Scapular Upward Rotator Morphologic Characteristics in Individuals With and Without Forward Head Posture: A Case-Control Study

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Original Research

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Running Title: Scapular Upward rotators in forward head posture

Abstract

Objectives: There are several reports suggesting forward head posture (FHP) contributes to alteration in scapular kinematics and muscle activity leading to the development of shoulder problems. Currently, it is unknown if FHP alters the thickness of the scapular muscles. The aim of this study was to compare the thickness of the serratus anterior and the upper and lower trapezius muscles at rest and during loaded isometric contractions in individuals with and without FHP.

Methods: Twenty individuals with FHP and twenty individuals with normal head posture (NHP) participated in this case-control study. Three separate ultrasound images of the serratus anterior and the upper and lower trapezius muscles were captured under two randomized conditions: at rest and during a loaded isometric contraction.

Results: The thickness of each muscle significantly increased from rest to the loaded isometric contraction (P < 0.001). The only difference between the groups was that the thickness of the serratus anterior muscle at rest in the NHP group was larger than in the FHP group (P = 0.01).

Conclusion: The conclusion was that FHP appears to be related to the atrophy of the serratus anterior muscle, which may contribute to the development of shoulder problems. Further research is required to identify more about the association of FHP with the imbalance of shoulder girdle muscles and the impact of head posture on upper quadrant pain.

Key Words: scapular muscles, serratus anterior, trapezius, thickness, ultrasonography

Introduction

Faulty neck postures cause abnormal stresses on the cervical and upper thoracic structures, as well as on the craniomandibular joint and the shoulder girdle. These stresses are considered to be the predisposing factors of pain and disability in the upper quadrant of the body.[1-3] Forward head posture (FHP) is the most common faulty head posture observed in patients with neck and shoulder pain.[4-6]

There are several shared muscle attachments between the scapula and the shoulder and axial skeleton, including the upper trapezius and the levator scapulae.[7] FHP may induce negative effects in muscles, including muscle imbalance, not only in the neck,[8] but also in the thoracic spine and shoulder girdle.[9] Recent research has examined the effects of head posture on the scapular upward rotator muscles, which involve the serratus anterior and the upper and lower trapezius muscles, and have demonstrated that there are alterations in the activity of these muscles.[1,10,11] Weon et al[1] reported that the electromyography (EMG) activity of the trapezius muscles increased, while the EMG activity in the serratus anterior muscle decreased during loaded isometric shoulder flexion in individuals with simulated FHP compared with normal head posture (NHP). Thigpen et al[10] demonstrated that the activity of the serratus anterior muscle during loaded arm flexion and overhead reaching activities decreased in individuals with FHP compared with a control group.

Understanding the relationship between FHP and the trapezius and serratus anterior muscles may provide a way to improve shoulder mechanics and decrease the risk of shoulder pain. However, there is currently no knowledge about the extent of possible morphological changes that occur in the scapular upward rotator muscles in individuals with FHP. Rehabilitative ultrasound imaging with good clinimetric properties has been used to measure morphology, including the thickness, cross-sectional area, and muscle volume, in a variety of muscles.[12-14] Furthermore, ultrasound is considered to be sensitive enough to detect absolute changes in muscle thickness from rest to a contracted condition.[15]

The aims of this study were to compare the thickness of the serratus anterior and the upper and lower trapezius muscles at rest between individuals with and without FHP, to identify the differences in the thickness of these muscles between the two groups during a loaded isometric contraction, and to investigate the changes in muscle thickness from rest to a contracted condition activation in each group. We hypothesized that the thickness of the scapular upward rotator muscles at rest and during a loaded isometric contraction changed in participants with FHP compared with participants with NHP. We also hypothesized that the thickness of these muscles increased in both groups from rest to a loaded isometric contraction.

