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Research Paper: Ultrasonography Method of Deep Cervical Muscles and Thickness Measurement Reliability in Cervicogenic Headache and Healthy Subjects: A Pilot Study

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ABSTRACT

Introduction: In Cervicogenic Headache (CGH), motor control of muscles is impaired and deep upper neck muscles (extensor and flexor muscles) become atrophied. In this research, thickness measurement of Longus Capitis (LCap), Rectus Capitis Posterior Major (RCPM), and Obliquus Capitis Superior (OCS) muscles were conducted and intra-rater reliability of the thickness measurement of these muscles was assessed in CGH and healthy subjects.

Materials and Methods: Twenty subjects, including 10 healthy subjects (19-32 years old) and 10 CGH patients (20-35 years old) participated in this study. LCap thickness was measured at the level of C3-C4 in the supine position and posterior muscles (RCPM and OCS) thickness at the C1-C2 level in the sitting position. All ultrasound images were captured by a linear probe with a 50-mm footprint in B mode option and frequency range of 9-12 Hz. Intraclass Correlation Coefficients (ICC), Standard Error Of Measurement (SEM), and the Smallest Detectable Difference (SDD) were calculated for data analysis.

Results: The ICC for thickness measurement of LCap was from 0.70 to 0.91 (good to excellent), for RCPM thickness was from 0.69 to 0.94 and for OCS muscle thickness was from 0.87 to 0.98. SEM values for LCap were between 0.08 and 0.25 and the SDD values between 0.22 and 0.71. SEM values for RCPM were between 0.22 and 0.43 and these values were reported for OCS muscle between 0.19 and 0.45.

Conclusion: The results indicated that the presented position and the level of ultrasonography in this study are appropriate and ultrasound is a reliable tool to measure the deep upper neck muscle thickness in CGH and healthy subjects.

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1. Introduction

Cervicogenic headache (CGH) is related to musculoskeletal dysfunction of the cervical region and is one type of frequent intermittent headache that affects the community [1]. Its prevalence has been estimated to be between 14% and 18% of all chronic headaches in different studies [2, 3].

Impairment in cervical muscles following neck pain or CGH causes motor control impairment, including changes in the function, structure, and size of the muscles. For example, atrophy of deep extensors [4, 5] and deep flexor muscles consisting of Longus Colli (LCo) and Longus Capitis (LCap) muscles play a major role in cervical segmental stability [6-8].

The size of a muscle may be a good indicator of the muscle strength and ability to do its normal function. Magnetic Resonance Imaging (MRI) and computed tomography scan (CT scan) are expensive tools, needle Electromyography (EMG) is an invasive technique, and surface EMG recording may be influenced by the electrical activity in adjacent muscles [9].

Compared to the mentioned tools, ultrasound is a very cost-effective, noninvasive, and feasible method with acceptable reliability in the evaluation of deep muscles [10, 11]. Therefore, it has converted to a clinical tool to help therapists to diagnose motor control dysfunction [12].

Ultrasonography has been successfully used to measure different aspects of muscle morphology, including Cross-Sectional Area (CSA) and various dimensions of muscle in the cervical region, in healthy subjects, in patients suffering from neck pain [9] and CGH [13]. Measurement of the muscle size by ultrasound can provide an objective assessment of muscular atrophy and hypertrophy [14] and muscle thickness is highly correlated with CSA and strength in many muscles [15-18]. Ultrasound has been used to assess the size and dimensions of different posterior and anterior cervical muscles in healthy subjects, patients with neck pain, and frequent intermittent headache [8, 10, 13, 19-23].

Deep anterior and posterior upper cervical muscles act in synergy in upper cervical rotation motion [24] that is being impaired in CGH [4, 7]. However, no study was found that investigated the deep upper cervical muscle thickness associated with the stability and mobility of this region and its measurement reliability, in CGH subjects by ultrasonography.

The purpose of this study was to introduce a suitable method and position for LCap, Rectus Capitis Posterior Major (RCPM), and Obliquus Capitis Superior (OCS) muscle ultrasonography. Also, we want to evaluate the within-day and between-days reliability of these muscle thickness measurements for diagnostic aims in patients suffering from CGH.

