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The effect of shoulder muscle fatigue on acromiohumeral distance and scapular dyskinesis in women with generalized joint hypermobility

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Abstract

Muscle fatigue is considered to be one cause of shoulder pain, and subjects with generalized joint hypermobility (GJH) are affected more by shoulder pain. The purpose of this study was to examine the effects of muscle fatigue on acromiohumeral distance (AHD) and scapular dyskinesis in women with GJH. Thirty-six asymptomatic participants were assigned to either a GJH (n=20) or control group (n=16) using the Beighton scale. Before and after elevation fatigue trials, AHD was measured with ultrasonography at rest and when the arm was in 90° active elevation. A scapular dyskinesis test was used to visually observe alterations in scapular movement. Our results showed that in both groups, the fatigue reduced AHD in the 90° elevation position and increased the presence of scapular dyskinesis; however, no differences were found between the two groups. Although GJH has been identified as a factor for developing musculoskeletal disorders, generalized joint hypermobility did not result in changes to scapular dyskinesis or AHD, even after an elevation fatigue task. More studies are needed to evaluate the effects of muscle fatigue in subjects with GJH and a history of shoulder instability.

Keywords: acromiohumeral distance, scapular dyskinesis, generalized joint hypermobility, shoulder muscles fatigue.

Word Count: 3490

Introduction

Generalized joint hypermobility (GJH) is a term used when the majority of synovial joints in the body can perform movements beyond the normal range of motion.[1,2] Several studies have shown that individuals with GJH have an increased risk of joint injury.[3-5] It is known that in individuals with GJH, there is an increased maximal stretch tolerance in the lax muscle tendon unit and impaired joint proprioception.[6,7] Strain and tearing of the surrounding tissues because of excessive joint motion can reduce joint position sense, stability and coordinated movement of the joints in addition to causing pain.[8]

It has been suggested that GJH may be related to shoulder pain and glenohumeral joint instability.[9-11] Normal shoulder function depends on the combination of intact static stabilizers and normal synchronous activity of the shoulder muscles. In other words, it depends upon both capsulo-ligamentous structures and neuromuscular control.[12] Elevation of the arm first requires normal function of the rotator cuff to stabilize the humeral head in the glenoid fossa and then coordinated motion of the scapula.[13,14] During arm elevation, the scapula rotates upward, tilts posteriorly and rotates externally.[15] These scapular motions depend on the normal function of the scapular stabilizers, including the trapezius, rhomboids and serratus anterior muscles.[16,17]

High repetitive use of the arm in an elevated position and heavy workloads are considered risk factors for developing shoulder pain from inducing changes in shoulder girdle kinematics.[18-20] Most of the patients below 60 years of age who have shoulder impingement syndrome relate their symptoms to overhead work or sport activities.[21] They frequently elevate or sustain their arm above 60° of abduction, especially by holding a tool during overhead activities.[22] Therefore, elevation tasks potentially lead to shoulder impingement syndrome.

Upper extremity repetitive movements create rotator cuff fatigue, which causes superior humeral head translation and can decrease the subacromial space.[23,24] Additionally, subsequent altered kinematics of the scapula or scapular dyskinesis (downward rotation, anterior tilt and internal rotation) related to dysfunction or fatigue of scapular stabilizing muscles contribute to impingement syndrome by decreasing the subacromial space, therefore reducing the volume of the rotator cuff outlet.[25,26] Both of these mechanisms may cause the encroachment of the subacromial structures during glenohumeral elevation and possibly make the shoulder susceptible to impingement syndrome or rotator cuff pathologies. However, other studies suggest that the changes in scapular orientation have minimal effects on the subacromial space width.[27,28]