Material and Methods

Participants

This cross-sectional study was carried out on 20 women with FHP (aged 18–31 years) and 20 women with NHP (aged 18–27 years); the women with NHP acted as the control group. The participants were recruited from the staff and students of University of Social Welfare and Rehabilitation Sciences, Tehran, Iran. Participants were assigned to the groups based on the measurement of the craniovertebral angle (CVA). Individuals with a CVA that was less than 49° were allocated to the FHP group; those with a CVA greater than 50° were placed in the control group.[16] All participants were right-handed to eliminate any possible effects of handedness on muscle thickness.[1,17,18] Individuals were included in the study if they had a full active pain-free range of motion at the neck and shoulder[18,19] and a body mass index (BMI) less than 25. The

BMI was important because it was difficult to obtain clear ultrasound images of muscles covered with several layers of fat.

Individuals were excluded from the study if they had a history of pain, injury, or surgery anywhere in the neck, shoulder, or thorax that limited the range of motion of the neck or shoulder such that they required time off work or a consultation with a health care practitioner.[10,11,20] Exclusion criteria also included structural or functional scoliosis, considerable kypholordotic posture,[10,11] continuous participation in sport activities,[11] participation in training programs that involved the scapular muscles,[19,21] malignant diseases,[17] pregnancy,[19,21]. The study protocol was fully explained to all individuals, and written informed consent was obtained from all participants. The study was approved by the research ethics committee of the University of Social Welfare and Rehabilitation Sciences, Tehran, Iran.

Procedure

Forward Head Posture Assessment

Evaluation of the head posture was conducted by measuring the CVA,[16,22] which is the angle between the horizontal line passing through the seventh cervical spinous process (C7) and the line extending from the tragus of the ear to the spinous process of C7. Digitalized lateral-view photography was used to measure the CVA. The camera was placed at shoulder level, 1.5 m from the participant's right shoulder, and positioned perpendicular to the ground. The tragus of the ear was marked and a plastic pointer was attached to the skin overlying the C7 spinous process, which was recognized by palpation. Participants were asked to stand in their usual standing posture while looking forward and to keep their heads in a relaxed position. They were then asked to perform cervical flexion and extension three times prior to standing still to achieve what they considered to be their relaxed head posture. Once the photograph was obtained, Adobe Photoshop CS5, Auto Desk, was used to measure the FHP, as quantified by the CVA.[16]

Ultrasound Imaging

Ultrasound images were produced using a real-time ultrasound device (Ultrasonix ES500, Ultrasonix Medical Corporation, USA) with a 45-mm linear transducer in the B-mode. The frequency of the imaging was set at 12 MHz in all measurements in order to standardize the measurement protocol for all participants. All imaging was conducted by the principal investigator using a previously described protocol that had documented reliability in quantifying the thickness of the serratus anterior and the upper and lower trapezius muscles at rest and during a loaded isometric contraction.[19,21,23] The main investigator had six years of experience with ultrasound imaging. Measurements of the muscle thickness were taken from the participant's right side at rest and during the loaded isometric contraction while holding a 1-kg hand weight.[17] None of the participants reported pain or discomfort during any of loaded conditions. The order in which the muscles were tested was randomized in all participants.

Ultrasound imaging of the serratus anterior muscle

Positioning**:** Each participant was instructed to sit relaxed in a chair with their head and neck in a relaxed position. They were then asked to place their right arm on a padded surface on an adjustable bar while the shoulder was positioned in flexion of 120° in the sagittal plane. The position was measured with a goniometer. Images of the serratus anterior muscle were taken at rest and during the loaded isometric contraction. For the rest condition, participants were verbally encouraged to relax the arm being measured while keeping it in the test position. For the loaded isometric contraction, participants were asked to maintain their arms in 120° of the shoulder flexion while holding a 1-kg hand weight for 5 s. Verbal instruction was given to prevent participants from putting their hands on the adjustable bar. The investigator captured an image during this period. Each condition was performed three times and a mean of the measurements was used for data analysis.

Transducer location: While the participant's arm flexion was at 120°, the ultrasound transducer was placed vertically on the midaxillary line with the superior border tangential to the horizontal line passing the inferior scapular angle. The transducer was manually adjusted and tilted until the echogenic borders of the ribs and the muscle fascia were well visualized. When the clear borders of the serratus anterior muscle could be seen, the image was taken. The thickness of the serratus anterior muscle was measured as the greatest linear distance between the hyperechoic margins of the muscle over the center of the rib to the subcutaneous fascia. This method has demonstrated acceptable reliability in measuring the thickness of the serratus anterior muscle.[21,23] The ultrasound images of the serratus anterior muscle are shown in Figure 1.

