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Effect of Motor Control and Strengthening Exercises on Pain, Function, Strength and the Range of Motion of Patients with Shoulder Impingement Syndrome

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Abstract. [Purpose] The aim of the study was to evaluate the effect of an intervention, including shoulder control and strengthening exercises, on the shoulder function of persons with shoulder impingement. [Subjects] The subjects were patients who visited our hospital due to shoulder impingement syndrome and they were randomly allocated to two groups: a shoulder control and strengthening exercises group (n=17) and a conservative therapy group (n=18). [Methods] Both groups received conservative therapy for 3 sessions (45 minutes per week) for 4 weeks. The shoulder control and strengthening exercises group practiced additional motor control and strengthening exercises for 30 minutes. Values of the pain, function, isokinetic strength and the range of motion were compared with those of the conservative therapy group. [Results] There were significant differences in the amount of change of the pain, function, isokinetic strength and range of motion between the two groups ($p<0.05$); however as a measure of isokinetic strength, the peak torque of the internal rotators at 60°/sec did not show a significant difference. [Conclusion] The motor control and strengthening exercise program training improved pain, function, strength and the range of motion. These results suggest that a motor control and strengthening exercise program is feasible and suitable for individuals with shoulder impingement syndrome.
Key words: Motor control, Shoulder impingement syndrome, Strengthening exercise

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INTRODUCTION

The shoulder joint has the most extensive range of motion (ROM) among the joints in the human body and it is easy to damage due to subluxation, dislocation and ligament tear[1,2]. Shoulder impingement syndrome (SIS) is a disease of the shoulder joint and its incidence is 44–65% of all the cases of shoulder disease. The term SIS was introduced by Neer (1972) and it is also called supraspinatus syndrome and painful arc syndrome[3]. In many cases, this disease shows a chronic prognosis and pain and impairment due to functional restriction.

The causes of SIS are an irregular shape of the acromion, rotator cuff weakness, muscle imbalance around the shoulder, kinematic dysfunction between the glenohumeral and scapulothoracic joints, an insufficient blood supply, degenerative change and trauma[1,4]. Shoulder pain is exacerbated by lifting the arm, especially in forward bending like flexion, and the decreased ability to control the muscles due to inappropriate movement between the glenohumeral and scapulothoracic joints, muscle weakness, hypotonia and abnormal myotonus may lead to instability of the shoulder joint and a decrease of the subacromial space[5–9].

According to previous studies of SIS intervention, the effects of nonsurgical methods such as administering pharmacotherapeutic drugs to the subacromial bursa (local anesthetics, steroid or NSAIDs), using a brace, ultrasound, electrical stimulation, stretching, strengthening exercise and manual therapy has been verified[2,10–12].

A recent notable intervention is an exercise program that emphasizes appropriate movement aiming to strengthen the muscle power of the shoulder joint. Intervention methods based on exercise control theory have been prescribed for musculoskeletal patients. According to this theory, abnormal movement by damage or disease reorganizes the cerebral cortex, finally leading to changes in the brain[7,13] and the altered brain is reorganized by performing the correct exercise strategy[14,15]. Based on this, normal movement can be achieved without inflammation and pain of the subacromial tissue[16,17]. Roy et al. (2009) reported that intervention based on motor control theory for SIS patients changed the quality of the activity of the shoulder

Table 1. Subject characteristics

Group (N=35)	Sex (male/female)	Side of Injury (R/L)	Age (years)	Height (cm)	Weight (kg)
Experimental (N=17)	6/11	11/6	49.9 ± 5.5	161.7 ± 7.7	59.1 ± 8.6
Control (N=18)	6/12	14/4	48.3 ± 4.3	162.0 ± 7.6	62.7 ± 8.5

NOTE. Values are frequency or mean ± SD.

bones and muscles and it improved the abnormal movement and instability of the glenohumeral and scapulothoracic motion and the sternoclavicular joint[18]. From the kinetical aspect, this result showed an improved ability to control movement and the importance of exercise control as an intervention for SIS patients.

