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Original Article

The reliability and effectiveness of shoulder joint evaluation by ultrasonography in stroke patients: deltoid muscle thickness, acromion-humeral distance, acromion-lesser tuberosity distance

Shan Liu, PT, MS[1]*, Jing Chen, PT[2], Hualong Xie, PT, PhD[3], Qiuchen Huang, PT, PhD[4],
Meng Ge, PT, MS[1], Lu Yin, PT, MS[1], Mingdong Zhang, PT, PhD[5], Ming Huo, PT, PhD[6],
Ko Onoda, PT, PhD[1], Hitoshi Maruyama, PT, PhD[1]

[1] Department of Physical Therapy, International University of Health and Welfare: 2600-1
    Kitakanemaru, Otawara city, Tochigi 324-0021, Japan
[2] The Affiliated Hospital of Inner Mongolia Medical University, China
[3] Wangjing Hospital of China Academy of Chinese Medical Sciences, China
[4] China Rehabilitation Research Center, China
[5] ChangChun University of Chinese Medicine, China
[6] Department of Physical Therapy, Faculty of Medical Health, Himeji Dokkyo University, Japan

Abstract. [Purpose] This study aimed to evaluate the reliability of the intraclass correlation coefficient (ICC) in measuring deltoid muscle thickness (DMT) at different angles, acromion-humeral distance (AHD), and acromion nodule tuberosity (ALT) distance in a resting position in stroke patients using ultrasonography. [Participants and Methods] We included 40 stroke patients. During the measurement of parameters by ultrasonography, we measured the deltoid muscle thickness on both sides at three test angles (0°, 30°, and 60° abduction) and AHD and ALT on both sides at 0° angle. The ICC was used to assess intra- and interrater reliability. The relationship between the hemiplegic and non-hemiplegic sides and each angle were analyzed using a two-way repeated-measure analysis of variance (ANOVA). [Results] When the shoulders were at three testing angles (0°, 30°, and 60° abduction), the deltoid muscle thickness of the hemiplegic and non-hemiplegic sides showed good reliability; the AHD and ALT of the shoulder joint at 0° angle equally showed good reliability. There was a significant difference in each abduction angle of the shoulder joint between the thickness of the hemiplegic and non-hemiplegic deltoid. [Conclusion] Measuring deltoid muscle thickness by ultrasonography showed excellent reliability and can be used in stroke patients.
Key words : Deltoid muscle thickness, Acromion-humeral distance, Ultrasonography

INTRODUCTION

Owing to the improvements in ultrasonic diagnostic imaging equipment, obtained images have become extremely clear recently. It is extremely important, particularly, for physiotherapists specializing in sports to observe muscles, ligaments, tendons, joint capsules, nerves, and cartilage in real time. Ultrasonic diagnostic imaging equipment can simply and safely evaluate deep tissues; however, ultrasonic diagnostic imaging of skeletal muscle has not been widely performed. Compared with magnetic resonance imaging (MRI) and computed tomography (CT), ultrasound imaging is inexpensive and non-invasive and is useful for evaluating the effect of exercise therapy in clinical settings. In particular, changes in the muscles

*Corresponding author. Shan Liu (E-mail: Liushan201708@126.com)

and joints can be observed during exercise[1].

In the early stage of a stroke, the muscles around the shoulder joint relax, and the arrangement of the scapula and humerus changes. At this stage, the dynamic stability mechanism does not work; the static stability mechanism works, which is pulled excessively by the weight of the upper limb. Due to the loss of normal shoulder movement and the decrease in upper limb muscle tension, the humeral head moves down or back and forth. The joint capsule, muscle, tendon, and ligament are stretched under gravity[2].

One of the important functions of the deltoid muscle is to prevent dislocation of the humeral head when loading weight. Additionally, it ensures accurate and rapid movement of the glenohumeral joint when operating the hands and upper limbs. The deltoid muscle is responsible for raising the arm on the scapular plane and raising the humeral head. In addition, during the first 30–60 °of arm elevation, the humeral head can still move up by 1–3 mm[3]. In a previous study, electromyography showed that the supraspinatus and deltoid muscles acted together to "pull" the humeral head into the joint socket[4]. Therefore, they are usually the target points of functional electrical stimulation (FES) treatment in clinical practice[5].