The effect of muscle fatigue on shoulder kinematics is well investigated in healthy non-symptomatic individuals. However, GJH individuals with inherent laxity of connective tissues or poor static stabilizers might respond differently to cumulative working factors, such as overhead postures or repetitive activities. According to recent study subjects with joint hypermobility syndrome have impaired shoulder function and higher neck and shoulder pain compared to non-hypermobile subjects.[29] One explanation could be reduced shoulder proprioception in GJH subjects compared to non-hypermobile individuals.[6] This is an important issue as less neurological feedback and dynamic stabilization would result in more glenohumeral translation and shoulder instability.[30] So far, no researcher has compared the effect of muscle fatigue on shoulder of subjects with GJH and non-hypermobile individuals. Acromiohumeral distance is the linear measurement of the subacromial space outlet and is measured by ultrasonography.[31-33] Ultrasonography is a reliable and valid technique in AHD measurement.[34,35] Therefore, the purposes of this study were to firstly, compare the effects of an elevation fatigue protocol on AHD in 0° and 90° arm elevation and visual alteration in scapular dyskinesis in individuals with GJH and without. Secondly, determine the relationships between scapular dyskinesis and AHD. Specifically, we hypothesized that there would be more AHD reduction in the subjects with GJH compared to subjects without GJH when the shoulder muscles were fatigued and the scapular dyskinesis became more severe. Further, it was hypothesized that there would be a relationship between AHD and scapular dyskinesis**.**

Methods

Thirty-six women (20 women with GJH and 16 without GJH) participated in the study. Prior studies suggest that, generalized joint hypermobility is gender related and is more prevalent among female subjects; therefore, female participants were enrolled in the study.[36,37] Subjects were selected if they had no history of shoulder girdle pain and pathology during the last 6 months. The Beighton scale was used to diagnose GJH.[38] According to the Beighton method, participants were given numerical scores from 0 to 9. One point was given for the ability to perform each of the following tests: (1) passive hyperextension of the fifth finger beyond 90º; (2) passive opposition of the thumbs to the flexor aspects of the forearms; (3) hyperextension of elbows beyond 10º; (4) hyperextension of knees beyond 10º (note that these first four maneuvers were performed on the right and left sides); and (5) forward flexion of the trunk so that the palms easily touch the floor. Participants with the score of four or higher met the Beighton criteria for GJH.[39] In the current study, subjects with score of 6 or higher were considered to be the GJH group. Individuals in the control group scored below 3. The purpose of this grouping system was to study the participants with the highest and the lowest Beighton scores. Before participating in the study, all subjects signed an informed consent form approved by the Ethical Committee of the University of Social Welfare and Rehabilitation Sciences.

In this study, the AHD was measured via ultrasonography (Mindray device model dp6600 with a linear probe and 12 MHz frequency). Acromiohumeral distance was measured by a physical therapist with 4 years of experience who was trained for the purpose of this study for approximately 2 months prior to data collection. Subjects were instructed to sit upright without slumping in the chair and to place their feet on the floor. The long axis of the linear probe was placed along the supraspinatus muscle fibers. Standardization of the measurement technique was performed by using the midpoint of the acromion.[40] Bony landmarks on the humerus and acromion were used to make the measurement technique reliable.[40,41] Acromiohumeral distance was measured as the shortest distance between the lateral edge of the acromion and the humeral head.[40,42] Sonographic measurements were performed in two arm positions: one with the arm at rest beside the body, with the palm of the hand toward the body and the other with the arm actively held in 90° abduction in the plane of scapula (40° front of the frontal plane) with the elbow fully extend and the hand in neutral position with the thumb pointed up.[33,40](Figure 1). Participants tended to drop their arm during ultrasonography specifically post fatigue; however, examiners encouraged subjects to maintain 90° abduction and to ensure that the desired position was maintained a manual goniometer was used to measure the position of the arm.

Prior to data collection, test retest intersession reliability of AHD was obtained for ten subjects. AHD measurements were conducted three times in hour intervals.

For assessment of the scapular position, the scapular dyskinesis test was used, which is reliable and valid compared to 3-dimensional scapular motion. Using scapular dyskinesis test, Tate et al found athletes with observable dyskinesis compared to subjects without dyskinesis had less upward rotation with 3-D motion analysis.[43,44] Subjects were instructed to stand with their arms resting next to their body. The examiner stood behind them at a 1.5 meter distance and captured video posteriorly. The full can movement was performed in the plane of the scapula (40° anterior to the frontal plane) with the thumbs pointed up. Subjects were told to elevate their arms as high as they could for 3 seconds and to lower them in the same period of time, and the movement was repeated 5 times. Scapular dyskinesis was rated as obvious dyskinesis if dysrhythmia or an inferior angle and/or a medial border striking prominence occurred during at least 3 repetitions. Subtle dyskinesis was defined as having mild or questionable evidence of an abnormality less than 3 repetitions. Finally, the movement was rated normal if there were no signs of abnormality (Figure 2). Examiners were trained in the dyskinesis visual observation method as proposed by the developers of the test.[43] The examiners were licensed physiotherapists one had 4 years of musculoskeletal physical therapy experience, and the other was a PhD-level examiner with specialized experience in shoulder girdle kinematics and rehabilitation. Scapular dyskinesis ratings were based on the videos that were collected. Both examiners rated scapular dyskinesis together and recorded one score for each video. There were three subjects that examiners did not have 100% agreement on their scapular dyskinesis test, therefore the videos were reviewed, discussed and an agreement was obtained. The examiners were blinded to which group the subjects were in, as well as the pre- to post-fatigue conditions. Prior to data collection, the reliability of the scapular dyskinesis test was obtained for ten subjects. Each video was observed on two different days that were five to seven days apart.

