Original article

Differences in trunk muscle thickness and echo intensity in elderly people with and without post-stroke hemiplegia

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Abstract

Previous studies have reported on trunk muscle strength of post-stroke patients with hemiplegia yet the relationship between trunk muscle atrophy and physical function is still unclear. The purpose of this study was to determine the relationship between trunk muscle and physical functions by examining trunk muscles atrophy in post-stroke patients with hemiplegia. Eight patients with hemiplegia (6 men, 2 women) and 10 age-similar healthy controls were recruited (4 men, 6 women). We made ultrasound measurements of muscle thickness and muscle echo intensity of the external oblique abdominis (EOA), internal oblique abdominis (IOA), transverse abdominis (TrA), and psoas major (PM). We also performed functional tests for stroke with hemiplegia. TrA and PM muscle thickness was significantly lower in patients with hemiplegia than healthy subjects, and muscle echo intensity was higher in patients with hemiplegia than healthy subjects. There was a significant correlation between stroke impairment assessment set (SIAS) score and muscle thickness of the EOA, IOA, and TrA. TrA and PM muscles in post stroke with hemiplegia showed significant atrophy with fatty and fibrotic changes compared to healthy subjects. In addition, SIAS score may reflect the muscle thicknesses of EOA, IOA, and TrA.

Introduction

Circulatory diseases are the third biggest cause of long term stay in hospital; with stroke being the longest stay among these diseases in Japan [1], due to impairments from stroke, and elderly patients generally have a longer stay [2]. Increased length of stay in hospital is caused not only by the effects of hemiplegia from stroke, but also from reduced physical function in aging.

Therapeutic exercise has been recommended by stroke treatment guidelines to improve physical function, such as gait, and Activities of Daily Living (ADL) [3]. Treatment targets include upper, lower extremities and trunk; improving trunk function was especially important for ADL function [4].

Many studies have investigated the trunk muscles of stroke patients with hemiplegia. Tanaka et al. [5,6] reported that patients with hemiplegia had weaker trunk flexors, extensors, and rotators com-

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pared to healthy subjects. Dickstein et al. [7] reported reduced muscle activity of abdominal muscles in patients with hemiplegia at rest in the sitting position compared to healthy subjects. On the other hand, there was no differences in the size of superficial muscles such as rectus abdominis (RA) and erector spinae in stroke patients with hemiplegia compared to healthy subjects [8]. More recently, Ryan et al. [9] and Monjo et al. [10] also reported quantitative and qualitative changes on the paretic side with skeletal muscle atrophy and increased fat within the muscle. However, most studies focused on the superficial muscles of the trunk and did not include specific deep muscles of the trunk, which are especially important for ambulation or ADLs. Identifying trunk muscular changes due to stroke, such as muscle atrophy, might improve physical therapy intervention and lead to reduce length of stay in hospital.

The purpose of this study was to identify the differences in trunk muscle atrophy in patients with hemiplegia to determine the relationship between the trunk muscles and physical function.

Materials and Methods

Eight hemiplegia patients (6 men and 2 women, mean age 66.8 ± 11.5 years) were recruited to this study out of the 63 stroke patients admitted to the Niigata rehabilitation hospital from July to December 2012. Exclusion criteria included significant brain dysfunction, bilateral brain damage, and obesity. Ten healthy individuals living in the Niigata City neighborhood (4 men, 6 women, mean age 65.3 ± 8.4 years) were recruited as a control group (Table 1).

Physical function of hemiplegia patients was assessed with various evaluation tools. Gait function was assessed with the Functional Independence Measure (FIM). Trunk function was assessed with the Stroke Impairment Assessment Set (SIAS). Lower extremity function of the paralyzed side was assessed with the Brunnstrom Recovery Stage (BRS).

Four muscles, the external oblique abdominis (EOA), internal oblique abdominis (IOA), transvers abdominis (TrA), and psoas major (PM), were assessed in patients with hemiplegia and healthy subjects. Measurements of muscle thick-

Table 1. Basic information of hemiplegic and healthy subjects.

Item	Hemiplegic group (n = 8)	Control group (n = 10)	P value
Age (year)	66.8 ± 11.5	65.3 ± 8.4	0.743
Height (㎝)	159.3 ± 9.4	157.5 ± 6.6	0.627
Weight (㎏)	55.7 ± 9.7	58.1 ± 8.3	0.583
BMI (kg/m^2)	21.8 ± 2.4	23.3 ± 2.1	0.172
Gender (M / F)	(6 / 2)	(4 / 6)	
Type (Hemo / Infa)	(7 / 1)		
SIAS (Trunk) (4 / 5 / 6)	(1 / 5 / 2)		
BRS (L/E) (Ⅱ / Ⅳ / Ⅴ)	(2 / 4 / 2)		
FIM (gait) (2 / 3 / 4 / 5)	(2 / 2 / 2 / 2)		
Duration of disease (Day)	99.3 ± 53.5		

