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Original Article

Relationship between the ability to stand and physical function in stroke survivors with hemiplegia: a pilot study

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ABSTRACT
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Objective: This study aimed to identify the physical functions necessary to enable stroke survivors with hemiplegia to stand from a chair.
Methods: Fifteen patients who had suffered a hemiplegic stroke were divided into two groups, the pull and unable groups, based on their ability to stand by pulling a handrail. Their motor palsy, Stroke Impairment Assessment Set, and unaffected muscle strength were assessed.
Results: Patients in the pull group had less motor palsy, higher muscle strength of the upper extremity on the unaffected side, and greater angle of ankle dorsiflexion on the affected side, compared to the patients in the unable group.
Conclusion: The function of the affected lower limb and the unaffected upper limb's muscle strength determines the ability of patients who have suffered a hemiplegic stroke to lift their body upwards while standing from a chair.
Key words: stroke, standing up motion, physical function

Introduction

Standing from a chair is one of the most common movements in daily life. Various functions, such as lower limb and trunk muscle strength [1−3], balance ability [4, 5], and sensory function [6, 7] are reportedly required for rising from a chair. In addition, environmental aspects such as chair height, foot position, and movement speed also affect the movement [7]. Patients who have suffered a stroke are usually affected by unilateral motor and sensory paralysis, resulting in weakness in their lower extremities and trunk muscles. Moreover, they are also affected by weight-bearing asymmetry, thus increasing the difficulty of movements while standing [8].

Use of the upper limb facilitates standing motion when a patient experiences a significant decline in physical functions, such as muscle strength. While pushing is based on the reaction force applied to a seat or cane, pulling is based on the reaction force to pulling a handrail. Use of the upper limb during a standing motion generates kinematic and dynamic characteristics that are different from the normal circumstances. Pushing produces a degree of trunk flexion, similar to the usual sit-to-stand (STS) motion. In contrast, pulling causes almost no trunk flexion [9, 10]. Moreover, the hip flexion angle and ankle dorsiflexion angle reportedly increase with a low handrail height and vice versa [11]. Pushing generates shoulder joint flexion moment and elbow joint extension moment as the patient pushes a handrail. However, pulling generates a shoulder joint extension moment and elbow joint flexion moment as the patient pulls a handrail, thus decreasing the trunk flexion angle. This eventually produces a larger knee joint extension moment [12, 13].

The author previously reported the relationship between the ability to perform a standing movement and physical function in stroke survivors with hemiplegia [14]. In that report, the difficulty of executing STS motion was classified as follows: "STS motion without using the upper limbs," "the push method," and "the pull method." Patients who could only stand using the pull method had a significantly lower ability to maintain the standing position than those who could only use the push method. Nonetheless, there was no significant difference in their physical functions, such as the muscle strength on the unaffected side and paralyzed function. Despite the insufficiency of the lower limb function to raise the center of gravity, a patient can use their upper limb to compensate for the decline in standing balance and lower limb function while standing. This is particularly relevant for patients having a certain level of physical

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function. Therefore, this study explored the physical functions necessary for a person requiring assistance while rising from a chair. Patients who could stand using the pull method were compared with those who needed assistance to determine the degree of physical function required to stand independently.

The purpose of this study was to obtain preliminary findings on the relationship between the ability to stand using the pull method and physical functions in stroke survivors with hemiplegia.

It was hypothesized that patients who require assistance to stand might have severe motor palsy, weak lower limb muscles on the unaffected side, and weak upper limb muscles to compensate for this condition.

Materials and methods

1. Patients

Thirty-six stroke survivors with hemiplegia had been admitted to the general wards. The inclusion criteria were as follows: (i) those who had been diagnosed with a first cerebral hemorrhage or cerebral infarction and (ii) who were able to stay in a seated position independently. The exclusion criteria were as follows: (i) patients with ataxia, bilateral paralysis, severe hunchback, painful joint disease, and unilateral spatial neglect and (ii) those with difficulty in understanding instructions during the evaluation and measurement. Furthermore, they were classified according to several standup conditions. Eventually, 15 stroke survivors were included in this study (Figure 1). They provided written and verbal informed consent and agreed to participate in the study. The study was approved by the Research Ethics Committee of the Yamagata Prefectural University of Health Sciences and Shinoda General Hospital.

