Ultrasonography for the assessment of the upper trapezius properties in healthy females: a reliability study

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Summary

Background: to date, an assessment of morphometric features, muscle stiffness and blood flow in the upper trapezius among healthy females at rest and contraction states has not been conducted. So, in the current research, the intra-rater reliability of ultrasonographic features of upper trapezius in healthy females was examined.

Method: in this study stiffness and thickness of the upper trapezius in rest and contraction states were measured by ultrasonography on 12 healthy female subjects (28.33±5.05 years old). Color Doppler imaging was used to assess muscle circulation in the rest state only. Every step and calculation of measurements was repeated 3 times with the same rater. Therefore, in total 36 measurements were done for each variable.

Results: according to the analysis, the value of intra class correlation coefficient (ICC) for total variables showed an excellent level of reliability. Thickness at contraction had maximum reliability (ICC= 0.993) and Minimum Diastolic Velocity had the lowest reliability (ICC=0.771).

Conclusions: the results of current research demonstrated that real time ultrasonography is a reliable method for measurement of various parameters of upper trapezius, including morphometric features, its stiffness and blood supply in non-symptomatic females. These mentioned variables can likely be used for objective assessment and provide numerical reference value for clinical plans.

KEY WORDS: blood flow, stiffness, ultrasonography, upper trapezius.

Introduction

Pain in the shoulder and cervical regions, is one of the prevalent musculoskeletal problems, especially in employed population. Pain and increased muscle tension of the upper trapezius are the most common complains of these people¹. Considering various functional role of this muscle in neck and shoulder movements, its tenderness or increased tension can result in imbalance of the scapular force couples and will cause shoulder or neck pain¹⁻³. There are several factors, including: poor head or shoulder posture, pattern of breathing, dysfunction in temporomandibular joint and arousal states (depressed, anxious) that could affect the function of this muscle or formation of trigger points⁴. It's believed that muscle pain is developed in response to continuous low-level contractions. This form of contraction in people with neck pain could enforce alterations in slow oxidative motor units, including: decreasing in blood flow or capillarization, metabolic changes and mitochondrial disturbances, that may decrease the threshold of nociceptors^{5,6}. On the other hand, endurance training is often consistent with circulation adaptation in the tendon and muscle and lead to increased capacity of aerobic metabolism⁷. So, evaluation of muscles in different rest and contraction states may help us to prevent neck or shoulder pain in susceptible people or control the output of clinical programs in various disorders relevant to neck or shoulder. While, clinical assessment have been routinely used to diagnose muscle or

tendon lesions, imaging tools, such as ultrasound with 93% sensitivity in detection of location or severity of structural injuries have been reported to be more effective in the prediction of recovery time⁸. In other words, the need for more accurate evaluation of neck muscles due to the high probability of injury, lead to the development of imaging techniques⁹.

In the last three decades, there have been lots of studies conducted by researchers in the field of musculoskeletal ultrasonography with the purpose of assessing behavior and morphometric parameters of muscle in clinical programs^{10,11}. Ultrasonography is a suitable noninvasive method for achieving dynamic and real time images of body structures, such as connective tissue, muscle and blood flow parameters¹². Quantification of the mechanical properties of tissues is another ability of ultrasonography devices. Due to the importance of detection of changes in the viscoelastic features of tissue and correlation between structure and function of muscles, it seems that the use of this device is effective^{13,14}. Objective information and real time images from target tissues can help us to increase accuracy of diagnostic decision making, clinical examination and therapeutic intervention selections¹⁵.

According to high incidence of shoulder and neck pain that could be the consequence of changes in blood flow or muscle stiffness and considering no published paper in this area was found, the purpose of the present study is to assess intra rater reliability of ultrasonographic features of upper trapezius, including muscle thickness, elasticity and circulation in healthy females.

Methods and materials

Subjects

Students and staff of School of Rehabilitation who had no history of pain or direct trauma in neck and shoulder regions were invited to participate in this study. Twelve healthy females aged between 19 and 38 (mean $\pm$ SD: 28.33 ± 5.05) with right dominant hand were included in the present study. The protocol and goals of the study which was approved by Ethics committee of Tehran University of Medical Sciences, were explained to participants who signed the consent form. Current study meets the ethical standards of Muscles, Ligaments and Tendons Journal¹⁶.

Ultrasonography

In order to obtain homogenous images from all subjects, the same spot of upper trapezius has been marked. Initially, spinous process of 7th cervical vertebra (C7) and acromion process of right scapula were determined by palpation and then were marked. Afterwards, the distance between these two points was measured and the midpoint of this distance was marked on subjects' skin. After preparation of subjects, ultrasonography was performed. This producer

was classified in 3 steps: 1) Gray-scale or B mode imaging, 2) Ultrasound elastography, 3) Color Doppler imaging.

