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Effect of Neuromuscular Training on Shoulder Proprioception and Isometric Internal Rotators Muscle Strength in Patients with Shoulder Impingement Syndrome: A Double-Blinded Randomized Controlled Trial

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ABSTRACT

Background: The most common musculoskeletal condition affecting the upper extremities is shoulder impingement syndrome, it is a chronic painful shoulder condition produced by a reduction in the subacromial space. It has also been demonstrated that rotator cuff injuries result in lower shoulder proprioception. The most important characteristic of shoulder impingement syndrome is decrease in isometric strength of the shoulder muscles; it might be due to the subsequent deconditioning of the muscles or due to deficits in motor control of the muscles. neuromuscular training exercises encourage both afferent signals and cerebral mechanisms that maintain dynamic joint stability to facilitate unconscious motor responses.

Purpose: To investigate the effect of neuromuscular training on shoulder impingement syndrome in terms of shoulder proprioception and internal rotators muscle strength.

Methods: Through non-probability sampling, thirty four patients of both sexes were chosen. Their ages ranged from 25 to 45 and were diagnosed with shoulder impingement syndrome (Neer's stage II). They were assigned into one of two groups at random. Traditional strength training group (I). Upper extremity neuromuscular training exercises group (II). Patients were assessed before and after therapy (6 weeks) using an inclinometer to assess shoulder proprioception and a hand-held dynamometer to assess the isometric muscle strength of the shoulder internal rotators.

Results: In both groups, there was a significant improvement in shoulder proprioception and shoulder internal rotator muscle strength (P< 0.05). There was a significant difference between both groups regarding shoulder proprioception (P<0.05) while there was no significant difference between them regarding shoulder internal rotators muscle strength.

Conclusion: neuromuscular training was superior to traditional strength training in improving shoulder proprioception.

Key Words: *subacromial impingement syndrome; functional shoulder exercises; inclinometer; joint position sense; Hand held dynamometer; traditional shoulder strength training*

INTRODUCTION

One of the most frequently reported non-traumatic problems that originate from the arm, neck, and shoulder regions is shoulder pain (SP) (1), with significant prevalence rates in many different countries (2-5). Prevalence rates of SP in the general population are roughly 11% in Canada (2), 14% in the UK (3), 27% in the US (4), and 22% in Australia (North West Adelaide) (5). It is thought that SP is a significant symptom of shoulder impingement syndrome (SIS), a number of radiological and clinical abnormalities relating to tendinitis and bursitis of the rotator cuff (RC) and the surrounding tissues (1,6), reduced function, mobility and quality of life are usually related to SIS (7).

The history and physical examination are necessary for the diagnosis of SIS. People will experience pain when elevating their affected arm or sleeping on that side. They may report loss of motion or night time pain that keeps them awake. Weakness and stiffness can result from pain (8). Patients are sometimes unable to describe a direct trauma or triggering incident that causes the pain. SIS usually has a delayed or insidious onset and normally develops over weeks to months (9).

It has also been demonstrated that RC injuries lead to lower shoulder proprioception. Also, the effectiveness of treatment strategies has been evaluated using proprioception as a dependent variable (10). The majority of SIS treatments are conservative methods (11), including exercises intended to improve muscle function and range of motion (ROM) through regaining shoulder mobility, proprioception, and stability (12). Exercise regimens for the RC and scapular muscles, a variety of medicines, manual therapy approaches, modifications of the daily activities, and different physical therapy modalities are examples of the conservative methods (13).

Great evidence of the effectiveness of exercise therapy in pain management, function enhancement and improving ROM in patients suffering from sub-acromial pain. Exercise therapy is proved to be as effective as surgical procedures (14).

Several techniques of exercise methods have been successful in treating SIS. Traditional therapeutic exercises are frequently used in clinical practice and are effective in reducing pain, strengthening the RC and scapular stabilizing muscles, improving ROM and increasing muscle elasticity. Exercise therapy includes strengthening exercises with weights, stretching exercises for the anterior and posterior capsule, Codman pendulum exercises, and exercises against Thera Band resistance (15).