2. Methods

2.1 Standing action

The patients were asked to perform the following three standing motions based on a previous study [14]: (i) with arms crossed and no upper limb support, (ii) using the push method: by pushing on the surface of the seat only with the unaffected upper limb, and (iii) using the pull method: by pulling the anterior vertical handrail only with the unaffected upper limbs. The patients were classified into the following two groups: those who were able to stand using the pull method only (the pull) and those who could not stand even with upper limb support (the unable) (Figure 1). They were asked to perform each standing motion up to five times after several practice sessions. This helped us determine their ability to perform the standing movement. The height of the seat was matched to the length of the lower leg in the stand-up movement. Moreover, the initial position in the sitting posture had a 5° ankle dorsiflexion. Furthermore, the center of the thigh was positioned at the anterior end of the platform. The position of the anterior vertical handrail was adjusted to the tips of the fingers while raising the patient from a seated position to 90° of flexion of the non-paralyzed shoulder joint. Moreover, the grasping position was free.

2.2 Physical assessment

The patients were assessed for motor paralysis by using a 12-grade hemiplegia functional test. In addition, the Stroke Impairment Assessment Set (SIAS) was administered as a comprehensive functional assessment.

A hand-held dynamometer (μTas F-1, Anima Co., Ltd.) was used to measure the isometric strength of the upper and lower extremities on the unaffected side. The measurement was performed at the following sites: shoulder flexion, extension, elbow flexion, extension, hip flexion, abduction, knee extension, and ankle dorsiflexion muscle group. A belt was used to measure the limb position based on Bohannon's

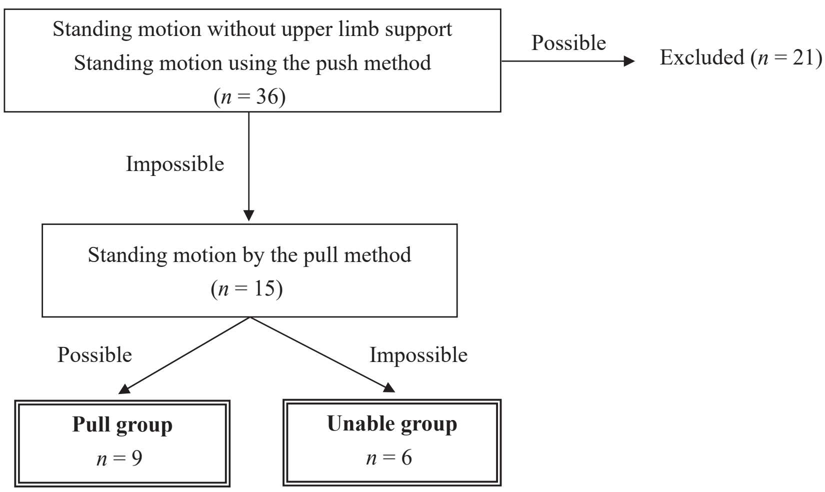

Figure 1. Classification by standing motion.

method [15]. The torque value was calculated by multiplying the muscle strength value by the torque length. To exclude the effects of gender and other factors, muscle strength was divided by body weight for comparison (N•m/kg). Each parameter was measured three times and the maximum value was selected.

2.3 Statistical analyses

A two-sample *t*-test was used for comparing the parametric data, while the Mann-Whitney *U*-test was used for group-wise comparison of the nonparametric data, such as the 12-grade hemiplegic function tests, SIAS total, and sub-item scores, and muscle strength. The level of significance was set at 5% in all cases. IBM SPSS Statistics version 23 was used for the analyses.

