

Original Article

# Evaluation of supraspinatus muscle changes in the shoulder joint of stroke patients with hemiplegic and shoulder subluxation using ultrasonography: comparison between affected and unaffected sides

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**Abstract.** [Purpose] The shoulder joint has a very unstable structure yet a significantly wide range of motion. Weakness of the muscles around the shoulder joint may cause shoulder joint subluxation. This study aimed to determine changes in supraspinatus muscle thickness between different shoulder abduction angles using ultrasonography and to compare differences in supraspinatus muscle thickness changes between the affected and unaffected sides depending on shoulder joint subluxation. [Participants and Methods] Forty hemiplegic patients with stroke were recruited (20 patients with and 20 without shoulder subluxation). Using ultrasonography, we measured supraspinatus muscle thickness at three shoulder joint abduction angles and calculated the differences in supraspinatus muscle thickness. Depending on subluxation, we separately analyzed the thickness and variations in the supraspinatus muscle on both the affected and unaffected sides. [Results] In stroke patients with shoulder subluxation, the difference in supraspinatus muscle thickness was significantly less in the affected side than in the unaffected side. [Conclusion] The thickness and rate of supraspinatus muscle thickness change was significantly less in the affected side than in the unaffected side in stroke patients with shoulder subluxation.

**Key words:** Supraspinatus muscle thickness, Ultrasound imaging, Stroke

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## INTRODUCTION

The shoulder joint has a small socket and a large humeral head. Despite its very unstable structure, the shoulder joint has a very wide range of motion and is fragile<sup>1)</sup>. Shoulder stability depends on muscle and ligament structures, not bone morphology<sup>2, 3)</sup>. As the muscles around the shoulder joint are weak, shoulder joint subluxation may occur. The supraspinatus and posterior deltoid muscles are the most important muscles involved in maintaining shoulder stability<sup>4)</sup>.

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The supraspinatus muscle is one of the four muscle groups that make up the rotator cuff and is located at its top. As an internal muscle, it can abduct and stabilize the shoulder joint and hold the humeral head to the glenoid fossa. The important functions of the supraspinatus muscle include exerting the forming force of the fulcrum when abduction is performed in a drooping position and holding the bone to the glenoid fossa<sup>5</sup>). However, since the stopping point of the supraspinatus muscle occupies most of the anterior part of the greater tuberosity, it is speculated that shoulder joint abduction is enhanced when the supraspinatus muscle is rotated outwards and that flexion/internal rotation is enhanced when the supraspinatus muscle is rotated inwards. Supraspinatus muscle contraction increases the horizontal tension of the shoulder joint capsule and keeps the humeral head in contact with the shoulder fossa. Therefore, in stroke patients with hemiplegia, due to muscle paralysis centered in the supraspinatus muscle around the shoulder joint, it is difficult to maintain the weight of upper limbs, resulting in shoulder joint subluxation<sup>1, 4, 6</sup>). Therefore, it is particularly important to evaluate the supraspinatus muscle and contractility after stroke.

Ultrasonography is an inexpensive, non-invasive method of quantifying muscle morphology and behavior and has been increasingly used as a clinical tool for research and whole rehabilitation processes. It is a very useful evaluation method in clinical practice, especially for accurately studying changes in muscles and joints during exercise<sup>7, 8</sup>). It has been reported that ultrasonic imaging is highly reliable for measuring supraspinatus muscle thickness when shoulder joint abduction is 0°, 30°, and 60° in patients with stroke<sup>9</sup>).

This study aimed to determine changes in the thickness of the supraspinatus muscle at different shoulder joint abduction angles, compare differences in thickness between the affected and unaffected sides, depending on whether shoulder subluxation is present, understand the contraction state of the supraspinatus muscle, and provide suggestions for further evaluations and treatments for patients with shoulder subluxation.

