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Analysis for Sit-to-Stand Performance According to the Angle of Knee Flexion in Individuals with Hemiparesis

Mi Young Lee, PhD[1)], Hae Yong Lee, MS[2)]*

[1)] *Department of Physical Therapy, College of Health and Therapy, Daegu Haany University, Republic of Korea*
[2)] *Department of Rehabilitation Science, Graduate School, Daegu University: Naeri-ri, Jillyang, Gyeongsan-si, Kyeongsangbuk-do, Republic of Korea*

Abstract. [Purpose] Sit-to-stand (STS) is one of the important functional tasks people perform throughout the day. This study investigated whether varying angles of knee flexion affect STS patterns in individuals with hemiparesis by using a foot plantar pressure measurement system. [Methods] Fifteen stroke patients with hemiparesis participated for this study. They performed sit-to-stand with three angles of knee flexion (70°, 90°, and 110°). We measured the trajectory of the center of pressure, peak plantar pressure, and symmetry index using a Mat-scan system (Tekscan, South Boston, MA, USA). [Results] As a result, we found that there were significant differences among the three angle conditions (trajectory of center of pressure, peak plantar pressure on the affected side, and symmetry index). However, there was no significant difference in peak pressure according to the knee flexion on the unaffected side. [Conclusion] In the current study, we found that stroke patients with hemiparesis had a compensated STS pattern according to knee flexion angles. This indicates that the peak value of plantar pressure increased and that the trajectory of the center of pressure widened as the angle of knee flexion increased. We also suggest that hemiparesis patients should be more concerned about proper knee angle for symmetrical STS pattern.
Key words: Sit to stand, Plantar pressure, Hemiparesis

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INTRODUCTION

Sit-to-stand (STS) movement is performed frequently and is an important functional activity in our daily lives[1, 2)]. It is a prerequisite for functional activities such as transfer, ambulation, and walking up and down stairs[1, 3)]. Thus, STS ability is a key factor and indicator in functional independence[4)]. Performance of STS results in physiological changes from a stable position to a less stable position with a higher center of mass and small base of support due to extension of the lower extremities[5)]. For this, it requires a greater joint torque as well as precise control of center mass motion within the base of support[6, 7)].

STS can be often altered in stroke patients with hemiparesis. They utilize an asymmetrical weight-bearing pattern when performing STS, which puts less weight on the affected limb[3, 8)]. In addition, the time required to perform STS increases[3, 9)]. These have been associated with muscle weakness and loss of postural control[1, 10, 11)]. Furthermore, stroke patients with hemiparesis who have an altered pattern of STS are at risk of falling down and have mobility problems[5)].

The human feet provide surfaces for interaction with the environment. Therefore, it is important to examine foot plantar pressure characteristics and to diagnose foot problems. Recently, foot plantar pressure measurement system is available to apply accurately and efficiently[12)]. Thus, it has been widely used in a number of clinical fields[13–17)]. During rehabilitation, it is quite useful to measure the effort exerted by the lower limbs in stroke patients[15, 16)].

Therefore, in the current study, we investigated whether varying angles of knee flexion affect on the trajectory of the center of pressure, peak plantar pressure, and symmetry of plantar pressure during STS in the individuals with hemiparesis using a foot plantar pressure measurement system.

SUBJECTS AND METHODS

Fifteen patients (age: 53.60 ± 16.01 years; range 21–72 years; 11 male) with hemiparesis due to cerebral infarction (53%) and hemorrhage (47%) participated. Eight patients presented a left-side hemiparesis. Patients for this study were selected based on the following inclusion criteria: (1) first-ever stroke, (2) unilateral cerebral infarct or hemorrhage, (3) at least 6 months after onset and, (4) able to rise from a chair alone. Patients who showed severe sensory loss or cortical symptoms such as neglect or apraxia, cognitive

*Corresponding author. Hae Yong Lee (E-mail: cyberlhy@nate.com)

Table 1. Characteristics of pressure measurements according to the different angles of knee flexion

		70°	90°	110°
TCOP (cm)	ML displacement*	5.80±1.45†	7.34±2.27‡	8.03±1.91‡
	AP displacement*	6.91±2.17†	8.18±1.93‡	8.23±2.06‡
PP (kPa)	Affected side*	81.60±29.81†	88.66±29.45†	103.72±26.14‡
	Unaffected side	171.13±61.30	177.26±51.85	176.83±55.23
SI*		0.17±0.10†	0.16±0.06†	0.12±0.08‡

Values are expressed as the mean±SD. An asterisk (*) indicates a significant difference (p<0.05). Values with different superscripts (†, ‡) in the same column indicate the results of one- factor analysis with contrast tests and significance at the p<0.05 level.
TCOP, Trajectory of center of pressure: ML displacement, Medial-Lateral displacement: AP displacement, Anterior-posterior displacement: PP, peak pressure: SI, symmetry index

deficits sufficient to impair cooperation, or severe spasticity (modified Ashworth scale > 2) were excluded from this study. All of the stroke patients understood the purpose of this study and provided their written informed consent prior to their participation in the study. This protocol was in accordance with the ethical standards of the Declaration of Helsinki.