Results

There were nine and six patients in the pull and unable group, respectively. Table 1 summarizes their characteristics. Table 2 outlines the results of the 12-grade hemiplegia functional test and SIAS total and sub-item scores. The muscle strength of the unaffected side of each patient is shown in Table 3.

It was found that the degree of motor paralysis in the pull group was significantly milder for the 12 grades of lower limb function than in the unable group. Despite no significant difference in the SIAS subgroups in the paralyzed lower limb function ($p = 0.063-0.079$), the median values were higher in the pull group. There was no significant difference in total SIAS scores.

The positional sense of the upper limb had a median of 2 (range: 0−3) in the pull group, compared to a median of 3 (range: 2−3) in the unable group, with significantly higher scores in the latter. The median dorsiflexion angle of the lower limb was 2 in both the pull (range: 2−3) and unable (range: 1−2) groups. Nonetheless, the range of motion of the ankle joint on the paralyzed side was significantly greater in the pull group. Furthermore, those in the pull group showed substantially greater muscle strength in the shoulder and elbow flexion than that in unaffected muscles in the weight ratio. However, there was no significant difference in muscle strength in the lower limbs.

Discussion

The standing motion utilizes lower limb muscles to lift the center of gravity forward and upward to maintain balance. Patients can compensate for weak muscles of the lower limb by using the upper limb. Furthermore, caregivers can provide assistance to accomplish the movement. Despite no difference in the muscle strength of the unaffected lower limb between groups, the motor function of the affected lower limb was higher in the pull group. This indicated the importance of the motor function of the lower limbs. A bilateral knee extension force >330 N in the lower extremities or 50% of the lower extremity muscle strength to body weight ratio is required to stand from a chair [3, 16], highlighting the significance of the total bilateral muscle strength. The strength of the unaffected lower limb muscles was similar to that of the knee extension muscles in the same age group in a previous study [17]. Therefore, it is considered that the strength of the paralyzed leg muscles affected the ability to move.

In this pilot study on stroke survivors with hemiplegia, a significant difference was found in the dorsiflexion angle of the unaffected side, suggesting the inability of the patients to perform sufficient dorsiflexion while standing. Thus, they could not shift their center of gravity forward. The pull method supposedly has less trunk flexion and the required angle of ankle dorsiflexion was rather small. However, this angle is >20° during a normal chair-raise motion [18], suggesting its effect.

In addition, there was a significant decline in the

Table 1. Characteristics of the patients.

	The pull group (*n*=9)	The unable group (*n*=6)
Age (years)	70.4±8.6	73.2±14.3
Sex (number)	Male: 5; Female: 4	Male: 3; Female: 3
Height (cm)	156.1±10.7	156.2±7.8
Weight (kg)	48.3±8.5	50.7±7.8
Days after stroke (days)	78.9±48.8	127.2±31.3
Affected side (number)	Right: 6; Left: 3	Right: 2; Left: 4
Brain lesions (number)	Thalamus: 2 Putamen: 1 Distribution of middle cerebral artery: 3 Corona radiate: 1 Basal nucleus: 1 Sub cerebral cortex: 1	Thalamus: 2 Putamen: 1 Distribution of middle cerebral artery: 2 Internal capsule, posterior limb: 1

Average ± standard deviation.

Table 2. Results of motor paralysis, SIAS.