## PARTICIPANTS AND METHODS

The required number of samples was calculated using G\*Power software (Institute of Experimental Psychology, Heinrich Heine University, Düsseldorf, Germany). The effect size was set to 0.8, and the power was  $(1-\beta=0.8)$ ; the required number of samples was six<sup>10</sup>). Forty hemiplegic patients with stroke were recruited in the rehabilitation department of one hospital (33 males, 7 females; 26 had right hemiplegia, whereas 14 had left hemiplegia). Twenty patients had shoulder subluxation, and the other 20 did not. The distance from the acromion to the tubercle was measured via finger breadth palpation; patients were diagnosed with shoulder subluxation if the distance was  $>1/2$ -finger gap<sup>11, 12</sup>). Twenty patients had no gap, 5 had a  $1/2$ -finger gap, 6 had a 1-finger gap, 5 had a  $1\frac{1}{2}$ -finger gap, and 4 had a 2-finger gap. A physiotherapist performed the measurements. 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 active movement and can be maintained for more than 5 seconds; additionally, it allows for the taking of all measurements. Exclusion criteria were an unstable general condition, nervous system symptoms, cognitive and mental disorders, osteoarthritis, fracture, shoulder disease, and respiratory and circulatory diseases with brainstem or bilateral lesions or limited movement. All participants provided informed consent for participation in this study, and experimental procedures were reviewed and approved by the ethics review committee of the International University of Health and Welfare (approval number: 19-Io-45).

An ultrasound scanner (SonoSite Ultrasound System 180 plus, SonoSite, Inc., Bothell, WA, USA) combined with a 7.5 MHz linear transducer was used to measure the supraspinatus muscle thickness on both sides at three test angles (0°, 30°, and 60° abduction) in all participants, and the same physiotherapist took all measurements.

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 at 90° flexion, and the forearm was rotated forward. The forearm was placed on a pillow on the patient's thigh, and the elbow joint 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. The three abduction angles (0°, 30°, and 60° abduction) were attained using an arthrodistal protractor, and the thickness of the supraspinatus muscle was measured<sup>9</sup>).

When measuring the supraspinatus muscle using ultrasonography, the probe was vertically placed at the midpoint of the middle scapula and subsequently moved in parallel until we determined the thickest cross-section of the supraspinatus muscle. The image was frozen, and the distance to the thickest part of the supraspinatus muscle was determined<sup>9</sup>). The supraspinatus muscle thickness on both the affected and unaffected sides was measured twice, and the average value of both measurements was recorded.

The rate of change of supraspinatus muscle thickness was defined as follows: 0–30° was the thickness of the supraspinatus muscle at 30° abduction minus the thickness of the supraspinatus muscle at 0° abduction; 0–60° was the thickness of the supraspinatus muscle at 60° abduction minus the thickness of the supraspinatus muscle at 0° abduction.

At three test angles, the relationship between supraspinatus muscle thickness at the affected and unaffected sides and shoulder subluxation 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. The statistical significance level was set at 0.05.

## RESULTS

**Table 1** summarizes patient demographic characteristics. The two-way repeated-measures ANOVA demonstrated interactions between the supraspinatus muscle thickness in the affected and unaffected sides and shoulder subluxation. In the non-shoulder subluxation group, at 0°, 30°, and 60° shoulder joint abduction, there were no significant differences in supraspinatus muscle thickness between the affected and unaffected sides. In the shoulder subluxation group, there was a significant difference in supraspinatus muscle thickness between the affected and unaffected sides when shoulder abduction was 0°, 30°, and 60° (Tables 2–4). There was a significant difference in supraspinatus muscle thickness in the affected side at each shoulder abduction angle in the non-shoulder subluxation group. In the shoulder subluxation group, there was no significant difference in supraspinatus muscle thickness in the affected side between 0° and 30° abduction angles. When shoulder abduction was 0°, 30°, and 60°, there was a significant difference in supraspinatus muscle thickness in the affected sides between the non-shoulder subluxation and the shoulder subluxation groups (Table 5).

The two-way repeated-measures ANOVA showed a relationship between shoulder subluxation and the rate of supraspinatus muscle thickness change in affected and unaffected sides. In the no-shoulder subluxation group, there were no significant differences in the rate of supraspinatus muscle thickness change at 0–30° and 0–60° between the affected and unaffected sides. In the shoulder subluxation group, there were no significant differences in the rate of supraspinatus muscle thickness change at 0–30° between the affected and unaffected sides. However, there were significant differences in the rate of supraspinatus muscle thickness change at 0–60° between the affected and unaffected sides (Table 6).

**Table 1.** Participant characteristics

	Non-subluxation group (n=20)	Subluxation group (n=20)	All participants (n=40)
Age (years)	63.5 ± 10.8	55.4 ± 12.7	59.4 ± 12.3
Height (cm)	170.2 ± 6.2	171.1 ± 8.4	170.6 ± 7.3
Weight (kg)	70.7 ± 17.0	74.5 ± 12.0	72.6 ± 14.6

Data are reported as mean ± standard deviation unless otherwise indicated.