Although many studies have reported the effectiveness of exercise programs in treatment of SIS as a nonsurgical intervention, research on the combination of motor control and muscle strengthening exercise is currently insufficient. Roy et al. (2009) reported that a combination of motor control and muscle strengthening exercise decreased pain and improved function[19]. However, this research had a single-subject design and the author noted the need for a control group in a further study.

Thus, the aims of this study were to investigate the effects of a combination of motor control and muscle strengthening exercise on pain, function, strength and range of motion of SIS patients and to develop a more effective intervention method. Moreover, this study provides basic research material for further study of motor control and rehabilitation of SIS patients

SUBJECTS AND METHODS

The subjects of this study were thirty-five patients who had at least one positive finding in any of the following categories[9,19]: a painful arc of movement during flexion or abduction, positive Neer or Kennedy-Hawkins impingement signs, or pain on resisted lateral rotation, abduction or the Jobe test. The exclusion criteria were a type III acromion, calcification or fracture, shoulder instability, previous shoulder surgery and cervicobrachialgia or shoulder pain during neck movement. All the subjects signed an informed consent form (Table 1).

The thirty-five participants were randomly assigned to two groups: the experimental and control groups. The control group underwent conservative physical therapy for 45 min per day, three times a week for 4 weeks. The experimental group underwent the motor control and strengthening exercise for additional 30 min. after performing conservative physical therapy for 45 min per day, three times a week for 4 weeks.

The motor control and strengthening exercises were similar to those of previous studies. First, exercise was performed to adjust motor control, strengthening exercises were carried out becaused the loss of normal mobility causes pain and dysfunction, and strength training must be perform in the full range of motion without pain and contracture. This exercise was also performed to emphasize motor control to promote proper function of the muscle-tendon-bone unit in movement of the shoulder.

Motor control training was performed to increase the mobility of the scapular against gravity during arm elevation. Shoulder control progressed following 6-phase retraining exercises to control arm elevation in the frontal, sagittal and scapular planes. The exercise intensity was adjusted for the movement pattern and the pain in the shoulder joint. Movement training was performed under the supervision of a physiotherapist who gave feedback aimed at correcting the shoulder girdle movement[19]. The retraining phases were graded according to: the level of resistance applied to the shoulder during arm elevation (no resistance/passive movement, active assisted, active with or without external resistance); and the use of feedback during the movement. The phases ranged from no resistance with feedback to active movement with external resistance without feedback. During each retraining phase, the ROM was gradually increased as shoulder control improved until proper control was achieved for the full ROM in each vertical plane. When the subject was able to perform a series of 10 repetitions with proper control, exercise series were added to reach three. The subject then moved up to the next phase. Once abduction over a range of 90 degrees was properly controlled, humeral lateral rotation at 90 degrees of abduction was performed (Tables 2, 3). The strengthening exercise was performed to increase the muscle strength around the scapulothoracic and scapulohumeral joints. The strengthening exercises included; external rotation and internal rotation, scaption, chair press, push-up plus, press-

Table 2. Manual feedback was given according to scapular dyskinesis

Types of dyskinesis	Manual feedback
Decrease of the scapula lateral rotation	Guidance of lateral rotation with lateral pressure placed on the inferior angle of the scapula
Tilt of the scapula inferior angle	Restriction of the tilt with anterior pressure placed on the inferior angle of the scapula
Elevation of the superior border of the Scapula	Restriction of the scapular elevation with inferior pressure placed on the acromion
Tilt of the medial scapula border	Restriction of the tilt with anterior pressure placed on the medial border of the scapula

Table 3. Phase for retraining the shoulder control according to scapular dyskinesis

Phases	Steps for retraining the shoulder control			
	1	2	3	4
1[a]	Passive elevation	Final position actively kept for 5 sec	Active return with manual feedback if needed	Verbal feedback
2[a]	Active assisted elevation	Final position actively kept for 5 sec	Active return with manual feedback if needed	Verbal feedback
3[a]	Active elevation with manual feedback if needed	Final position actively kept for 5 sec	Active return with manual feedback if needed	Verbal feedback
4[a]	Phase 3, but without manual feedback			
5	Phase 4, but without visual feedback			
6	Phase 5, but with the elevation performed faster, and then with a load			

[a] In front of a mirror (visual feedback)