2. Materials and Methods

In this methodological (cross-sectional) study, 20 subjects, including 10 healthy individuals (19-32 years old) and 10 CGH patients (20-35 years old) participated. The method of sampling was a convenience sampling method and the maximum sample size was determined according to a similar study [23]. The subjects joined the research team voluntarily via an advertisement in the university. The healthy subjects were selected from students with no history of neck pain or headache or other structural changes in the cervical region. The CGH patients were selected from university students and patients in physiotherapy clinics in university.

CGH criteria were according to the Cervicogenic Headache International Study Group (CEHISG) criteria, including a unilateral headache with a cervical range of motion reduction, particularly rotation of the upper cervical part, cervical pain in external pressure/palpation, and limitation of the physiological passive movements in the upper cervical segments, and at least 3 months duration of headache [25].

Study Subjects

Healthy subjects and CGH patients aged 18-35 years with a BMI of 16–32 kg/m^2 were included in this research.

CGH subjects would not be included if they had problems such as torticollis, thoracic scoliosis, uncorrected visual or auditory impairment, myopathic disorders, or a history of cancer, diabetes, or pulmonary diseases. Patients suffering from other types of headaches, cervical radiculopathy, myelopathy, fibromyalgia, and severe cervical osteoarthritis were not included in this study, as well [13]. Subjects would be excluded from the study if their headache got worse, developed a sensitivity to ultrasound gel, or were unwilling to continue the study.

Ultrasonography

The real-time B mode ultrasound device (SonoAce R7-Samsung Medison 2014, South Korea) was used with a

bandwidth frequency of 9-12 MHz (resolution frequency) in the depth of 4 cm for posterior muscles and 4.5 cm for anterior muscle, by a linear probe with 50 mm footprint, perpendicular to the muscle surface. In this study, the thickness of the muscles was identified as the maximal distance between the fascias surrounding the anterior to posterior direction.

For ultrasound evaluation of the RCPM and OCS, the subject sat on the chair with his or her head in the neutral position [21]. The first prominence that is touched after the occiput is C2, the probe was placed in the distance between the occiput and C2 and it was moved laterally to determine the lamina of the first and second cervical vertebrae that were seen whiter from other structures. The probe was moved up and down to specify the edge of the RCPM. To determine the edge of the OCS muscle, the examiner moved the probe superiorly and laterally. Both muscles were seen as an oval shape (Figures 1 and 2).

For the LCap muscle imaging, the subjects were positioned supine on an examination table with both arms lying along the sides of the body and head and neck in the neutral position. A folded towel was placed under the head so that it was elevated from the examination table by 3-4 cm [13]. The images were taken at the C3-C4 level in the anterior cervical part in both sides separately in the relaxed position of the muscle and the probe with a sufficient amount of gel, to prevent additional compression of the tissue was placed perpendicular to the long axis of the muscle. To make sure the probe was in the right position, after training, the subject contracted the deep neck flexor muscle (nodding) and then relaxed it. The probe was moved from the center outwards and an image was taken when the appropriate view was reached (Figure 3). The outlines of the LCap were identified by the carotid artery on the inside of the muscle, LC muscle at the bottom, and sternocleidomastoid (SCM) above the LCap muscle (Figure 4).

Each muscle was scanned three times; two images were taken on one day with an interval of 2 hours (for within-day reliability) and the third image was taken 2 days later (for between-days reliability). Additionally, each time measurements were repeated three times and their average was recorded to avoid possible errors. The ultrasonography measurements were performed by an expert physiotherapist with 7 years' experience in musculoskeletal ultrasonography.

Data management and analysis

The independent t test was used to investigate the thickness differences between groups. The average measurement of ICC, with a confidence interval of 95% and a significance level of 0.05 was used to measure within-day and between-days reliabilities.

SEM and SDD (minimum amount of change in a person's score that ensures the change is not the result of measurement error) were used to test the reliability of the measurements of the muscles thickness using ultrasound at rest. The SD used in the SEM formula is the average value of SD in two measurements in ICC calculation.

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

$$2)\ SDD=1.96\times\sqrt{2}\times SEM$$

According to Rosner (2006), the ICC <0.4 indicates poor reliability, 0.4-0.75 shows fair to good and >0.75 depicts excellent reliability [26]. Also, the Bland and Altman method by 95% confidence interval (95% CI) of the range of differences between the two measurements was used as another method for better expressing the reliability results, which describes the agreement between measurements in different sessions [27]. The obtained data were analyzed in SPSS V. 16.