1) Gray-scale or B mode imaging

Subjects were asked to sit on the chair while they were in an upright and relaxed position. They were instructed to put their forearms in the pronation position on the armrest of the chair. All the images were taken by expert sonographer in the field of musculoskeletal imaging. Linear probe of ultrasonography with frequency of 7-11 MHz (my lab70, xvision, Italy) was used for imaging. Probe of the device was placed on the specified spot (parallel to horizontal fiber of upper trapezius) of the subjects' dominant arm (Fig. 1A). In this position, thickness of upper trapezius was measured. Thickness of muscle is defined as the greatest distance between two hyper echogenic fascial layers (Fig. 2A). This measurement was repeated in contraction state as well (Fig.1B). For this purpose, participants were instructed to maintain shoulder abduction (90°) with external rotation while their thumbs were toward the roof, images were taken and muscle thickness in contraction state was calculated (Fig. 2B).

2) Ultrasound elastography

This step was done in the same position as in the gray scale scanning. The probe was placed on the marked spot of upper trapezius and was compressed rhythmically with the frequency of 2 Hz on this point. With compression of probe, color coded images appeared on the gray scale. Muscle stiffness (tissue de-

Figure 1. Location of ultra-sonogram transducer for imaging of upper trapezius muscle A) in rest position B) in contraction state.

Figure 2. Ultrasonography image for measurement of upper trapezius muscle thickness. A) In resting position; B) in contraction state. Vertical distance between two echogenic fascial layers was marked for measurement of upper trapezius thickness.

formation in response to compression load) was determined by changing the color in this new image. The value of compression force was kept constant based on pressure indicator of ultra-sonogram. According to the classification of stiffness in this set up, the presence of red color was an indication of more stiffed zone and green color was the indication of a softer zone. Proper images were frozen and circle region of interest (ROI) were defined in two different

zones with size of 3-5 mm². Reference ROI was adjusted in the sub cutaneous space and another ROI was located in the bulk of upper trapezius muscle below the reference ROI (Fig. 3). Histogram and strain rate of each region were computed using the device software. Muscle stiffness was calculated with dividing the strain rate of muscle zone by reference zone. Similar to the previous step, muscle stiffness was calculated in contraction state, and this measurement was repeated in 90° of shoulder abduction. Participants were instructed to perform this action and maintain this condition.

3) Color Doppler imaging

Upper trapezius circulation was scanned by color Doppler ultrasonography. Peak Systolic Velocity (PSV), the Minimum Diastolic Velocity (MDV), and Resistance Index (RI) are common measurable parameters in the sono Doppler. The RI is a ratio that is achieved by dividing the difference between peak systolic and minimum diastolic velocities by the peak systolic velocity. Participants were asked to sit in the same position similar to previous steps and the probe was placed in marked location. Mentioned variables were examined in the ascendant part of the transverse neck artery or major arterioles in the visible window, merely in the relaxed position.

For every step, taking images and calculation of measurements were repeated 3 times with a 20 minutes interval. Therefore, in total 36 measurements were done per variable. Indeed, the ability of ultrasonography images for assessing upper trapezius features and morphological parameters were examined in one session in healthy subjects with the same rater.

Statistical analysis

SPSS software version 16.0 was used for data analysis. In order to distinguish normal distribution of variables ($p > 0.05$), one-sample Kolmogorov-Smirnov

Figure 3. Ultrasound elastography of upper trapezius. A circular region of interest (ROI) was adjusted in the (Z1) sub cutaneous space and another ROI was placed in the (Z2) bulk of upper trapezius, then the strain ratio was calculated as $Z2/Z1$. The ultrasonogram image is superimposed onto the B-mode image, displays a color-coded map of elasticity. The color bar in the left of the screen presents the stiffness of the tissues within the ROI, ranging from green (soft) to red (hard).

test was done. Reliability analysis was carried out by Intraclass Correlation Coefficient (ICC) with two way random effects model and 95% confidence intervals. According to Rosner suggestion¹⁷, the value of ICC was subdivided to 3 levels as follow: reliability of <0.4 offers poor reproducibility, 0.4 up to 0.75 shows moderate or fair to good reproducibility and higher or equal to 0.75 illustrates excellent correlation. The numerical value of standard error of measurements (SEM) was calculated for all parameters using bellow formula:

$$SEM = SD \sqrt{1-ICC}$$

Results

In the current study, intra rater reliability of upper trapezius thickness in rest and contraction states, muscle circulation and its stiffness were defined in healthy women. Descriptive data of anthropometric features of healthy subjects which participated in the present study are shown in Table 1. Intra rater single and average ICC, 95% confidence interval and SEM of each variable are reported in Table 2. The ICC scores of total variables in our study had excellent level of reliability. Based on our findings, thickness at contraction state had maximum reliability (ICC= 0.993) and minimum diastolic velocity had the lowest reliability (ICC= 0.771).

