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Original Article

Reliability of ultrasonography measurement for the longus colli according to inward probe pressure

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Abstract. [Purpose] To investigate the intra- and inter-rater reliability of the cross-sectional area (CSA) and muscle thickness (MT) of the longus colli according to the inward pressure of an ultrasonography (US) probe (0.5 and 1 kg). [Subjects] Thirteen subjects (11 males and 2 females; age, 23.1 ± 2.9 years) were recruited via convenience sampling of university students. [Methods] Real-time US measurements of the CSA and MT of the longus colli were recorded. Repeated US measurements using a standard protocol were performed on the same day 1 hour apart to assess intra- and inter-rater reliability. Intra-class correlation coefficients (ICC; 2, 1) were used to determine the intra- and inter-rater reliability of the CSA and MT measurements. [Results] This study demonstrated that the US measurements (0.5 and 1 kg) of the CSA and MT of the longus colli give reliable and consistent results. [Conclusion] Based on these results, a consistent inward pressure of the probe is needed to ensure precise US measurement of the longus colli muscle.

Key words: Inward pressure, Longus colli, Ultrasound

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INTRODUCTION

Owing to the multi-directional movement of the cervical spine, it must be mechanically stable under both static and dynamic conditions[1)]. To accomplish cervical stability, deep and segmental cervical muscles, such as the longus colli, are important for the control and support of cervical alignment and postural maintenance[2–4)]. Longus colli muscle dysfunction, including a lack of strength and endurance, has been demonstrated in patients with neck pain and whiplash injury[5–7)].

To measure the longus colli muscle strength, the cranio-cervical flexion test using bio-feedback pressure, magnetic resonance imaging (MRI), electromyography, and ultrasonography (US) have been used[8–11)]. Of these measurement techniques, US is the most cost-effective and feasible method for tissue measurement, which is visualized in real-time. Measurements can be obtained when muscle are relaxed or contracting as well as during movement[12)]. On US measurement, cross-sectional area (CSA) and muscle thickness (MT) are commonly used to quantify longus colli muscle strength[13, 14)].

The US measurement must be reliable and sensitive to provide accurate and relevant information[15)]. Previous studies found moderate reliability and questionable validity in longus colli muscle measurement using US and MRI[12)]. Therefore, greater accuracy may be required when measuring the CSA and MT. To ensure an accurate measurement, steady probe position, orientation, and inward pressure are required during US[16)]. Previous studies reported that the examiner should attempt to maintain consistent inward pressure of the probe to quantify the minimal change in MT on US measurements[17, 18)].

To our knowledge, no study has investigated the effects of different inward US probe pressure on the longus colli muscle (CSA and MT). Therefore, the purpose of this study was to investigate the intra- and inter-rater reliability of measurements of the CSA and MT of the longus colli according to the inward US probe (0.5 and 1 kg).

SUBJECTS AND METHODS

Thirteen subjects (11 males and 2 females) were recruited via convenience sampling of among a university student population. The subjects' characteristics are presented in Table 1. The exclusion criteria were: 1) neuromuscular or musculoskeletal disorder; 2) history of clavicle fracture, metal implant, or surgery; and 3) current neck pain. The principal investigator explained the procedure to the subjects prior to the experiment using detailed written and verbal in-

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formation, and all subjects signed an informed consent form. The study was approved by the Yonsei University Wonju Campus Human Studies Committee.

Real-time US (SONOACE X8, Medison, Inc., Seoul, South Korea) was used to measure the CSA and MT of the right longus colli in the M-mode with a 4.5 cm, 5–12 MHz linear probe head (L5-12EC). This was connected to a screen that showed an image of the consistent inward pressure of the US probe at 0.5 and 1.0 kg. The spring gauge (Kirin Co. Ltd., Seoul, Korea) was suspended from a perpendicular fixed bar. The spring gauge had a force-measuring capacity 0.0–30.0 kg in 0.1 kg increments. The probe was secured to the end of the spring gauge using non-elastic sports tape (BSN Medical, Hamburg, Germany) between the fixed bar and the spring gauge. A hands-free probe holder (high-density foam cube) was used to improve the accuracy of US.

The subjects were placed in a neutral supine position with their knees and hips bent and arms along the sides of the body. To make cervical lordosis, a folded towel was used to support the posterior neck. The inward pressure was set at 0 kg in contact with the skin during the application of the probe while a height-adjustable table was used to precisely apply the two different inward pressures (0.5 and 1.0 kg) using a spring gauge to produce consistent pressure.

For the cross-sectional area, the probe was positioned perpendicular to the long axis of the anterior neck. The bottom of the laryngeal prominence of the thyroid cartilage, which corresponds to the C5 level, served as a reference point. To measure the thickness of the longus colli muscle, the probe was positioned longitudinally on the anterior of the neck parallel with the trachea and approximately 5 cm from its midline. The US image of the longus colli muscle was captured, stored, and measured by two experienced examiners, who were both therapists with clinical orthopedic physical therapy experience of 5 and 2 years, respectively. To minimize bias, the examiners collected the measurements in a separate room and were blinded to each subject's information and each other's results. Examiner training sessions were conducted by the principal investigator to ensure familiarization with and standardization of the US measurements, including the precise location of the landmarks to reduce measurement errors. The study protocol was explained simultaneously in the 1-hour training session prior to the testing.

