was also measured isometrically in the scapular plane. The measurements were done during 5-sec isometric contractions, and 20-sec intervals were given between contractions. The average of three trials was calculated. A standard verbal motivation was given for isometric contractions during tests.

Functional Assessment

The functional assessments were carried out using the Turkish Version of the WORC index[16] and the ASES evaluation.[15] The shoulder index of the ASES consists of a pain score and a section of self-assessed ADL. The total possible score for the entire index is 100 points.

The WORC has been developed to measure the quality-of-life of patients with rotator cuff disease. It is a self-assessment instrument that has 21 items representing the five domains (physical symptoms, sports and recreation, work, lifestyle, and emotions) that assess all aspects of health. A score of 0 implies no reduction in health related to quality-of-life, and a score of 2100 is the worst score possible.

All assessments were done at baseline and at 6 and 12 wks by a blinded researcher (BD).

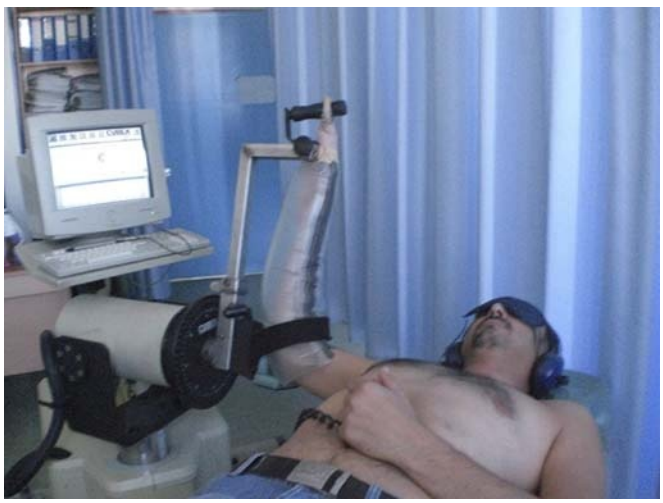

FIGURE 8 *Proprioception assessment. The patient positions for assessment of proprioception.*

Radiologic Assessment

The shoulder magnetic resonance images of the patients were reexamined by an experienced radiologist (MM) and the stages of the SIS were classified according to Zlatkin et al.[17] According to this classification, grade 1, tendinitis/tendinosis; grade 2, degeneration in the tendon morphology (partial tear); grade 3, a full-thickness tear.

Statistical Analysis

Statistical evaluation was performed using SPSS 15.0 (SPSS Inc, Chicago, IL). Data were analyzed using Shapiro-Wilk tests to establish whether there was a normative distribution. Normally distributed data were expressed as means and SDs. For data that were not normally distributed, the median was used as the measure of central tendency, with variability expressed as the interquartile range. Analysis of variance in repeated measures and the Bonferroni test for pairwise comparisons were used for normally distributed parameters (WORC index, isometric abduction muscle strength at 20 degrees, and isometric ER muscle strength at scapular plan). The Friedman test was used for non–normally distributed parameters (proprioception, pain, ROM, ASES, and isometric abduction muscle strength at 90 degrees). Groups were compared for differences using the Mann-Whitney *U* test, and within-group differences were analyzed using the Wilcoxon signed rank test for differences between baseline, 6 wks, and 12 wks. Comparisons of the measures were assessed with the Bonferroni correction in the Wilcoxon signed rank test, and the significance level was set at $P < 0.016$ for these measures. For all other measures, the significance level was accepted as $P < 0.05$. All analyses were carried out per protocol and also intention to treat. Per-protocol analysis was conducted to demonstrate the effects of the intervention on those who adhered to the treatment. In the intention-to-treat analysis, the last observation carried forward method was used, in which the last observation obtained from a patient was substituted for all subsequent observations that were either missing or obtained after the patient was no longer considered to be evaluable. In the post hoc power analysis, performed using sample sizes, means, and SD values for the significance level (α) of 0.05, the power was calculated using the statistical software PASS.