Mean ± SD.
Student's t-test was used for statistical comparisons.
Body Mass Index (BMI), Cerebral Hemorrhage (Hemo), Cerebral Infarction (Infa), Stroke Impairment Assessment Set (SIAS), Brunnstrom Recovery Stage (BRS), Functional Independence Measure (FIM).

ness (MT) were obtained using ultrasound sonography (prosound α6, HITACHI Aloka Medical, Japan) with the B-mode method. Two probes were utilized to obtain measurements: a 7.27 MHz linear type for EOA, IOA, and TrA, and a 5 MHz linear type for PM.

In this study, MT was defined as the distance between the superficial and deep hypoechoic fasciae (Figure 1). Echo intensity (EI) of muscle was measured by Image J [11,12], which is a free software to analyze ultrasound images. EI was evaluated by analyzing images displaying 256 grayscale levels, with the EI of each muscle expressed as a value between 0 (black) and 255 (white). The same setting for gain and frequency were applied for measurements performed on all muscles. To measure EI, it was necessary to determine the distance to be analyzed and thus this included the full distance of MT in this study (Figure 2).

All measurements of MT and EI were performed by the same skilled and experienced physical therapist to minimize interobserver variations. The locations to measure the abdominal muscle group were determined between the navel and the mid- axillary line as previously described by Gnat et al. [13]. Subjects were positioned supine and the probe was placed in the transverse plane. The PM was measured at a position of 10 cm lateral to the fourth lumbar spinous process in the prone position. The angle of the probe was then adjusted to optimize visualization of the image. We applied the minimal contact pressure of the probe to identify all muscles to clearly identify the muscle fascia. The MT measurement was made at the end of

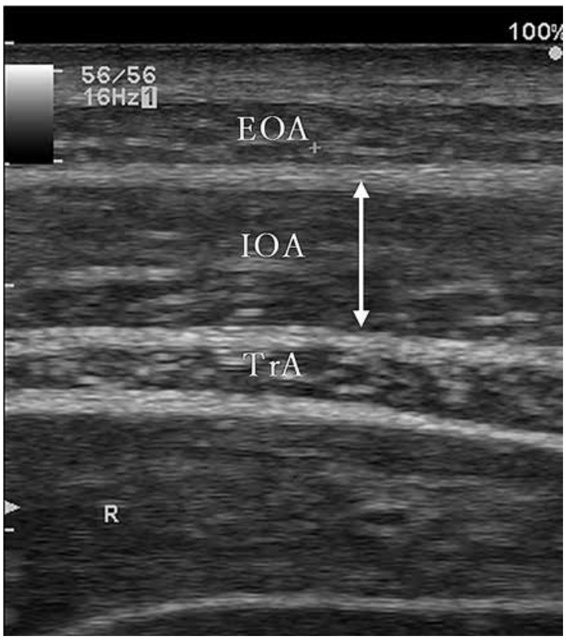

Figure 1. Ultrasound image of the trunk muscles. From above External oblique abdominis (EOA), Internal oblique abdominis (IOA), Transverse abdominis (TrA).
↕ : The muscle thickness definition is that the enclosed region upper and under muscle fascia.

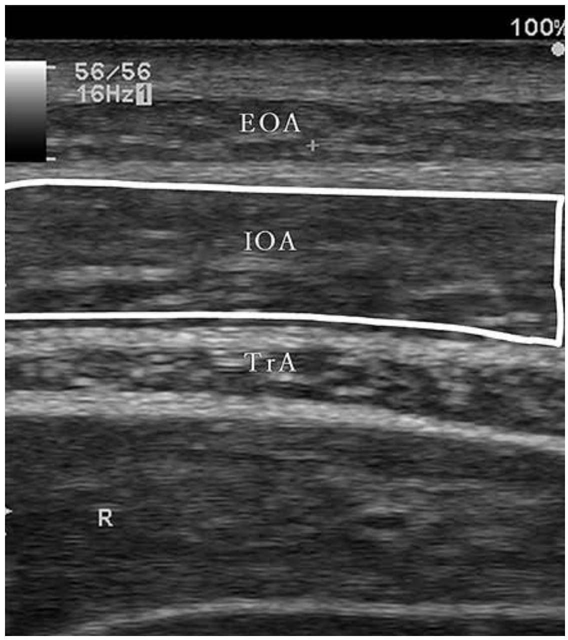

Figure 2. Ultrasound image of abdominal muscles of a healthy subject.
From above External oblique abdominis (EOA), Internal oblique abdominis (IOA), Transverse abdominis (TrA).
The echo intensity of Internal oblique muscle was measured as a range which is surrounded by white.

exhalation during quiet breathing.

