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Comparison of the Plantar Pressure Distributions at Different Cane Lengths

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Abstract. [Purpose] The purpose of this study was to compare plantar pressure distributions of the affected side of stroke patients during walking with canes of three different cane lengths. [Subjects] Thirty-four stroke patients participated in this study. [Method] The three different lengths of cane were: to the top of the greater trochanter, 5 cm above the greater trochanter, and 10 cm above the greater trochanter. The measured parameters were foot contact area, length, width, pressure, and the center of pressure trajectory during the stance phase, from heel-strike to toe-off. [Results] Our data revealed significant increments in the contact width and pressure of the hind foot at the cane length of 10 cm above the greater trochanter. Anterior/posterior center of pressure trajectory also significantly increased at cane lengths of 5 and 10 cm of above the greater trochanter. [Conclusion] The plantar pressure distribution for cane lengths above the greater trochanter were clinically beneficial and more effective at increasing weight shifting to the affected hind foot and harmonizing paralyzed heel strike with better displacement of pressure.
Key words: Cane length, Plantar pressure, Hemiplegic patients

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INTRODUCTION

Walking ability is important for stroke patients because it is necessary for conducting activities of daily living and many tasks for independent living[1)]. Unfortunately, stroke patients have abnormal gait and it is well-documented that 57% of patients who survive a stroke are unable to walk without human assistance for a week, but 50–85% of them are expected to recover some degree of walking[2,3)]. Chronic stroke patients often exhibit considerable gait impairment, decreased gait velocity[4)], increased compensatory pelvic movement at toe-off[5)], and temporal gait asymmetry[6)].

A cane improves hemiplegic gait by assisting the affected limb to smoothly shift the center of body mass forward and to enhance push-off during the preswing phase. It also improves balance and mobility, including circumduction gait during the swing phase[7,8)].

Many different types of device for aiding walking have been developed. For proper usage of this assistance, there are several guidelines for measuring the length of walking aids in a clinical setting for people who need assistance with everyday activities[9–11)].

A commonly used method for determining the ideal cane length is to measure the distance from the floor to the greater trochanter[12,13)]. However, Kumar et al.[14)] reported that the proper cane length should be measured from the floor to the distal wrist crease, and that was a more comfortable length for countering weak balance during walking than to the greater trochanter. Recent evidence[15)] suggests that the cane length ought to be adjusted to the individual's arm length because of the unique physical characteristics of individuals.

What's important is two thirds of hemiplegic patients have used canes that were too long and most of them have used a cane higher than the distal wrist crease or greater trochanter[16)]. To our knowledge, there is no study that has investigated the proper cane length for hemiplegic patients or conducted a detailed analysis of plantar pressure distribution while they are walking with a cane. Therefore, the objective of this study was to investigate the plantar pressure distribution of the affected side of hemiplegic patients during walking with three different cane lengths.

SUBJECTS AND METHODS

Thirty-four stroke patients (male/female, 15/19) with no history of major injuries such as fracture or surgery to their lower extremity were recruited for this study. All of the patients received comprehensive rehabilitation immediately after stroke and subjects who could independently walk over 10 m with a cane were recruited. Participants were excluded if they had vestibular impairment that may have resulted in falls, or were able to walk without a cane over the same distance. The subjects were acquainted with the purpose of this study, instructed about the experimental procedure, and requested to sign an informed consent from prior to participation in the experiment. The baseline demographic characteristics of the subjects enrolled in the study are described in Table 1.

A quad-cane (four-point cane) whose length could be adjusted in 1-cm increments was selected because it has a wide base of support and helps hemiplegic patients to control posture while walking[8, 11]. The F-Scan system® (Tekscan, USA) which uses disposable sensors and a spatial resolution of 3.9 sensors/cm^2 was used to collect in-shoe plantar pressure data. An F-Scan insole has 954 force-sensing resistors, evenly distributed at 0.5 cm (0.2 in) intervals and can be trimmed to any shoe size. This system was calibrated for each subject according to the manufacturer's guidelines.

Three different lengths of cane were used. The patient stood erect wearing comfortable shoes, and the length of the cane was adjusted so that the top of the cane corresponded to the top of the greater trochanter (GT), 5 cm above the greater trochanter (A5GT), or 10 cm above the greater trochanter (A10GT). The lower tip of the cane was placed at a point 6 inches lateral to the little toe[14]. The subjects wore their own shoes and the insoles which were trimmed to their shoe sizes. The cuff unit was attached to the lower leg with a Velcro strap. A 9.25 m cable connected the sensor cuff and data was collected at 50 Hz for 4 sec. Before the trials, to ensure equilibration of the temperature of the insole and to calibrate the equipment, the subjects were asked to walk at least ten meters along the experimental way[17]. If there were any high-pressure areas or the sensor wrinkled, or if it was too big to fit inside the shoe, the sensors were either repositioned or re-trimmed. After calibration, all of the subjects were asked to walk at their most comfortable speed, location of cane contact, step length, and step width three times along the walkway using the three different cane lengths. Plantar pressure was recorded for 3 walks of approximately 3 strides in the middle of the test walk and the mean value was calculated. After the pressures were read and saved, they were processed with custom-made software, F-Scan version 4.19F.