Ultrasound imaging of the lower trapezius muscle

Positioning: Imaging of the lower trapezius muscle was carried out at rest and during the loaded isometric contraction. Participants were asked to lay prone with their heads and necks in the midline. A medium-sized pillow was placed under the abdomen to eliminate any lumbar hyperextension. The participant's right arm was passively moved to 120° of abduction with the elbow extended and the thumb pointing upward. The arm was placed on a table at the appropriate angle as measured by a goniometer. For the rest condition, participants were verbally encouraged to relax their arms, which were supported by the table. For the loaded isometric contraction, participants were instructed to maintain their arms in the same position with no table support while holding a 1-kg hand weight for 5 s. The investigator captured an image during this period. Three separate ultrasound images of the lower trapezius muscle were taken for each condition and the mean of the three measurements was used for analysis.

Transducer location: First, the spinous process of the eighth thoracic vertebra (T8) was identified. To do this, the spinous process of the sixth cervical vertebra (C6) was palpated after asking each participant to extend their neck while in a prone position. The first level above the cervicothoracic junction that became less palpable was identified as the C6 spinous process. The spinous processes that were inferior to C6 were then palpated and counted until the spinous process of the T8 was recognized. The transducer was placed horizontally over the T8 spinous process and moved laterally to the right side of T8 to observe the thickest part of the muscle in way that the investigator observed the lateral border of vertebral spine on the screen. When the muscle borders were clearly apparent, the image was frozen on the monitor. The thickness of the lower trapezius muscle was measured as the linear distance between the two echogenic muscle fascias. The reliability and validity of this procedure for measuring the lower trapezius muscle have been previously established.[19,20,23] The ultrasound images of the lower trapezius muscle are shown in Figure 2.

Ultrasound imaging of the upper trapezius muscle

Positioning: Participants were asked to stand upright and to place both arms at their sides. They were instructed to keep their head and neck in a neutral position. Images of the upper trapezius muscle were captured at rest and during the loaded isometric contraction. Encouragement and consistent verbal commands were given to the participant to relax the neck and shoulder muscles when the image of the resting condition was being captured. For the loaded isometric contraction, participants held a 1-kg hand weight in their right hands and were instructed to perform a smooth scapular elevation of 3 cm in a way that their acromioclavicular joints reached an adjustable horizontal bar that was placed by their side. Participants were instructed to hold this position for 5 s. One image was frozen on the screen during 5 s. Each condition was measured three times and the average thickness measurement was used for data analysis.

Transducer location: To capture an ultrasound image of the upper trapezius muscle, the transducer was placed at the midpoint of the line extending from the acromial tip to the spinous process of C7. The linear transducer was put in a coronal plane over the landmark. Once a good quality image was obtained, the image was frozen on the screen and stored. The inside edge of the muscle borders was measured. The procedure for measuring the upper trapezius muscle have been previously discussed.[17,24] The ultrasound images of the upper trapezius muscle are shown in Figure 3.

Statistical Analysis

Data were collected and analyzed using the Statistical Package for the Social Sciences (IBM SPSS) for Windows, version 21. The demographics of the participants, including age, weight, height, and BMI, were expressed as the means ± standard deviations for both the FHP and NHP groups. The mean thickness of each muscle was calculated by taking the average of the measurements from the three separate trials for each of the rest and loaded isometric contraction conditions in order to reduce the measurement error. The thicknesses of the muscles were normalized to the individual's body weight; the normalized values were used in the statistical analysis to eliminate the effects of weight on muscle size. It is recommended that normalized values be used because muscle thickness is known to be affected by gender and BMI.[25,26] The independent t-test was used to determine any difference in demographic data between the NHP and the FHP groups for each condition. Repeated measures of analysis of variance (ANOVA) were used to investigate the effects of the within-group factor of contraction (rest and isometric contraction) and the between-group factor of head posture (FHP and NHP) on the thicknesses of the muscles. The intraclass correlation coefficient (ICC), confidence interval (CI), and standard error of measurement (SEM) were calculated for each condition and for each muscle to determine the relative and absolute reliability of the ultrasound measurements by the examiner.

