



Design and Evaluation of the Walking Cane Handle Grip

Kimitomo Taniguchi^{1,*} and Atsuo Takanishi²

¹Hiroshima International University and Graduate School of Waseda University

²Waseda University

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*Corresponding author email: taniguchi.po@gmail.com

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Abstract: This study seeks to optimize the grip shape of canes used as walking aids. We developed a prototype shaped to reduce the dorsiflexion of the wrist joint, which we believe is a cause of wrist pain. The stability of the prototype grip is evaluated using a floor reaction force gauge based on a Nintendo Wii Balance Board [RVL-021]. The grips of conventional (S grip) and the prototype (P grip) cane were compared to find a significant difference in the behavior of anterior-posterior movement. These results indicate that the prototype showed good weight shift, and that the proposed grip design improved the stability of weight transfer during walking.

Keywords: Biomechanics, gait aid, walking cane handle grip

Introduction

Aging societies are increasingly concerned with fall prevention and many studies assessed the ability of assistive devices to prevent falls [1]. Hand grips on such devices are manufactured to fit the shape of the palm, but few studies have specifically investigated optimization of grip shape [2]. Many users report wrist pain due to cane use, and the palm-fitting design of most canes may actually be less than ideal for comfort during stable walking. The joint angle of the wrist is seen as the most important consideration [3-7] and we suspect that continued dorsiflexion of the wrist is a major factor contributing to the development of wrist pain (Fig. 1).

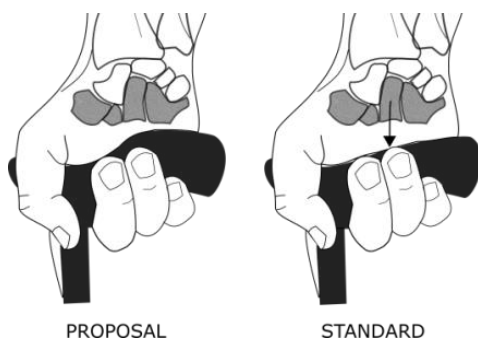


Figure 1. Prototype and standard grips

The present study develops a prototype grip (P grip) to limit dorsiflexion of the wrist joint to reduce pain in the wrist. The shape of the P grip supports the carpal bones to limit dorsiflexion, while a conventional standard grip or "S" grip provides no support of the carpal bones, allowing the carpal bones converge with increasing wrist dorsiflexion. The P grip, by contrast, suppresses dorsiflexion of the wrist by supporting the carpal bones.

In our previous study [8], the P grip was found to be more stable than the S grip under static conditions. The current experiment changed some parameters. First, the study was performed under dynamic conditions, in which participants walked while using the cane. Next, we prepared three prototypes with different features and a different circumference. Finally, we compared the differences between the P grips and the S grip with respect to the trajectory of the operating point and the load amount.

Subjects and Methods

This experiment was performed using a floor reaction force gauge to compare the operating point and the load amount of the S grip and the P grips. We performed five trials for each grip and used the mean value for analysis.



Subjects

Eleven healthy, middle-aged individuals (3 men, 8 women) participated in the study. Their mean height was 157.2cm (standard deviation, 8.12cm), and their mean age was 68 years old (standard deviation, 4.69 years).

Prior to the experiment, participants were clearly informed about the study purpose and were advised they could terminate the experiment at any time. The experimental process was explained in detail. Our study obtained Hiroshima International University’s institutional review board approval.

Measurement equipment

The experiment was performed indoors. We used a Nintendo Wii Balance Board [RVL-021] as a floor reaction force gauge. The instrument has four strain gauge force sensors, and it can measure load weight and load position. It utilizes wireless communication via Bluetooth, leaving participant movement free from constraint. With this system, it is possible to obtain measurements from a state extremely close to the actual walking environment. We used Osculator as software to connect with the Wii Balance Board. Osculator supports genuine Nintendo© devices including the Wiimote, Wiimote Plus, and the Balance Board. While most third party devices also work with Osculator, they are not guaranteed to be perfectly compatible. The Wii Balance Board is easily connected and up to four Wiimotes can be reliably and simultaneously connected to Osculator. Furthermore, this instrument is not only highly portable, but also provides reliable and precise measurement [9]. Thus, this instrument has been used as experimental equipment for research in various fields [10].