Table 4. Muscle strengthening exercise

Exercise	Description
External rotation & Internal rotation	Secure the elastic band at the waist level. Hold the elbow at 90° with the arm at the side. Pull the hand away (external rotation) from the body. Pull the hand across (internal rotation) the body.
Scaption	Hold the arm 30° forward, thumb up or down, and raise the arm. May add resistance. This exercise should be done only if there is no pain.
Chair press	While seated, press up on the chair to lift the body off the chair. Try to keep the spine straight
Push-up plus	Do a push-up (either on your hands or forearms) and then really push to bring your spine to the ceiling.
Press-up	Lie on the back, elbows locked straight, weights in hands. Move your arm up toward the ceiling as far as possible.
Rows	Seated or standing, bend your elbows and pull the elastic cord back. Try to pinch your shoulder blades behind you.
Upright row	Do one arm at a time. While standing, lean over a table and bend at the waist. Pull the hand weight back with pulling the shoulder blade back.
Low trapezius	Stand upright. Grasp the elastic bands. Keep your elbows straight and pull. Try to reach behind you.

up, rows, upright rows, and low trapezius exercise. Each exercise was performed as 3 sets of 10 repetitions20[20] (Table 4). The intensity of the exercises was assessed according to the movement plane, the range of motion, the repetitions, the velocity and the resistance. A 10-min rest period was provided between the motor control and the strengthening exercise. All exercises were performed pain free[19–20]. Before the exercise, the physical therapist educated the subjects about the exercise programs using illustrations. Conservative physical therapy consisted of applied hot packs (20 min.), transcutaneous electrical nerve stimulation (20 min) and ultrasound (5 min).

The outcome measurements included the shoulder pain and disability index and the active ROM between baseline and after 4 weeks of intervention. The Shoulder Pain and Disability Index (SPADI) is a valid and reliable self-administered questionnaire[21]. The SPADI is a self-report questionnaire developed to measure the pain and disability associated with shoulder pathology. The SPADI consists of 13 items in two subscales: pain (5 items) and disability (8 items); originally the items were presented in a visual analog format[19]. Isokinetic assessment of external rotation and internal rotation in the shoulder joint was performed using an isokinetic dynamometer (Cybex 770, USA). Concentric isokinetic evaluations were performed at two speeds: 60°/sec and 180°/sec. The maximal peak torque of the 5 repetitions was used for analysis. To ensure familiarity before the evaluation, 3 submaximal repetitions were performed at each speed. A 5-min rest period was provided between each test[22]. The shoulder range of motion was assessed using a goniometer during active shoulder movement without pain[23,24]. The range of motion included flexion, extension, abduction, adduction, external rotation and internal rotation of the shoulder joint.

The analysis of data was performed using SPSS version 12.0. The paired t test was used to compare the pain, function, strength and range of motion in the same group between the pre and post intervention tests. Independent t tests were used to test for differences between the experimental and control groups. The significance level was chosen as 0.05.

RESULTS

After completion of 4 weeks intervention, the SPADI was significantly decreased compared with before intervention ($p<0.05$) in both groups. There was significant difference between the experimental group and control group at post-intervention ($p<0.05$). The strength had increased significantly at post intervention in the maximal peak torque of the muscles at all angular velocities ($p<0.05$) in the experimental group. However, in the control group, none of

Table 5. Comparison of SPADI within groups and between groups

Measures	Values				Change Values	
	Experimental group (n=17)		Control group (n=18)		Experimental (n=17)	Control (n=18)
	Pretest	Posttest	Pretest	Posttest	Post-Pre	Post-Pre
SPADI(point)	54.6 ± 11.8	20.7 ± 4.1***	50.9 ± 10.7	32.1 ± 6.0***	33.9 ± 10.8***	18.6 ± 6.7

NOTE. Values are mean ± SD. Abbreviation: SPADI: Shoulder pain and disability index. *p<0.05, **p<0.01, ***p<0.001 by paired t-test and independent t-test.