The subluxation of the glenohumeral joint can be evaluated by measuring the distance between the acromion and the humerus. Park et al.[6] confirmed that the increase in the acromion nodule tuberosity (ALT) distance is highly correlated with glenohumeral subluxation (GHS). Previous studies have shown that the acromion tubercle (AGT), acromion-humeral distance (AHD), supraspinatus muscle thickness, and deltoid muscle thickness can be measured using MSUS[2, 7, 8]. In addition, the reliability of the ultrasound in measuring the thickness of the supraspinatus muscle in the shoulder joints of stroke patients at different abduction angles has been verified[9]. However, the reliability of the measurement of the deltoid muscle in different abduction positions in stroke patients has not been elucidated, and the reliability of the measurement of AHD and ALT in stroke patients has rarely been studied.

The hypothesis of this study is that AHD, ALT, and deltoid thickness of the shoulder joint at different abduction angles can be measured and evaluated by an ultrasonic portrait diagnostic instrument, and there are differences in deltoid thickness between the hemiplegic and non-hemiplegic sides. The main purpose of this study was to evaluate the reliability of the intraclass correlation coefficient (ICC) in measuring AHD and ALT of the shoulder joint of stroke patients by ultrasound and assess the reliability and efficacy of deltoid muscle thickness measurement when the shoulder joint is at rest position in the abduction angle. In addition, the changes in the deltoid thickness of the shoulder joint at three testing abduction angles and the difference in deltoid thickness between the hemiplegic and non-hemiplegic sides were discussed.

PARTICIPANTS AND METHODS

With an effect size of 0.8 and a power (1-β) of 0.8, the required number of samples was calculated to be six using G*Power software[10]. This study included 40 stroke patients with hemiplegia (mean age, 57.4 ± 11.9 years; mean height, 169.1 ± 8.1 cm; mean weight, 70.3 ± 12.1 kg). Table 1 summarizes the demographic characteristics of the patients included in this study. The inclusion criteria for participants were as follows: patients with hemiplegia after stroke for the first time, an onset period within six months, and an ability to sit independently. The shoulder joint of the hemiplegic side can abduct more than 60° under the condition of active movement and can be maintained for more than 5 seconds; additionally, it has the ability to perform all measurements. In contrast, the exclusion criteria were as follows: unstable general condition, nervous system symptoms, osteoarthritis, and cognitive and mental disorders. Patients with respiratory and circulatory diseases with brainstem or bilateral lesions or limited movement were similarly excluded. All participants provided informed consent to participate in this study. All experimental procedures in this study were reviewed and approved by the Ethics Review Committee of the International University of Health and Welfare (approval number: 20-Io-164).

The deltoid muscle thickness on both sides at three test angles (0°, 30°, and 60° abduction) and AHD and ALT on both sides at 0° were measured using an ultrasound scanner (SonoSite Ultrasound System 180 plus, SonoSite, Inc., Bothell, WA, USA) combined with a 7.5 MHz linear transducer for all participants. One examiner measured the deltoid thickness, AHD, and ALT twice using ultrasound, and another examiner measured the same parameters after 24 hours. Each measurement was performed two times, and the average values were obtained. The intrarater and interrater reliability measurements were subsequently evaluated. The changes in the deltoid thickness of the shoulder joint at three testing abduction angles and the difference in deltoid thickness between the hemiplegic and non-hemiplegic sides were discussed.

Ultrasonic measurement of body position: the patients were seated, with both feet flat on the ground, in a resting position. At 0°, the shoulder joint was in the drooping position, the elbow joint was in 90° flexion, and the forearm was rotated forward. The forearm was placed on a pillow on the patient's thigh, and the elbow joint itself had no support. At 30°, the shoulder joint abduction was 30°, and the elbow joint was straight. At 60°, the shoulder joint abduction was 60°, and the elbow joint was straight. Three abduction angles (0°, 30°, and 60° abduction) and the thickness of the deltoid muscle were measured[9].

Measurement method of deltoid muscle thickness: When the measuring posture was 0°, 30°, or 60° abduction, the probe was vertically placed at the midpoint of the joint between the lateral acromion edge of the shoulder peak and deltoid tuberosity. The probe was moved in parallel until the thickest cross-section of the deltoid muscle was determined; the image was frozen, the distance of the thickest part of the deltoid muscle was measured twice, and the average value was obtained[8].