3. Results

Table 1 presents the demographic characteristics of the participants. Also, the descriptive analysis of variables and the mean thickness of the muscles (RCPM, OCS, and LCap) were shown in Table 1. All variables had a normal distribution in both groups, so the parametric tests were used for analysis.

All three muscles intra-rater reliability of thickness measurement was good to excellent (ICC=0.69- 0.98) in this study. The exact results of ICC with standard deviation, SEM, and SDD for within-day and between-days reliability of thickness measurement of muscles were presented in Tables 2, 3, and 4 for muscles, sides, and groups.

The limits of agreement (Bland and Altman method) were defined as the mean difference between the two Mean±SD, Which are drawn in two lines. This is better that, these two lines were closer together ; this means that the mean difference should be zero or there is no significant difference between two means. In the observations that are higher or lower than these lines (are outside of these lines), the difference between two observations is more than the amount that can be attributed

Table 1. Demographic characteristic, the thickness of RCPM, OCS, and LCap muscles

Variables	Mean±SD	
	Healthy (n=10)	CGH (n=10)
Age (y)	24.60±4.76	25.10±4.45
BMI (kg/m^2)	21.60±2.54	22.10±3.41

Side	Mean ±SD			
	Left	Right	Left	Right
RCPM (cm)	7.38±0.90	7.01±1.01	6.82±0.71	6.70±0.84
OCS (cm)	9.71±1.29	9.46±1.15	9.01±1.20	8.86±0.94
LCap (cm)	4.35±0.47	4.27±0.51	4.07±0.32	4.04±0.26

JMR

CGH: cervicogenic headache; RCPM: rectus capitis posterior major; OCS: obliquus capitis superior; LCap: longus capitis.

Table 2. The results of within-day and between-days reliability for the left and right RCPM thickness in the healthy subjects and CGH patients

Groups	Sessions	ICC[3]±SD		SEM		SDD %95	
		Left	Right	Left	Right	Left	Right
Healthy	Within day	0.90±1.01	0.90±1.06	0.33	0.34	0.90	0.93
	Between days	0.93±0.96	0.82±1.00	0.25	0.43	0.69	1.19
CGH	Within day	0.92±0.85	0.94±0.88	0.23	0.22	0.65	0.60
	Between days	0.69±0.76	0.78±0.93	0.42	0.44	1.17	1.21

JMR

RCPM: rectus capitis posterior major; CGH: cervicogenic headache; ICC: intraclass correlation coefficients; SEM: standard error of measurement; SDD: the smallest detectable difference with 95% confidence interval.

Table 3. The results of within-day and between-days reliability for the left and right OCS thickness in the healthy subjects and CGH patients

Groups	Sessions	ICC[3] ±SD		SEM		SDD %95	
		Left	Right	Left	Right	Left	Right
Healthy	Within-day	0.94±1.31	0.87±1.23	0.31	0.45	0.86	1.25
	Between-day	0.98±1.30	0.89±1.24	0.19	0.42	0.53	1.17
CGH	Within-day	0.89±1.26	0.96±1.03	0.41	0.22	1.15	0.60
	Between-day	0.95±1.16	0.94±0.93	0.27	0.24	0.74	0.66

JMR

OCS: obliquus capitis superior; CGH: cervicogenic headache; ICC: intraclass correlation coefficients; SEM: standard error of measurement; SDD: the smallest detectable difference with 95% confidence interval.

Table 4. The results of within-day and between-days reliability for the left and right LCap thickness in healthy subjects and CGH patients

Groups	Sessions	ICC ±SD		SEM		SDD 95%	
		Left	Right	Left	Right	Left	Right
Healthy	Within-day	0.76±0.47	0.91±0.58	0.23	0.17	0.64	0.48
	Between-days	0.81±0.58	0.78±0.55	0.25	0.25	0.70	0.71
CGH	Within-day	0.84±0.29	0.93±0.29	0.11	0.08	0.32	0.22
	Between- days	0.86±0.31	0.70±0.31	0.12	0.17	0.32	0.47

JMR

LCap: longus capitis; CGH: cervicogenic headache; ICC: Intraclass correlation coefficients; SEM: standard error of measurement; SDD: the smallest detectable difference with 95% confidence interval.

to chance and the two observations have a significant difference [27].

Figures 5-10 illustrate an agreement between thickness measurements of RCPM, OCS, and LCap for within-day and between-days evaluations. According to the Figures, examining the results of two evaluations in the patient or healthy group in the first, second or third observations, showed the mean of measurements is within the two lines (Mean±SD) and indicates good reliability.