Date of resting MT and EI of each muscle and results from physical functional evaluation were analyzed. Representative values of MT and EI were calculated as the mean value of two measurements in both hemiplegic and non-hemiplegic sides. The statistical software used was R2.8.1. The differences in MT and EI of each muscle between the hemiplegic and control group were examined using Student's t-test or Mann- Whitney U-test, and Welch's t- test. Student's t-test was used when data were parametric, and the variances were equal and Welch's t-test was used when the data were parametric, but the variances were not equal. When neither was used, Mann-Whitney U test was used. Relationships between MT and EI, and physical function were examined using the Spearman's rank correlation test. The statistical significance level in all tests was set at $P < 0.05$.

This study was approved by the Ethics Committee of Niigata University of Health and Welfare (Approval No:17261-111002). Written informed consent was obtained from all subjects before collecting any data. All examinations were performed in private room to protect the patient's privacy due to exposing their body part to measure MT and EI.

Results

In the hemiplegic group, MT of TrA ($p = 0.042$) and PM ($p = 0.021$) was significantly lower than the control group. However, there was no significant difference in the MT of the EOA and IOA between the two groups (Table 2).

In the hemiplegic group, EI of TrA ($p = 0.001$) and PM ($p = 0.018$) was significantly higher than the control group. There was no significant difference in EI of the EOA and IOA between goups (Table 3).

There was a positive correlation between physical function as measured by SIAS and MTes of the EOA ($r = 0.77$, $p = 0.03$), IOA ($r = 0.87$, $p = 0.005$), and TrA ($r = 0.83$, $p = 0.009$). However, there was no correlation between muscle EI of the trunk muscles and physical function (Table 4, 5).

Table 2. The comparison of muscle thickness in the control and hemiplegic groups.

	Hemiplegic group (n = 8)	Control group (n = 10)	P value
EOA	4.72 ± 0.91	4.33 ± 1.47	0.528
IOA	7.90 ± 1.46	8.25 ± 2.32	0.724
TrA	3.68 ± 1.39	5.12 ± 1.96	0.042
PM	38.1 ± 5.98	43.9 ± 4.74	0.021

unit: mm, mean ± SD.
Student's t-test and Mann-Whitney's U-test were used for statistical processing.
External oblique abdominis (EOA), Internal oblique abdominis (IOA), Transvers abdominis (TrA), Psoas major (PM).

Table 3. Comparisons of muscle echo intensity between the control and hemiplegic groups.

	Hemiplegic group (n = 8)	Control group (n = 10)	P value
EOA	64.7 ± 8.45	70.8 ± 17.7	0.414
IOA	56.2 ± 11.1	50.3 ± 5.98	0.236
TrA	32.1 ± 11.3	15.0 ± 5.10	0.001
PM	63.6 ± 3.81	54.5 ± 8.90	0.018

unit: pixel, mean ± SD.
Student's t-test and Weltch's t-test were used for statistical processing.
External oblique abdominis (EOA), Internal oblique abdominis (IOA), Transvers abdominis (TrA), Psoas major (PM).

Table 4. Relationships between trunk muscle thickness and physical function in hemiplegia. (n = 8)

	EOA	IOA	TrA	PM	BRS	SIAS (trunk)	FIM (gait)
EOA		0.64*	0.78*	0.14	0.39	0.77*	0.59
IOA			0.75*	0.59	0.23	0.87**	-0.05
TrA				0.56	0.47	0.83**	0.40
PM					0.43	0.43	-0.44
BRS						0.27	0.32
SIAS (trunk)							0.25
FIM (gait)							

*: $p < 0.05$, **: $p < 0.01$
The above table show the correlation coefficient.
Spearman's rank correlation test was used statistical processing.
External oblique abdominis (EOA), Internal obliwue abdominis (IOA), Transvers Abdominis (TrA), Psoas Major (PM), Brunnstrom Recovery Stage (BRS), Stroke Impairment Assessment Set (SIAS), Functional Independence Measure (FIM).

Table 5. Relationships between trunk muscle echo intensity and physical function in hemiplegia. (n = 8)

	EOA	IOA	TrA	PM	BRS	SIAS (trunk)	FIM (gait)
EOA		0.46	-0.07	-0.32	0.51	0.66	0.28
IOA			0.79*	-0.89*	0.12	-0.09	-0.28
TrA				-0.71*	-0.46	-0.41	-0.40
PM					-0.12	-0.04	0.48
BRS						0.41	0.07
SIAS (trunk)							0.38
FIM (gait)							

*: $p < 0.05$
The above table show the correlation coefficient.
Spearman's rank correlation test was used statistical processing.
External oblique abdominis (EOA), Internal obliwue abdominis (IOA), Transvers Abdominis (TrA), Psoas Major (PM), Brunnstrom Recovery Stage (BRS), Stroke Impairment Assessment Set (SIAS), Functional Independence Measure (FIM).