It has been demonstrated that exercises that target the neuromuscular deficiencies enhance shoulder functional stability. Exercises for scapular stabilizers, strengthening the muscles of the glenohumeral (GH) joint, and core strengthening are the first stage of rehabilitation and conditioning programs. To regain the neuromuscular control, those previous exercises must be followed by exercises that improve proprioceptive function (16). Reflexive neuromuscular control is enhanced by weight bearing on unstable surfaces like wobble boards, foam pads, or partially inflated balls. Moreover, the unstable platform results in abrupt, quick changes in position and different forces on the joint (17).

Age-related alterations in proprioception have been documented in numerous studies (18). Exercises of neuromuscular training consist of balance, coordination, proprioception, and strength and were integrated into several body positions to improve functional shoulder stability (19). According to previous research; neuromuscular training can be used as a prophylactic and therapeutic approach in knee and ankle injuries (20, 21). Yet, there is a dearth of literature on evaluating the effectiveness of neuromuscular training on shoulder function (22). Subsequently, the objective of our current study was to trace the effect of neuromuscular training on shoulder proprioception and internal rotator muscle strength.

METHODS

Study Design

Double-blinded randomized controlled trial (P.T.REC/012/003246), in which participants were randomly assigned to one of the two intervention groups, traditional strength training group (I) or neuromuscular training group (II) using an online random generator (www.graphpad.com). All participants and the outcome assessors were blinded to treatment assignment. Joint position sense was assessed using a digital inclinometer and shoulder internal rotator muscle strength was assessed using a hand-held dynamometer (HHD).

Eligibility Criteria

Participants were eligible for inclusion in our study, if they were aged from 25 and 40 years old, were willing to participate in the intervention, had a clinical diagnosis of SIS (Neer's stage II) (23), had SP for at least three months, had a painful arc of movement during flexion or abduction, positive Neer's or Kennedy-Hawkins Test (24), pain during resisted external rotation and abduction (25). Participants were excluded if they had prior history of cervical radiculopathy symptoms, neurological disorders, inflammatory disorders, widespread pain condition, complete RC tear and any previous surgery to the affected shoulder. All participants were referred by orthopedic surgeons who were responsible for the diagnosis of SIS. Evaluation and treatment were accomplished at a physical therapy clinic after the approval of the Institutional Review Board of Cairo University’s Faculty of Physical Therapy

Participants

34 participants (men and women) were included in the study; 4 participants were excluded because they did not fit the requirements of the inclusion criteria, and 2 participants declined to participate, as shown in the flow chart (Figure 1). The cases were allocated to one of the two groups: Group 1 (n=17): (5 men, 12 women) with a mean age of 32.88 ± 5.349 received traditional strength training program. Group II (n=17): (6 men, 11 women) with a mean age of 31.24 ± 5.985 received neuromuscular training exercises (Table 1).

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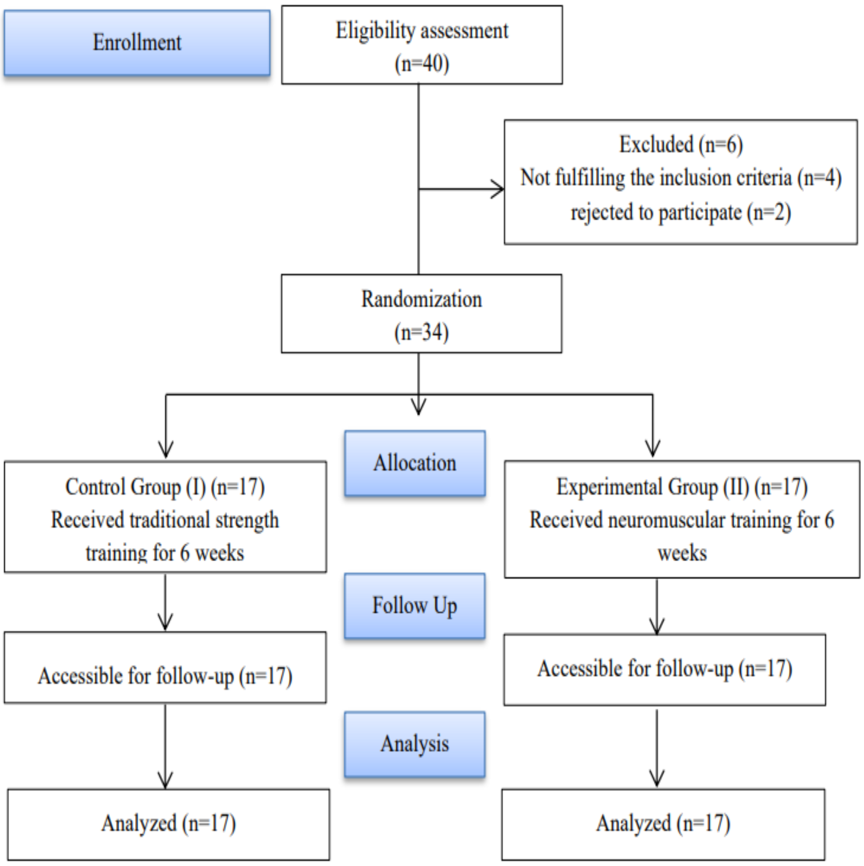

