A Study on the Distribution of Plantar Pressure in Adult Hemiplegia during Gait with the Use of Cane

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Purpose: The purpose of this study was to investigate the plantar pressure distribution between the affected and unaffected side in adult hemiplegia during gait with the use of a quad-cane.

Methods: Thirty-four stroke patients from 34 to 83 years of age were enrolled in this study, and in random order, all patients were asked to walk at their most comfortable speed three times along a walkway with the use of quad-cane over a period of three days. Plantar pressure distribution was measured with regard to foot contact pattern and center of pressure (CoP) trajectories during the stance phase, progressing from heel-strike to toe-off. The F-scan system was used to compare the foot pressure of the affected and unaffected sides.

Results: A significant reduction in the total contact area, the width of fore foot (FF) and hind foot (HF), and anterior/posterior (AP) CoP trajectory of the affected side was found. However, contact pressure of the hind foot on the affected side during walking increased when compared to that on the unaffected side.

Conclusion: We demonstrated that plantar pressure distribution on the affected side of adult hemiplegia patients was generally poorer than that on the unaffected side when these patients walked with cane assistance. However, the use of a quad-cane was shown to increase contact pressure of the hind foot on the affected side because weight can be borne on the affected side during heel-strike with use of the cane.

Keywords: Quad-cane, Plantar pressure, Hemiplegia

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I. Introduction

Stroke is a common neurological disease and a leading cause of chronic disability worldwide.[1] Awareness of stroke warning symptoms and risk factors as well as knowledge of available treatment options may be considered in high-risk populations. Among individuals who survive a stroke, the most frequent motor deficiency is hemiparesis or hemiplegia, with corresponding physical limitations.[2,3] The important issues in rehabilitation of stroke patients include activity and participation. Activity is the nature and extent of functioning in the personnel, which includes taking care of oneself, performing a job, and daily life activities, whereas participation is an individual's involvement in life situations related to health conditions, bodily functions and structures, and activities. After stroke, the general trend is toward decreased activity and participation.[4,5]

Walking ability is important to the stroke patient because it plays a crucial role in performing activities of daily living and many tasks for independent lives. Unfortunately, the stroke patients consequently perform abnormal gait and it was well documented that 57% of patients with stroke are unable to walk without human assistance.[6-8] A cane improves the hemiplegic gait by assisting the affected limb to smoothly shift the center of body mass toward the sound limb and to enhance inadequate shock absorption at heel strike and push off to maintain forward propulsion during preswing phase.[9,10] Mulley[11] described that the use of long stick in the unaffected arm encourages the patients to bear more weight through the affected side by producing a

better gait pattern. Chen et al.[12] also mentioned that one-point cane provides support and a braking function for people with hemiplegic stroke.

For proper usage of cane, there are several guidelines for measuring the length of cane in a clinical setting, investigating the efficacy for people who need assistance with everyday activities.[9,13] However, there is no practical documentation that compares the aspects of plantar pressure between affected and unaffected side during stance phase of gait in hemiplegic patients with the use of quad-cane. Therefore, the objective of this study was to find out the distribution of plantar pressure between affected and unaffected side in hemiplegic patients with the use of quad-cane.

II. Materials and Methods

1. Subjects

Thirty-four stroke patients with no history of major injuries such as fracture or surgery to their lower extremity were included in this study. All of the patients performed immediately comprehensive rehabilitation after stroke and the subject who can independently walk over 10 m with using of cane were participated. The participants were excluded if they had vestibular impairment that could affects elements to arouse fall down, or were able to walk without usage of cane for the equal condition to compare. The subjects were instructed about the experimental procedure and requested to sign in consent form prior to participating in the experiment. The baseline demographic characteristics of the subjects enrolled in the study are described in Table 1.