RESULTS

One hundred thirty-six patients met the inclusion criteria during their routine outpatient physical and radiologic examinations for SIS. After reviewing inclusion and exclusion criteria, 63 patients (42 women, 21 men) were included in the trial. These patients were randomly allocated into control ($n = 30$) or intervention ($n = 31$) groups. One patient in each group was lost during follow-up and 61 patients completed the study (see Supplemental Digital Content 2, http://links.lww.com/PHM/A129). No complications were observed in the groups during the study.

There were no significant differences between groups in terms of age, sex, occupation, education, trauma, magnetic resonance imaging stages, number of exercises carried out, analgesic drug intake, and exercise phases they reached ($P > 0.05$) (Table 1).

At baseline, there was no significant difference between the two groups in terms of active flexion, abduction, active and passive ER, pain during rest and movement, muscle strength, and functional tests ($P > 0.05$). However, in the intervention group, pain at night was significantly higher and passive flexion and internal rotation values were significantly lower than those of the control group at baseline.

Thirty-seven (60.7%) patients were affected in their right shoulders and 58 (95.1%) of them had

TABLE 1 Demographic and clinical characteristics of the groups

	Intervention Group ($n = 31$)	Control Group ($n = 30$)	*P*
Age, mean (SD), yrs	50.06 (10.83)	48.20 (9.74)	0.48
Sex (female/male)	23/8	19/11	0.41
Education level	15/16[a]	21/9[a]	0.44
Symptom duration, mean (SD), mos	16.96 (22.18)	17.10 (24.55)	0.98
Trauma (yes/no)	4/27	2/28	0.67
Stages of MRI (grade 1/2/3)	16/9/6	15/8/7	0.92
NSAID intake, mean (SD)	11.9 (7.24)	9.96 (7.34)	0.34
No. exercise, mean (SD)	138.19 (29.81)	137.86 (32.76)	0.96
Exercise phase (phase 2/3)	25/6	24/6	1.00

[a]Primary school and pre–primary school/post–primary school.

MRI, magnetic resonance imaging; NSAID, nonsteroidal anti-inflammatory drugs.

TABLE 2 Pain scores of groups

	Intervention Group (n = 31), Median (25%–75%)		Control Group (n = 30), Median (25%–75%)		*P*a/*P*-int
Pain at rest					
Beginning	5.00 (4.00–700)	*P*e < 0.001[a]	5.00 (4.00–6.77)	*P*e < 0.001[a]	0.54/0.61
6 wks	1.50 (0.00–2.50) *P*b[b]		0.00 (0.00–1.00) *P*b[b]		0.67/0.64
12 wks	0.00 (0.00–1.50) *P*c[b], *P*d[b]		0.00 (0.00–1.12) *P*c[b]		0.73/0.78
Pain at night					
Beginning	7.80 (6.40–10.00)	*P*e < 0.001[a]	5.00 (4.00–8.55)	*P*e < 0.001[a]	0.04[a]/0.05
6 wks	2.00 (0.00–5.00) *P*b[b]		1.00 (0.00–5.00) *P*b[b]		0.23/0.28
12 wks	0.50 (0.00–2.50) *P*c[b], *P*d[b]		0.25 (0.00–3.00) *P*c[b]		0.96/0.99
Pain during ADL					
Beginning	7.70 (6.50–10.00)	*P*e < 0.001[a]	6.75 (5.00–8.05)	*P*e < 0.001[a]	0.11/0.17
6 wks	2.50 (1.20–5.00) *P*b[b]		3.00 (0.37–6.00) *P*b[b]		0.76/0.65
12 wks	1.30 (0.00–4.00) *P*c[b], *P*d[b]		0.00 (0.00–2.00) *P*c[b], *P*d[b]		0.08/0.10

*P*a/*P*a-int, difference between groups (Mann-Whitney *U* test, [a]$P < 0.05$, significant value).
*P*b/*P*b-int, within-group difference between baseline and 6 wks (Wilcoxon test, [b]$P < 0.016$, significant value).
*P*c/*P*c-int, within-group difference between baseline and 12 wks (Wilcoxon test, [b]$P < 0.016$, significant value).
*P*d/*P*d-int, within-group difference between 6 wks and 12 wks (Wilcoxon test, [b]$P < 0.016$, significant value).
*P*e/*P*e-int, the differences of measurements within groups (Friedman test, [a]$P < 0.05$, significant value).
int, intention-to-treat analysis.

dominance of the right side. Therefore, the relationship between the dominance and the affected side could not be assessed.