FIGURE 1: Flow chart of study participants.

Instrumentation

1- Inclinometer to assess shoulder proprioception.

2-lafayette HHD to measure muscle strength.

3- A universal scale was used for weight measurement and a measuring tape to assess height.

4-Resistant bands and weights.

Procedures for assessment

A-Shoulder joint proprioception

A digital inclinometer was used to evaluate joint position sense (JPS) of shoulder flexion at 30° and 90°, the device was firmly attached to the subject‘s arm using straps. The patient wore an eyes mask to eliminate any visual cues and at the target angle, the therapist told the patient to concentrate on that position of the arm. Then the therapist returned the arm to the starting point, and the patient was instructed to return it back to the target angle (active replacement). When he/she had the feeling that the right position is achieved, the investigator recorded the angle on the inclinometer. The protocol was the same for the two different target angles. The entire test was repeated three times by the same assessor, with five minutes of interval time. The error score (obtained by the average of the three trials) was measured as the difference between the target angle (30° and 90°) and the observed angle (26).

B-Internal rotators muscle strength assessment

Lafayette HHD was used to evaluate internal rotators muscle strength in prone position while shoulder in 90° abduction and 0° rotation while elbow positioned in 90° flexion and the therapist asked the patient to perform internal rotation. The tester stabilized the humerus distally. The therapist put the HHD just adjacent to the ulnar styloid process on the anterior surface of the forearm to assess internal rotation strength (27). A small tape was used during assessment to improve the stabilization of HHD during the test and prevent it from being affected by the relative strengths of the assessor and the participant.

Treatment procedure

Group I (control group)

Traditional strength training group consisted of seventeen patients. The exercise program consisted of seven exercises (28) and required 35–45 minutes of exercising per session, three times per week for six weeks. Each exercise was completed in three sets, with each set having ten repetitions. Exercises were progressed by using heavier weights and more sets of repetitions. The program included shoulder retraction, posterior capsule stretch, shoulder scaption, internal rotation of the shoulder, external rotation of the shoulder while lying on the side, protraction and extension of the shoulder.

Group II (Experimental group)

neuromuscular training group consisted of seventeen participants. The program consisted of three sessions per week for six weeks, with all exercises being done unilaterally on the affected side. Each exercise was performed for 1 set of 10 repetitions with light resistance bands the first week, and then repetitions increased during the 2nd and 3rd week. During the final three weeks of the training period, exercises were advanced using heavier resistance bands (light, medium, heavy, and very heavy), if the quality of motion control was perfected without experiencing noticeable discomfort or exhaustion and the exercise was no longer a challenge while performing each exercise three sets of ten repetitions.

Neuromuscular training exercises were in the form of bilateral scapular retraction with shoulder external rotation in the neutral position using resistance band loops (29) , External rotation and internal rotation with elastic band (30) Eccentric exercise for the external rotators (31), Dynamic hug exercise (30), Blackburn exercises (32) which consists of six exercises; Prone horizontal abduction (neutral and full external rotation) during the 1st and 2nd weeks, Prone horizontal scaption (neutral and full external rotation) during the 3rd and 4th weeks, Prone horizontal external rotation and prone horizontal extension during the 5th and 6th weeks, Closed chain exercise (33), Scapular-clock exercise (34).