Discussion

The results of the current research demonstrated that ultrasonography with explained protocol is a reliable method for measurement of morphometric features of upper trapezius, its mechanical properties and circulation in healthy women. According to our knowledge, the present study is the first research to indicate that images from ultrasonography provide reliable measurements of variable parameters, such as muscle dimension, stiffness and blood flow in non-symptomatic females. But in the current literature, intra rater reliability of female subjects was only examined, therefore, evaluation of inter rater reliability of upper trapezius muscle is recommended in both genders.

Biceps brachii is the first muscle that was evaluated by ultrasonography in 1960¹⁰. This evaluation was continued on other muscles, such as masseter, pelvic floor muscles and lumbar multifidus. Correlation between pathology and muscle size has also been examined in several studies. Some of the relevant studies for measurement of reliability by ultrasonography imaging in neck muscles are explained below.

Evaluation of reliability in measurements of thickness in lower and middle parts of trapezius using ultrasonography were reported in researches of O'Sullivan et al.¹⁸ and Bentman et al.¹⁹. In the study of Bentman et al.¹⁹ 16 healthy subjects and 3 examiners participated. According to their finding, for middle trapezius between examiner reliability was presented

Table 1. Descriptive data of anthropometric features of healthy subjects (N: 12).

	Age(year)	Height(cm)	Weight(kg)	*BMI(kg/m ²)
MEAN(SD)	28.33(5.05)	164.4(4.29)	60.33(10.48)	22.34(3.60)
Range (min-max)	19-38	158-172	41-80	16.46-27.68

*BMI: body mass index.

Table 2. ICC (single and average measurement), confidence interval, p value and SEM of upper trapezius thickness, its stiffness and blood flow in healthy females by use of ultrasonography for intra rater reliability (N=12).

	Single measurement ICC (95%CI)	p value	Average measurement ICC (95%CI)	p value	SEM
Thickness at rest (mm)	0.960(0.898-0.987)	0.000	0.986(0.963-0.996)	0.000	0.28
Thickness at cont (mm)	0.980(0.949-0.994)	0.000	0.993(0.982-0.998)	0.000	0.28
Stiffness at rest	0.588(0.349-0.841)	0.000	0.810(0.498-0.941)	0.000	0.71
Stiffness at cont	0.731(0.451-0.904)	0.000	0.891(0.711-0.966)	0.000	1.10
PSV (cm/s)	0.710(0.417-0.895)	0.000	0.880(0.682-0.962)	0.000	0.61
MDV (cm/s)	0.529(0.178-0.812)	0.002	0.771(0.394-0.928)	0.002	0.56
RI	0.720(0.433-0.899)	0.000	0.885(0.696-0.964)	0.000	0.03

Abbreviations: CI, confidence intervals; ICC, intra class correlation coefficient; SEM, standard error of measurement; PSV: peak systolic velocity; MDV: Minimum diastolic velocity; RI: Resistance Index; Stiffness: strain ratio; cont: contraction state.

within good level (ICC: 0.8 & SEM: 0.94 mm) and same examiner between days reliability indicated in moderate level (ICC: 0.67 & SEM: 1.0 mm). In another study conducted by O'Sullivan et al.¹⁸ which was performed on 16 healthy volunteers, good level for intra-rater reliability and moderate level for inter-rater reliability of lower trapezius were reported. No study – to the best of our knowledge – has used such set of the ultrasonographic scanning to establish the reliability of thickness measurement of upper trapezius.

Ultrasound measurements validity in upper trapezius was examined in another study²⁰. In this research, correlation between MRI and ultrasonography in upper trapezius muscle in C6 level was calculated and a fair level was reported (r: 0.52). Poor correlation between two methods refers to the difference methodology of two imaging techniques (including different subject's positioning and scanning orientation on muscle). Unfortunately, our method was different from their ultrasonography imaging method and there was no possibility for comparison between the results of mentioned study and the present research.