The subjects were seated on an armless, backless chair with their shoes off. They had to sit up with both arms crossed over the chest and stand up at their own pace from a height-adjustable chair. The chair height was determined based on three angles of knee flexion (70°, 90°, and 110°). Throughout the three tasks, the subjects were instructed to keep their feet in the same positions. Subjects looked ahead at a target placed 2 meters and maintained their standing position for approximately 5 s. The tasks were repeated three times, and the sequence of the tasks was assigned randomly. Before beginning each task, all subjects were given the instruction “stand up at a comfortable speed whenever you are ready.”

A Matscan System (Tekscan, South Boston, MA, USA) was used to measure peak plantar pressure, trajectory of the center of pressure, and symmetry of plantar pressure. This system consists of a 5-mm-thick floor mat (width of 702.579 mm) incorporating 2288 resistive sensors. The pressure was recorded at 50 Hz for all trials. After the pressure was read and recorded, data were processed with custom-made software, Tekscan Pressure Measurement System (version 5.23). In addition, we calculated the symmetry index for plantar pressure as follows:

$$SI = \frac{\text{(PP of unaffected side} - \text{PP of affected side)}}{\text{(PP of unaffected side} - \text{PP of affected side)} / 2} \times 100\%$$

A symmetry index value of 0 indicates perfect bilateral symmetry (SI= symmetry index, PP= peak pressure).

Statistical analysis was performed using SPSS 14.0 for Windows (SPSS Inc., Chicago, IL, USA), and significance was set at $\alpha=0.05$. For all data satisfying the normal distribution, a parametric test was performed. To assess the differences in plantar pressure parameters according to the various angles of knee flexion (70°, 90°, and 110°), a series of one-way repeated measuring analyses were performed. Contrast tests to examine repeated effects as within-joint angle factors were used.

RESULTS

We found differences in plantar pressure parameters according to knee flexion during STS. There were significant differences in the trajectory of the center of pressure (medial/lateral, anterior/posterior displacement) and the symmetry index according to the different angles of knee flexion ($p<0.05$). In addition, there was also a significant difference in peak pressure according to the angle of knee flexion on the affected side ($p<0.05$). However, there were no significant differences according to the angle of knee flexion on the unaffected side ($p>0.05$). The results of the contrast test are shown in Table 1.

DISCUSSION

In this study, we assessed the plantar pressure during performance of STS in individuals with hemiparesis. We found that the trajectory of the center of pressure showed wide displacement when knee flexion was increased. In addition, peak pressure intensified with increased angles of knee flexion on the affected side only. Also, we discovered that symmetry of plantar pressure between the affected and unaffected limbs was evident at increased angles of knee flexion.

Commonly, stroke patients with hemiparesis have a reduced ability to rise from a chair, thus, showing compensated movement patterns for performing this task. In particular, longer periods to perform STS, altered displacement of the center of mass, and asymmetrical vertical force are often observed in them[1, 3, 8, 9, 19]. Also, previous studies have demonstrated that stroke patients exhibit asymmetrical weight-bearing patterns due to weakness of the muscle of the paretic limbs[1, 10]. Lomaglio and Eng[1] reported that there was a high correlation between paretic knee extensor strength and weight-bearing symmetry during STS movements. Likewise, our results revealed that there were discrepancies in peak pressure between the affected and unaffected limbs during performance of STS.

In addition, performance of STS could be affected by various extrinsic conditions. Hennington et al.[18] explained that children with cerebral palsy needed an increased extension phase duration and the maximum vertical ground reaction force during STS with a low seat height. Roy et al.[19] reported that foot position influenced the asymmetry of the knee extensor moment during the STS task. Therefore, they suggest that patients should be positioned with the affected foot behind the unaffected one for symmetrical knee moment during performance of STS. Similarly, Masaya et al.[20] reported that cushion thickness affected STS motion among the elderly. They elucidated that increased cushion thickness induced inclined trunk anteriority and required greater knee extensor strength during STS motion. Like previous studies related to extrinsic conditions during STS, our present results also showed that various knee flexion angles (70°, 90°, and 110°) influenced STS patterns.

In conclusion, the present study investigated whether different degrees of knee flexion influence the performance of STS using various chair heights. We found that a wider trajectory of the center of pressure and the higher peak pressure on the affected limb were induced as the angle of knee flexion increased. In addition, we observed more symmetrical plantar pressure when the degree of knee flexion was increased. We believe that our results are supported by the results of previous studies that demonstrated compensation patterns during STS in the patients with hemiparesis. Our findings also suggested improvements concerning our understanding of the mechanisms underlying motor function recovery in stroke patients. We further suggest that hemiparesis patients should be more concerned about proper knee angles for symmetrical STS pattern. However, a limitation of our study is that we did not examine data from healthy subjects. Also, the subjects in our study had mildly impaired motor functions, and thus future study on the STS pattern is necessary for patients with various levels of motor function.

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