In order to begin shoulder fatigue protocol, we explained and demonstrated all the steps of the experimental procedure to the subjects. They were instructed to sit on a chair and asked to elevate their dominant arm in the plane of the scapula to 120° abduction with a 0.5 kg dumbbell and their thumb pointed up. In our pilot study, 0.5 kg was a weight that all the subjects were able to lift at least one time. Participants were asked to elevate their arm in one second and lower it in one second as well. During the protocol, the examiner used a manual goniometer to evaluate the correct performance of the elevation fatigue task in terms of elevating and lowering the arm in a total range of motion and being in the plane of the scapula. Additionally, a metronome was used to maintain the correct speed for the movement. Subjects were asked to rate the amount of perceived exertion that they felt periodically with the Modified Borg Scale.[45] This scale is a numeric 0 to 10 scale that is used to rate the amount of perceived exertion. When each of the following key points were observed, the fatigue protocol was stopped: reporting rate of perceived exertion ≥ 8, inability to maintain the correct movement in terms of correct speed or angle of movement, or using substitute motions such as trunk-side flexion to the opposite side. The subjects were not made aware of the criteria to stop the protocol. Then immediately examiner measured the maximum voluntary isometric force prior to and immediately after the fatigue protocol with a handheld dynamometer (Lafayette Instrument®, Lafayette, IN). The examiner held the dynamometer proximal to the radial styloyid process. Subject was asked to push the dynamometer as hard as possible while the arm was held in 90° abduction in the plane of the scapula and thumb pointed up. Thirty percent reduction in isometric force could confirm fatigue.[28]

The intra-class correlation coefficient (ICC) and standard error of measurement (SEM) values were used to assess intra-tester reliability of the measurements. To determine the influence of dominant shoulder fatigue on AHD in two groups, the analysis of covariance (ANCOVA) was used before and after fatigue for 0 and 90° separately. The covariant was pre-fatigue AHD. The Wilcoxon test was used to compare scapular dyskinesis before and after the fatigue protocol in each group. In addition, the Man-Whitney U test was used to compare scapular dyskinesis in two groups. Finally, to examine the correlation between scapular dyskinesis and AHD, the Spearman correlation test was used. A significance level of 0.05 was used for all statistical tests. The data were analyzed using SPSS statistical software version 17.

Results

There were no statistically significant differences in the participants' characteristics (p > .05) with regard to age and BMI between the two groups. The mean ± SD of age and BMI of the participants in the GJH and control groups were 21.1 ± 2.4 y, 21.7 ± 3.8 kg·m^{-2} and 22.6 ± 2.9 y, 22.4 ± 2.4 kg·m^{-2}, respectively.

Before the fatigue protocol, the rating of perceived exertion in the GJH and non-hypermobile groups was 0.4 ± 0.6 and 0.4 ± 0.6. After fatigue, this scale reached to 8.5 ± 0.8 in the GJH group and 8.3 ± 0.8 in the non-hypermobile group. The duration of the fatigue protocol and the number of elevation trials in GJH and non-hypermobile groups were 118.8 ± 46.5 seconds and 117.8 ± 45.5 seconds and 43.4 ± 16.1 and 39.8 ± 11.2 repetitions of elevation, respectively. In the hypermobile group, maximum isometric contraction force was reduced by 31% ± 8.7 kg, and in the non-hypermobile group, it was reduced by 34% ± 14.4 kg. There were no differences between the two groups in these variables (p > .05).

The ICC values of AHD in the rest and abduction positions were 1 and 0.9 respectively. The SEM of the AHD in 0 and 90° abduction positions were 0.2 mm. The ICC value for the scapular dyskinesis test was 0.8 (95% CI, 0.5-0.9).