Discussion

The present study is the first one that specifically investigates the reliability of ultrasonography in posterior and anterior upper cervical muscles as synergy in cervicogenic headache patients that showed good to excellent reliability in this regard.

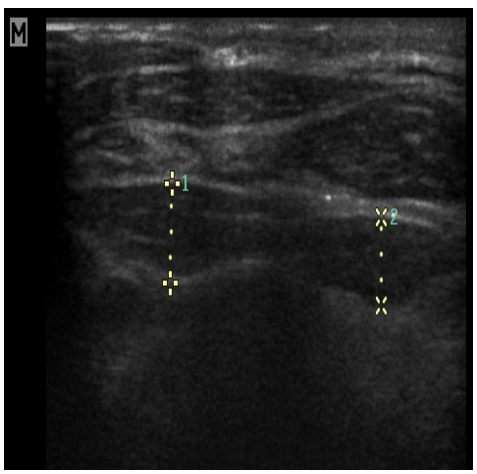

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Figure 1. Ultrasonography imaging of 1- obliquus capitis superior, 2- rectus capitis posterior major muscles in the left side.

Posterior muscles

Several studies have examined cervical muscle dimensions using ultrasonography. Rankin's study [14] reported ICC values of 0.98 and 0.99, respectively for within-day and between-days reliability for deep posterior muscles (semispinalis cervicis, multifidus, and rotators) and Semispinalis Capitis (SECM) in the prone position in five healthy subjects. Larger sample size and comparison of two groups (CGH and healthy subjects) are the strengths of the present study compared with their study that was more similar to the Rezasoltani study [5]. He measured the size, anterior-posterior dimension (APD), and Lateral Dimension (LD) of the SECM in two healthy and neck pain groups in the sitting position, and reported the high reliability of LD and thickness measurement (0.86<ICC <0.95). To find out which position is better, Rezasoltani [21] showed that different sitting and prone position did not affect CSA measurement

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Figure 2. The subject's position for obliquus capitis superior, and rectus capitis posterior major muscles imaging.

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Figure 3. The subject's position for longus capitis muscle imaging

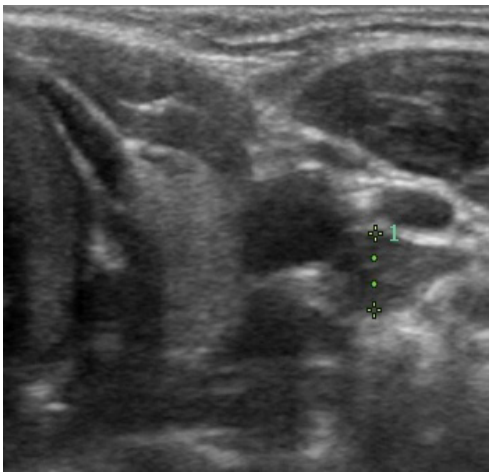

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Figure 4. Ultrasonography imaging of longus capitis muscle

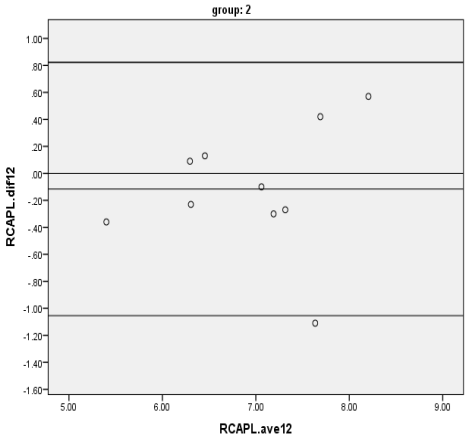

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Figure 5. The first and fourth lines are the Mean±SD (mm) and the second and third lines show the average of the first and second measurements of rectus capitis posterior major thickness on the same day in the cervicogenic headache group.