Statistical methods

Data were statistically described in terms of mean ± standard deviation (± SD), median and range, or frequencies (number of cases) and percentages when appropriate. Numerical data were tested for the normal assumption using Kolmogorov Smirnov test. Comparison of numerical variables between the study groups was done using Student t test for independent samples. Within group comparison of numerical variables was done using paired t test. For comparing gender, Chi-square ($\chi 2$) test was performed. Two-sided p values less than 0.05 was considered statistically significant. IBM SPSS (Statistical Package for the Social Science; IBM Corp, Armonk, NY, USA) release 22 for Microsoft Windows was used for all statistical analyses.

RESULTS

General Characteristics

Participants in both groups (traditional strength training and neuromuscular training) did not differ in their demographics, table (1) summarizes the demographics of patients in the two groups. The Mean± standard deviation (SD) of the age height and body mass index (BMI) for the two groups are shown at baseline, there was no significant difference between groups (P> 0.05).

TABLE 1: Participants' demographics including age, sex, and BMI values for both tested groups at baseline (n=34)

Items	Group 1	Group 2	Comparison	S
	Mean±SD	Mean±SD	P-value	
Age	32.88 ± 5.349	31.24 ± 5.985	0.404	NS
BMI	26.37 ± 1.942	25.87 ± 2.742	0.545	NS
Sex distribution				
	GROUP A	GROUP B	P-value	
Female	11(64.7%)	12(70.6%)	0.714	NS
Male	6(35.3%)	5(29.4%)		

*SD: standard deviation, P: probability, S: significance, NS: non-significant.

1) Shoulder proprioception (Absolute angular error of shoulder flexion at 30°, 90°) between-group differences

Student t test for independent samples revealed that the mean of the pretest absolute angular error values at 30° ,90° shoulder flexion between both groups showed no significant differences with (p= 0.594) , (p= 0.730) respectively. on the other hand, student t test for independent samples revealed that there was significant difference of the mean values of the "post" test between both groups with (p<0.05) as shown in table (2) and figures (2,3) .

TABLE 2: Absolute angular error of shoulder flexion at 30°, 90° between-group differences Mean±SD and P values

JPS shoulder flexion 30°	**Pre test**	**Post-test**
	Mean±SD	**Mean±SD**
Group 1	10.35±2.092	8.481±1.8858
Group 2	10.71±1.779	6.203±1.2700
P-value	0.594	<0.05
JPS shoulder flexion 90°	Mean±SD	Mean±SD
Group 1	8.118±1.7303	6.70±1.527
Group 2	7.906±1.8164	4.96±0.931
P- value	0.730	<0.05

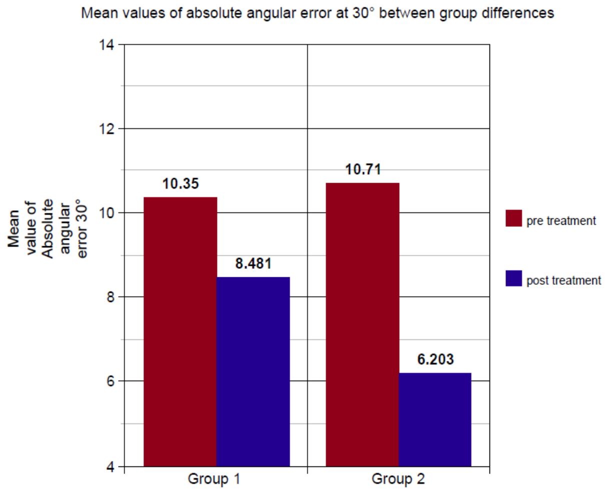

FIGURE 2: Mean values of absolute angular error of shoulder flexion at 30° between-group differences