In both groups, there were significant improvements in ROM, all pain scores, isometric muscle strength at all angles, kinesthetic sense at 0 degrees ER, and ASES and WORC index scores ($P < 0.05$) (Tables 2–8). At 0 degrees ER RPP, there was no significant improvement in either group ($P > 0.05$). In the control group, there was no significant difference in sense of kinesthesia at 10 degrees ER and RAP and RPP at 10 degrees ER. However, these parameters significantly improved in the intervention group ($P < 0.05$) (Tables 2–8).

When two groups were compared, no significant difference was found in any of the parameters at 12 wks ($P > 0.05$) (Tables 2–7). Also, no significant relation between group and time was found in the case of WORC, isometric ER, and 20 degrees abduction muscle strength changes from baseline to 12 wks according to analysis of variance test (Table 8).

The post hoc power analysis is performed using sample sizes, means, and SD values for the significance level (α) 0.05. The power was found below 50% for overall changes in the sense of kinesthesia, RAP, and RPP at 12 wks.

DISCUSSION

Proprioceptive mechanisms seem to play an important role in stabilizing the glenohumeral joint and may serve as a means for interplay between the static stabilizers and the dynamic muscle restraints.[18] Proprioceptive exercises are widely used in rehabilitation after lower extremity injuries and

TABLE 3 ASES scores in groups

ASES-100	Intervention Group (n = 31), Median (25%–75%)		Control Group (n = 30), Median (25%–75%)		*P*a/*P*a-int
Beginning	45.00 (27.75–53.00)	*P*e < 0.001[a]	52.50 (33.06–57.12)	*P*e < 0.001[a]	0.08/0.08
6 wks	77.50 (62.50–90.00) *P*b[b]		89.37 (74.06–96.56) *P*b[b]		0.02[a]/0.02[a]
12 wks	90.00 (78.75–97.50) *P*c[b], *P*d[b]		95.62 (87.81–100.00) *P*c[b], *P*d[b]		0.06/0.06

*P*a/*P*a-int, difference between groups (Mann-Whitney *U* test, [a]$P < 0.05$, significant value).
*P*b/*P*b-int, within-group difference between baseline and 6 wks (Wilcoxon test, [b]$P < 0.016$, significant value).
*P*c/*P*c-int, within-group difference between baseline and 12 wks (Wilcoxon test, [b]$P < 0.016$, significant value).
*P*d/*P*d-int, within-group difference between 6 wks and 12 wks (Wilcoxon test, [b]$P < 0.016$, significant value).
*P*e/*P*e-int, the differences of measurements within groups (Friedman test, [a]$P < 0.05$, significant value).
int, intention-to-treat analysis.

TABLE 4 Isometric muscle strength at 90 degrees abduction in groups

Isometric Muscle Strength	Intervention Group (n = 31), Median (25%–75%)		Control Group (n = 30), Median (25%–75%)		*Pa*/*Pa*-int
Beginning	3.00 (1.00–7.00)	*Pd* < 0.001[a]	5.00 (1.75–11.25)	*Pd* < 0.001[a]	0.48/0.55
6 wks	8.00 (5.00–15.00) *Pb*[b]		7.50 (4.00–14.75) *Pb*[b]		0.56/0.61
12 wks	12.00 (9.00–16.00) *Pc*[b]		13.00 (9.75–26.00) *Pc*[b]		0.59/0.68

