Original Article

The effect of stabilization and conscious control training on clavicular kinematic in females with scapular dyskinesis

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Abstract

Background & Aims: Previous studies showed that alteration in scapular kinematic may cause changes in clavicle and shoulder and finally lead to disorders in the upper quarter. To expand treatment options for patients with forwarding head and shoulder posture, this study investigated the effects of scapular stabilization and conscious control training on clavicle selected kinematic variables in

Materials & Methods: in this semi-experimental study, forty-four female subjects with scapula dyskinesis (inferior angle & medial border pattern) were randomly assigned to 3 groups: stabilization (n=15), conscious control (n=15) and control (n=14). All the subjects were tested (i.e., a pre-test and a post-test) for investigating the degree of disorder in the clavicular kinematic (using motion analysis system). Then, the subjects in scapular stabilization and conscious control were trained three days a week for six weeks (45 minutes for each session). The paired *t*-test and analysis of covariance were used for statistical analysis.

Result: There were significant within-group changes in angle of clavicle (90 degrees) in the conscious group (p=0.028) but no significant differences were observed in stabilization and control groups. There were significant differences between conscious and stabilization study groups, but only conscious group demonstrated significant differences when compared to the control and stabilization groups. No significant changes were observed for other degrees (p>0.05).

Conclusion: The findings of the present study supports the effectiveness of conscious exercise-therapy in improving clavicular kinematic. Based on the data average changes in pre-test and post-test of both groups, it can be claimed that conscious control and stabilization protocol training improves the orientation and motion of the clavicle in patients with scapular dyskinesis. The use of scapular conscious control and stabilization training along with other exercise-therapy protocols of shoulder complex is suggested for improving scapular and clavicular kinematic in patients with scapular dyskinesis.

Keywords: dyskinesis; clavicle; kinematic; exercise-therapy

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Introduction

The movement of the shoulder is the result of the coordination movements among humerus, scapula, clavicle and four joints in this region. These four joints include the glenohumeral joint, sternoclavicular joint (SC), acromioclavicular joint (AC), and scapulothoracic

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(ST) joint. ST joint is a functional joint. This joint is not between two bones, but rather between the bone and the muscles(1). The dysfunction in the 3-d motion of the rotation of clavicle on thorax has been linked with various shoulder pathologies including tendonitis, impingement, rotator cuff tears, and glenohumeral inferior instability(2). The clavicle rotation is the result of the simultaneous motion of the AC joint and the SC joint(3). The scapula motion is attributed to the clavicular motion in the AC joint which joins two bones of the scapula and clavicular. SC joint on which the clavicle rotation is done joins the clavicle and thorax(2).

Inman et al. (1994), were the first to measure the clavicular motion and its position in the normal function of the shoulder(4). Their study revealed that the clavicle in the SC joint is elevated in shoulder flexion and abduction. Previous researchers reported that during scapula elevation, the clavicle is elevated and retracted in SC joint. The role of the scapula has remained unspecified in previous studies; however, it is supposed to reduce the need to raise the shoulder joint and external rotation, and also to elevate the anterior lateral angle of the acromion(5). Upward Scapula rotation elevates the lateral acromion, while its posterior tilting elevates the anterior acromion. Therefore the appropriate cooperation between scapula and clavicle along with the movement of shoulder joint can reduce the sub-acromial pressure. The change in the shoulder kinematic is due to the disorder in the muscles around the shoulder and the trunk kinematic chain in the upper limb. Different studies have shown that clavicular discontinuity causes a change in the shoulder girdle kinematics which decreases the external rotation, upward rotation and posterior tilting of the scapula. The decreased scapular rotation could increase the motion demand on the glenohumeral joint and increase subacromial pressure, possibly resulting in secondary impingement(6, 7). Different factors may contribute to the development of impingement syndrome. These factors include abnormal acromial morphology, aberrant kinematic pattern due to poor rotator cuff or scapular muscle function, capsular abnormalities, aging, vascular causes, alteration in mechanical features and the structure of tendon, poor posture and overuse secondary to repetitive eccentric loading or sustained use of the arm above 90 degrees of elevation, and also researchers reported that impingement syndrome changes the scapula kinematic(8, 9).

The alteration in scapula kinematic is called scapula dyskinesis. Multiple causes of scapular dyskinesis include bony abnormalities, ligamentous injury, neurologic injury, muscle weakness or fatigue. Malposition or abnormal scapular motion leads to increased patient pain and disability in conducting daily activities(10). Scapular dyskinesis leads to impingement syndrome, shoulder instability, and neck pain (11). Shield et al. (2015) stated that females in dominant extremitywere more prone to dyskinesis(12). Fractures of the clavicle may also be the cause of scapular kinematics. Various studies have shown alterations in scapular position, shoulder motion, and strength with varying degrees of clavicle shortening(13). Chronic neck pain will develop in 30% of cases with neck pain and 14% will have chronic neck pain for more than 6 months(14). Female sex and prior history of neck pain are the strongest and most consistent risk factors for new-onset of neck pain(15).

Abnormal scapular motions and positions relative to the thorax lead to different shoulder pathologies such as tendonitis, impingement, rotator cuff tears, and glenohumeral inferior instability. Impingement, scapular winging, decreased upward rotation, posterior tilting, and increased internal rotation are observed in subjects with shoulder tendonitis(16). The upward scapular rotation is decreased in subjects with glenohumeral inferior instability. Since scapular motion results in motion at the SC joint and/or AC joint, abnormal scapular motions could be related to the abnormal motion at one or both of these joints(16). Because of the ligamentous and capsular attachments of the scapula to the clavicle and clavicle to the thorax, ST motion demands SC or AC joint motion, or some combination of motion at both joints(4).