	The pull group (*n*=9)	The unable group (*n*=6)
12-grade hemiplegia functional test (U/E)	4.6±4.6	2.0±1.3
(L/E)*	7.2±2.2	4.2±2.1
SIAS total score	46.1±10.8	42.3±3.6
SIAS subscore		
Knee-Mouth Test	1(0−4)	1(0−2)
Finger-Function Test	1(0−4)	1(0−1)
Hip- Flexion Test	3(1−4)	1(1−2)
Knee-Extension Test	3(1−5)	1.5(1−2)
Foot-Pat Test	1(0−4)	0(0−2)
Deep Tendon Reflex (U/E)	1(0−3)	1.5(1−2)
(L/E)	1(0−3)	1(0−2)
Muscle tone (U/E)	1(1−3)	1.5(1−2)
Muscle tone (L/E)	2(1−3)	2(1−2)
Tactile sensation (U/E)	2(0−3)	3(2−3)
Tactile sensation (L/E)	2(0−3)	3(2−3)
Position sense (U/E)*	2(0−3)	3(2−3)
Position sense (L/E)	2(0−3)	3(2−3)
Range of motion (U/E)	3(1−3)	2(1−2)
Range of motion (L/E)*	2(2−3)	2(1−2)
Pain	3(1−3)	2(1−3)
Strength of abdominal m.	3(1−3)	2(1−3)
Verticality test	3(3)	3(3)
Visuospatial cognition	3(3)	3(3)
Language	2(1−3)	3(2−3)
Strength of quadriceps femoris m.	3(2−3)	2.5(2−3)
Grip strength of unaffected side	2(1−3)	2(1−2)

12-grade hemiplegia functional test, SIAS total score; Average ± standard deviation. SIAS subscore; Median (Range).
*$p < 0.05$
U/E, Upper extremity; L/E, Lower extremity. SIAS, Stroke Impairment Assessment Set.

Table 3. Results of weight-ratio muscle strength of the unaffected side.

		The pull group (*n*=9)	The unable group (*n*=6)
Shoulder joint	Flex*	0.45±0.17	0.28±0.09
	Extension	0.58±0.17	0.42±0.19
Elbow joint	Flex*	0.60±0.18	0.36±0.17
	Extension	0.52±0.17	0.36±0.14
Hip joint	Flex	0.71±0.18	0.61±0.16
	Abduction	0.71±0.25	0.55±0.18
Knee joint	Extension	0.96±0.21	0.86±0.40
Ankle joint	Dorsiflexion	0.40±0.14	0.31±0.08

Average ± standard deviation, Units: N・m/kg.
*$p < 0.05$

muscle strength for the elbow and shoulder flexion in the unable group. The pull method requires shoulder extension and elbow flexion movement (Fig. 2) [12, 13]. Moreover, the weakness of the unaffected muscles of the upper limb might have prevented the subjects from standing. In contrast, those in the unable group displayed a higher function in the sense of position of the paralyzed upper limb. However, it was difficult to consider the impact of the results on the ability to stand. This can be attributed to the failure of the upper limb on the affected side to affect the movement. Furthermore, bias due to the small sample size was considered to affect the results.

The limitations of this study included the inability

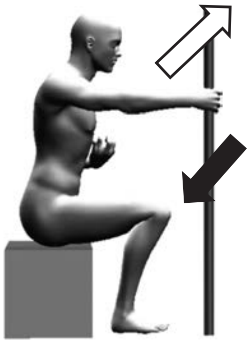

Figure 2. Stand-up motion by the pull method.
In the pull method, the pulling motion (black arrow) is performed by extending the shoulder joint and flexing the elbow joint. The reaction mechanism (white arrow) lifts the body upward.

to find a relationship between each of the body functions. This might have been a consequence of their independent assessment. The coordination of each joint and various factors affected the standing motion [19, 20]. Therefore, this relationship could not be extracted by comparing the various items. In addition, various environmental conditions, such as foot position, handrail position, and chair height, affected the standing movement. Hence, it is necessary to investigate the effects under various conditions.

The present study was conducted as a pilot study using a small sample size under fixed conditions. Nonetheless, differences in physical functions were observed, indicating the importance of the functions of the affected side and that of the upper limbs. In the future, it is necessary to increase the sample size and analyze various conditions to identify the conditions and characteristics that enable people to stand from a chair.

This study's findings suggest that stroke survivors with hemiplegia need to improve the motor function of the paralyzed lower limb, range of motion of the ankle dorsiflexion, and strength of the unaffected upper limb muscles to be able to stand from a chair.

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