Pa/*Pa*-int, difference between groups (Mann-Whitney *U* test, [a]$P < 0.05$, significant value).
Pb/*Pb*-int, within-group difference between baseline and 6 wks (Wilcoxon test, [b]$P < 0.016$, significant value).
Pc/*Pc*-int, within-group difference between baseline and 12 wks (Wilcoxon test, [b]$P < 0.016$, significant value).
Pd/*Pd*-int, the differences of measurements within groups (Friedman test, [a]$P < 0.05$, significant value).
int, intention-to-treat analysis.

there are many studies in the literature emphasizing their importance in both therapy and prevention.[19–24] Although they are suggested in the rehabilitation of upper extremity problems in everyday practice, research about this subject is limited.[13,25,26] This study is the first randomized controlled research in patients with SIS investigating the effectiveness of proprioceptive exercises on proprioception, clinical, and functional assessments.

The authors found a significant improvement in terms of pain, ROM, function, muscle strength, and proprioceptive assessment in both groups. In SIS, conservative therapy is the option preferred initially. In rehabilitation, the main goal is to relieve pain, regain ROM, restore normal shoulder mechanics, and obtain functional recovery.[27] Studies show that conservative treatment decreases pain and improves function.[28–30] The effectiveness of physiotherapy exercises in SIS was reported in a systematic review and meta-analysis.[28] In a multicenter prospective cohort study, nonoperative treatment using physical therapy program was found effective for treating atraumatic full thickness rotator cuff tears, in approximately 75% of patients followed for 2 yrs.[29] In another study, a specific, progressive exercise program focusing on training the rotator cuff and scapular stabilizers was found effective in improving function, decreasing pain, and reducing the need of surgery for patients with chronic SIS.[30] In the study conducted by Baydar et al.,[31] conservative treatment yielded significant improvements in pain, ROM, function, isokinetic strength, and quality-of-life in patients with full-thickness rotator cuff tears, observed for a period of 6 mos. In accordance with the literature, this study showed similar results. Significant improvements were found in ROM, pain, function, and muscle strength with conventional therapy group. When two groups were compared, although proprioceptive measurements improved better in the intervention group, there were no statistically significant differences in any of the parameters. The authors think that a proprioceptive exercise combined with a conventional physiotherapy program does not seem to have an additional positive effect on pain, ROM, muscle strength, and function. In a recent systematic

TABLE 5 Sense of kinesthesia in groups

	Intervention Group (n = 31), Median (25%–75%)		Control Group (n = 30), Median (25%–75%)		*Pa*/*Pa*-int
Kinesthesia ER 0					
Beginning	0.50 (0.00–1.25)	*Pd* = 0.002[a]	0.50 (0.00–1.31)	*Pd* < 0.001[a]	0.94/0.94
6 wks	0.25 (0.00–0.50) *Pb*[b]		0.00 (0.00–0.25) *Pb*[b]		0.12/0.13
12 wks	0.00 (0.00–0.25) *Pc*[b]		0.00 (0.00–0.25) *Pc*[b]		0.85/0.87
Kinesthesia ER 10					
Beginning	1.00 (0.75–1.50)	*Pd* < 0.001[a]	1.00 (0.25–1.56)	*Pd* = 0.10	0.30/0.33
6 wks	1.00 (0.25–1.25) *Pb*[b]		0.87 (0.43–1.00)		0.97/0.97
12 wks	0.50 (0.25–0.75) *Pc*[b]		0.50 (0.25–1.00) *Pc*[b]		0.63/0.65

Pa/*Pa*-int, difference between groups (Mann-Whitney *U* test, [a]$P < 0.05$, significant value).
Pb/*Pb*-int, within-group difference between baseline and 6 wks (Wilcoxon test, [b]$P < 0.016$, significant value).
Pc/*Pc*-int, within-group difference between baseline and 12 wks (Wilcoxon test, [b]$P < 0.016$, significant value).
Pd/*Pd*-int, the differences of measurements within groups (Friedman test, [a]$P < 0.05$, significant value).
int, intention-to-treat analysis.