Results

For this investigation, the data for 20 individuals with FHP and a mean age of 22.90 ± 2.57 years and 20 participants with NHP and a mean age of 23.00 ± 3.59 years were analyzed (two participants were excluded from the analyzes due to suboptimal image resolution). Table 1 shows the mean and standard deviation of the demographic data of the participants in both groups. The results of the t-test showed there was no significant difference in the demographic variables between the NHP and FHP groups ($P > 0.05$).

Changes in muscle thickness during the contraction and between the groups

The group had a significant effect on the thickness of the serratus anterior muscle (F = 4.55, P = 0.04). The between-group comparison showed that the serratus anterior muscle in the NHP group had a larger thickness at rest ($P = 0.01$) than in the FHP group, but not during the contraction ($P > 0.12$). No significant effect of group was observed for the thickness of the upper trapezius muscle (F = 0.68, $P = 0.41$) and the lower trapezius muscle (F = 0.01, $P = 0.90$), which indicated that there was no difference in the thickness of the upper and lower trapezius muscles in the FHP group compared with the NHP group at rest ($P > 0.38$) or during the loaded isometric contraction ($P > 0.47$). The loaded isometric contraction condition had a significant effect on the thickness of the serratus anterior muscle (F = 25.41, $P < 0.001$), the upper trapezius muscle (F = 335.06, $P < 0.001$), and the lower trapezius muscle (F = 109.89, $P < 0.001$) compared with the rest condition in all muscles. There was no interaction effect of group × contraction on the thickness of the serratus anterior muscle (F = 0.71, $P = 0.40$), the upper trapezius muscle (F = 0.003, $P = 0.96$), or the lower trapezius muscle (F = 0.09, $P = 0.76$), which indicated that there was a similar rate of change in the thickness of each muscle between the participants with and without FHP. The mean thicknesses of the evaluated muscles are presented in Table 2.

The ICC and SEM values of measured muscle thickness at rest and during loaded isometric contraction are presented in table 3. The intrarater reliability (ICC >0.93) was excellent for serratus anterior and lower trapezius thickness measurements during rest condition and loaded isometric contraction. However, the reliability of the upper trapezius thickness measurements was good during loaded isometric contraction (ICC = 0.82) and moderate at rest condition (ICC = 0.74).

Discussion

This study is the first study to evaluate the extent of morphological changes that occur in the scapular upward rotator muscles in individuals with FHP. The results of this study demonstrated that the thickness of the serratus anterior muscle in the FHP group was decreased compared with the muscle in the NHP group. Based on the theoretical framework linking altered posture to changes in muscle length,[2] we speculated that these findings may be related to differences in the muscle length between the groups. These differences are caused by the biomechanical changes that take place in the cervical spine in FHP. FHP is usually associated with the shortening of the posterior neck extensor muscles and the tightening of the anterior neck muscles.[27] Studies have reported that the levator scapulae, a cervical extensor, tends to have a short length as a postural muscle with a high level of activity in individuals with FHP.[28,29] Therefore, the shortening of this muscle might lead to a downward rotation of the scapula. Consequently, the serratus anterior muscle, as an upward rotator muscle, may be elongated when at rest. The reduced thickness of the serratus anterior muscle could result from the gradual maintenance of this elongated position.[30]

However, the results of this study demonstrated that the thickness of the serratus anterior muscle during the loaded isometric shoulder flexion did not significantly differ between the FHP and NHP groups. It is speculated that under the contraction condition, participants with FHP may require more muscle activity to act as a compensatory mechanism for the reduced muscle thickness at rest.[23,31] In addition, it is possible that individuals with FHP are forced to improve their posture in order to complete their shoulders range of motion. Previous studies reported there was a decreased activity of the serratus anterior muscle in participants with FHP compared with participants with NHP.[1,10,11] One possible reason for this discrepancy may be the fact that EMG records the electrical activity of the muscles, while ultrasound imaging measures the structural changes of the muscles. Because these parameters are different, it seems that recording the electrical activity of a muscle may be more sensitive to small changes than measuring the structural changes. However, there is a possibility of cross-talk and recording the electrical activity from other muscles during the recording of the EMG of muscles.[32] Furthermore, individuals with shoulder pain were excluded from the present study because pain was recognized as a confounding factor due to its inhibitory effects on muscle activity.[33] Therefore, the decreased activity of the serratus anterior muscle observed in patients with concomitant shoulder pain and FHP might have been due to the presence of pain.