Worsley et al., (2013) concluded that 64% of subjects with shoulder instability and 100% of subjects with impingement manifest traces of abnormal scapular motion(17). Different intervention strategies for the improvement of impingement syndrome are dependent on the mechanism this syndrome(18). Additionally, improvement or correction of abnormal scapular mechanics can decrease the symptoms associated with shoulder pathology (e.g., full-thickness rotator cuff tears).

Treatment of impingement syndrome with exercise was effective in decreasing shoulder pain, but not for all patients with this syndrome. Since, the exercise program does not sufficiently load the rotator cuff to promote remodeling of the tendon and muscle. The exercise program relied on eccentric loading of the rotator cuff during shoulder external rotation exercises and it was effective in reducing shoulder pain. Scapular plane elevation (scaption) exercises are often used to strengthen the supraspinatus in rehabilitation. Scaption exercises are conducted with external and internal rotation of the shoulder both of which lead to increased activity of the supraspinatus(19).

There exist various therapies for scapular disorders, including manipulation, electrotherapy, mobilization of scapula, mobilization of cervical and thoracic vertebra, and surgery. Exercise-therapy is another treatment method for scapula disorders; however, the effect of these exercises on clavicle has not been measured yet.

Scapula stabilization training program is used to gain the stability and strength of peripheral scapula muscles with the purpose of maintaining the proper scapula status, reducing the associated pain and disorder symptoms. These trainings frequently are prescribed as one of the main components in rehabilitation programs for different kinds of shoulder pain syndromes. Scapular conscious control and stabilization training can be considered as the mostly used trainings in musculoskeletal disorders. This training can also helps to the improvement of proprioception, scapula rest position, and the progress of trapezius activity. Scapular conscious control is based on a central concept that neck, shoulder and scapular postural muscles are organized to act in concert with each other as “muscle chains and also educational feedback” located anterior and posterior to the scapula. It has been hypothesized that specific clinical presentations are caused by “muscle chain retractions” associated with scapular and shoulder pain. Scapular conscious control aims to stretch and elongate these muscles, which are in a shortened state, by using prolonged active postures and by enhancing contraction of the antagonist muscles to promote ideal muscle balance, and postural feedback restoration and symmetry (19, 20). Previous studies have investigated the effect of the scapula conscious control on scapula kinematic and its relationship with the muscle activity and their findingsrevealed the effectiveness of these interventions(20, 21).

Conscious control

Although different researches have investigated the effect of these trainings under different conditions such as impingement syndrome, and scapula dyskinesis; the studies on the effect of these trainings on the clavicle of the individuals with scapular dyskinesis is limited, and also the kinematic of the clavicle has been so far measured statically or by the use of indirect techniques. Despite the anatomic connection of the scapula and the clavicle, few studies have been conducted on the kinematic of these two bones(2). Exact training program for abnormal scapular kinematics would not be possible without the ability to measure clavicular kinematic(4).

In contrary to the resistance and stabilization exercises that help correct the postural abnormality and pain of scapula dyskinesis by increasing muscle strength of the shoulder girdle muscles and improving the shoulder girdle alignment, feedbacks or conscious exercises can also be effective in resolving the problems of these individuals. They can improve the alignment of the trunk and subsequently improve the clavicular kinematic and alignment. Considering the positive effect of stabilization and conscious exercises on individuals with scapula dyskinesis, we would like to know whether these exercises can resolve problems associated with disruption through correction of alignment and reduction of impaired kinematics in individuals with scapula dyskinesis. We also try to know which exercise can be more effective. Therefore, the aim of this study was to compare the effect of scapular stabilization and conscious exercises on the clavicle selected kinematic variables in patients with scapular dyskinesis.

Methodology

This study has the code of ethics No.IR.umsu.rec.1395.589 dated 1395.12.11 from Urmia University of Medical Sciences.. Each subject signed the informed consent and completed the health history questionnaire; we then reviewed the questionnaire for inclusion and exclusion criteria.

A quasi-experimental design was used to quantify and compare the effect of scapular stabilization and conscious control exercises on the clavicle selected kinematic during shoulder scaption of individuals with scapular dyskinesis.

The sample size in this study consisted of 45 females with scapula dyskinesis who had the required feature to be included in the sample (inferior angle and medial border prominence). Considering the purpose of the study, females were randomly assigned to three group:control group (n=15; mean of 26.00±1.7 years, height of 165.7±4.13 cm, and the mass of 55.1± 3.34 kg), conscious control group (n=15; mean age of 26.20± 2.03 years, height of 168.4±4.2 cm and the mass of 56.8 ±2.78 kg) and stabilization group (n=15; mean age of 25.80 ±1.47 years, height of 163±4.04 cm, and mass of 53.4±3.82 kg).