To assess separate regions of plantar pressure distribution, the affected side foot was divided into three regions: forefoot (FF), midfoot (MF) and hindfoot (HF), 40%, 30% and 30% of the total foot length, respectively[18]. The parameters were contact area (CA), contact length (CL), contact width (CW), contact pressure (CP), and center of pressure trajectories (e.g. anterior/posterior trajectory (APT) and medial/lateral (MLT)). They were calculated and averaged during the stance phase, from heel-strike to toe-off.

Repeated measures ANOVA was performed to estimate differences in plantar pressure distributions of the affected foot among the three different cane lengths. Data were analyzed with the SPSS package (version 17.0), and the level of significance chosen as 0.05.

RESULTS

CW and CP of HF were significantly different for the three different cane lengths. The cane length of A10GT gave a wider width, stronger pressure, and longer APT than the cane length of GT. APT of A5GT was significantly longer than any other length (Table 2, 3).

Table 1. Demographic data of the hemiplegic patients

Variable	
Cane type (MC/QC)	15/19
Cane length (GT/A5GT/A10GT)	7/14/13
Age (yrs)	64.1 ± 11.3
Height (cm)	159.1 ± 9.3
Weight (kg)	59.9 ± 9.8

Values are expressed as frequency or mean ± standard deviation. MC: Mono-cane, QC: Quad-cane

Table 2. Comparisons of mean plantar pressure distributions of the affected side of the three different cane lengths

Parameters		GT	A5GT	A10GT
CA (cm^2)		79.2 ± 22.9	78.6 ± 23.2	79.5 ± 23.5
CL (cm)		21.5 ± 2.3	21.8 ± 2.0	21.7 ± 2.3
CW (cm)	FF	5.9 ± 1.8	5.9 ± 1.7	6.0 ± 1.6
	MF	3.4 ± 1.4	3.4 ± 1.4	3.3 ± 1.5
	HF*	5.1 ± 0.7	5.1 ± 0.7	5.2 ± 0.8
CP (%TBW)	FF	71.3 ± 24.3	57.1 ± 31.7	66.8 ± 29.5
	MF	51.0 ± 28.0	49.0 ± 27.7	49.5 ± 25.7
	HF*	45.9 ± 17.4	49.1 ± 24.3	53.2 ± 20.0
APT (cm)*		12.5 ± 4.0	13.4 ± 3.7	13.2 ± 3.8
MLT (cm)		3.0 ± 1.1	3.1 ± 1.2	3.3 ± 1.4

Values are expressed as mean ± standard deviation. * Significant difference ($p<0.05$), TBW: Total body weight

Table 3. Multiple comparisons of plantar pressure distributions of the affected side of each cane length

Parameters	(I) Cane length	(J) Cane length	M(I-J)
CW of HF(cm)	GT	A5GT	–0.1
		A10GT**	–0.2
	A5GT	A10GT	–0.1
CP of HF(%TBW)	GT	A5GT	–3.2
		A10GT**	–7.4
	A5GT	A10GT	–4.1
APT(cm)	GT	A5GT**	–0.9
		A10GT*	–0.8
	A5GT	A10GT	0.1

** Significant difference ($p<0.01$)

DISCUSSION

Traditionally, it has been recommended that cane lengths for hemiplegic patients correspond to the height of the GT. However, 75% or more of hemiplegic patients have been using cane lengths greater than GT height, and no quantified study has investigated or compared plantar pressure distributions of different cane lengths. Therefore, we studied the effect of different cane lengths on the plantar pressure distribution with adult hemiplegic patients as subjects.

The present results show that CW and CP of HF, and

APT of A10GT cane length, and APT of A5GT cane length, were greater than those of GT cane length. These results imply that cane lengths greater than GT height are beneficial for increasing foot pressure, harmonizing heel-strike, and improving center of pressure movement of the affected foot during walking. As the cane length gets longer, elbow flexion increases and more weight is shifted to the affected side. This allows hemiplegic patients to move the plantar pressure more easily and effectively for normalized heel contact.