TABLE 6 Sense of position in groups

	Intervention Group (n = 31), Median (25%–75%)		Control Group (n = 30), Median (25%–75%)		*Pa*/*P*-int
RAP ER 0					
Beginning	2.00 (1.25–2.75)	*P*d = 0.32	2.12 (1.68–2.81)	*P*d = 0.02[a]	0.24/0.25
6 wks	1.50 (15.33–22.66)		1.50 (1.18–2.25)		0.98/0.99
12 wks	1.50 (1.25–2.00)		2.00 (1.25–2.50)		0.20/0.21
RAP ER 10					
Beginning	2.75 (1.75–3.25)	*P*d < 0.001[a]	2.62 (2.00–3.00)	*P*d = 0.06	0.46/0.51
6 wks	1.75 (1.25–2.50) *P*b[b]		2.00 (1.00–2.25) *P*b[b]		0.64/0.65
12 wks	1.50 (1.25–2.25) *P*c[b]		2.00 (1.50–2.75)		0.20/0.21
RPP ER 0					
Beginning	2.75 (2.00–3.75)	*P*d = 0.05	2.50 (2.00–3.81)	*P*d = 0.11	0.65/0.65
6 wks	1.75 (1.50–3.00) *P*b[b]		2.12 (1.25–3.50) *P*b[b]		0.70/0.73
12 wks	2.50 (2.00–3.50)		2.45 (1.68–3.06)		0.36/0.38
RPP ER 10					
Beginning	2.25 (2.00–3.25)	*P*d = 0.01[a]	2.50 (1.68–3.62)	*P*d = 0.27	0.91/0.93
6 wks	1.75 (1.50–3.00) *P*b[b]		2.00 (1.25–2.81)		0.90/0.92
12 wks	2.00 (1.50–2.75)		2.00 (1.00–3.00)		0.72/0.73

Pa/*P*a-int, difference between groups (Mann-Whitney *U* test, [a]$P < 0.05$, significant value).
*P*b/*P*b-int, within-group difference between baseline and 6 wks (Wilcoxon test, [b]$P < 0.016$, significant value).
*P*c/*P*c-int, within-group difference between baseline and 12 wks (Wilcoxon test, [b]$P < 0.016$, significant value).
*P*d/*P*d-int, the differences of measurements within groups (Friedman test, [a]$P < 0.05$, significant value).
int, intention-to-treat analysis.

TABLE 7 ROM of groups

	Intervention Group (n = 31), Median (25%–75%)		Control Group (n = 30), Median (25%–75%)		*P*a
Flexion A					
Beginning	140 (130–160)	*P*e < 0.001[a]	155 (140–168)	*P*e < 0.001[a]	0.06/0.08
6 wks	170 (160–180) *P*b[b]		177 (160–180) *P*b[b]		0.69/0.72
12 wks	180 (165–180) *P*c[b], *P*d[b]		180 (170–180) *P*c[b]		0.35/0.40
Flexion P					
Beginning	160 (150–170)	*P*e < 0.001[a]	170 (160–180)	*P*e < 0.001[a]	0.02[a]/0.03[a]
6 wks	180 (170–180) *P*b[b]		180 (170–180) *P*b[b]		0.76/0.79
12 wks	180 (180–180) *P*c[b]		180 (180–180) *P*c[b]		0.61/0.64
Abduction					
Beginning	150 (140–165)	*P*e < 0.001[a]	160 (143–180)	*P*e < 0.001[a]	0.05/0.10
6 wks	180 (170–180) *P*b[b]		180 (165–180) *P*b[b]		0.87/0.90
12 wks	180 (170–180) *P*c[b]		180 (173–180) *P*c[b]		0.66/0.73
Internal rotation					
Beginning	12.50 (5.00–15.25)	*P*e <0.001[a]	15.00 (12.75–16.00)	*P*e = 0.01[a]	0.01[a]/0.02[a]
6 wks	14.50 (12.75–16.00) *P*b[b]		16.00 (13.00–17.00)		0.30/0.35
12 wks	15.50 (13.75–16.00) *P*c[b], *P*d[b]		16.00 (14.00–16.00)		0.49/0.53
ER A					
Beginning	80 (70–90)	*P*e < 0.001[a]	90 (80–90)	*P*e = 0.001[a]	0.20/0.25
6 wks	90 (90–90) *P*b[b]		90 (87.25–90) *P*b[b]		0.98/0.99
12 wks	90 (90–90) *P*c[b]		90 (90–90) *P*c[b]		0.98/0.98
ER P					
Beginning	70 (60–90)	*P*e < 0.001[a]	80 (70–90)	*P*e < 0.001[a]	0.17/0.19
6 wks	90 (80–90) *P*b[b]		90 (80–90) *P*b[b]		0.68/0.71
12 wks	90 (85–90) *P*c[b]		90 (88.75–90) *P*c[b]		0.64/0.65