ALT measurement method: When the measurement position was 0°, the probe was placed on the lateral acromion edge of the shoulder and the medial edge of the tendon of the biceps longus, and the shoulders were scanned along the longitudinal

J. Phys. Ther. Sci. Vol. 34, No. 1, 2022

32

axis of the humerus. When the lateral acromion edge of the shoulder and the upper edge of the lesser tuberosity appeared on the screen simultaneously, the image was frozen, ALT was measured and recorded twice, and the average value was obtained[8].

Measurement method of AHD: When the body position was 0°, the transducer was placed on the front edge of the shoulder in the coronal plane. When the acromion and humeral head simultaneously appeared on the screen, the image was frozen, the shortest distance between the acromion and humerus was measured twice, and the average value was obtained[8].

Intraclass correlation coefficients (ICCs) were used to evaluate the intrarater and interrater reliability of the ultrasound imaging. The relationship between the hemiplegic and non-hemiplegic sides and each angle was analyzed using a two-way repeated-measures analysis of variance (ANOVA). The data were statistically analyzed using the SPSS software package version 23.0 (IBM, NY, USA), suitable for Windows.

RESULTS

The results of the ICC showed that when the shoulders were at the three testing angles (0°, 30°, and 60° abduction), the deltoid muscle thickness of the hemiplegic and non-hemiplegic sides showed good reliability. Moreover, AHD and ALT of the shoulder joint at 0° angle showed good reliability (Tables 2–5).

A two-factor repeated-measures ANOVA showed an interaction. The deltoid thickness of the hemiplegic side was not significantly different between the 0° abduction angle and the 30° abduction angle ($p > 0.05$). The deltoid thickness of the hemiplegic side was significantly different between the 0° abduction angle and the 60° abduction angle ($p < 0.05$). The deltoid thickness of the hemiplegic side was significantly different between the 30° abduction angle and the 60° abduction angle ($p < 0.05$). The deltoid thickness of the non-hemiplegic side was significantly different at the three abduction angles ($p < 0.01$). There was a significant difference between the thickness of the hemiplegic deltoid muscle and non-hemiplegic deltoid muscle when shoulder abduction was 0°, 30°, and 60° ($p < 0.01$) (Table 6).

DISCUSSION

In this study, the intrarater and interrater reliability of measuring the deltoid muscle thickness by ultrasound at different abduction angles of the shoulder joint was evaluated; additionally, the intrarater and interrater reliability of measuring AHD and ALT in the drooping position of the shoulder joint was evaluated. ICC is a reliability index that reflects both the degree of correlation and agreement between measurements. It has been widely used in conservative care medicine to evaluate interrater, test-retest, and intrarater reliabilities of numerical or continuous measurements. Reliability was considered excellent, fair to good, and poor if the ICC value was greater than or equal to 0.75, 0.50 to 0.75, and less than 0.50, respectively[11]. The results showed that the intrarater and interrater reliability of the deltoid muscle thickness, AHD, and ALT measured by ultrasonic imaging was excellent; similarly, those of both the hemiplegic and non-hemiplegic sides were found to be excellent. Therefore, we successfully evaluated the deltoid muscle thickness, AHD, and ALT via ultrasonic imaging.

In addition, when shoulder abduction was 0°, 30°, and 60°, there were significant differences between the thickness of the deltoid muscle on the hemiplegic side and that on the non-hemiplegic side. The thickness of the deltoid muscle on the hemiplegic side was significantly lower than that on the non-hemiplegic side in stroke patients with hemiplegia. The thickness of the hemiplegic deltoid muscle was not significantly different between the 0° and 30° abduction angles. The hemiplegic deltoid muscle did not significantly contract. Therefore, it is considered that paralysis of the hemiplegic deltoid muscle after stroke leads to insufficient contraction during shoulder abduction; further, there is no significant change in muscle thickness during shoulder abduction.