Randomization and allocation

Our study was an interventional study so blinding the participants and caregiver was not possible. However, we followed especial strategies to reduce bias: 1.as it was the first time that these stabilization and conscious exercises were used in these fixed protocols, and we were going to see whether they are effective or not, so participants and the caregiver were informed that there was no evidence to estimate the superiority of any of these interventions over the other. In other words, subjects were blinded to interventions, 2.Setting and time spent with patient and motivation of therapists, treatment and assessment protocols were controlled carefully, 3. Subjects of two groups did not interact with each other, 4.Those who did randomization, and also the statistician and the researcher who analyzed data were blinded to intervention and also group allocation. For randomization, we asked an independent individual to allocate a number to each eligible participant. Then, numbers were given to the person who did randomization. Using a simple, computer-based randomization strategy, numbers (one to 45) were randomly divided into three groups. To conduct concealed allocation, the numbers were then written on three papers and each paper was put in a black envelope. Then, the statements" stabilization intervention, conscious intervention and no intervention" were written on three different papers and were put in three white envelopes. Then, another person was asked to randomly put one black and one white opaque sealed envelope to another envelope. These three envelopes were then given to the person who allocated numbers. He called the participants and informed them about their interventions. The size of each group was: stabilization group (n=15), conscious group (n=15) and no intervention group (control group) (n=15).

With regard to the purpose of the study and previous literature, the minimum size of the present sample was estimated to be 12 using the following formula and taking into account the 95% confidence interval, the of 90% test power, the average and 3 standard deviations. It is worth mentioning that because of the sample drop and for more certainty, 15 participants were included in each group.

$$n = \frac{(Z^2_{1-\frac{\alpha}{2}} + Z_{1-\beta})^2 \sigma^2_\delta}{\delta^2} + \frac{Z^2_{1-\frac{\alpha}{2}}}{2}$$

The questionnaire which was filled out through the interview with the subjects had the background information and medical records of them. The subjects with the required criteria for inclusionsigned the letter of satisfaction after getting informed of the method of the research.

Inclusion criteria: The active females with the age range of 25-30 and with the body mass index (BMI) of 20-25. Other requirements for inclusion were having one of the four categories of the Kibler`s Classification of Scapular Dyskinesis. This classification includes inferior angle prominence, medial border prominence, excessive and early elevation of the scapula during elevation(10).

Exclusion criteria: Having any history of surgery, or prior upper limp joint fracture, suffering from any postural malalignment affecting the research process, participating in any exercise therapy and rehabilitation programs in the last six months, subjects with diabetes, osteoporosis, rheumatoid arthritis, and cancer in shoulder girdle, rotator cuff tear, and surgery for shoulder stabilization and inability in flexion and 150 ° of abduction, not participating in two consecutive sessions, three non-consecutive sessions and also disinclination of the subjects to continue the research. The subjects having the above-mentioned criteria were excluded from the research(13). In the post-test, one subject dropped out from the study due to unavailable time during the post-test period.

Clavicle kinematic measurement in shoulder scaption: In order to determine the position and 3-D orientation of scapula in pre-test and post-test, six cameras with motion analysis system (MXT 40s) and Vicon Nexus software were used, and standard inclinometer was used to measure the shoulder scaption range of motion. For conducting the experiment, the cameras were located during the preliminary study, and the location of cameras was not changed until the end of data collection. The instrument was calibrated at the beginning of each day, and the subject was investigated by standing before the coordinate reference system (between 6 Vicon cameras). Before kinematic measurement, the determined markers were defined based on the International Society of Biomechanics standard protocol. The land marking procedure in this study was based on the joint coordinate system (JCS), and 9-millimeter markers were used to connect to the scapula, clavicle, thorax, and the dominant humerus anatomical landmarks. In this study, 17 markers were used to connect to the medial epicondyle, lateral epicondyle, four-marker humerus cluster, three-marker AC joint cluster, SC joint, xiphoid process, jugular notch, scapula inferior angle, acromion angle, scapula trigonum spine, seventh cervical spine process vertebra and eighth thoracic spine process vertebra(22).

Since the only suggested solution in the recent and related literature for the 3-D kinematic dynamics of the scapula and clavicle with motion analysis system was making acromion cluster marker, it was designed based on the standards of the Vicon by the researchers. Then, inclinometer was used to determine the shoulder elevation angles. At the next stage, the intended shoulder was elevated in scapula plate actively by the subject herself, and at the end, each of 30, 60, 90, 120 degrees was examined. The subject completed these procedures in the scapula plate, and in order to prevent fatigue, a 5-minutes break was considered (23, 24).

The frequency of recording of motion analysis system was 100 hertz which enjoys a high recording rate based on the similar studies and allows recording of dynamic movements of the shoulder complex(1). The kinematic data from the Vicon motion analyzer, acromion and humerus marker cluster were recorded and then were put on prepared MATLAB program which was established according to the International Society of Biomechanics protocol, and used to define the anatomical coordinate systems. The Euler-Carden angles of the rotational matrices of the humerus, clavicle, and scapula with respect to the thorax were then calculated and after formulating the local coordinate system (LCS) in humerus, scapula, and clavicle segments, 3-D rotational matrices (the rotation of one LCS relative to other LCS) were made. In fact, this 3-D rotational matrix is obtained by the succession of the rotation of three coordinate axes. In this research, the succession of the Euler XYZ was used(25). After conducting the pre-test, the subjects were classified into three groups of conscious control, stabilization, and control group, and two experimental groups participated in two training protocols. The purpose of the designed protocols was to strengthen the inhibited muscles in the scapula. The training protocol was 18 sessions, and the experimental groups performed the exercises for six weeks (three sessions in a week, and every week for 30 to 45 minutes) under the supervision of the researchers. In this study, six different exercises which were a combination of stretching, strength and conscious control exercises were prescribed for two experimental groups. These exercises were prescribed to strengthen the scapular stabilizing muscles.