2. Experimental equipment

The quad-cane (four-point cane) as adjustable fitting length by the 1 cm was selected for what produces the wide base of support and makes hemiplegia increase postural control while walking.[14,15]

Table 1. Demographic data of the hemiplegic patients

Variable (M15/F19)	Mean	SD
Age (yrs)	64	11.33
Height (cm)	159	9.33
Weight (kg)	59	9.81
Foot length (mm)	240	5.35
Onset period (months)	41.35	37.07

The F-scan system (Tekscan, USA) was used to measure foot pressure. The pressure was recorded at 50 Hz with a pressure sensitive insole consisting of a 0.15 mm thick sensor with an embedded grid work of 960 pressure-sensing cells, evenly distributed at 0.5 cm (0.2 inches) intervals. Before use, the disposable insole was trimmed to fit into the shoes.

3. Procedure

The quad-cane was constructed to the patient who stood erect with wearing comfortable indoor shoes. Each height of the cane was adjusted so that the top of the cane corresponded to the top of the greater trochanter. The lower tip of the cane was placed at a point 6 inches lateral to the little toe. The subjects wore their own indoor shoes and were fitted with the portable equipment and the insoles, which were trimmed to their shoe size and the cuff unit is attached to the lower leg with a Velcrostrap. A 9.25 m cable connects the sensor and the sensor was set to collect data at 50 Hz for 4 sec. Because temperature changes of the insole might alter the data, temperature equilibration is essential. This was ensured by a pretrial 5-minute period during which the foot was in the shoe with the sensor in place: the system was then calibrated. Using their indoor shoes bilaterally, the subjects performed 3 walks of approximately 3 steps each with the use of quad-cane for three days. Plantar pressure was recorded for 3 steps in the middle of the test walk and the mean value was calculated. After the pressure was read and saved, they were processed with custom-made software, F-Scan version 4.19F.

To assess the plantar pressure distribution with the use of cane, both sides of foot were divided in three regions: forefoot (FF), midfoot (MF) and rearfoot (RF); that is 40%, 30% and 30% of the total foot length, respectively. The measurements of parameters were grouped into 2 categories: measurements of foot contact pattern and the measurement of centre of pressure (CoP) trajectories (antero-posterior (AP) and medio-lateral (ML) trajectory).

4. Data analysis

Foot plantar pressure distributions between affected and unaffected side at the cane length of greater trochanter during walking in hemiplegic patients were analyzed with independent sample t-test of SPSS 12.0 package. The alpha level for significance was set at 0.05.

III. Results

1. Foot contact pattern

Table 2 shows the dynamic plantar pressure distribution at the cane length of greater trochanter between affected and unaffected side. There were significant differences in the total contact area, the width of FF, and HF between affected and unaffected side. Values of affected side were smaller than those of unaffected side. However the contact length and the width of MF did not have the significant differences. HF of contact pressure (%BW) did have significant difference on affected side rather than on unaffected side. There were not significant differences in FF and MF contact pressure (%BW) between affected and unaffected side in hemiplegic patients.

2. Center of pressure trajectory

The length of AP displacement of CoP did significantly differ between the affected and unaffected side. The trajectory of affected side was shorter than that of the unaffected side. The length of ML displacement of Cop was not significantly different.

IV. Discussion

Plantar pressure measurement systems are useful tools that obtain not only plantar pressure but force data while dynamic movements. Especially, the benefits of in-shoe pressure monitoring by F-scan system are that pressures to specific areas of the foot can be investigated and visualized during walking while patients wear shoes or orthotics and it is also reported that the parameters of F-scan have good reliability (ICC>0.94) and good linearity (r=0.96) and it is one of the most commonly used to measure plantar pressure distribution for gait analysis.14A normal gait pattern was composed of the sequence of heel strike, foot flat, mid-stance, and push-off. Heel strike is a loading response to absorb the vertical shock, and push-off provides a propulsive force at the end of stance phase. Hence, foot contact pattern can be a simple and reliable indicator of waling in hemiplegia and it is also related to patient's neurologic status.[15] During walking, CoP is defined as the point at which there is no movement from all of the applied forces is only in the heel when the heel is in the first part of the step, after that, heel-off, it can be measured overly, then plotted over a picture of the foot and a pathway of the CoP is eventually produced.[16] Additionally, it also reflects accurately the topographical features of the plantar pressure distribution, provides information specific to each lower extremity and the neuromotor fluctuations that are part of motor control, and the CoP displacement corresponded to 83% of the foot contact length and 18% of the forefoot contact width.[17]