Our method for thickness measurement of upper trapezius in rest condition was similar to the Sikdar et al. study¹³. In their research, measurement was performed on patients with myofascial pain syndrome, while the present study was conducted on healthy subjects, moreover the reliability was calculated in our study. In another study²¹, reliability of ultrasonography on 10 healthy subjects was examined in contraction state. In their study, thickness and cross sectional area (CSA) of cervical multifidus in contraction and rest conditions at different neck levels were measured. Within-subject coefficient of variation was used to assess the reliability and acceptable intra rater reliability in both conditions was reported. Also, based on our analysis in current study in contraction state of upper trapezius, excellent reliability (ICC: 0.993) with small SEM (0.28 mm) was also reported. Reliability of ultrasonography in evaluation of longus colli muscle (15 healthy and 10 patient with neck pain) was investigated in another study²². Variable parameters, such as thickness, CSA and shape ratio were measured. ICC plus SEM were calculated and results of their analysis showed that value of reliability for thickness measurement was good (ICC: 0.60-0.90 SEM: 0.12- 4.38).

Based on critical literature reviews, there are no adequate studies about morphometric features assessment of cervical muscles with ultrasonography²³ which is necessary to be evaluated in future studies. Although MRI was reported as a golden instrument in muscle imaging, finding precise borders of muscles, especially in subjects with low fat is challenging. Therefore, standardization of imaging by ultrasonography seems necessary²⁰.

Quantification of mechanical properties in muscular tissue is one of the advantages of ultrasonography. In our device, muscle stiffness has been determined by deformation of tissues in reply to manual compression stress. One of the studies about the quantifica-

tion of this parameter on upper trapezius with a different method was reported in 2007²⁴. This study was performed on 15 healthy females using myometric and alteration of muscle stiffness by changing position was reported. In another article, validity and reliability of muscle stiffness by ultrasound elastography were examined. In their research, young's moduli of medial gastrocnemius and tissue mimicking material were computed and high level of reliability (ICC: 0.77) was reported for intra and inter rater reliability. Their results confirmed that measuring stiffness using ultrasonography is a reliable and valid method²⁵. In spite of differences of target muscles, the findings of our study (ICC: 0.81 for rest and 0.89 for contraction state) were similar to their results.

Sono Doppler is one of the effective tools to evaluate muscle circulation. Based on our information, there was no published article about reliability of blood flow indices measurement in upper trapezius. Our method was only similar to Sikdar et al. methods¹³ in measurement of blood velocity in the vessels of upper trapezius. Ultrasonography is an accessible and cost effective technique for imaging assessment of muscular tissue and it can be applied as a first level diagnostic instrument in coordination with clinical examination⁸. The results of current research suggest that real time ultrasonography is a reliable method for measurement of upper trapezius features in healthy women. Various parameters, such as muscle thickness, mechanical properties and blood flow can be likely used for objective assessment and provide numerical reference value for exercise settings and clinical plans in various disorders relevant to neck or shoulder. Also our finding from assessment of this muscle may help to prevent neck or shoulder pain in susceptible people. In the present study, intra rater reliability of female participants was only evaluated. This is a limitation of current research, therefore, examination of inter rater reliability ultrasonographic features of upper trapezius is recommended. Effects of individual anthropometrics variables, such as gender, age, BMI, and sport habits should be taken into consideration in future studies. Also, this study should be performed on larger population and other muscles for determination of the reference values of muscle features in both gender.

Conflict of interests

The Authors declare that they have no conflict of interests regarding the publication of this paper.