Pa/*P*a-int: difference between groups (Mann-Whitney *U* test, [a]$P < 0.05$, significant value).
*P*b/*P*b-int, within-group difference between baseline and 6 wks (Wilcoxon test, [b]$P < 0.016$, significant value).
*P*c/*P*c-int, within-group difference between baseline and 12 wks (Wilcoxon test, [b]$P < 0.016$, significant value).
*P*d/*P*d-int, within-group difference between 6 wks and 12 wks (Wilcoxon test, [b]$P < 0.016$, significant value).
Pe/*Pe*-int, the differences of measurements within groups (Friedman test, [a]$P < 0.05$, significant value).
A, active; int, intention-to-treat analysis; P, passive.

TABLE 8 Analysis of variance results of WORC index, isometric muscle strength at 20 degrees abduction, and isometric muscle strength at ER in groups

	Intervention Group (n = 31), Mean (SD)	Control Group (n = 30), Mean (SD)	Source	P/P-int
WORC index				
Beginning	1334.90 (370.77)	1217.13 (394.49)	Group (G)	0.11/0.12
6 wks	745.00 (318.75)	655.43 (485.23)	Time (T)	<0.001[a]/<0.001
12 wks	597.22 (421.75)	390.20 (427.29)	Interaction (G × T)	0.47/049
Isometric muscle strength at 20 degrees abduction				
Beginning	19.64 (10.69)	20.76 (9.22)	Group (G)	0.25/0.27
6 wks	23.41 (11.02)	26.70 (12.47)	Time (T)	<0.001[a]/<0.001[a]
12 wks	26.41 (11.33)	31.26 (13.71)	Interaction (G × T)	0.20/0.21
Isometric muscle strength at ER				
Beginning	10.70 (3.95)	10.81 (3.95)	Group (G)	0.33/0.36
6 wks	13.64 (4.31)	13.10 (5.18)	Time (T)	<0.001[a]/<0.001
12 wks	13.74 (4.21)	14.56 (5.31)	Interaction (G × T)	0.87/0.89

[a]Significant P value < 0.05.

int, intention-to-treat analysis.

review about rehabilitation after anterior cruciate ligament reconstruction, neuromuscular interventions were found to provide small benefits, and the authors suggested that they should not be performed to the exclusion of strengthening and ROM exercises.[24]

Contrary to this study's findings, a recent randomized controlled study by Marzetti et al. suggested that neurocognitive rehabilitation using proprioceptive exercises was effective in reducing pain and improving function in patients with SIS. However, there are some methodological differences between their study and ours. Marzetti et al.[13] included only subjects with Neer stage I SIS without any tendon tears or subacromial bursitis. Also, their follow-up is longer and control patients did not receive any physical therapy.

Studies concerning shoulder instability and lower extremity injuries show that exercise improves proprioception with the restoration of neuromuscular control.[5,32,33] In this study, significant proprioceptive improvements were found in both groups. Although no proprioceptive exercises were given in this study's conventional therapy group, sense of kinesthesia (ER 0) and RAP (ER 0) were also improved. Similarly, in the literature, there are studies advocating the fact that conventional rehabilitation programs after subacromial decompression and instability surgery improve proprioception.[33–37] There may be reasons for proprioceptive improvement in the conventional therapy group. Safran et al.[38] demonstrated disturbed kinesthesia in throwers with rotator cuff tendinopathy and suggested that, increased nociceptor activity in the painful shoulder overrides proprioceptive input. Conventional therapy may be effective in improving sense of kinesthesia by reducing pain. On the other hand, strengthening rotator cuff and scapular stabilizing musculature with closed and opened kinetic chain exercises in conventional therapy may increase numbers of activated muscle spindles. Tensile loading of joint receptors with strengthening and stretching exercises may also result in increased mechanoreceptors input in the joint capsule and ligaments. Therefore, stimulation of both articular and muscular mechanoreceptors with these exercises may provide proprioceptive information and reflex joint stabilization.

