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Research Article

Investigating the Reliability of the Measurement of the Cervical Muscle's Echo Intensity

Sedigheh Sadat Naimi[1], **Fateme Bokaee**[2*]

1. Physiotherapy Research Center, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
2. Department of Physiotherapy, School of Rehabilitation Sciences, Isfahan University of Medical Sciences, Isfahan, Iran.

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ABSTRACT

Introduction: The skeletal muscle's echo intensity (EI) is a measurement that can be used to assess the quality of the muscle and any muscle damage caused by training or activity. To determine its reliability, a limited number of studies have investigated the measurement of cervical muscles' EI. This study determines whether the EI of the cervical muscles can be reliably quantified using the Adobe Photoshop software.

Materials and Methods: The mean EI of the cervical muscles was measured using the standard histogram function of Adobe Photoshop CS6 in 20 healthy women.

Results: The measurement of EI of cervical muscles using Adobe Photoshop CS6 is reliable in healthy women (intra-class coefficient >0.9). The values of the standard error of measurements of longus coli, sternocleidomastoid, levator scapula, semispinalis capitis, rectus capitis posterior, and oblique capitis superior muscles were 1.81, 2.09, 1.46, 2.02, 1.47 and 1.26, respectively. The values of the smallest detectable difference of longus coli, sternocleidomastoid, levator scapula, semispinalis capitis, rectus capitis posterior, and oblique capitis superior muscles were 7.11, 8.22, 5.74, 7.93, 5.79, and 4.97, respectively.

Conclusion: Assessing the EI of the cervical muscles with Adobe Photoshop software is a viable method to determine the quality of the muscles.

*** Corresponding Author:**
Fateme Bokaee, Assistant Professor.
Address: *Department of Physiotherapy, School of Rehabilitation Sciences, Isfahan University of Medical Sciences, Isfahan, Iran.*
Tel: *+98 (31) 37925046*
E-mail:*fatemebokaee@yahoo.com*

Introduction

Using imaging modalities, scientists are discovering more about the effects of exercise, illness, aging, and inactivity on skeletal muscle [1]. The gold standard techniques to assess muscle mass include dual-energy x-ray absorptiometry, computed tomography (CT), and magnetic resonance imaging. Modern methods can be used to measure the ratio of non-contractile tissue to contractile tissue to determine muscle quality. The equipment required for these methods is substantial and expensive [2]. Neck pain causes changes in the neck muscles which is why it is essential to look at the morphology of the muscles. These morphological changes may impact the progression of the condition from acute to chronic and treatment strategies [3]. Since muscle quality impacts maximum strength independently of muscle size, researchers have recently focused on muscle quality (i.e. changed fibrous tissue content and intramuscular adiposity) [4]. In individuals with neck discomfort and whiplash-related disorders, evidence showed alterations in muscle quality (increased fatty tissue buildup and fatty infiltration) and a decreased cross-sectional area of the cervical multifidus [3].

Researchers and physicians may benefit from non-invasive imaging methods that measure muscle size and quality [4]. Ultrasound in the brightness (B) mode helps detect changes in skeletal muscle (normal and pathological). Previous studies have shown that ultrasound is faster, safer, and more cost-effective than other imaging modalities [5]. Different ultrasound parameters, including muscle thickness and echo intensity (EI), have been utilized to evaluate adaptation changes due to immobility, age, training, and neuromuscular disorders [5]. Increased intramuscular adipose tissue and qualitative changes can be quantified using EI [6]. Non-contractile components, such as intramuscular adipocytes and fibrous tissue provide the cornerstone of EI's theory of skeletal muscle. EI is increasingly used as a metric for muscle quality or composition in rehabilitation research and exercise physiology [7]. There is growing interest in measuring muscle EI. Muscle EI, size, architecture (pennation angle), and subcutaneous adipose tissue thickness may be measured concurrently due to the widespread access to ultrasonic imaging. Muscle and body composition can be described more accurately using these metrics [7]. EI appears to be a better predictor of functional results than muscle size [8, 9]. Eccentric damage and concentric training-induced growth may be distinguished using EI [10, 11], and EI degrades more rapidly during inactivity [12]. EI may give new insights into how muscle quality affects health and illness. Compared to other technologies (such as CT), ultrasound-derived EI has no restrictive constraints (such as metal implants or pacemakers) and no radiation danger [7].