Conscious control exercises intervention: The participants began to perform the movements, which required achieving a neutral position of the scapula. Auditory, verbal, and kinesthetic feedbacks concerning the subjects` resting positions and the chosen exercise-specific position with different participant-specific loads helped them achieve the neutral scapular position. "Retract the scapula" was one of the main instructions given to the participants in order to correct poor posture and excessive scapular internal rotation, and also a supplemental instruction " widen the chest" was also given to them to help them achieve a neutral scapular position. Participants continued the posture exercise till satisfactory correction was achieved. When the participants could hold the corrected scapular position for 5 seconds without assistance, they performed the 3 chosen exercises (arm scaption, side-lying external rotation), resting for three minutes before the next exercise (20).

Scapular stabilization exercise intervention: These exercises included stretching and scapular stabilization exercises. The stretching exercises included 3 sets of different repetitions of the trapezius stretching, rhomboids stretching and posterior neck stretching. The participants maintained each position for 20 seconds. The scapular stabilization exercises were performed by using an elastic band and consisted of 3 sets of 10 repetitions of the overhead press, chest press, and horizontal pull-apart resisted retraction plus external rotation and resisted shoulder extension. All of the participants performed three sessions of the exercise per week for 6 weeks. To choose the optimal resistance level appropriate for each participant, one day before the intervention period, the participants were asked to perform 5 repetitions of each scapular stabilization exercises with different levels of resistance(21).

Finally, after six weeks the subjects were invited to the laboratory to conduct post-test, and the scapula kinematic was examined using a motion analysis system.

Statistical analyses: Descriptive statistics were used to describe data. The normal distribution of data was measured by Shapiro-Wilk test. For analyzing the intergroup changes of experimental groups paired sample *t*-test was used, and also the analysis of covariance was used in order to investigate intra-group changes, and Bonferroni post hoc test was used to compare the average of the groups. The analysis of the data was done using SPSS software (version 22, IBM Corporation, Armonak, NY) with the *p*-value of $p \leq 0.05$.

Results

After completing the training protocol, a significant difference was not observed in intragroup differences at 30°,60°, and 120° angles of clavicular kinematic in conscious control a stabilization group, but for the conscious control group at 90° angle, there was a significant difference in pre-test and post-test of this group.

Table 1.Means (SD), pre-test and post-test of the clavicle angles during scaption

Group (number)	movement	Angle (deg.)	Average (deg.) (SD) Pre-test	Post-test	Paired sample t-test Intra-group differences
Conscious control (n=15)	Elevation	30	9.59±4.41	11.46±5.69	0.446
		60	10.87±5.09	13.71±6.55	0.342
		90	13.83±5.53	17.70±4.47	0.028*
		120	20.58±5.09	23.45±7.12	0.338
	Retraction	30	7.35±24.84	6.25±27.58	0.480
		60	8.17±25.33	6.89±28.50	0.417
		90	8.25±27.22	8.35±30.88	0.479
		120	34.30±7.24	36.74±7.29	0.556
Stabilization (n=15)	Elevation	30	5.39±10.44	6.45±11.14	0.449
		60	6.45±10.69	8.11±12.67	0.548
		90	5.24±13.43	7.06±16.32	0.473
		120	6.76±19.96	6.33±21.16	0.842
	Retraction	30	7.20±23.74	5.47±26.46	0.570
		60	8.27±25.77	5.34±27.47	0.998
		90	7.79±26.72	7.34±30.07	0.121
		120	7.25±35.68	6.85±36.75	0.512
Control (n=14)	Elevation	30	3.73±9.36	4.85±9.36	0.997
		60	8.21±10.60	7.14±10.47	0.959

Group (number)	movement	Angle (deg.)	Average (deg.) (SD) Pre-test	Post-test	Paired sample t-test Intra-group differences
		90	5.62±13.36	6.32±13.70	0.901
		120	4.66±20.93	5.59±21.53	0.754
	Retraction	30	6.85±23.83	5.83±23.60	0.929
		60	7.08±25.26	6.25±25.75	0.895
		90	8.37±26.82	7.41±27.39	0.837
		120	6.72±33.08	7.33±32.97	0.910

* Significant differences ($p \leq 0.05$).

As shown in the Table 1, there were no significant differences in the control group from pretest to post-test.

The results of the covariance of the variables (Table 2) revealed that there was not a significant difference between the rate of angular alterations of 3-D kinematic of the clavicle in the stabilization and conscious control groups, and also showed that both training methods applied in this study have changed the 3-D kinematic angle of the clavicle to the same extent.

Table 2.The comparison of the three groups` post-test

Movement	Angle (deg.)	Analysis of covariance (ANCOVA) P	F
Elevation	30	0.648	0.442
	60	0.590	0.539
	90	0.348	1.104
	120	0.672	0.404
Retraction	30	0.279	1.346
	60	0.500	0.713
	90	0.451	0.824
	120	0.230	1.563

Discussion

The purpose of this study was to compare the effect of the conscious control and stabilization training on the clavicle kinematic of the females with scapula dyskinesis. The findings of the study showed that the conscious control and stabilization exercises both had a role in correcting clavicle kinematic; however, no significant differences were observed in the clavicle kinematic of the control group.