Repeated US measurements using the same protocol were performed to assess intra- and inter-rater reliability on the same day with an 1-hour break between them. Each examiner measured the US image (i.e., CSA and MT) under both the 0.5 and 1.0 kg conditions once for each subject in a given session. The examiners were blinded to their own previous findings as well as the US measurement results. The order of the measurements and examiners was randomized using a random number generator (Excel, Microsoft Corp., Redmond, WA, USA). Calipers were used to measure the CSA and MT in centimeters.

The mean and standard deviation (SD) of each subject's characteristics and US image (CSA and MT) data were calculated. Intra-class correlation coefficients (ICC 2, 1) were used to determine the intra- and inter-rater reliability of the CSA and MT measurements. Intra-rater reliability was calculated across test sessions by examiner 1. Inter-rater reliability was calculated across raters in test session 1. For the purpose of interpretation, an ICC > 0.75 was considered "excellent", 0.40–0.75 was "fair to good", and 0.00–0.40 was "poor"[19]. The standard error of measurement (SEM) was calculated for each measurement to assess absolute consistency [SEM = SD$\sqrt{1 - ICC}$]. The minimum detectable difference (95% confidence interval; MDD^{95}) scores were calculated [$MDD^{95} = SEM \times \sqrt{2} \times 1.96$][20]. Statistical analyses were performed using SPPS for Windows software (ver. 18; SPSS Inc., Chicago, IL, USA).

Table 1. Descriptive data (N = 13)

	Mean ± SD	Range
Age (years)	23.1±2.9	20–28
Height (cm)	169.8±9.9	153–187
Weight (kg)	64.9±12.7	46–88

SD: standard deviation

Table 2. Intra-rater reliability of the CSA and MT of the longus colli according to inward probe pressure of US

	Examiner 1			
	CSA		MT	
	0.5 kg	1.0 kg	0.5 kg	1.0 kg
ICC	0.99	0.99	0.98	0.96
SEM	0.01	0.02	0.00	0.05
MDD^{95}	0.04	0.05	0.01	0.14

CSA: cross-sectional area; MT: muscle thickness; ICC: intra-class correlation coefficient (95% confidence interval); SEM: standard error of measurement; MDD^{95}: minimum detectable differences (95% confidence interval)

Table 3. Inter-rater reliability of the CSA and MT of the longus colli according to inward probe pressure of US

	Test session 1			
	CSA		MT	
	0.5 kg	1.0 kg	0.5 kg	1.0 kg
ICC	0.98	0.99	0.97	0.96
SEM	0.02	0.02	0.01	0.05
MDD^{95}	0.06	0.05	0.02	0.15

CSA: cross-sectional area; MT: muscle thickness; ICC: intra-class correlation coefficient (95% confidence interval); SEM: standard error of measurement; MDD^{95}: minimum detectable differences (95% confidence interval)

RESULTS

The longus colli muscle measurement data (ICC, SEM, and MDD^{95}) are shown in Tables 2 and 3.

DISCUSSION

The purpose of the present study was to determine intra- and inter-rater reliability of measurements of the CSA and

MT of the longus colli according to the inward pressure of the US probe (0.5 and 1 kg). We believe that this study is the first to investigate these parameters in this manner.

Concerning the intra- and inter-rater reliability, the present study demonstrates that US measurements (0.5 and 1 kg) of the CSA and MT of the longus colli have excellent reliability due to the experimental protocol used. First, the spring gauge provided consistent inward probe pressure that enabled precise and consistent measurements. Additionally, a height-adjustable perpendicular fixed bar was helpful in the adjustment of the precise probe height, with respect to its contact with the surface of the skin over the longus colli in response to different degrees of inward pressure. A previous study suggested that US requires a strict measurement protocol because slight angulations of the probe and variations in the probe pressure exerted on the underlying muscle greatly influenced the images produced[10]. Ishida and Watanabe[18] reported that maintenance of a consistent inward probe pressure is required to enhance the reliability of US measurements of the lateral abdominal muscle. Jeon et al.[17] suggested that maintaining a consistent inward pressure is essential to ensuring the reliability of the results when the MT of the psoas major is measured by different examiners. Second, the hands-free probe holder can also affect reliability: to steady the position, orientation, and inward pressure of the US probe, a hands-free probe holder is required during US measurements[16–18]. Hands-free probe holders may be better able to prevent US measurement errors than hand-held probes.

The present study had several limitations. First, our results are not widely generalizable because all of the participants were healthy students. Thus, additional research is needed to establish whether our findings apply to participants with neck pain. Second, the present study was performed when the muscle was relaxed. Thus, further studies are necessary to assess the muscle contraction status.

The present study demonstrated that US measurement of the CSA and MT of the longus colli has excellent intra- and inter-rater reliability when a consistent inward pressure is maintained. Based on these results, a consistent inward probe pressure must be maintained to enable precise US measurement of the longus colli muscle.

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