Gray-scale analysis can be performed to analyze EI to determine intramuscular fat content and fibrous structure [13]. The pixel intensity of various tissues varies. Meanwhile, fibrous and intramuscular adipose tissue appear white (hyperechogenic) [7]. The B-mode US image of normal muscle shows a moderately hypoechoic structure (low EI) [14]. EI is measured as the mean pixel intensity of a muscle calculated by measuring the darkness of a region. Greater EI is linked to increased adipose and intramuscular connective tissue, and the black color denotes high muscle quality [3]. Greater fat and fibrous tissue infiltration and lower muscle quality are associated with greater grayscale [15]. Skeletal muscle function is thought to be influenced by muscle quality. Previous studies demonstrated a significant decrease in muscle strength despite the maintenance of muscle size [7] and during aging, changes in muscle composition were associated with muscle weakness independent of decreased muscle mass or thickness. Extensor muscle strength was correlated with muscle thickness in middle-aged and older people and researchers concluded that EI is a significant criterion for muscle strength [2]. The reliability of the measurement of muscle EI must be established before it can be used in clinical or academic research or decision-making because reliability studies are essential to provide the framework for future muscle quality assessments. Although some previous studies looked into measuring EI in the leg or lumbar muscles, there are only limited studies that examined the accuracy of measuring EI in the cervical muscle [3, 13]. Therefore, it was decided to investigate the intra-rater reliability of EI measurement using the Adobe Photoshop software in healthy women.

Material and Methods

Study participants

A total of 20 female university students in the age range of 20 to 36 years participated in the present repeated measures reliability design. The sample size of this study was 20 as a sample size between 15-25 is good for reliability studies [16]. They were informed about the study via printed advertising. The inclusion criteria were being an asymptomatic female and having 20 to 40 years of age. The exclusion criteria were neck, shoulder, or upper limb pain, history of musculoskeletal or neuromuscular diseases of the cervical spine, history of neck, thoracic,

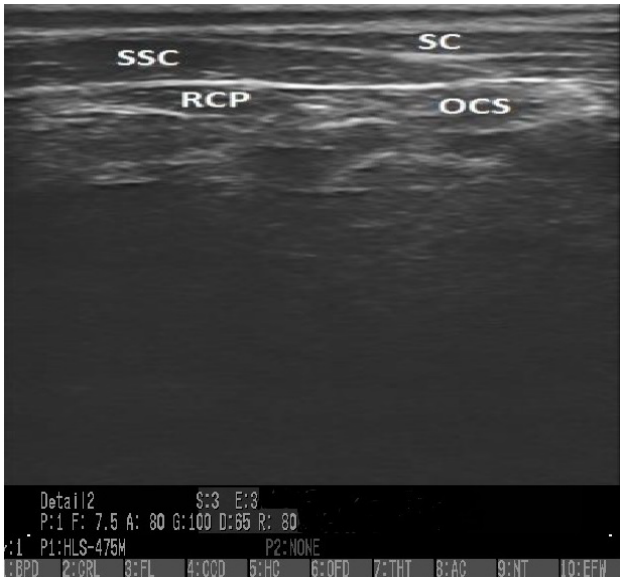

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Figure 1. Ultrasonographic image of the semispinalis capitis, oblique capitis superior and rectus capitis posterior muscles

Abbreviations: SSC: Semispinalis capitis; SC: Splenius capitis; OCS: Oblique capitis superior; RCP: Rectus capitis posterior.

or shoulder pain, history of traumatic injury or surgery of the neck, thoracic, or shoulder area.

Study procedures

Before the study, the objectives and procedures of the study were explained to the participants, and written informed consent was obtained. The present study was conducted in a laboratory setting between October to November 2015.

Ultrasonography images of the cervical muscles, including longus colli (LCo), sternocleidomastoid (SCM), semispinalis capitis (SSC), rectus capitis posterior (RCP), and oblique capitis superior (OCS) were taken using a 7-cm linear probe in the B-mode by an ultrasound scanner (Ultrasonic scanner, HS 2100, Honda

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Figure 2. Ultrasonographic image of the longus colli and sternocleidomastoid muscles

Abbreviations: LCo: Longus colli; SCM: Sternocleidomastoid; CA: Carotid artery.

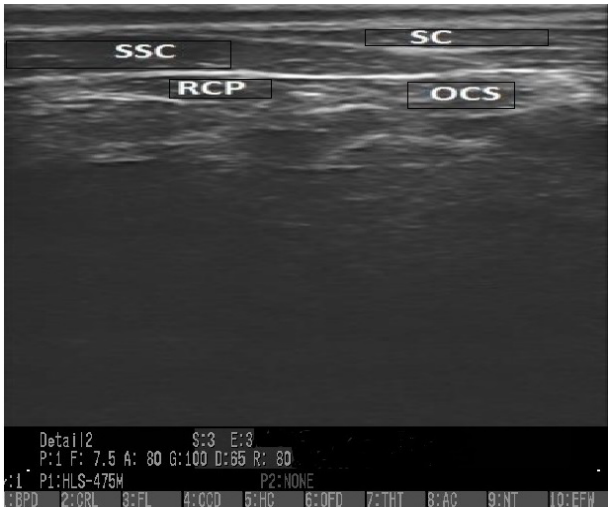

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Figure 3. Detection of region of interest for measurement of echo intensity of the semispinalis capitis, oblique capitis superior, and rectus capitis posterior muscles

Abbreviations: SSC: Semispinalis capitis; SC: Splenius capitis; OCS: Oblique capitis superior; RCP: Rectus capitis posterior.