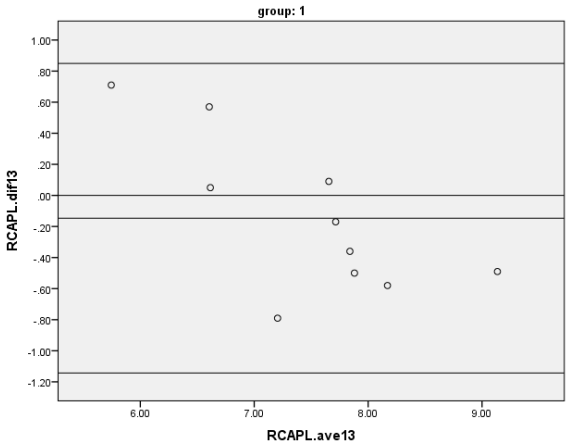

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Figure 6. The first and fourth lines are the Mean±SD (mm) and the second and third lines show the average of the first and third measurements of rectus capitis posterior major thickness measured 2 days later in the healthy group.

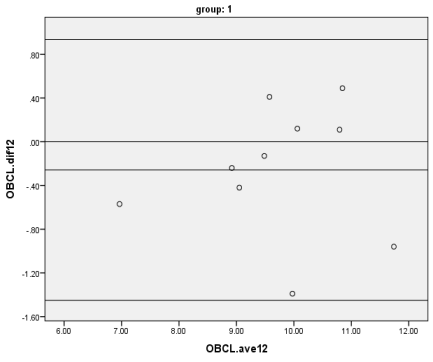

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Figure 7. The first and fourth lines are the Mean±SD (mm) and the second and third lines show the average of the first and second measurements of OCS thickness measured on the same day in the healthy group.

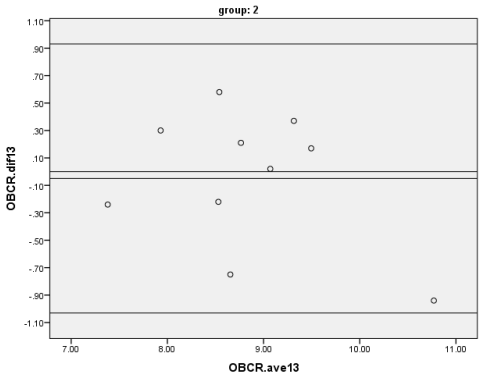

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Figure 8. The first and fourth lines are the Mean±SD (mm) and the second and third lines show the average of the first and third measurements of OCS thickness measured 2 days later in the cervicogenic headache group.

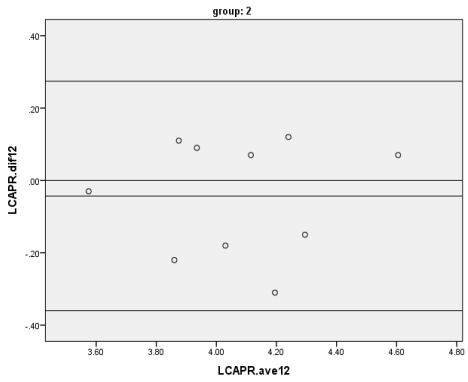

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Figure 9. The first and fourth lines are the Mean±SD (mm) and the second and third lines show the average of the first and second measurements of LCap thickness measured on the same day in the healthy group.

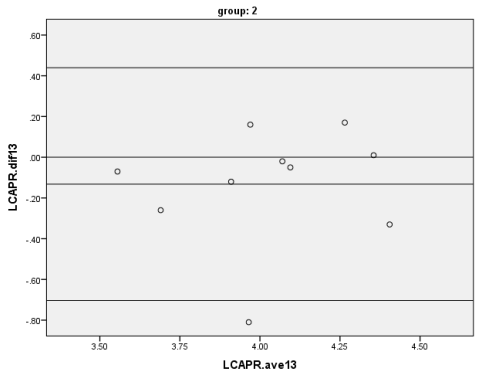

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Figure 10. The first and fourth lines are the Mean±SD (mm) and the second and third lines show the average of the first and third measurements of LCap thickness measured 2 days later in the cervicogenic headache group.

and the ultrasonography reliability was excellent in both positions. In the present study, the sitting position on the chair was used but the muscular layers were deeper than the Rankin and Rezasoltani studies.

In the other reliability study of measuring the thickness of the dorsal upper cervical muscles (RCPM, OCS, SECM, and splenius capitis) for upper cervical extension in the sitting position, Lin et al. reported that ICC was 0.89-1 for within-day and 0.66-0.98 for between-days reliability [22]. The lower ICC of the OCS thickness measurement in Lin's study was because of the lack of bony landmarks and between-subjects variations. In the present study, the ICC of the RCPM muscle was 0.69 in the CGH group, while this value was 0.93 in the healthy subjects. The reason for this difference could be muscular atrophy and fatty infiltration in the patients' muscles, which impedes the detection of muscle borders. Besides, in this study, the probe was placed on the vertebrae and by searching and moving it to the lateral, the first oval muscle observed was RCPM, and the next oval muscle along the RCPM was OCS. Two muscles looked like eyeglasses, hence, the detection of OCS muscle and its imaging would be easier and more accurate.