Table 6. Comparison of strength within groups and between groups

Measures	Values				Change Values	
	Experimental group(n=17)		Control group(n=18)		Experimental(n=17)	Control(n=18)
	Pretest	Posttest	Pretest	Posttest	Post-Pre	Post-Pre
ERPT60°/sec(Nm)	14.7 ± 5.3	21.1 ± 5.4***	13.2 ± 5.0	14.5 ± 4.6**	6.4 ± 2.0***	1.3 ± 1.8
ERPT 180°/sec(Nm)	14.7 ± 5.5	65.2 ± 6.6***	12.8 ± 5.2	68.4 ± 7.3	39.4 ± 8.8***	35.2 ± 5.6
IRPT 60°/sec(Nm)	23.9 ± 4.8	24.7 ± 4.5*	22.6 ± 5.7	22.8 ± 5.7	0.8 ± 1.3	0.2 ± 1.2
IRPT 180°/sec(Nm)	24.2 ± 6.8	26.1 ± 6.3***	21.7 ± 7.5	21.9 ± 7.5	1.9 ± 1.1***	0.2 ± 0.4

NOTE. Values are mean ± SD. Abbreviation: ERPT: Peak torque of external rotator, IRPT: Peak torque of internal rotator. *p<0.05, **p<0.01, ***p<0.001 by paired t-test and independent t-test.

Table 7. Comparison of range of motion within groups and between groups

Measures	Values				Change Values	
	Experimental group (n=17)		Control group (n=18)		Experimental(n=17)	Control(n=18)
	Pretest	Posttest	Pretest	Posttest	Post-Pre	Post-Pre
Flexion(angle)	130.3 ± 18.5	155.6 ± 8.4***	136.3 ± 8.4	146.2 ± 10.9**	25.3 ± 13.8***	10.0 ± 8.1
Extension(angle)	34.6 ± 5.8	40.2 ± 4.8***	35.2 ± 5.6	36.2 ± 5.8	5.7 ± 3.1***	1.0 ± 2.0
Abduction(angle)	97.0 ± 10.5	129.1 ± 19.7***	100.1 ± 10.5	106.6 ± 10.4**	32.1 ± 16.9***	6.4 ± 8.5
ER(angle)	65.2 ± 6.6	76.5 ± 4.5***	68.4 ± 7.3	70.1 ± 6.3***	11.2 ± 7.4***	1.6 ± 1.4
IR(angle)	39.4 ± 8.8	47.0 ± 8.5***	43.1 ± 8.7	43.7 ± 7.7	7.5 ± 4.5***	0.6 ± 2.0

NOTE. Values are mean ± SD. Abbreviation: ER: External Rotation, IR: Internal Rotation. *p<0.05, **p<0.01, ***p<0.001 by paired t-test and independent t-test.

the maximal peak torques showed any significant differences except the peak torque of the external rotators at the angular velocity of 60°/sec. There were significant differences between the groups in all the outcome measures for the all areas, except the peak torque of the internal rotators at 60°/sec. In the range of motion, the experimental group showed a significant increase, post-intervention, over the pre-intervention value ($p<0.05$), and in the control group, there was significant improvement in the range of motion of flexion, abduction and external rotation. There were significant differences between the groups for all the ranges of motion (Tables 5,6,7).

DISCUSSION

The dynamic stability of the glenohumeral joint is required for muscle activation at the appropriate time and balanced control of the shoulder muscles. Roy et al. (2009) reported that motor control training that gives feedback can change the exercise strategy and improve movement control from a kinematic point of view, and their results showed the effects of motor control training conducted for patients with shoulder impingement syndrome[19].

Our present study showed a decrease in pain and a positive effect on function recovery represented by the SPADI decrease in the experimental group, and there were statistically significant differences between the experimental group and the control group in the SPADI. Several previous studies conducted single exercise programs and they reported that pain and function were improved in both the exercise and the control groups, with no significant differences between the groups[28,29]. However, Senbursa et al. (2007) reported that a group following a manual therapy with exercise program and an exercise only program resulted in decreases in pain and improvement of function[1], but as statistically significant improvements were found only in the manual therapy with exercise program group, as was noted in the present study. These results suggest that strengthening exercise with intervention aiming to achieve proper motion is more useful for increasing joint mobility, decreasing pain and improving the functional ability than strengthening exercise alone[1,23].