Considering the exercise therapy interventions on the clavicle kinematic of subjects with scapula dyskinesis, to the best of researchers' knowledge the present study is one of the rare studies conducted in this area. A few studies have conducted on the normal clavicle kinematic, and this is due to the subtle motion of this bone. There is a close interrelationship between the clavicle and shoulder joint. Fung et al. (2001), also report the same patterns when tracking 3-D clavicular motion during passive humeral elevation in a cadaver model. During elevation of the arm, the clavicle generally undergoes slight elevation, slight retraction, and posterior long-axis rotation(26). Teece et al. (2008), explored the couplings of SC and AC joint rotations and the contribution of each joint rotation to ST rotations. They concluded that SC and AC joint rotations contribute in a complementary manner to ST upward rotation. Clavicle retraction at the SC joint contributes to ST external rotation but the external rotation motion produced by clavicle retraction is partially offset by AC joint internal rotation(2). In another study conducted by Paula, it was releveled that the clavicular is elevated approximately 2° and 8° at 25° and 110° of humeral elevation in the scapular plane, and 4°and 11° in flexion. In another study, Mcculre et al. (2001) reported approximately 19° and 28° for scapular plane abduction and 17°and 25°for flexion at the 25°and 110° humeral elevation angles, respectively(16, 27). Any change in the anatomy and kinesiology of the clavicle influences the movement of scapula to a great degree(7).

No study has been conducted on the effect of the abnormal scapula kinematic on the clavicle so far. The purpose of the present study was to investigate the relationship between scapula dyskinesis and Clavicle kinematic and to measure the effect of the specific exercises for scapula dyskinesis on the clavicle kinematic. Dyskinesis refers to the changes in the position and movements of the scapula. Abnormal medial border prominence and inferior angle prominence relative to the thorax in static or dynamic status can be mentioned as the symptoms for it(28). The scapula dyskinesis has been observed in the patients with the following disorders: strain shoulder joint, decreased subacromial space, changes in the strength and activities of the shoulder muscles(29, 30).

Another cause of the scapula dyskinesis is clavicle shaft fracture which causes the non-union of the clavicle, pain, early fatigue, visual deformity, and decreased muscle strength in the shoulder girdle (31-33). Some articles associate the pain of short muscle length and non-union of the clavicle with the change in the kinematic of shoulder girdle (6, 7, 34). In the case of a distal clavicular comminuted fracture, a study of the real motion of the AC joint after hook plate fixation reported that the operative shoulder showed less internal rotation and more anterior translation of the distal clavicle with respect to the medial acromion at the full abduction position(35). However, in another study, it was reported that the clavicular fractures did not affect the scapular rotation or translation. Another pattern of scapula dyskinesis in AC joint dislocation has been observed. AC reduction using a hook plate without coracoclavicular ligament repair may cause scapular dyskinesis in a different pattern from other injuries around the shoulder(36). The dyskinesis group had less clavicular elevation at 30° and 60° during arm elevation. This result is line with the SICK scapula syndrome, which Burkhart et al. (2003) described as scapular malposition, inferior medial border prominence, coracoid pain, malposition, and dyskinesis of scapular movement(6). The scapular malposition in the SICK scapula appears as a dropped or lower scapula on the involved side in symptomatic throwing athletes and may be known kinematically as a depressed clavicle in people with obvious dyskinesis. In this disorder, the inferior medial border undergoes a prominence which is known kinematically as anterior tilting(6). Tate et al. (2009),concluded that normal participants tilted during arm elevation in either plane about 10, whereas those with dyskinesis tilted posteriorly only about 4°(i.e., in people with scapula dyskinesis), in other words, there is not anterior tilting of the scapula, rather decreased posterior tilting which appears as scapular winging. The decrease in the muscle bulk and the activity of infraspinatus and supraspinatus in athletes may result in the reduction of the ability of the scapular tracking jig to grasp the scapular spine and detect anterior-posterior tilting motion. The finding of this study showed significant differences between the groups in clavicular elevation, clavicular protraction, and upward rotation at multiple points in the range of motion, particularly in the lower ranges. The group with dyskinesis began in a more protracted position and remained more protracted than the normal group during both arm elevation and lowering. The findings of our study support this assertion that the protracted position of the people with scapula dyskinesis leads to decreased clavicle retraction(37).

The researchers found out that the scapula dyskinesis result in decreased performance level in the shoulder, impingement, and pain in shoulder joint(34). In another study, Bertof et al. (1993) concluded that with the scapula in a protracted position, the opening of the subacromial space reduces which in turn leads to the increase of pressure in this space. The greater protraction in those with dyskinesis may be relevant to the compression of structures within the subacromial space. Winging may result from increased scapular internal rotation or increased anterior tilting which results in scapula medial border prominence(38).