Electronic Co, Japan; 7.5 MHz). The images were taken by an examiner as they observed the best image on an ultrasonography monitor. The examiner was a PhD. candidate in physiotherapy trained by a musculoskeletal ultrasonography researcher for a year. The participants were instructed to sit on a chair, keep their head and neck in a neutral posture, and retain their knees and hips at a 90-degree angle. The height and width of the chair were 45 cm and 40 cm, respectively. The participants were asked to keep their upper arms by their sides, forearms, and hands on the thigh. The posture of the thoracic spine was a neutral position during the test. The distance between feet on the floor was shoulder width. The examiner placed the ultrasonography probe transversely on the C2 spinous process to take pictures of RCP, OCS, and SSC muscles. A lateral and vertical probing motion was then performed, allowing the examiner to determine the location of the C2 lamina. The examiner angled the probe upwards or downwards to find the RCP muscle. The examiner moved the probe further laterally at the

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Figure 4. Detection of region of interest for measurement of echo intensity of the longus colli and sternocleidomastoid muscles

Abbreviations: LCo: Longus coli; SCM: Sternocleidomastoid; CA: Carotid artery.

Table 1. Demographic characteristics of the participants

Variables	Mean±SD
Age (y)	25.6±5.51
Height (m)	1.63±6.88
Weight (kg)	58.75±9.43
BMI (kg/m²)	22.12±3.69

BMI: Body mass index.

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same level as when measuring the RCP to see the OCS muscle. The picture of the SSC muscle was obtained at this level (Figure 1). The ultrasonography probe was positioned transversely at the C6 level to visualize the LCo muscle. The examiner positioned the probe transversely on the SCM muscle between the origin and insertion of this muscle at the C6 level to take these pictures of the SCM muscle (Figure 2). The probe was placed transversely in the present study for better orientation of the image according to the previous studies [17-19]. Each image was taken with the probe removed and replaced at the same level. Three images of each muscle were frozen and stored for analysis of muscle EI [14]. Cervical muscle images were only obtained on the right side of all subjects because they were all right-handed.

The Adobe Photoshop software was used to measure EI in previous studies and these studies indicated that this software is a reliable software for this measurement [20, 21]. In addition, previous studies evaluated the correlation between the EI of muscle obtained by the Adobe Photoshop software with CT as the gold standard. The results indicated that there were significant correlations between EI obtained by Adobe Photoshop software and CT. These studies suggested that the measurement of EI by Adobe Photoshop software can be substituted for CT in the assessment of muscle composition [21]. The analysis of EI by Adobe Photoshop software is a computer-assisted greyscale analysis of images. In the present study, the mean EI of the muscles on each image was measured by the histogram function of Adobe Photoshop software. In this method, EI is defined as the mean pixel intensity in a region of interest [21]. EI is expressed as a value between 0 and 255. An EI value of 0 represents pure black and a value of 255 represents pure white [22]. Each muscle's EI was measured in a rectangle muscle area, excluding bone and surrounding fascia [14]. This rectangle area was a maximum rectangular region of muscle, excluding bone or surrounding fascia [23]. EI was measured on two separate days. The average value of the mean EI for each muscle was calculated for the statistical analysis (Figure 3 and Figure 4) [24].

Statistical analysis

The authors performed the statistical analysis using the SPSS statistical software, version 16. The intraclass correlation coefficient (ICC), standard error of measure-

Table 2. Reliability of echo intensity of cervical muscles

Muscle	ICC	95% of ICC	SEM	SDD
LCo	0.96	0.93–0.98	1.81	7.11
SCM	0.96	0.93–0.98	2.09	8.22
LS	0.98	0.96–0.99	1.46	5.74
SSC	0.98	0.96–0.99	2.02	7.93
RCP	0.99	0.98–0.99	1.47	5.79
OCS	0.99	0.98–0.99	1.26	4.97

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Abbreviations: ICC: Intra-class correlation coefficient; SEM: Standard error of measurements; SDD: Smallest detectable difference; LCo: Longus coli; SCM: Sternocleidomastoid; LS: Levator scapula; SCC: Semispinalis capitis: RCP: Rectus capitis posterior; OCS: Oblique capitis superior.

ments (SEM), and smallest detectable difference (SDD) were calculated to assess the intra-rater reliability. SEM was calculated as SD×√(1-ICC), and SDD was computed as SEM×1.96×√2.