Isokinetic equipment can accurately measure the muscle strength that occurs at constant angular velocity and a range of motion, and the peak torque is a very important index for estimating the maximum motor ability of muscles[27]. Our present study measured the peak torque of the external rotators and internal rotators at an angular velocities of 60°/sec and 180°/sec using an isokinetic muscle tester. The functional stability of the shoulder joint requires an appropriate couple force from the rotator cuff muscles and accurate timing of the muscle activation[6]. The cocontraction of muscles and the degree of activation of each muscle with appropriate movement are important factors for the coordination of muscles. Very tiny changes of shoulder muscle movement can have a effect on the direction of movement and the power of the scapluohumeral joint[25,28], and the vector of power in other shoulder muscles can show the presence of instability of the scapluohumeral joint[26,29]. Torque is also influenced by the coordination of muscles, and coordination depends on the muscle capacity, which causes torque[30]. In general, the external rotators and internal rotators have a 2: 3 strength ratio, and it's very important to maintain this power balance for coupled activation of normal muscles and stability of the scapluohumeral joint, but in the case of a patient with shoulder impingement syndrome, the balance of power can be lost or the strength of the external rotators can become weak, causing an imbalance of muscle coordination during rotation of the shoulder[8,30,31]. Roy et al. (2009) conducted motor control and strengthening training for 4 weeks for 8 patients who suffered from shoulder impingement syndrome[19]. The patietns' pain was significantly reduced, and 3 patients showed an increase in isometric peak torque of the abductors, and 4 patients showed an increase in isometric peak torque of the external rotators, but without statistical significance. The patients of Roy et al. underwent motor control training for 4 weeks, and the period of the strengthening exercise was short because the strengthening exercise was only carried out after good performance in motor control was achieved, so it was unlikely that a significant difference in muscle power would have been found. We conducted a progressive resistance exercise program for 60 shoulder impingement syndrome patients, twice a week for 8 weeks in order to assess pain relief, strengthen, function and improvements in the quality of life. At the angular velocity of 60°/sec for isokinetic action, the peak torque of the external rotators increased 1 Nm from 11.00 Nm to 12.00 Nm, the peak torque of the internal rotators increased 4.23 Nm from 24.70 Nm to 28.93 Nm, the total work of the external rotators increased 4.64 J from 12.73 J to 17.37 J, and the total work of the internal rotators increased 4.23 J from 24.70 J to 28.93 J[22]. Muclure et al. (2004) reported that increasing isometric strength was a consequence of applying strengthening exercise for 6 weeks[32]. However, they also reported that motor control and strengthening exercises after the establishment of a proper exercise strategy are needed to prevent recurrence of pain and to improve function rather than using mediation, and our present study focused on increasing the strength of shoulder impingement syndrome patients. The results of the present study show that the peak torque of the external rotators and internal rotators significantly increased after intervention, and they were also significantly increased compared to those of the control group. However, there was a difference in the mediation period between this study and the previous two studies cited. Our results show that motor control training, which gives feedback about the shoulder joint, made the patients recognize their motion making the proper shoulder joint movement possible and decreasing the imbalance of the muscles. Therefore, we obtained significant results eventhough this study was performed for a shorter period than previous studies.

When a patient with shoulder impingement syndrome elevates his/her arms forward, the pain becomes severe, causing inconvenience in daily life because of the limitation of motion. Also, if it continues for a long period, then shoulder impingement can progress to frozen shoulder, so the recovery of range of motion is very important[8,33,34]. A study by Senbursa et al. (2007) showed that range of motion was significantly increased when a group that received a manual therapy and strengthening program incorporating flexion, external rotation and abduction, but the range of motion was not significantly increased when another group received only the strengthening program[1]. In this study, the range of motion of flexion, extension, internal rotation, external rotation and abduction for the experimental group was significantly increased compared with that of the control group. This means that motor control and strengthening training helps the proper movement strategy[14,15] and the recovery of range of motion[7,16,19] by controlling inappropriate motion so patients can elevate their arms without any pain.

We found that motor control and strengthening exercises for patients with shoulder impingement syndrome were effective at improving pain, function, strength and the range of motion. Therefore, the results of this study suggest an effective training method for improving pain, function, strength and the range of motion of shoulder impingement syndrome patients, and also provide basic data for future studies on the rehabilitation of such patients.

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