Most of the studies in the literature have reported decreased scapular external rotation, scapular upward rotation, and posterior scapular tilting in patients with shoulder impingement syndrome(39). The decreased scapular elevation and scapular tilting due to the decreased clavicular elevation and retraction lead to the reduction in subacromial space, which makes the soft tissues in this space, undergo a compression. In the normal (without shoulder disorder) subjects, during elevation of the arm, the clavicle generally undergoes slight elevation, slight retraction, and posterior long-axis rotation. The findings suggest some kinematic differences between the normal subjects and dyskinesis group. In people with subtle dyskinesis, the intervention in the ways such as scapular exercise, taping, bracing would likely be based more on factors other than motion assessment, whereas a rating of subjects with obvious dyskinesis would form a stronger basis for intervention. The greatest difference between the normal athletes and those with dyskinesis was in the upward rotation, with dyskinesis group being roughly 9° more downwardly rotated at rest through 60° of humeral elevation in the sagittal plane. Impingement symptoms are commonly observed during a 60° to 120° arc of arm elevation. In impingement, where the cuff most closely approximates the acromion, the suprahumeral structures, namely the rotator cuff, subacromial bursa, and long head of the biceps tendon, are likely to incur greater compression with a reduction in the upward rotation. The literature repeatedly refers to serratus anterior muscle weakness in scapular winging and its relation with scapula dyskinesis (40). The improvement in clavicle mobility in this study may be due to the facilitation of the activity of this muscle with the help of these exercises. In line with the present conclusion, Kamkar et al. (1993) suggested that upward rotation of the scapula due to serratus anterior muscle activity is vital to prevent the humeral head from impinging on the acromion and that excessive winging or anterior tilting leads to a relative decrease in the subacromial space (39). Ludewig and Cook (2000), found that the patients with impingement symptoms show 58° at 120° scapulae anterior tilting during humeral elevation in scaption. They consider anterior tilting as the main cause of impingement(41). The shortened clavicle is also another cause of excessive scapular anterior tilting during shoulder elevation up to 100°(42).

In the present study, it was also shown that the average of clavicle elevation and retraction in both training groups had increased after six weeks of training and this difference was significant in the conscious control group, but the insignificant differences in other angles seem to be related to the limited time span of this research process. A similar study conducted by Roy et al. (2009) has reported that supervised movement training with feedback leads to short-term improvement in the kinematic of the trunk, clavicle and shoulder(43). In other words, the trainer feedback on the correctness of the exercises results in the improvement of the intended disorder. This improvement is accompanied by a reduction of pain, suggesting that a closer to normal upper limb movement may lead to less shoulder pain during reaching. The disorder in shoulder movement is considered asone of the factors in explaining the cause of intensification of impingement. As a result, the improvements in this disorder may lead to the normal function of the shoulder(44). Oyama et al. (2010), in a study concluded that the 3-dimensional motion of the scapula and the clavicle while subjects performing various exercises, in the prone position, that retract (externally rotate) the scapula could be effective for restoring normal scapular and clavicular kinematics and might be effective for patients with shoulder pathologies(45). In another study Timoon et al., concluded that Empty can exercise in people with shoulder impingement syndrome had a great effect on the scapular and clavicular motion. In their study, the internal rotation of the shoulder of subjects with this syndrome had been improved during the ascending phase in the empty can exercise. They suggested that the use of the empty for eccentric loading the rotator cuff may increase the impingement of the rotator cuff due to the decreased posterior tilting and increased internal rotation(19). Deyle and Bange (2000), in a comparative study, compared a training group that received supervised exercise with manual therapy with another group that received supervised exercise without manual therapy. They found out that the subjects who received manual therapy showed better results than the subjects who did not receive manual therapy for all variables(46). Brox et al. (1993) compared three groups: the first group (a supervised exercise program), the second group (acromioplasty group), and the third group (placebo laser treatment in 125 patients with shoulder impingement). The exercises consisted of low-resistance, repetitive rotation exercises which were performed daily for 1 hour with twice-a-week supervision for between 3 and 6 months. The researchers found that both groups (training and acromioplasty group) had improved impingement test scores, and also, in a follow-up of these patients 2.5 years later, both the training and acromioplasty groups had higher impingement test scores compared with the placebo group(47).

In another six-week training program study done by Macclure et al. (2004), it was shown that the exercises aimed at strengthening the rotator cuff, increasing the flexibility of the posterior glenohumeral capsule, and encouraging upper thoracic extension and a retracted head position may have resulted in improved muscle force, motion, pain, and function in a group of patients with shoulder impingement(8). In this study, the use of strengthening stabilization program also leads to the improvement of the clavicular kinematic average. The cause of this change seems to be the facilitator of the activities of the muscles associated with the scapula and the close interrelationship of this bone with the clavicle.

Exercise therapy is one of the treatment methods of the scapula and shoulder girdle disorder. Scapula stabilization and conscious control exercises can be mentioned as effective exercises for improving these kinds of disorders. With this assumption that the change in the normal scapular kinematic changes clavicular kinematic, it seems that using these two training components increases the strengths of shoulder girdle muscles, and biomechanical shoulder joint kinematics, and ST joint, and clavicle.

Conclusion

The results of the present research showed that stabilization and conscious control interventions can alter the clavicular kinematicby improving the strength of the scapular stabilizers and axial muscles, as well as improving the scapular positioning among individuals with scapular dyskinesis. On the other hand, the results of this study emphasized the greater impact of conscious control exercises on all variables as compared to the stabilization. Hence, it is recommended that therapists and corrective exercise specialists take advantage of the stabilization and especially the conscious control exercises to return the scapula and clavicle ideal kinematics when planning to correct abnormalities related to scapular dyskinesis.

Limitations of the study: The limitation of this study was the lack of related research in the literature to compare the results with. In the present study, the individuals with the first and second type of symptoms (medial border and inferior angle prominence) were included and the participants with the third type of symptoms were excluded from the study. As the participants were not available after the research process, a follow-up of the exercise results could not be done. In addition to that, the use of skin markers, the measurement of rotational movements of the scapula in its longitudinal axis was not possible. Learning the testing process by the participants in post-test, inability in controlling daily activities, diet, and mental states were other limitations of this research.