There were no differences between two groups in AHD at the rest position and 90° abduction (p > .05). Fatigue reduced AHD at 90° abduction (p < .001); however, at rest position fatigue did not lead to significant changes in AHD. Also, by elevating the arm, the amount of AHD was reduced compared to the resting position (p < .001) (Figure 3).

The result of the Wilcoxon test showed that fatigue led to increased severity of scapular dyskinesis in the two groups ($p < .001$). However, based on the Mann-Whitney U test, there were no differences in the scapular dyskinesis test between the two groups in both the pre- and post-fatigue conditions ($p > .05$) (Table 1).

The results of the Spearman correlation analysis showed there were no significant correlations between the scapular dyskinesis test and AHD at each position before and after fatigue ($p > .05$).

Discussion

The results showed differences between groups for AHD and scapular dyskinesis test were not significant. Therefore, the hypothesis of this study was rejected. Another finding was that fatigue reduced AHD when the arm was held in 90° abduction, however the amount of AHD in the resting position after fatigue did not change, but fatigue also led to more severe scapular dyskinesis.

In addition to static stabilizers, such as ligaments, capsule and labrum, the shoulder joint needs dynamic stabilizers or muscles to maintain its stability. Static stabilizers play a stabilizing role mainly at end range positions or when they are fully stretched. In the resting position, as well as in the midrange positions, the static stabilizers are loose. This looseness means that the muscles are the main resources to maintain stability of the joint.[30,46] In this study, only two positions of rest and midrange were assessed. In the first, or resting, position, static elements are the main stabilizers, whereas muscles are minimally active. Thus, we cannot expect muscle fatigue to have an obvious effect on the subacromial space. This outcome might explain the fact that AHD in the resting position in both groups did not change after fatigue. In the second midrange position, or 90° abduction, the rotator cuff muscles are active to maintain the humeral head into the glenoid fossa. In this position, static stabilizers lose their stabilizing role. As a result, there were also no differences between the two groups in the second position. Accordingly, it seems that our sonography measurements were performed in positions where our two groups behaved in the same manner.

Our results also showed that AHD in 90° arm elevation in GJH individuals before and after fatigue were 6.7 ± 1.8 mm and 5.8 ± 1.7 mm, respectively, and in non-hyper mobile persons, the before and after measurements were 6.7 ± 1.3 mm and 6 ± 1.2 mm, respectively. In other words, in the 90° active elevated arm position, the AHD decreased statistically after fatigue in the dominant shoulder of both groups ($p < .005$).

There were two common mechanisms explaining reduced AHD after fatigue: (1) increased superior humeral head translation and/or (2) altered scapular kinematics (scapular downward rotation, anterior tilt and internal rotation).[47] In our study, it was found that repetitive elevation movements led to narrowing of AHD in the 90° elevated position. It has been shown that in the 90° abducted position, the tissues occupied approximately 91% of the subacromial space. Therefore, even small AHD changes may be very important.[48] Decreasing the subacromial space may result in shoulder impingement syndrome and compress the tissues occupied the space. Biceps tendon, subacromial bursa and of particular concern the supraspinatus tendon are within this space. Narrowing of the subacromial space is believed the beginning stage in rotator cuff pathologies that eventually result in tendon tearing.[48,49] However, Michener et al reported a minimal detectable change of 0.8 mm and Leong et al a minimal detectable change of 2.1 mm for AHD.[50,51] Assuming similar method in the sonography measurement of AHD as Michener et al, the AHD changes following fatigue would not be clinically significant. Unlike our results, Maenhout et al found that after fatigue, the AHD increased.[32] Their subjects were healthy overhead athletes, and the measurement angles were at the 45° and 60° elevated positions. Moreover, their fatigue protocol was a rotational task. In our study, subjects were healthy non-athletic individuals, and the AHD measurement was performed at the 90° elevation. Our fatigue protocol also included repeated elevation trials. These differences might explain the contradiction in the results between our study and the previous study.