Buurke et al.[19] concluded that the use of a cane should be considered for achieving normal gait patterns. A previous study[20], which analyzed foot contact pattern of hemiplegic patients, reported the anterior displacement of the foot area of the affected side was shorter than that of the unaffected side, and interventions were needed to increase center of pressure trajectory. In addition, Kuan et al.[7] indicated that weight support for the paralyzed foot was effective at improving the walking pattern. Thus, our results that cane lengths greater than GT height were beneficial for paralyzed heel contact find support in these previous studies. However, there is some disagreement about cane length. Kumar et al.[14] proposed it should be the height of the distal wrist crease. The reasons for this are mainly due them having only focused on the elbow flexion of normal elderly people when they used a cane.

The limitation of this study contains short recruited time; we had to use a standardized quad cane, disregarding of cane type. Moreover, the results cannot be generalized to stroke patients, since we did not investigate walking parameters such as speed, step length, and step width of the different lengths of cane. Therefore, further studies which address these limitations are necessary in order to provide the most beneficial and effective guidelines for selecting cane lengths for stroke patients.

In conclusion, cane length of 10 cm above the greater trochanter may be clinically beneficial for assisting and harmonizing heel-strike as well as weight shift of the affected hind foot. Cane lengths of 5 or 10 cm above the greater trochanter help to increase the center of pressure displacement of adult hemiplegic stroke patients during walking.

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REFERENCES

1) Chen CP, Chen MJ, Pei YC, et al.: Sagittal plane loading response during gait in different age groups and in people with knee osteoarthritis. Am J Phys Med Rehabil, 2003, 82: 307–312.
2) Skilbeck CE, Wade DT, Hewer RL, et al.: Recovery after stroke. J Neurol Neurosurg Psychiatry, 1983, 46: 5–8.
3) Friedman PJ: Gait recovery after hemiplegic stroke. Int Disabil Stud, 1990, 12: 119–122.
4) Goldie PA, Matyas TA, Evans OM: Deficit and change in gait velocity during rehabilitation after stroke. Arch Phys Med Rehabil, 1996, 77: 1074–1082.
5) Cruz TH, Lewek MD, Dhaher YY: Biomechanical impairments and gait adaptations post-stroke: multi-factorial associations. J Biomech, 2009, 42: 1673–1677.
6) Alexander LD, Black SE, Patterson KK, et al.: Association between gait asymmetry and brain lesion location in stroke patients. Stroke, 2009, 40: 537–544.
7) Kuan TS, Tsou JY, Su FC: Hemiplegic gait of stroke patients: The effect of using a cane. Arch Phys Med Rehabil, 1999, 80: 777–784.
8) Bateni H, Maki BE: Assistive devices for balance and mobility: benefits, demands, and adverse consequences. Arch Phys Med Rehabil, 2005, 86: 134–145.
9) Bauer DM, Finch DC, McGough KP, et al.: A comparative analysis of several crutch-length-estimation techniques. Phys Ther, 1991, 71: 294–300.
10) Mullis R, Dent RM: Crutch length: Effect on energy cost and activity intensity in non-weight-bearing ambulation. Arch Phys Med Rehabil, 2000, 81: 569–572.
11) Allen SM: Canes, crutches and home care services: the interplay of human and technological assistance. Policy Brief (Cent Home Care Policy Res), 2001, 1–6.
12) Jebsen R: Use and abuse of ambulation aids. JAMA, 1967, 199.
13) Mulley GP: Walking sticks. Br Med J (Clin Res Ed), 1988, 296: 475–476.
14) Kumar R, Roe MC, Scremin OU: Methods for estimating the proper length of a cane. Arch Phys Med Rehabil, 1995, 76: 1173–1175.
15) Kim K, Cha YJ: Cane length influence on the plantar pressure distribution of adult hemiplegia patients. J Phys Ther Sci, 2011, 23: 451–454.
16) Cha YJ, Kim K: The survey of cane length to adult hemiplegia. J Rehabil Res, 2011, 15: 345–357.
17) Randolph AL, Nelson M, Akkapeddi S, et al.: Reliability of measurements of pressures applied on the foot during walking by a computerized insole sensor system. Arch Phys Med Rehabil, 2000, 81: 573–578.
18) Chevalier TL, Hodgins H, Chockalingam N: Plantar pressure measurements using an in-shoe system and a pressure platform: A comparison. Gait Posture, 2010, 31: 397–399.
19) Buurke JH, Hermens HJ, Erren-Wolters CV, et al.: The effect of walking aids on muscle activation patterns during walking in stroke patients. Gait Posture, 2005, 22: 164–170.
20) Wong AM, Pei YC, Hong WH, et al.: Foot contact pattern analysis in hemiplegic stroke patients: An implication for neurologic status determination. ArchPhys Med Rehabil, 2004, 85: 1625–1630.