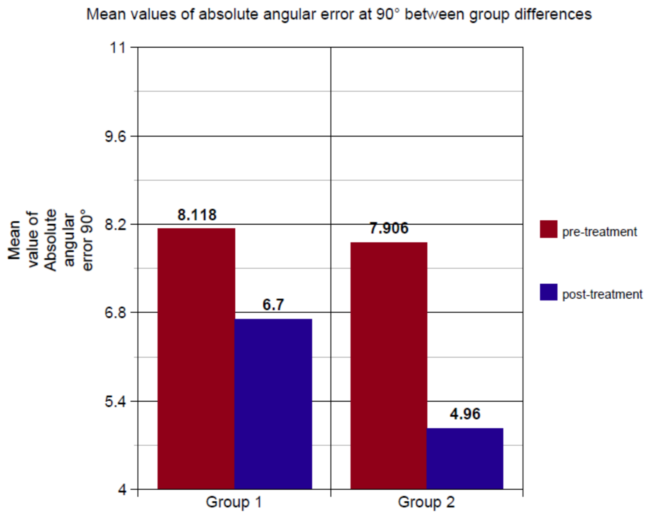

FIGURE 3: Mean values of absolute angular error of shoulder flexion at 90° between-group differences

2) Muscle strength assessment of shoulder internal rotators between-group differences

Student t test for independent samples revealed that the mean of the pretest HHD between both groups showed non significant differences neither pre test (p= 0.642) nor post test (p= 0.456) as shown in table (3) and figure (4).

TABLE 3: HHD for internal rotators pre and post-treatment between-group differences Mean±SD and P values.

HHD IR	Pre test Mean±SD	Post test Mean±SD
Group 1	0.467±0.1949	0.519±0.2155
Group 2	0.433±0.2231	0.588±0.3088
p-value	0.642	0.456

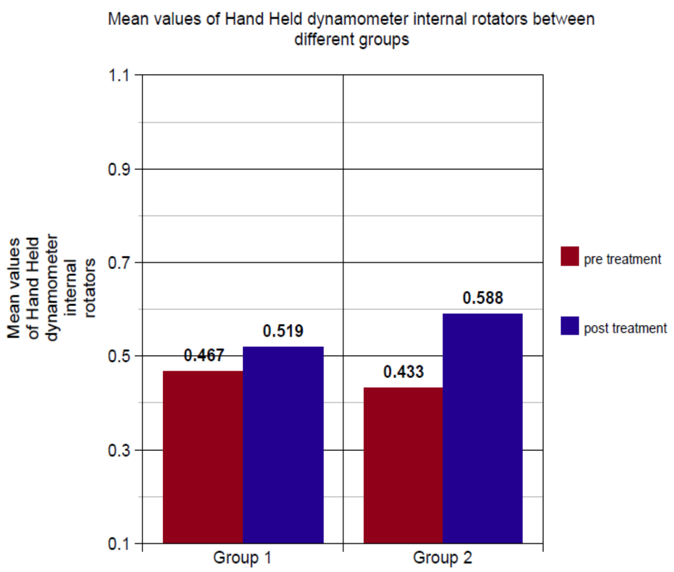

FIGURE 4: Mean values of HHD internal rotators between-group differences

DISCUSSION

This study was designed to detect the effect of neuromuscular training on shoulder proprioception, and internal rotator muscle strength in patients with SIS.

Neuromuscular training program is known to stimulate both afferent signals and central mechanisms by training enhancing unconscious motor responses so this type of training is responsible for the dynamic joint stability (35).

This study included thirty four participants of both sexes with SIS (Neer's stage II) who were diagnosed by orthopedic surgeons and referred to physical therapy treatment.

All patients underwent evaluations before and after therapy. JPS was evaluated using a digital inclinometer and internal rotator muscle strength was evaluated using HHD. Then, participants underwent a six-week program of traditional strength training (group I) and a six-week program of neuromuscular training exercise (group II).

The difference between the effects of traditional strength training program and neuromuscular training exercises on shoulder joint position sense:

The JPS of the shoulder markedly improved in both groups post treatment ($P<0.05$) compared to pre-treatment. There was a significant difference between the traditional training group and the neuromuscular training group; participants in the traditional training group had the least improvement. These findings confirmed the superior role of neuromuscular training exercises on JPS in SIS.