A comparative study of conventional *vs.* proprioceptive exercises in SIS assessing proprioception has not been encountered. When two groups were compared, the results of this study showed that the group that had additional proprioceptive exercises experienced better improvements in kinesthesia, RAP, and RPP senses in comparison to the control group, although there were no significant differences between groups. Therefore, specific exercise programs for proprioception may be included into these programs.

The goals of proprioceptive rehabilitation are to facilitate and maximize sensory input that increases the sense of joint movement.[39,40] Studies have shown that specific exercise programs (static and dynamic stabilization exercises) play an important role in improving the proprioception in cases such as ankle instability and anterior cruciate ligament injuries, which involve a decrease in kinesthetic and joint position sense.[41–46] Conventional shoulder rehabilitation program after capsulolabral repair or instability improves proprioception. This conventional

shoulder rehabilitation program included ROM, strengthening, and also closed kinetic chain stabilization exercises. These exercises improved proprioception by increasing muscle strength and endurance.[33,34,47] These incorporate techniques that define the sense of the joint position and aim to increase the strength and endurance that will thereby increase the proprioceptive input. Also, open and closed kinetic chain exercises seem to be equally effective in improving shoulder joint reposition sense.[48] It is suggested that, in workouts with athletes, open kinetic chain exercises be used first to improve proprioception, and then exercises move from open to closed kinetic chain. Certain exercises have been defined within the frame of closed kinetic chain exercises: rhythmic stabilization, balance exercises with both hands on the floor, a wobble board, a trampoline, and finally pylometric exercises.[49,50] An exercise program using special equipment providing vibrations to increase the sensory-motor activity has been suggested for SIS.[4] This uncontrolled study with a special sensory-motoric exercise program (vibrations generated by machines called "body blade" and "BOING," tai chi, and aquatic exercises) for 4 wks, yielded only a slight improvement in the sense of kinesthesia.[5] In this study with the proprioceptive exercise program of static and dynamic stabilization, improvements were found not only in kinesthesia but also in the sense of repositioning.

Study Limitations

There is a lack of control group that did not receive treatment, but forming such a control group was not found to be ethically correct. Also, there is no direct comparison of proprioceptive exercises and conventional exercises. The authors added proprioceptive exercises to conservative therapy consisting of conventional exercises and physical therapy modalities as used in daily practice. Physical therapy helped patients with visible pain and limitation to comply in exercise programs. The authors assessed proprioception with an isokinetic dynamometer system, and the reliability of this procedure was shown in studies before. The authors did not study the reliability of the procedure, which also may be considered as another limitation of this study. There was no suitable comparable study in the literature to use in the calculation of the sample size at the time the authors conducted the study; hence, the authors could not calculate sample size at the beginning of this study. Although the power of this study was found below 50% for proprioceptive changes at 12 wks, the authors found significant changes in most of the proprioceptive assessments in the intervention group. Moreover, the follow-up is relatively short. Further studies with larger sample sizes would be better to investigate the effects of proprioceptive exercises in patients with SIS.

There are no standardized suggestions regarding the effectiveness, number, or frequency of proprioceptive exercises in the evidence-based data. Furthermore, there is not enough evidence on the effectiveness of the proprioceptive exercises in patients with rotator cuff problems. This study, being a single-blinded randomized controlled trial, is valuable in providing evidence in its field.

CONCLUSIONS

The efficacy of conservative treatment was apparent in both groups. Although proprioceptive exercises may provide better proprioceptive acuity, no additional positive effect on pain, ROM, muscle strength, and function was found.

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