Fifty-five percent of GJH subjects had subtle or obvious scapular dyskinesis in the pre-fatigue condition, whereas it was 31.3% in the control group. Furthermore, fatigue led to increased severity of scapular dyskinesis in both groups ($p < 0.005$). However, there were no significant differences between the groups in both conditions. First of all, it should be mentioned that this test had just three levels of quality. Thus, although scapular dyskinesis test is a convenient clinical tool, it cannot identify the precise changes of shoulder girdle kinematics. As a result, we do not have adequate data to discuss if there were precise differences of scapular dyskinesis between the groups**.** Nodehi and Moghadam Salimee showed that, compared to subjects without GJH, hyper mobile subjects exhibited a more protracted and downward rotated scapula on their dominant side.[52] In addition, there have been some indications that individuals with scapular dyskinesis can have some scapulothoracic joint hypermobility.[33] Therefore, in future research studies, researchers need to examine the prevalence of scapular dyskinesis in GJH individuals compared to subjects without GJH. Huang et al, also showed that subjects with different patterns of scapular dyskinesis presented more scapular internal rotation and less scapular posterior tipping, as well as higher upper trapezius, less lower trapezius and less serratus anterior muscle activity.[53] No EMG data were recorded in our study to substantiate similar claims in individuals with GJH. In general, the literature describing shoulder girdle kinematics and muscle activity in GJH individuals is scarce.

The results of the Spearman analysis test showed there was no significant correlation between the scapular dyskinesis test and AHD. This result agrees with previous study that suggested AHD was not different in subjects with scapular dyskinesis and without. However, Seitz et al also found that manipulation of scapular orientation changed the AHD.[33] In the other ultrasonography study in healthy athlete participants, no correlation was found between AHD and upward rotation of the scapula.[54] However, Silva et al found that tennis players with scapular dyskinesis had smaller acromiohumeral distance than participants without scapular dyskinesis.[55]

There are several limitations to our study that should be acknowledged. A possible explanation for the lack of group differences could be that although the Beighton scale is a convenient method to diagnose GJH and has good to excellent reliability in screening young individuals, this scale has some flaws.[2] The scale cannot give the exact state of hypermobility in each joint exclusively. Thus, hypermobile subjects with a history of shoulder instability may respond differently to the fatigue protocol. Second, subacromial space is a three-dimensional structure and ultrasonography collects measurements in two dimensions. Because of this limitation, the images may not have been able to capture the most inferior aspect of the acromion because it may have been outside of the plane of measurement.[56,57] Third, for fatigue confirmation, we measured maximum voluntary isometric contraction and rate of perceived exertion before and after fatigue. We did not use electromyography data to confirm shoulder muscle fatigue, especially in the rotator cuff muscles.

The results of this study show no significant differences in AHD or the scapular dyskinesis test between the two groups. After fatigue, acromiohumeral distance in the 90° active elevated arm position decreased, and the fatigue led to increased severity of scapular dyskinesis in both groups. Further studies are needed to determine the effects of muscle fatigue on kinematics and EMG of the shoulder girdle in GJH individuals or GJH individuals with a history of shoulder instability. In addition, more studies are needed to evaluate and compare scapulohumeral kinematics in GJH and non-hypermobile subjects using more precise tools to determine detailed differences.

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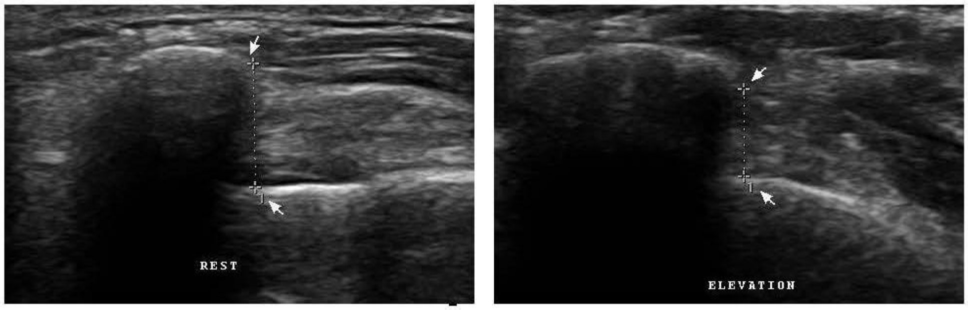

Figure 1: Sonographic measurement of the acromiuhumeral distance. The dotted line shows the shortest distance between the tip of the acromion and the head of the humerus, A: arm at rest, B: arm in 90° elevation.