Discussion

The purpose of this study was to identify the atrophy of trunk muscle, as well as determine the relationship between trunk muscle and physical function in stroke patients with hemiplegia.

In the hemiplegic group, MT of the TrA and PM was lower, and EI of the TrA and PM was higher than the control group. The MT was correlated with the amount of the adipose-fibrous tissue in the musculoskeletal system, suggesting that higher values of EI in muscle indicate greater atrophy with adipose-fibrous tissue mass in musculoskeletal system [14]. Therefore, these data suggest that the TrA and PM of patients with hemiplegia exhibits not only more muscle atrophy but also adipose-fibrous tissue changes compared to control subjects of the same age group.

Local muscles of the trunk, such as the PM or the lumbar multifidus control the fine-tuning of the positions of adjacent vertebrae. The TrA and the IOA are also considered as local muscles due to their connection through the thoracolumbar fascia. Unlike the local muscles, the global muscles like the RA and the EOA, are important for torque production and general trunk stability due to their indirect attachment to the spine [15,16].

Also, type Ⅱ fibers are greater in the RA, IOA, and EOA [17]. Verdijk LB et al. [18] reported that atrophy in senescent muscle is characterized by specific Type Ⅱ muscle fiber atrophy. Also, the trunk muscle of elderly people has been characterized with higher EI [19] and lower muscle strength [20]. Disuse of muscles such as in a spinal injury patient were characterized with severe atrophy of both Type Ⅰ and Ⅱ muscle fibers [18]. On the other hand, histochemical analysis of muscle fibers from hemiplegic stroke patients indicate either selective type Ⅱ fiber atrophy, both type Ⅰ and Ⅱ muscle fiber atrophy, or muscle fibers of normal size [21-23]. Therefore, the muscle atrophy observed in post-stroke patients with hemiplegia might be associated with both aging and disuse.

The reasons for atrophy and higher EI of the deep trunk muscles in stroke patients with hemiplegia are likely due to lower muscle function and physical activity. One study of paralyzed muscle function reported that muscle activity is lower due to paralysis, causing a reduction in intramuscular blood flow and thus resulting in lower muscle metabolism [24]. Moreover, the lower metabolism will increase the changes in adipose and fibrous tissue in the muscle, resulting in changes to the muscle fibers [25]. In addition, the superficial trunk muscles are utilized more in bed activities or ambulation resulting in continuation of lower activity level in the deep trunk muscles. At standing or sitting, TrA is activated with MF and PM for lumbar lordosis and pelvic anterior tilt [26], but many patients with post-stroke hemiplegia display lumbar kyphosis and pelvic posterior. Moreover, the functional pattern has small variations [27] but large differences in global and local muscle activity in hemiplegic patients.

On the other hand, we determined a significant correlation between MT of the EOA, IOA, and TrA, and SIAS score regarding a relationship between trunk muscles and physical function. The SIAS is a reliable evaluation tool to assess the physical function of stroke patients as recommended by stroke practice guidelines [3,28] and is frequently used in clinical practice. Trunk assessment of SIAS includes two categories: upright posture and abdominal muscle strength. Evaluation includes the ability to maintain an upright posture and abdominal strength, in which a subject is able to raise their trunk to the upright position from 45-degree backward angle against manual resistance during sitting at the edge of a bed. The TrA, which is recognized to correlate with SIAS, has different muscle performance aspects depending on muscle insertion [29]. The overall function of the TrA is to control abdominal pressure [30] and maintain an upright posture [31]. On the other hand, the IOA and EOA attach to the superficial area of the TrA and contribute to abdominal muscle strength with RA. No study has reported the relationship between the SIAS and trunk muscles, but we believe that trunk assessment of SIAS reflects these roles of the trunk muscles.

However, this study has some limitations which warrant discussion. One major limitation is the relatively small number of subjects, likely due to the strict exclusion criteria set in this study, which ensured that the ability of subjects to ambulate and have higher brain dysfunction. Thus, it is possible that the small number of subjects may influence the results. In addition, the degree of paralysis and the level of activities of daily living (ADL) of the subject are unequal. Future research is needed with an expanded cohort to address these limitations.

In conclusion, we found muscle atrophy of the TrA and PM in patients with hemiplegia. A High EI due to adipose-fibrous tissue changes were also found in patients with hemiplegia. The SIAS score was related to the MT of the trunk muscle group except for the RA; therefore, it is important to implement physical therapy intervention to the trunk muscle group in post-stroke patients.

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Conflicts of Interest

There are no conflicts of interest to declare.

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