Ultrasound measurements of the thicknesses of the upper and lower trapezius muscle at rest and during a loaded isometric contraction did not appear to be significantly altered by the presence of FHP. To our knowledge, this is the first study to report on the thicknesses of scapular muscles in individuals with FHP using ultrasound imaging. Similar to our result, Thigpen et al[10] did not find any statistically significant differences in the EMG activity of the upper and lower trapezius muscles during a loaded flexion and when performing an overhead reaching task between individuals with forward head and rounded shoulder posture and the control group. During elevation of an arm, the trapezius muscles, together with the serratus anterior muscle, produce an upward rotation, external rotation, and posterior tipping of the scapula, all of which are integral to optimal scapular kinematics.[34,35] Therefore, if the activity of the serratus anterior muscle is altered, the activity of the trapezius muscles changes to compensate for this defect.[36,37] In the present study, the thickness of the serratus anterior muscle was not reduced in the FHP group during the contraction condition. Thus, our results showed that there were similar amounts of activity in the upper and lower trapezius muscles between the groups.

However, the result of the present study disagreed with studies that reported a significant increase in the EMG activity of the trapezius muscle in a FHP group compared with a NHP group.[1,11] This discrepancy may be attributed to differences in population, participant positioning, movement patterns, external loads, and measurement techniques. For example, the participants in the present study were asymptomatic individuals without shoulder pain; however, other studies reported alterations in the activities of the upper and lower trapezius muscles in individuals with shoulder pain[36] or in individuals with simulated FHP[1]. Another possible explanation for the discrepancy may be the selection of movement patterns. Differences in the participant's arm position between studies could contribute to variations in the position of the scapula, which would affect the length of the scapular muscles when capturing an image for measuring the thickness of the muscles.[38] In prior studies, the EMG activities of upper and lower trapezius muscles were investigated when the participant was seated with their shoulder elevated in the sagittal plane[1,11] while in the present study, the upper trapezius muscle was measured during elevation of the scapula in the standing position and the lower trapezius muscle was measured during shoulder elevation in the frontal plane in a prone position.

In the present study, participants performed tasks with a 1-kg hand weight to simulate a real-life activity position. In a pilot study, individuals were asked to flex their right shoulder while holding a 2-kg or 1-kg hand weight and to hold the position for 5 s. Some participants complained of discomfort and fatigue in the right upper limb while holding the 2-kg hand weight. Therefore, we used the 1-kg hand weight for the external load for all participants. It is possible that the load in this study may not have provided an equal challenge to the upward rotator muscles of all participants and, thus, may not have required high levels of recruitment of the trapezius muscles.[39] Future research needs to investigate possible differences in large loads.

Limitations

Our study has some limitations that should be considered when interpreting the results. It is important to note that the participants were verbally encouraged to relax the arm when capturing the image of the muscles at rest. However, there was no objective way to determine the relaxation of these muscles. In future studies, a combination of simultaneous ultrasound and EMG might provide more accurate results.[40]

In the present study, it was not possible to image more than one portion of the serratus anterior and trapezius muscles at any one time. Imaging all portions of each muscle would provide a better understanding of the synchronous nature of contraction. However, this method would require multiple transducers and researchers and, thus, would ultimately lack clinical applicability.

Positions used in the present study for ultrasound imaging (arm elevation in frontal plane and in prone position), although recommended, may be a limitation of the present study. Elevating the arm in the sagittal or scapular planes during standing or sitting positions would be more appropriate tasks because they resemble daily activity tasks.

There is some potential measurement error related to landmark palpations.[41] Therefore. The results of the presented study should be interpreted considering this potential error. However, we evaluated the reliability and the standard error of measurements of the investigator measurements. The results were highly reliable giving strength to the findings of the present study.