Many researchers have studied the shoulder proprioceptive impairment in patients suffering from SIS as in a study by Sahin et al., (36) in which they investigated shoulder proprioception in patients with SIS. Their main outcome measure was proprioception which was assessed by an isokinetic dynamometer. They found out significant impairment in kinesthesia, passive and active shoulder JPS in affected shoulders at all angles ($P < 0.05$).

No studies have previously compared traditional strength training to neuromuscular training exercises in patients with SIS; however, some studies have investigated the impact of particular exercises (Black Burn, Closed Chain and Scapular Clock exercises) on shoulder proprioception. Those exercises were a part of the neuromuscular training program in our study.

In a study conducted by Baskurt et al. (37) on patients with SIS, whose ages ranged from 24-71, the authors compared the effects of stretching and strengthening exercises (group I) and scapular stabilization exercises (SSE) (group II) on pain intensity, shoulder range of motion (ROM), muscle strength, JPS, scapular dyskinesis, and quality of life. Their findings demonstrated that all measurements improved statistically in both groups after treatment ($p < 0.05$). Moreover the improvements in the muscle strength, JPS and scapular dyskinesia were significantly different in group II ($p < 0.05$).

In the treatment of SIS, SSE which is provided along with stretching and strengthening exercises may be more beneficial in improving muscular strength, enhancing the JPS, and reducing scapular dyskinesis (37).

Black burn exercises and scapular clock exercises are considered to be SSE, as those exercises are included in the neuromuscular training program so this may be the cause of the agreement between the results of the previous study and those results of our study and could be the reason of the superior role of neuromuscular training exercises on shoulder proprioception in the form of JPS.

Poor scapular stabilization can lead to kinetic chain dysfunction, which can lead to shoulder injuries and SIS. SSE as scapular-clock exercise facilitates the movement of the scapula to move in all four directions (elevation, depression, protraction and retraction) and improves shoulder joint kinesthesia and ROM (34).

In another experimental investigation by Thakur (38) who compared the effects of forward head posture (FHP) correction to the effects of shoulder stabilization exercises on scapular dyskinesia and shoulder proprioception in 40 athletes (18-30 years). They concluded that shoulder stabilization exercises were just as successful as FHP correction at correcting scapular dyskinesia and shoulder proprioception, but shoulder stabilization exercises showed slightly better improvement than FHP correction group in reducing proprioceptive errors.

The results of this investigation corroborated our findings, demonstrating the efficacy of SSE in influencing shoulder proprioception.

The effects of an 8-week strength-training program on shoulder JPS which were evaluated by Salles et al. (39) in a randomized controlled clinical trial (RCT), they examined whether using training intensities that are the same or divergent for the shoulder's dynamic-stabilizer muscles promote different effects on JPS. ninety right-handed men who had no history of injuries or shoulder instability participated in the trial. They performed two sets of each of the four exercises (bench press, pull down, shoulder press, and seated row). Their main outcome measure was shoulder JPS acuity by calculating the absolute error. They concluded that strength training using exercises at the same intensity produced an improvement in JPS compared with exercises of varying intensity.

The neuromuscular training group in our study comprised a series of exercises that were applied in a slow, controlled manner with the same intensity in each group of treatment sessions. This is how the prior study is similar to our study. The sensitivity of muscle spindles could be improved with exercises carried out with the same intensity and in a slow, controlled way, leading to enhanced neuromuscular control in the shoulder (39).

Saadatian et al., (40) conducted a RCT on 33 overhead athletes who were randomly classified into three groups: open kinetic chain (OKC), sling, and control groups. JPS was evaluated in external rotation (ER), internal rotation (IR), and abduction of the dominant arm in the target angle concerning the shoulder ROM with the Leighton flexometer. The study resulted in significant difference between groups, indicating that the sling exercises were more effective because they are close kinetic chain (CKC) and performed on an unstable level.

The similarity between the previous study and our study as the neuromuscular training exercises in the current study included CKC exercises which were performed on stable and unstable surface which may lead to the superior role of this program on shoulder JPS. It has been reported that the axial load which presents during CKC exercises could simulate biomechanical situations that promote muscle co-activation and leads to significant increasing of the proprioceptive stimulation, compared with OKC exercises.