In the Cho study [28] on the reliability of the cross-sectional area (CSA) measurement of the obliquus capitis inferior (OCI) muscle, ICC was found 0.73 in 20 healthy subjects. The reason for large SD (0.51) and low ICC for OCI in this study was the difficulty in distinguishing the muscular plane of OCI from the surrounding musculature in static images [28]. In the present study, OCS muscle was assessed at the C1 level, so its fascial boundary was clearer than OCI and ICC value in size measurement of this muscle was better than OCI in the Cho study.

Furthermore, similar to the present study, Overas et al. [29] reported good intra-rater and good to poor inter-rater reliability for the thickness measurement of deep cervical (Dce), RCPM and LCo muscles in patients with neck pain. Probably the lower reliability for the RCPM and Dce maybe because of morphological changes, as fat infiltration in these muscles that may make anatomical landmarks unclear and muscle borders more difficult to define [29]. Although only the intra-rater reliability for thickness measurement of OCS, RCPM, and LCap was examined in the present study, good to excellent values of ICC were obtained for all muscles.

Anterior muscle

Different studies have been conducted on deep cervical flexor (DCF) muscles, especially the LCo muscle, but due to the findings of the research team, few studies have conducted about LCap muscle. This study has focused on the LCap muscle and examined the thickness measurement reliability of this muscle, that is innervated by upper cervical nerves and impaired in CGH patients [7].

However, due to the lack of resources for this muscle, the authors have to discuss the DCF muscles in general. The results of this study are similar to the results of Jesus study [11] that investigated the DCF muscles thickness in healthy individuals and the subjects performed the craniocervical flexion test (CCFT), and changes in thickness from the resting baseline position to the full contraction in five incremental stages of the test were seen for DCF and SCM muscles using ultrasonography. These changes were expressed in different levels of contraction (CCFT) without providing any information about the exact thickness and separate assessment

of these muscles [11]. However, in the present study, the exact value of thickness and reliability of the measurement of LCap was assessed and reported.

In the other similar study, Cagnie showed that ultrasound measurements of the LCo muscle size at the C5-C6 level in healthy people were moderate (ICC=0.68-0.71) [30]. In this study, measurements were taken in a single session, which could increase the measurement error and therefore higher reporting of SEM and SDD. Hence, repeating the measurements for at least three times may reduce the error rate. This procedure has been done in the present study. However, the Javanshir [31] and Abaspour [13] conducted similar studies. Javanshir reported excellent reliability (ICC of 0.82-0.93) for within-day and between-days reliability for measuring LCo muscle CSA at the C6 level in the healthy and subjects with non-specific chronic neck pain [31]. Abaspour reported that the reliability of the ultrasound measurement of LCo was 0.84-0.98 in patients with CGH [13].

The higher reliability of ultrasonography measurement in these studies persuaded us to use the same method and position to measure the thickness of LCap in the present study, except for the fact that measurements were done at the C4 level in this study, to ensure that the LCap was measured separately without mixing with the LCo muscle.

Limitation and recommendation

As a limitation of this study, we did not compare muscle thickness and its reliability in different contraction states with pressure biofeedback. It is recommended that these issues be investigated in future studies.

5. Conclusion

The results of this study suggested that ultrasonography is a reliable, cost-effective, and appropriate method to diagnose deep cervical muscle dysfunction in CGH. Besides, the ultrasonography protocol of the present study, the position, and measurement level can be used with high confidence in future studies.

Ethical Considerations

Compliance with ethical guidelines

All participants signed an informed consent form and ethical clearance was sought from the Medical Ethics Committee of Iran University of Medical Sciences (Ethical Code: 1395.9211342209)

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Authors contributions

Conceptualization: Aabaspour, Akbari, Rezasoltani; Methodology, writing - review & editing: All author; Investigation, writing - original draft: Abaspour; Resources: Abaspour, Akbari; Supervision: Akbari.

Conflict of interest

The authors declared no conflict of interest.

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