Results

The demographic characteristics are provided in Table 1. The mean age and height of the participants were 25.6 years and 1.63 m, respectively. The mean weight and body mass index of the participants were 58.75 kg and 22.12 kg/m^2, respectively. The results for the intra-rater reliability are given in Table 2. The results showed that Adobe Photoshop CS6 was reliable for measuring the EI of cervical spine muscles in 20 healthy women (ICC >0.9).

Discussion

In this study, we assessed the reliability of Adobe Photoshop CS6 for measuring EI of images of cervical spine muscles obtained by ultrasonography because the importance of considering EI in the evaluation of muscle function and status has been emphasized in recent years [13]. There is not much research examining the reliability of assessing the EI of the cervical muscles.

In the present study, we used ICC as it has been regarded as the preferred statistical tool for assessing reliability [25]. To assess the EI of cervical spine muscles, the Adobe Photoshop software was proved to be reliable, with ICC values over 0.9 in our study. In addition, we calculated SEM values to assess absolute reliability, which is regarded as the most critical indicator in reliability research. Variability in scores between measurements and measurement error is reflected in SEM. With less reliable measurement SEM values become greater. In addition to the SEM value, the SDD value can reveal fundamental changes and remove measurement errors following treatments, making the SDD value more significant than the SEM value alone [26].

There are very limited studies that evaluated the reliability of Adobe Photoshop software for measuring EI in the spine area. To the best of our knowledge, this research is among the first to measure the reliability of measuring EI in the cervical muscles. Meanwhile, only two studies have investigated the reliability of measuring the EI of cervical muscle. Ahmadipour et al. examined the reliability of muscle EI in the LCo and RCP muscles of 20 women with forward head postures and 20 women without forward head postures. Ultrasonography was used to evaluate the EI of the cervical muscles in their investigation. The ICC, minimal detectable change, and SEM for EI were assessed in this study. The LCo and RCP muscles had ICC, SEM, and minimal detectable change values of between 0.50 and 0.51, 2.73, and 3.41, 7.56, and 9.46, respectively, whereas the RCP muscle had values between 0.48 and 0.49, 3.29 and 4.98, and 9.13 and 13.81, respectively [13]. To explain the discrepancies in reliability indices across different studies, it may be necessary to look at their methods. In the previous study, Ahmadipour et al. employed ultrasonography; however, in the present study, the researchers measured EI using Adobe Photoshop CS6. However, the reliability of EI measurements of cervical muscles was confirmed in both investigations.

Furthermore, Valera-Calero et al. examined intra- and inter-rater rater reliability of the cross-sectional area, perimeter, and EI of deep neck extensor muscles in asymptomatic individuals. The subjects with no symptoms were recruited for this investigation. For cervical multifidus and short rotators, two assessors randomly measured cross-sectional area, perimeter, and echo intensity in two days (one week apart). The ICC, SEM, and MDD were all analyzed. The results showed that in healthy participants, intra-rater and inter-rater reliability of muscle morphology and EI at the C4/C5 level was good-to-excellent [3].

In another study, Sarafraz et al. assessed the reliability of the measurement of EI of lumbar muscles by ultrasonography. The study was conducted on 15 subjects with sciatica and 15 controls. The Results indicated that ICCs ranged from moderate to high for echo intensity measurements [14].

Before generalizing the study's conclusions, it faced several limitations. Our study assessed only the intra-rater reliability of Adobe Photoshop CS6 for measuring EI of cervical spine muscles. More studies are required to assess the inter-rater reliability of Adobe Photoshop software for measuring EI. Only asymptomatic women were studied in this study. We recommend conducting a comparative study on patients (e.g. those with neck discomfort or headache) and women and men of all ages. Similar investigations might give information on the role of the EI of muscles in musculoskeletal disorders and help us evaluate therapeutic options.

Conclusion

The findings of this study show that Adobe Photoshop software may be used to measure the EI of cervical muscles reliably. This technique can be used to determine the

degree of intramuscular fatty infiltration and to assess muscle quality.

Ethical Considerations

Compliance with ethical guidelines

The present study was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences (Code: SBMU.REC.1393.529, 1393/10/14). The objectives and procedures of the study were explained to the participants and signed written informed consent was obtained.

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Authors' contributions

The authors contributed equally to preparing the present article.

Conflict of interest

The authors declared no conflict of interest.

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