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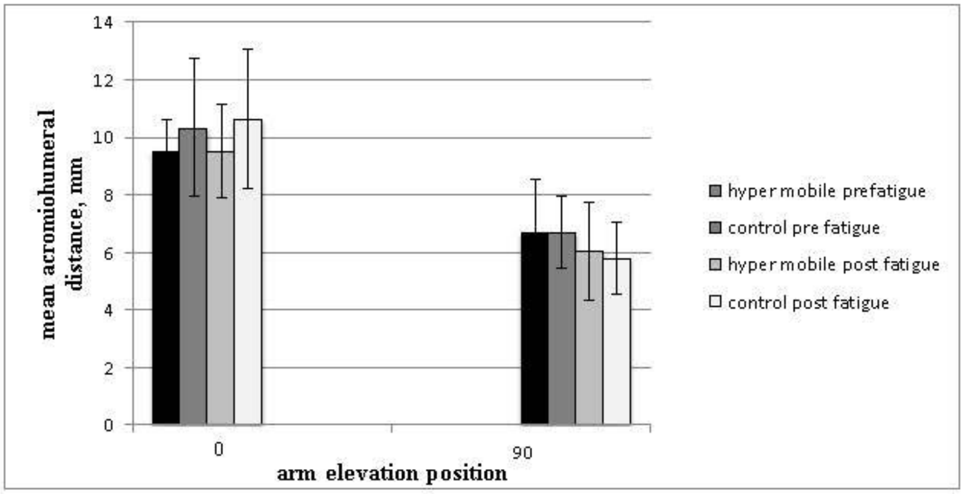

Figure 2: Mean ± (SD) mm acromiohumeral distance in 0 and 90° abduction in hypermobile and non-hypermobile groups before and after fatigue of the dominant shoulder. Y axis indicates acromiohumeral distance measurement in millimeter. X axis indicates arm position that sonography measurements were taken.

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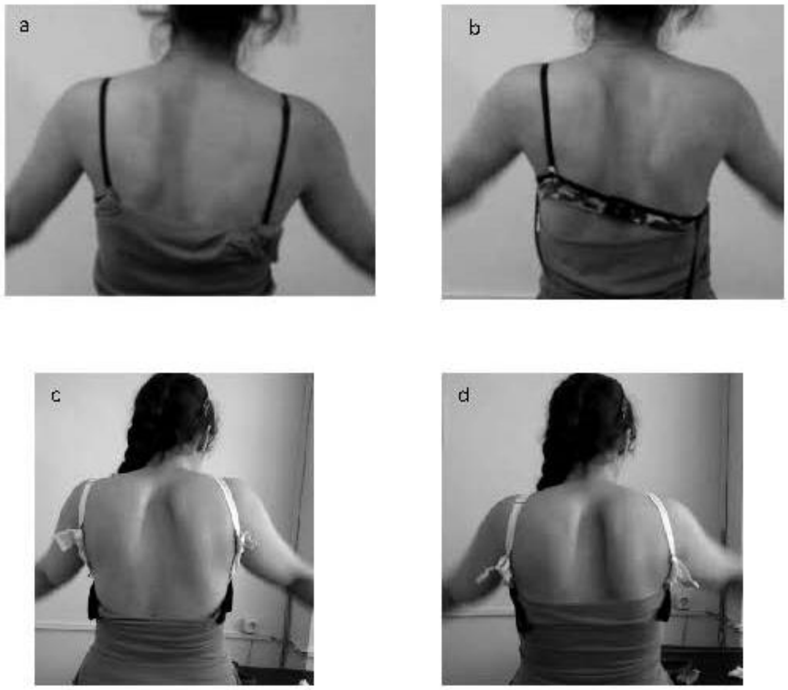

Figure 3: Subjects performing scapular dyskinesis test. A, right side was rated as normal and left side as mild. B. same subject after elevation fatigue task of the right side, right side rated as mild scapular dyskinesis and left side rated as mild. C. another subject, right and left sides rated as mild. B. after elevation fatigue task of the right side, right side rated as obvious and left side as mild.

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Table 1 The result of scapular dyskinesis test in hypermobile and non-hyper mobile groups before and after fatigue.

	hyper mobile			non-hypermobile		
	scapular dyskinesis			scapular dyskinesis		
	normal	subtle	observable	normal	subtle	observable
before	9 (45%)	8 (40%)	3 (15%)	11 (69%)	2 (12%)	3 (19%)
after	6 (30%)	6 (30%)	8 (40%)	4 (25%)	7 (44%)	5 (31%)