In this study, decrease of total contact area, decrease of the width of FF and HF, increase of the contact pressure of HF, and decrease of AP CoP displacement in the affected side indicated more differences than those of unaffected side during walking with the use of cane. Total contact area and contact width on the affected side decreased by shifting center of body mass toward the sound side. The reason for this still seems to bear more weight on the unaffected side even though they use the cane. However, the significant increase of contact pressure of hindfoot on affected side was shown when compared with the contact pressure of hindfoot on unaffected side with the use of cane

Table 2. Mean plantar pressure distribution of both sides with use of the quad-cane

Variation		Affected Side	Unaffected Side	p
Total contact area (cm^2)**		79.22 (22.87)	107.31 (27.51)	0.00
Contact length (cm)		21.54 (2.28)	21.90 (2.15)	0.21
Contact width (cm)	FF**	5.93 (1.81)	7.22 (1.23)	0.00
	MF	3.36 (1.42)	3.88 (1.37)	0.06
	HF**	5.05 (0.74)	5.71 (0.72)	0.00
Contact pressure (%BW)	FF	71.26 (24.25)	66.82 (32.60)	0.27
	MF	50.97 (28.01)	61.64 (21.77)	0.05
	HF*	49.08 (24.33)	34.76 (19.18)	0.01
AP CoP trajectory (cm)**		12.48 (4.01)	16.30 (3.00)	0.00
ML CoP trajectory (cm)		3.02 (1.14)	3.25 (1.21)	0.16

Mean (SD), *p<0.05, **p<0.01
FF: Fore foot, MF: Middle foot, HF: Hind foot

during walking. The reason for that seems that weight shift to the affected side from inadequate to adequate heel strike due to the use of cane was appropriate to transmit the force on hind foot of the affected side. In addition, decrease of AP Cop displacement can be considered as the result of uncontrolled forward transition in hemiplegic patients on the affected side with the use of cane. The reason seems to be related with decrease of mobility on the affected side even though they use the cane. These results were similar to previous study[18] which has shown that the hemiplegic side indicated the shortened heel strike time support interval and major alterations in reception and propulsion dynamics with decreased force values compared to the unaffected side. These results can be based on findings of previous researches[9,19] which has indicated temporal, spatial and kinematic variables of hip, knee, and ankle of hemiplegic patients using a cane and has shown that when walking with a cane, less muscle force is needed because weight is taken on the cane, and thus less EMG activity is generated. In addition, Chen et al.[12] reported that stroke patient's walking with cane assistance relies mostly on the sound limb for propulsion, while using the affected limb and cane for braking. This finding supports our results which indicate that the use of cane is able to harmonize heel strike and to bear the weights of HF to slow mobility. Accordingly, our present study will help the clinician to understand and to correct the imbalance of plantar pressure distribution between affected side and unaffected side of adult hemiplegia who walks using a cane.

The limitation of this study contains the small sample size and a recruited time. In addition, we couldn't help using their own quad-cane in all tests, but we selected standardized quad-cane which length adjust is possible. Since the results cannot be generalized to the stroke patient due to these above reasons, we need to increase the number of subjects for generalization of plantar pressure regarding the effect of cane. Further studies are necessary to examine the plantar pressures of their own one cane and quad-cane in hemiplegic patients.

V. Conclusion

The results of the present study indicate that quad cane may increase contact pressure of hindfoot on the affected side during stance phase and may decrease displacement of anterior/posterior center of pressure trajectory. We need to plan about the study to increase of AP COP trajectory representing mobility on the affected side with the use of quad-cane in patients with stroke.

Author Contributions

Research design: Kim K, Cha YJ
Acquisition of data: Cha YJ
Analysis and interpretation of data: Cha YJ
Drafting of the manuscript: Kim K, Cha YJ
Research supervision: Kim K

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