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References

1. Ballyns JJ, Shah JP, Hammond J, Gebreab T, Gerber LH, Sikdar S. Objective sonographic measures for characterizing myofascial trigger points associated with cervical pain. *Journal of Ultrasound in Medicine*. 2011;30(10):1331-1340.
2. Chester R, Smith TO, Hooper L, Dixon J. The impact of subacromial impingement syndrome on muscle activity patterns of the shoulder complex: a systematic review of electromyographic studies. *BMC musculoskeletal disorders*. 2010; 11(1):45.
3. Merolla G, Cerciello S, Paladini P, Porcellini G. Snapping scapula syndrome: current concepts review in conservative and surgical treatment. *MLTJ*. 2013;3(2):80-90.
4. Wallden M. The trapezius – Clinical & conditioning controversies. *Journal of Bodywork and Movement Therapies*. 2014;18(2):282-291.
5. Cagnie B, Barbe T, De Ridder E, Van Oosterwijck J, Cools A, Danneels L. The influence of dry needling of the trapezius muscle on muscle blood flow and oxygenation. *Journal of manipulative and physiological therapeutics*. 2012;35(9):685-691.
6. Elvin A, Siðsteen AK, Nilsson A, Kosek E. Decreased muscle blood flow in fibromyalgia patients during standardised muscle exercise: a contrast media enhanced colour Doppler study. *European Journal of Pain*. 2006;10(2):137.
7. Rooney SI, Loro E, Sarver JJ, et al. Exercise protocol induces muscle, tendon, and bone adaptations in the rat shoulder. *Muscles, Ligaments and Tendons Journal*. 2014;4(4):413.
8. Maffulli N, Oliva F, Frizziero A, Nanni G, Barazzuol M, Via AG, et al. ISMuLT Guidelines for muscle injuries. *Muscles, Ligaments and Tendons Journal*. 2013;3(4):241.
9. Conforti M, Fachinetti GP. High power laser therapy treatment compared to simple segmental physical rehabilitation in whiplash injuries (1 and 2 grade of the Quebec Task Force classification) involving muscles and ligaments. *Muscles, Ligaments and Tendons Journal*. 2013;3(2):106.
10. Whittaker JL, Stokes M. Ultrasound imaging and muscle function. *Journal of Orthopaedic & Sports Physical Therapy*. 2011; 41(8):572-580.
11. Sikdar S, Turo D, Otto P, et al. Ultrasound Imaging and Elastography for Characterizing Muscle Tissue in Myofascial Pain Syndrome. *PM&R*. 2013;5(9):S133.
12. Shankar H, Cummings C. Ultrasound imaging of embedded shrapnel facilitates diagnosis and management of myofascial pain syndrome. *Pain Practice*. 2013;13(5):405-408.
13. Sikdar S, Shah JP, Gebreab T, et al. Novel applications of ultrasound technology to visualize and characterize myofascial trigger points and surrounding soft tissue. *Archives of physical medicine and rehabilitation*. 2009;90(11):1829-1838.
14. D'Orsi GM, Giai Via A, Frizziero A, Oliva F. Treatment of adhesive capsulitis: a review. *MLTJ*. 2012;2(2):70-78.
15. Brandenburg JE, Eby SF, Song P, et al. Ultrasound elastography: the new frontier in direct measurement of muscle stiffness. *Archives of physical medicine and rehabilitation*. 2014.
16. Padulo J, Oliva F, Frizziero A, Maffulli N. *Muscles, Ligaments and Tendons Journal*. Basic principles and recommendations in clinical and field science research. *MLTJ*. 2013;3(4):250-252.
17. Rosner B. *Fundamentals of biostatistics*. Cengage Learning. 2010.
18. O'Sullivan C, Bentman S, Bennett K, Stokes M. Rehabilitative ultrasound imaging of the lower trapezius muscle: technical description and reliability. *Journal of orthopaedic & sports physical therapy*. 2007;37(10):620-626.
19. Bentman S, O'Sullivan C, Stokes M. Thickness of the middle trapezius muscle measured by rehabilitative ultrasound imaging: description of the technique and reliability study. *Clinical physiology and functional imaging*. 2010;30(6):426-431.
20. O'Sullivan C, Meaney J, Boyle G, Gormley J, Stokes M. The validity of rehabilitative ultrasound imaging for measurement of trapezius muscle thickness. *Manual therapy*. 2009;14(5):572-578.
21. Lee J-P, Tseng W-YI, Shau Y-W, Wang C-L, Wang H-K, Wang S-F. Measurement of segmental cervical multifidus contraction by ultrasonography in asymptomatic adults. *Manual therapy*. 2007;12(3):286-294.
22. Javanshir K, Mohseni-Bandpei MA, Rezasoltani A, Amiri M, Rahgozar M. Ultrasonography of longus colli muscle: A reliability study on healthy subjects and patients with chronic neck pain. *Journal of bodywork and movement therapies*. 2011; 15(1):50-56.
23. Javanshir K, Amiri M, Mohseni-Bandpei MA, Rezasoltani A, Fernández-de-las-Peñas C. Ultrasonography of the cervical muscles: a critical review of the literature. *Journal of manipulative and physiological therapeutics*. 2010;33(8):630-637.
24. Viir R, Virkus A, Laiho K, Rajaleid K, Selart A, Mikkelsen M. Trapezius muscle tone and viscoelastic properties in sitting and supine positions. *Scandinavian Journal of Work, Environment & Health*. 2007;33(3):76.
25. Chino K, Akagi R, Dohi M, Fukushima S, Takahashi H. Reliability and validity of quantifying absolute muscle hardness using ultrasound elastography. *Plos One*. 2012.