Ultrasonic imaging is clear and easy to perform. Therefore, it is increasingly being used as a research and clinical evaluation tool in clinical and rehabilitation settings[12]. This study provides evidence for the reliability of the ultrasonic measurement of the deltoid muscle. This study further proves that for hemiplegia, the measurement of the thickness of the deltoid muscle

Table 1. Patient demographics (n=40)

Gender	Male	28
	Female	12
Affected side	Right	20
	Left	20
Brunnstrom	Stage IV	19
	Stage V	17
	Stage VI	4

Table 2. Reliability of the deltoid muscle thickness ICC, (1. 2), (cm)

		1st time	2nd time	ICC
Hemiplegic	0°	1.42 ± 0.37	1.41 ± 0.37	0.93**
	30°	1.52 ± 0.42	1.56 ± 0.43	0.91**
	60°	1.64 ± 0.47	1.70 ± 0.48	0.84**
Non-hemiplegic	0°	1.58 ± 0.43	1.62 ± 0.42	0.92**
	30°	1.92 ± 0.42	1.95 ± 0.36	0.85**
	60°	2.16 ± 0.41	2.20 ± 0.39	0.92**

The 1st- and 2nd-time measurements were performed by the same examiner.
ICC: interclass correlation coefficient.
**$p < 0.01$.

is highly reliable at the 0° resting position. In addition, the reliability remained high at different abduction angles. Therefore, for hemiplegic patients with stroke, ultrasound is helpful in objectively evaluating the thickness of the deltoid muscle from different angles. Ultrasound can dynamically observe the change in the thickness of the deltoid muscle in real-time. In addition, the deltoid thickness was highly correlated with AHD, ALT, and shoulder subluxation in hemiplegic patients[8]. In this study, the thickness of the deltoid muscle in stroke patients with hemiplegia, measured by ultrasound, showed a significant difference between the hemiplegic and non-hemiplegic sides. Therefore, ultrasound can be used to evaluate the degree of shoulder subluxation in stroke patients.

Table 3. Reliability of the deltoid muscle thickness ICC, (2. 2), (cm)

		1st time	3rd time	ICC
Hemiplegic	0°	1.42 ± 0.37	1.43 ± 0.37	0.90**
	30°	1.52 ± 0.42	1.55 ± 0.41	0.87**
	60°	1.64 ± 0.47	1.72 ± 0.43	0.80**
Non-hemiplegic	0°	1.58 ± 0.43	1.59 ± 0.41	0.89**
	30°	1.92 ± 0.42	1.90 ± 0.39	0.88**
	60°	2.16 ± 0.41	2.20 ± 0.34	0.87**

The 1st- and 2nd-time measurements were performed by the same examiner, and the 3rd time measurement was performed by another examiner.
ICC: interclass correlation coefficient.
**$p<0.01$.

Table 4. Reliability of the AHD, ALT ICC, (1. 2), (cm)

		1st time	2nd time	ICC
Hemiplegic	AHD	1.56 ± 0.61	1.60 ± 0.62	0.92**
	ALT	2.09 ± 0.56	2.14 ± 0.54	0.91**
Non-hemiplegic	AHD	1.17 ± 0.19	1.19 ± 0.20	0.90**
	ALT	1.75 ± 0.38	1.73 ± 0.39	0.90**

The 1st- and 2nd-time measurements were performed by the same examiner.
ICC: interclass correlation coefficient; CI: Confidence Interval.
**$p<0.01$.

Table 5. Reliability of the AHD and ALT ICC, (2. 2), (cm)

		1st time	3rd time	ICC
Hemiplegic	AHD	1.56 ± 0.61	1.61 ± 0.50	0.89**
	ALT	2.09 ± 0.56	2.08 ± 0.48	0.86**
Non-hemiplegic	AHD	1.17 ± 0.19	1.21 ± 0.19	0.81**
	ALT	1.75 ± 0.38	1.78 ± 0.41	0.86**

The 1st- and 2nd-time measurements were performed by the same examiner, and the 3rd-time measurement was performed by another examiner.
ICC: interclass correlation coefficient.
**$p<0.01$.

Table 6. Deltoid muscle thickness (cm)

	Angles	M ± SD	
Hemiplegic	a. 0°	1.42 ± 0.37	a<c*, a<d**
	b. 30°	1.52 ± 0.42	b<c*, b<e**
	c. 60°	1.64 ± 0.47	c<f**
Non-hemiplegic	d. 0°	1.58 ± 0.43	d<e, f**
	e. 30°	1.92 ± 0.42	e<f**
	f. 60°	2.16 ± 0.41	

*$p<0.05$, **$p<0.01$. M ± SD: mean ± standard deviation.

J. Phys. Ther. Sci. Vol. 34, No. 1, 2022

34

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