Measurement conditions

In this study, the prepared cane came in three different lengths (76cm / 80cm / 84cm), and individuals completed the experiment with a cane of suitable length based on the participant’s height. Four participants used the 76-cm grip, three used the 80-cm grip, and four used the 84-cm grip. Subjects tried 4 grips with same length cane. We replaced the grips.(S grip, P1 grip, P2 grip and P3 grip). When the cane was placed on the balance board, the trajectory of the operating point and the load amount were sampled at a frequency of 50 Hz.

KIMITOMO TANIGUCHI is an Associate Professor in the Department of Assistive Rehabilitation, Hiroshima International University. He also belongs to the Graduate School of Waseda University. He is a certified prosthetist and orthotist in Japan.

ATSUO TAKANISHI is a Professor in the Department of Modern Mechanical Engineering, Waseda University, and a concurrent Professor and one of the core members of the HRI (Humanoid Robotics Institute), Waseda University.

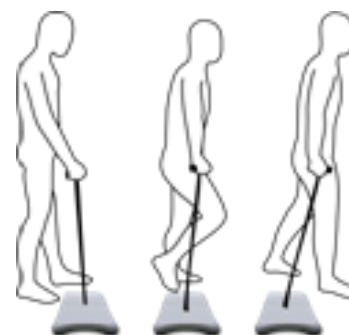


Figure 2. Experimental set-up

Prototype

Figure 3 illustrates the different designs of the various prototypes and the conventional cane, specifically the shape of the section marked “A” . Features related to handle circumference are shown in Table1.

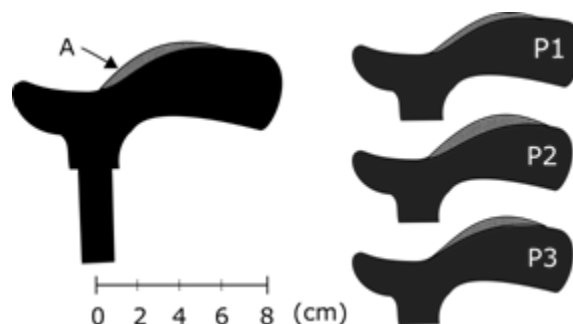


Figure 3. Grip features

	Distance from center of cane shaft		
	2(cm)	4(cm)	6(cm)
S	±0%	±0%	±0%
P1	+10%	+10%	±0%
P2	+20%	+20%	+5%
P3	+10%	+20%	±0%

Table 1. Prototype grip features

As shown in Table 1, the prototype circumference of each portion increased from that of the standard cane. The axis of the cane served as the reference point (0cm). The circumference changed at 2-cm intervals.

The standard grip is the original grip; its shape has not been changed. In the prototypes, putty was mounted on the top of the cane to increase the grip volume. The top surface was then trimmed and smoothed. The prototype, P1, increased in volume by 10% at 2cm and 4cm from the cane axis. Prototype P2 increased in volume by 20% at 2cm and 4cm from the cane axis. P2 additionally increased in volume by 5% at 6cm from the

cane axis. Prototype P3 increased in volume by 10% at 2cm from the cane axis. P3 additionally increased in volume by 20% at 4cm from the cane axis.

Evaluation index

Experimental results were evaluated using five evaluation indexes: the total length of the trajectory of the operating point (total track length: locus), the maximum width of the X-axis, the maximum width of the Y-axis (the maximum width: X-X, Y-Y), the median value of the load weight, and the maximum value of the load weight. Furthermore, the measured trajectory of each operating point was compared for each grip.