Shiravi et al. (41) evaluated 132 patients who had secondary SIS. All participants were subjected to the JPS examination at 30, 60, 90, 120, and 150 degrees of shoulder forward flexion. 45 patients in study group 1 used SSE, while 45 patients in the control group received no treatment at all. During six weeks, the SSEs were carried out for 30 minutes each day (three sessions per week). After six weeks, group 1 had significantly lower levels of pain ($p = 0.021$) and proprioception ($p = 0.033$). In the control group, there were no significant changes in proprioception or pain.

Proprioception is necessary for joint stability, motor control, and athletic performance. Recent research has shown that athletes have better proprioception when compared to inactive participants of the same age, demonstrating that physical activity may have an impact on proprioception (39).

The difference between the effects of traditional strength training programs and neuromuscular training exercises on shoulder isometric internal rotators muscle strength.

In physical therapy rehabilitation; strengthening the shoulder muscles is a main goal. This study compared the efficacy of neuromuscular training exercises with traditional strength training programs in terms of shoulder internal rotation muscle strength utilizing HHD. The results of our study showed a significant improvement in the mean values post treatment of HHD assessment in both groups. However, there was no significant difference between the two groups in terms of the tested dependent variable. The significant improvement in isometric strength in both groups is in line with other research findings which involved therapeutic exercises as:

In a randomized controlled trial (RCT) by Chaconas et al. (42) compared the results for participants with subacromial pain syndrome who underwent a 6-week treatment of eccentric training of the shoulder external rotators (ETER) to a general exercise (GE) protocol. The results demonstrated a non-significant difference in the ETER group but a statistically significant improvement in the mean values of IR muscle strength in the GE group post-treatment compared to the corresponding mean values pre-treatment.

Short-term neurological alterations may have contributed to the observed gain in muscle strength after only three weeks e.g., rate coding and motor unit recruitment. After prolonged exposure to training, mostly after eight weeks, increases in muscle cross-sectional size and hypertrophy are frequently connected with improvements in strength (43). Improvements in tendon stiffness that have been shown to occur after 14 weeks of training can also be linked to long-term improvement of muscle strength (44).According to the results of the previous study, we could attribute the statistically marked increase in the isometric internal rotators muscle strength in our study to the short-term neurological changes.

Shahpar et al. (45) conducted a study to compare the effects of eight weeks of OKC and CKC exercises on muscle torque of the IR of the shoulder in elite swimmers. Prior to the training, the peak torque of the IR of the shoulder was measured by the isokinetic HUMAC NORM machine at various speeds of 60, 120, and 180 degrees/s. The study findings demonstrated that shoulder internal rotator muscle torque at 60, 120, and 180 degrees per second was improved after eight weeks of training with OKC and CKC (P 0.05). The effect of OKC was greater than that of the CKC exercises, and there was a significant difference between the two groups.

Moghadam et al. (46) investigated the impact of shoulder core exercises on the isometric torque of GH joint movements in healthy young females. For six weeks, subjects in the experimental group performed press-ups and shoulder core exercises using progressive resistance training (scaption with humeral internal rotation, flexion, horizontal abduction with external rotation, and press-up). The participants in the control group did not exercise. The Dynatorq device was used to evaluate the isometric torque of shoulder movements in isolated test locations of GH muscles. The maximal isometric torques of shoulder internal rotation increased as a result of shoulder core exercise training (p=0.001), and these findings support the significant increase in shoulder internal rotation torque found in our current study.

After a few sessions (around four weeks) of strength training with vigorous voluntary contractions, the contractile apparatus undergoes only minimal alterations that contribute to an increase in muscle strength (47). In fact, over this time frame, the muscle's twitching characteristics in response to peripheral nerve stimulation remain constant (48). Hence, it is anticipated that brain adaptations account for a large portion of the increase in muscle force (49).

CONCLUSION

Neuromuscular training was more effective than traditional strength training at enhancing shoulder proprioception.

RECOMMENDATIONS

Further researches are recommended with follow-ups and longer treatment periods.

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