**Table 2.** Supraspinatus muscle thickness at 0° (cm), n=40

		Mean ± SD	
Subluxation group	a. Affected sides	1.58 ± 0.32	a<b**, a<c*
	b. Unaffected sides	1.94 ± 0.28	
Non-subluxation group	c. Affected sides	1.77 ± 0.24	
	d. Unaffected sides	1.87 ± 0.3	

\*p<0.05 and \*\*p<0.01. SD: standard deviation.

**Table 3.** Supraspinatus muscle thickness at 30° (cm), n=40

		Mean ± SD	
Subluxation group	a. Affected sides	1.68 ± 0.29	a<b**, a<c*
	b. Unaffected sides	2.08 ± 0.29	
Non-subluxation group	c. Affected sides	1.93 ± 0.26	
	d. Unaffected sides	1.98 ± 0.31	

\*p<0.05 and \*\*p<0.01. SD: standard deviation.

**Table 4.** Supraspinatus muscle thickness at 60° (cm), n=40

		Mean ± SD	
Subluxation group	a. Affected sides	1.77 ± 0.27	a<b**, a<c*
	b. Unaffected sides	2.26 ± 0.26	
Non-subluxation group	c. Affected sides	2.00 ± 0.27	
	d. Unaffected sides	2.10 ± 0.31	

\*p<0.05 and \*\*p<0.01. SD: standard deviation.

**Table 5.** Supraspinatus muscle thickness on affected sides (cm), n=40

	Angles	Mean ± SD	
Subluxation group	a. 0°	1.58 ± 0.32	a<b, c**, a<d*
	b. 30°	1.68 ± 0.29	b<e*
	c. 60°	1.77 ± 0.27	c<f*
Non-subluxation group	d. 0°	1.77 ± 0.24	d<e and f**
	e. 30°	1.93 ± 0.26	e<f*
	f. 60°	2.00 ± 0.27	

\*p<0.05 and \*\*p<0.01. SD: standard deviation.

**Table 6.** The rate of change of supraspinatus muscle thickness (cm), n=40

	At 0–30°		At 0–60°	
	Affected sides	Unaffected sides	Affected sides	Unaffected sides
Subluxation group	0.09 ± 0.09	0.15 ± 0.08	0.18 ± 0.14	0.32 ± 0.15*
Non-subluxation group	0.15 ± 0.10	0.11 ± 0.08	0.23 ± 0.12	0.24 ± 0.15

\*p<0.05.

## DISCUSSION

In this study, we used ultrasonic imaging to measure and analyze changes in supraspinatus muscle thickness during shoulder abduction in patients with stroke; additionally, there were differences in each parameter between the affected and unaffected sides was discussed, and the thickness of the supraspinatus muscle at different abduction angles of the shoulder joint was compared. In the shoulder subluxation group, supraspinatus muscle thickness was significantly lower in the affected side than in the unaffected side at all shoulder joint abduction angles.

The results showed that supraspinatus muscle thickness at the affected sides continued to increase up till an abduction angle of 60° in the subluxation group, although this increase was not significantly different when the shoulder abduction angle changed from 30° to 60°. Moreover, the supraspinatus muscle thickness at shoulder abduction angles of 0°, 30°, and 60° was significantly lower in the shoulder subluxation group than in the non-shoulder subluxation group. Regarding the rate of supraspinatus muscle thickness change during shoulder abduction, in the shoulder subluxation group, variations in the supraspinatus muscle when the shoulder abduction angle changed from 0° to 60° were significantly lesser in the affected sides than in the unaffected sides.

In conclusion, after stroke onset, regardless of shoulder subluxation, supraspinatus muscle thickness was increased at an abduction degree of 60°. In patients without shoulder subluxation, there were no significant differences in supraspinatus muscle thickness between the affected and unaffected sides, whereas, in patients with shoulder subluxation, supraspinatus muscle thickness and contraction were significantly lesser in the affected than in the unaffected side. Therefore, it is crucial to consider measuring and comparing supraspinatus muscle thickness between the affected and unaffected sides when evaluating the severity of shoulder joint subluxation in patients with stroke. Additionally, to treat shoulder subluxation, it is important to reduce differences in supraspinatus muscle thickness between the affected and unaffected sides and improve the supraspinatus muscle contractility and thickness. Regardless of whether they have shoulder subluxation, patients with stroke should actively train the supraspinatus muscle of the affected side to increase its thickness, muscle activity, and muscle strength. When training the supraspinatus muscle, the abduction range of the shoulder joint should reach >60°. Patients with shoulder joint subluxation should be trained intensively.

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### Conflict of interest

None.

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