Results

The results of the four grips (S, P1, P2, and P3) at each evaluation index are shown in Figs. 4-8. Figure 4 shows the maximum load weight. Figure 5 shows the median value of the load weight. Figure 6 shows the total track length. Figure 7 shows the maximum width in the medial-lateral direction. Figure 8 shows the maximum width of the anterior-posterior direction. The median values are shown in Table 2, which also shows whether the significance of differences between the median values of two groups for each evaluation item at a 3 percent significance level, as assessed using the Wilcoxon signed rank test as a non-parametric test of two paired groups.

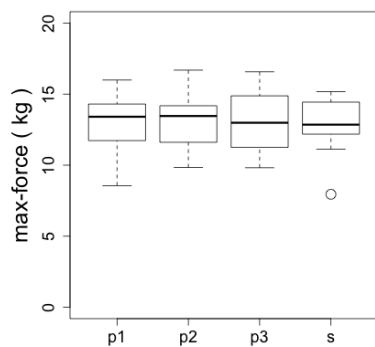


Figure 4. Maximum force value (kg)

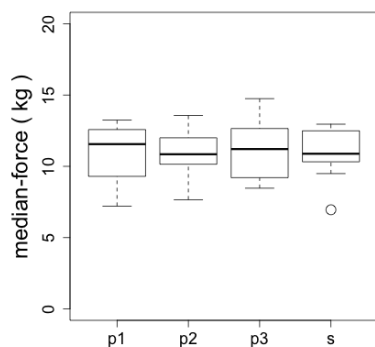


Figure 5. Median force value (kg)

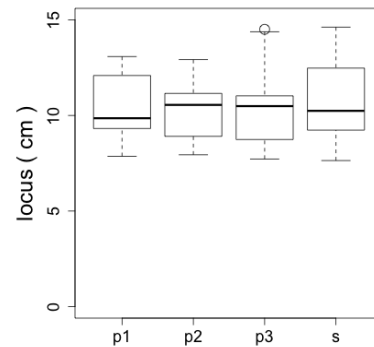


Figure 6. Total length of the operating track (cm)

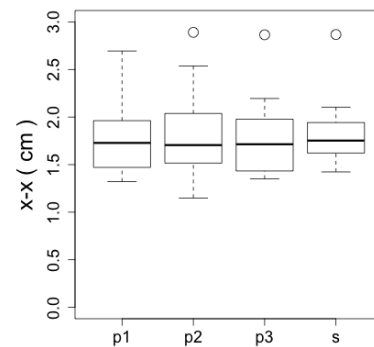


Figure 7. Maximum width in the medial-lateral direction (cm)

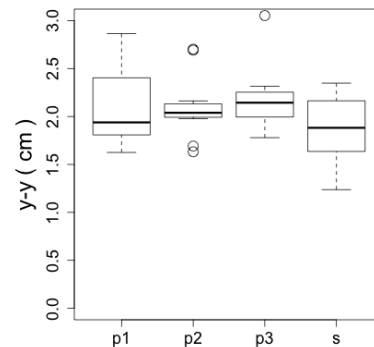


Figure 8. Maximum width in the anterior-posterior direction (cm)

The table also shows the results of the trajectory of the operating point from Figs. 9 to 12. The vertical axis is the anterior-posterior direction for the subject. The horizontal axis is the medial-lateral direction for each subject, with measurements marked in cm.