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References

1.Ahrens P. Biomechanics of the Shoulder. Fractures of the Proximal Humerus: Springer; 2015. p. 19-24.
2.Teece RM, Lunden JB, Lloyd AS, Kaiser AP, Cieminski CJ, Ludewig PM. Three-dimensional acromioclavicular joint motions during elevation of the arm. J Orthop Sports Phys Ther 2008;38(4):181-90.
3.Ogston JB, Ludewig PM. Differences in 3-dimensional shoulder kinematics between persons with multidirectional instability and asymptomatic controls. Am J Sports Med 2007;35(8):1361-70.
4.Inman VT, Abbott LC. Observations on the function of the shoulder joint. JBJS 1944;26(1):1-30.
5.Matsumura N, Nakamichi N, Ikegami H, Nagura T, Imanishi N, Aiso S, et al. The function of the clavicle on scapular motion: a cadaveric study. J Shoulder Elbow Surg 2013;22(3):333-9.
6.Burkhart SS, Morgan CD, Kibler WB. The disabled throwing shoulder: spectrum of pathology Part III: The SICK scapula, scapular dyskinesis, the kinetic chain, and rehabilitation. Arthroscopy: J Arthroscopic Related Surg 2003;19(6):641-61.
7.Kibler BW, McMullen J. Scapular dyskinesis and its relation to shoulder pain. J Am Acad Orthop Surg 2003;11(2):142-51.
8.McClure PW, Bialker J, Neff N, Williams G, Karduna A. Shoulder function and 3-dimensional kinematics in people with shoulder impingement syndrome before and after a 6-week exercise program. Physical Therapy 2004;84(9):832-48.
9.Seitz A, Uhl T. Assessing Minimal Detectable Change In Scapulothoracic Neuromuscular Activity. J Orthop Sports Physical 2012;42(1):A84-A5.
10.Kibler WB, Ludewig PM, McClure PW, Michener LA, Bak K, Sciascia AD. Clinical implications of scapular

dyskinesis in shoulder injury: the 2013 consensus statement from the ‘Scapular Summit’. Br J Sports Med 2013;47(14):877-85.

11.Warner J, Micheli LJ, Arslanian LE, Kennedy J, Kennedy R. Scapulothoracic motion in normal shoulders and shoulders with glenohumeral instability and impingement syndrome. A study using Moiré topographic analysis. Clin Orthop Relat Res 1992(285):191-9.

12.Shields E, Behrend C, Beiswenger T, Strong B, English C, Maloney M, et al. Scapular dyskinesis following displaced fractures of the middle clavicle. J Shoulder Elbow Surg 2015;24(12):e331-e6.

13.Cools AM, Struyf F, De Mey K, Maenhout A, Castelein B, Cagnie B. Rehabilitation of scapular dyskinesis: from the office worker to the elite overhead athlete. Br J Sports Med. 2013:bjsports-2013-092148.

14.Bovim G, Schrader H, Sand T. Neck pain in the general population. Spine 1994;19(12):1307-9.

15.Blanpied PR, Gross AR, Elliott JM, Devaney LL, Clewley D, Walton DM, et al. Neck pain: revision 2017: clinical practice guidelines linked to the international classification of functioning, disability and health from the orthopaedic section of the American Physical Therapy Association. J Orthop Sports Phys Ther 2017;47(7):A1-A83.

16.Ludewig PM, Behrens SA, Meyer SM, Spoden SM, Wilson LA. Three-dimensional clavicular motion during arm elevation: reliability and descriptive data. J Orthop Sports Phys Ther 2004;34(3):140-9.

17.Worsley P, Warner M, Mottram S, Gadola S, Veeger H, Hermens H, et al. Motor control retraining exercises for shoulder impingement: effects on function, muscle activation, and biomechanics in young adults. J Shoulder Elbow Surg 2013;22(4):e11-e9.

18.Brox JI, Staff PH, Ljunggren AE, Brevik JI. Arthroscopic surgery compared with supervised exercises in patients with rotator cuff disease (stage II impingement syndrome). Bmj 1993;307(6909):899-903.

19.Timmons MK, Thigpen CA, Seitz AL, Karduna AR, Arnold BL, Michener LA. Scapular kinematics and subacromial-impingement syndrome: a meta-analysis. J Sport Rehabil 2012;21(4):354-70.

20.Ou H-L, Huang T-S, Chen Y-T, Chen W-Y, Chang Y-L, Lu T-W, et al. Alterations of scapular kinematics and associated muscle activation specific to symptomatic dyskinesis type after conscious control. Manual Therapy 2016;26:97-103.

21.Buttagat V, Taepa N, Suwannived N, Rattanachan N. Effects of scapular stabilization exercise on pain related parameters in patients with scapulocostal syndrome: a randomized controlled trial. J Bodyw Mov Ther 2016;20(1):115-22.

22.Wu G, Van der Helm FC, Veeger HD, Makhsous M, Van Roy P, Anglin C, et al. ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion—Part II: shoulder, elbow, wrist and hand. J Biomech 2005;38(5):981-92.

23.Keshavarz R, Shakeri H, Arab A, Ibrahimi E. Reliability of 3-dimentional scapular kinematic measures of Acromion marker cluster in patients with shoulder impingment syndrome during humeral elevation and lowering. Pajouhan Sci J 2013;11(4):42-50.