Another limitation of the present study was that the results were not generalizable to the broad population because the participants in the study were healthy, young females. It is feasible to suggest that the high capability of the young participants in recruiting their muscles prevent us to observe the negative impact of atrophy on the muscle contraction.[42,43] Further research is warranted that involves older individuals with long-term FHP to determine whether time could lead to significant differences in the thickness of the scapular upward rotator muscles.

Conclusion

The present study revealed that FHP alters the ultrasound measurements of the thickness of the serratus anterior muscle at rest. This result provided support for the clinical theory that there is a relationship between FHP and atrophy of the serratus anterior muscle. Further studies are needed to learn more about the relationship of FHP with the imbalance of the shoulder girdle muscles. Research is also needed to assess the impact of head posture on upper quadrant pain.

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Table 1: Participant demographic information

Variables	FHP(Mean ± SD)	NHP(Mean ± SD)	p-value
age	23.00 ± 3.59	22.90 ± 2.57	0.92
weight	57.07 ± 7.17	52.32 ± 8.14	0.058
height	162.97 ± 5.21	161.97 ± 5.36	0.55
BMI	21.49 ± 2.59	19.89 ± 2.62	0.06

FHP = forward head posture, NHP = normal head posture, SD = standard deviation, BMI = body mass index

Table 2. Differences in scapular muscle thickness at rest (in mm) and during loaded isometric contraction between groups

Muscles	**condition**	**NHP (Mean/weight ± SD)**	**FHP (Mean/weight ± SD)**
Serratus anterior	rest	0.12 ± 0.02	0.10 ± 0.03
	contraction	0.14 ± 0.03	0.12 ± 0.03
lower trapezius	rest	0.06 ± 0.02	0.07 ± 0.02
	contraction	0.09 ± 0.03	0.09 ± 0.02
Upper trapezius	rest	0.18 ± 0.02	0.17 ± 0.04
	contraction	0.26 ± 0.03	0.25 ± 0.05

FHP = forward head posture, NHP = normal head posture, SD = standard deviation

Table 3. Intraclass correlation coefficient (ICC) and standard error of the measure (SEM) for the thickness measures of scapular upward rotator muscle in all participants.

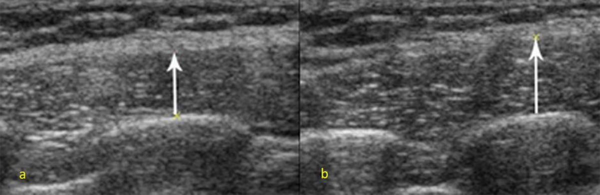
Muscles	Condition	ICC (95% CI)	SEM
Serratus anterior	Rest	0.93	0.008
	contraction	0.95	0.011
lower trapezius	Rest	0.96	0.008
	contraction	0.96	0.009
Upper trapezius	rest	0.74	0.014
	contraction	0.82	0.025

Figure legends

Figure 1. Thickness measurement of serratus anterior in images taken at rest (a) and loaded isometric contraction (b)

Figure 2. Thickness measurement of lower trapezius in images taken at rest (a) and during loaded isometric contraction (b)

Figure 3. Thickness measurement of upper trapezius in images taken at rest (a) and loaded isometric contraction (b)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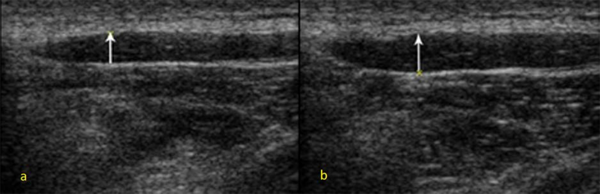
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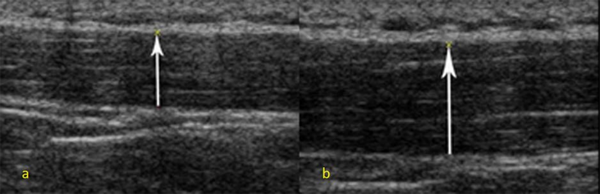
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