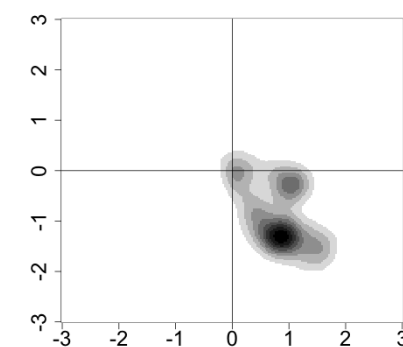


Figure 9. Operating track of the standard grip (S-grip)

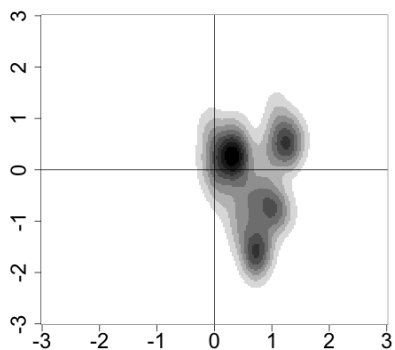


Figure 10. Operating track of the prototype grip (P1-grip)

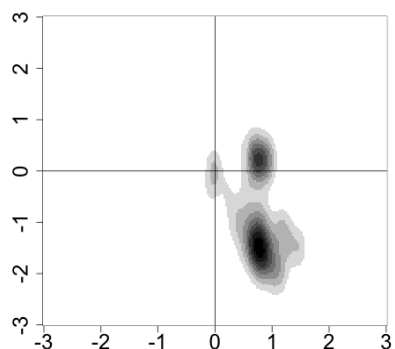


Figure 11. Operating track of the prototype grip (P2-grip)

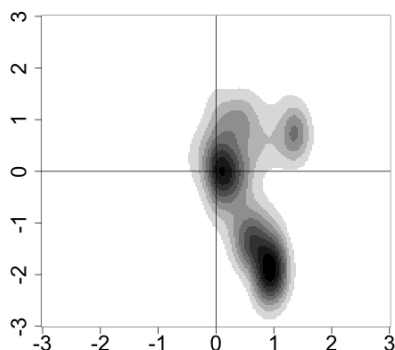


Figure 12. Operating track of the prototype grip (P3-grip)

	S	P1	P2	P3
Max-Force (kg)	12.85	13.41	13.46	12.99
Median-Force (kg)	10.88	11.56	10.85	11.21
Locus (cm)	10.24	9.85	10.55	10.49
X – X (cm)	1.75	1.73	1.71	1.71
Y – Y (cm)	1.88	1.94*	2.04*	2.14**

Significance value * p<0.03 ** p<0.01.
 S: standard grip, P1, P2, and P3: prototype grips.
 Table 2. Results of the evaluation index

Discussion

Our previous study found the P-grip to be more stable and efficient than the S-grip. We confirmed the prototype showed a significant difference in terms of static load. In the

case of a dynamic load, we checked to significant differences in terms of load amount and trajectory of the operating point. The mean value of the measurement time was 1.27 second and no significant differences were found between the grips. From the results shown in Table 2, the maximum value of the load weight, the median value of the load weight, and the total trajectory length were not significantly different between the various grips. However, in the anterior-posterior direction, there was a significant difference in the trajectory of the operating point between the conventional grip and all prototypes (P1,P2, and P3), with P3 having the most significant difference (Fig. 12). The range of anterior-posterior motion at the operating point with the P3 grip was 2.14 (cm), as opposed to 1.88 (cm) for the conventional grip (S). These results show that the prototypes allow for smoother weight shifting and that the prototypes facilitated stable weight transfer based on the handle grip shaped to support the carpal bones.

Conclusions

Experimental results found a significant difference in the point of trajectory (anterior-posterior direction) between a conventional cane grip and prototype grips. Our previous study found a significant difference in the maximum load value of load, but such a difference was not replicated here. This discrepancy is likely due to the measurement time being too short to observe a significant difference. However, given such a short timeframe, it is interesting to note the significant difference at the operating point in anterior-posterior direction. Our results showed that the prototype grips facilitated smooth weight shifting during walking. Thus, the prototype was more reliable and smooth than the standard cane, and the weight shift showed that the improved design allowed for a steady, smooth gait. Future work will examine other walking aids using the shape of the P3 grip.

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