24.mohammad golipor agdam g, letafatkar a, hadadnezhad m. comparison of the scapular stabilization and conscious control training on selected kinematic of scapular in subjects with scapular dyskinesis. Urmia Med J 2018;29(1):74-84. (Persian)

25.Hoard RW, Janes WE, Brown JM, Stephens CL, Engsberg JR. Measuring scapular movement using three-dimensional acromial projection. Shoulder elbow 2013;5(2):93-9.

26.Fung M, Kato S, Barrance PJ, Elias JJ, McFarland EG, Nobuhara K, et al. Scapular and clavicular kinematics during humeral elevation: a study with cadavers. J Shoulder Elbow Surg 2001;10(3):278-85.

27.McClure PW, Michener LA, Sennett BJ, Karduna AR. Direct 3-dimensional measurement of scapular kinematics during dynamic movements in vivo. J Shoulder Elbow Surg 2001;10(3):269-77.

28.Huang T-S, Ou H-L, Huang C-Y, Lin J-J. Specific kinematics and associated muscle activation in individuals with scapular dyskinesis. J Shoulder Elbow Surg 2015;24(8):1227-34.

29.Silva RT, Hartmann LG, de Souza Laurino CF, Biló JR. Clinical and ultrasonographic correlation between scapular dyskinesia and subacromial space measurement among junior elite tennis players. Br J Sports Med 2010;44(6):407-10.

30.Tate AR, Mcclure P, Kareha S, Irwin D. Effect of the scapula reposition test on shoulder impingement symptoms and elevation strength in overhead athletes. J Orthop Sports Phys Ther 2008;38(1):4-11.

31.Canadian OTS. Nonoperative treatment compared with plate fixation of displaced midshaft clavicular fractures. A multicenter, randomized clinical trial. J Bone Joint Surg Am 2007;89(1):1.

32.McKee MD, Pedersen EM, Jones C, Stephen DJ, Kreder HJ, Schemitsch EH, et al. Deficits following nonoperative treatment of displaced midshaft clavicular fractures. JBJS 2006;88(1):35-40.

33.Matsumura N, Ikegami H, Nakamichi N, Nakamura T, Nagura T, Imanishi N, et al. Effect of shortening deformity of the clavicle on scapular kinematics: a cadaveric study. Am J Sports Med 2010;38(5):1000-6.

34.Ledger M, Leeks N, Ackland T, Wang A. Short malunions of the clavicle: an anatomic and functional study. J Shoulder Elbow Surg 2005;14(4):349-54.

35.Kim YS, Yoo Y-S, Jang SW, Nair AV, Jin H, Song H-S. In vivo analysis of acromioclavicular joint motion after hook plate fixation using three-dimensional computed tomography. J Shoulder Elbow Surg 2015;24(7):1106-11.

36.Kim E, Lee S, Jeong H-J, Park JH, Park S-J, Lee J, et al. Three-dimensional scapular dyskinesis in hook-plated acromioclavicular dislocation including hook motion. J Shoulder Elbow Surg 2018.

37.Tate AR, McClure P, Kareha S, Irwin D, Barbe MF. A clinical method for identifying scapular dyskinesis, part 2: validity. J Athl Train 2009;44(2):165-73.

38.Solem-Bertoft E, Thuomas K-A, Westerberg C-E. The influence of scapular retraction and protraction on the width of the subacromial space. An MRI study. Clin Orthop Relat Res 1993(296):99-103.

39.Ichihashi N, Ibuki S, Otsuka N, Takashima S, Matsumura A. Kinematic characteristics of the scapula and clavicle during military press exercise and shoulder flexion. J Shoulder Elbow Surg 2014;23(5):649-57.

40.Kamkar A, Irrgang JJ, Whitney SL. Nonoperative management of secondary shoulder impingement syndrome. J Orthop Sports Phys Ther 1993;17(5):212-24.

41.Ludewig PM, Cook TM. Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. Physical Therapy 2000;80(3):276-91.

42.Kim D, Lee D, Jang Y, Yeom J, Banks SA. Effects of short malunion of the clavicle on in vivo scapular kinematics. J Shoulder Elbow Surg 2017;26(9):e286-e92.

43.Roy J-S, Moffet H, Hébert LJ, Lirette R. Effect of motor control and strengthening exercises on shoulder function in persons with impingement syndrome: a single-subject study design. Manual Therapy 2009;14(2):180-8.

44.Hébert LJ, Moffet H, McFadyen BJ, Dionne CE. Scapular behavior in shoulder impingement syndrome. Arch Phys Med Rehabil 2002;83(1):60-9.

45.Oyama S, Myers JB, Wassinger CA, Lephart SM. Three-dimensional scapular and clavicular kinematics and scapular muscle activity during retraction exercises. J Orthop Sports Phys Ther 2010;40(3):169-79.

46.Bang MD, Deyle GD. Comparison of supervised exercise with and without manual physical therapy for patients with shoulder impingement syndrome. J Orthop Sports Phys Ther 2000;30(3):126-37.

47.Brox JI, Gjengedal E, Uppheim G, Bøhmer AS, Brevik JI, Ljunggren AE, et al. Arthroscopic surgery versus supervised exercises in patients with rotator cuff disease (stage II impingement syndrome): a prospective, randomized, controlled study in 125 patients with a 212-year follow-up. J Shoulder Elbow Surg 1999;8(2):102-11.