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Original Paper

The Influence of Cane Tip Mobility on the Activities of the Upper Limb Muscles and the Load Amount on the Cane during Walking

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Abstract

The purpose of this study was to clarify the influence of cane tip mobility on walking and to obtain basic information for selecting canes. Thirteen healthy adult males participated in this study. The surface electromyogram of upper limb muscles, the load amount on the cane and subjective evaluation of usability were assessed according to two conditions: fixed cane tip and the movable cane tip. The activities of the posterior part of the deltoid, pectoralis major, and triceps brachialis and the load on the cane with a movable cane tip were significantly lower than those with the fixed cane tip. The subjective evaluation of usability with the fixed cane tip was significantly lower than that with the movable cane tip. Since the movable cane tip requires lesser muscle activities of the upper limb than does the fixed cane tip during walking, it is an effective assistive device for maintaining the walking ability of the user who has upper limb muscle weakness.

1. Introduction

It is essential for elderly people to maintain and improve their walking abilities so that they can extend their healthy life expectancy by performing their activities of daily living[1]. Thus, several exercises and muscle training programs have been developed for walking disability caused by impaired range of motion for the lower extremity and decreased muscle strength with aging[2,3]. There is no doubt about the usefulness of these programs for maintaining walking ability. On the other hand, several elderly people cannot participate in these programs from a safety perspective[4]. To deal with such a situation, a variety of rollators and canes have been used to assist with their walking ability by preventing falls and other kinds of fatigue. The Association for Technical Aids (ATA) cites 14 items such as canes, rollators, and wheelchairs, as welfare equipment relating to mobility[5]. In our previous study, we examined the influence of the rollator's structure on the walking ability of the elderly and reported the selection criteria by grip shape[6]. However, the structure of the canes, which are widely used as a walking support tool have not been discussed yet.

A cane is one of the important welfare tools for preventing falling and improving walking ability for

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those with decreased walking ability, and consists of a tip, a shaft, and a grip. Previous studies reported on measurements of kinematic factors, adaptation of cane lengths, type of cane, and grip size[7-9]. Although Aikawa reported about the friction of the cane tip rubber[10], no study focusing on the difference in shape and structure of the cane tip has been conducted. However, due to the structure of the cane, the cane tip is the only point of contact with the ground and greatly affects the stability of walking[10]. Although there are various types of cane tips, one which has a joint structure introduced between a shaft and a tip has been commercialized recently. It allows the ground contacting surface of the cane tip to move according to the condition of the floor[11,12]. The cane tip is important as a point of contact with the ground and its mobility is shown to affect walking stability, but its selection criteria are unclear. In addition, the selection of a cane should be evaluated comprehensively from the load amount on cane and lower limb, the balance ability, and the muscle activity of the upper limb. However, previous studies on the cane focused on the trunk and lower limb when using the cane[7,13-16]. There are few reports on the muscle activity of the upper limb and the load amount on the cane[17,18].

The purpose of this study was to clarify the influence of a cane tip mobility on walking by assessing the muscle activity of the upper limb, the load amount on the cane, and subjective evaluation and to obtain basic information for selecting canes.

2. Methods

2.1 Participants

Thirteen healthy males (age: 27.5 ± 7.5 years, height: 173.3 ± 4.7 cm, weight: 68.8 ± 11.8 kg) participated in this study. Participants provided written, informed consent prior to inclusion in the study. The study was approved by the Ethics Committee of the Kawasaki University of Medical Welfare (no.17-022).

2.2 Measurements

A cane tip with legs divided into three branches (GOODGEAR, Makitech, Japan) was connected to a T-cane (ORTOP COMFORT CANE, Pacific Supply, Japan) for use in the experiment. GOODGEAR is a cane tip with moderate mobility, and it is possible to contact the ground even if load is applied by tilting the shaft up to 65 degrees (Figure 1). In addition to GOODGEAR, another cane tip was used for this experiment. It was the same shape as GOODGEAR, but there was no mobility between the shaft and the cane tip.

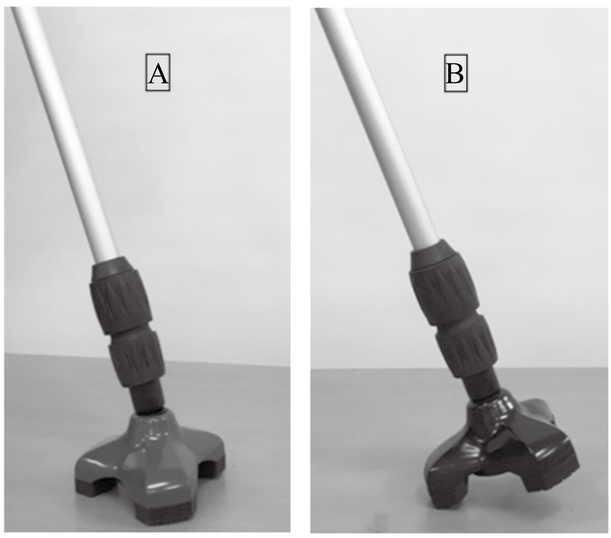

Figure 1 Experimental conditions

A: The movable cane tip has moderate mobility, and it is possible to contact the ground even if load is applied by tilting the shaft up to 65 degrees. B: The fixed cane tip had the same shape as the movable cane tip, but there was no mobility between the shaft and the cane tip.

Experimental conditions were two: one with the normal GOODGEAR attached to the T-cane (the movable cane tip) and the one with the GOODGEAR which had no mobility (the fixed cane tip). The subjects walked on a 5-m walkway on a concrete floor in a laboratory room. The length of the cane was adjusted so that the subjects' elbow joint flexed was at a 30-degree position when holding the grip. The cane tip was placed at a 15-cm anterior-lateral position relative to their left small toe during standing. The subjects used a cane with their left upper limbs, and they walked using a two-action gait, which consists of a cane and with a contracted right lower limb which were released on the floor at the same time. A shoe type foot pressure measuring device (GATE CODER, Anima, Japan) was used to confirm that the load on the foot is not greater than 90% of the subjects' body weight. We referred to the report of Robert[19], for shifting the load on the cane from the foot. The cadence was set to 70 steps per minute using a metronome. The subjects walked in two-action gait under two different conditions randomly. A trial was invalidated when a load of 90% or more of body weight was applied to an affected lower limb. Prior to the measurement, each subject was allowed to practice sufficiently until their cane walk stabilized.

Muscle activities of upper limbs were measured using surface electromyogram (Vital Recorder 2, Kissei Comtech, Japan). The target muscles were anterior, middle, and posterior parts of the deltoid, pectoralis major, latissimus dorsi, biceps brachialis, and triceps brachialis of the left side, which were related to the stability of cane gait[20]. The landmarks of the electrodes applied were based on the reference by Shimono[21]. After adequate skin preparation, surface electrodes (Blue Sensor N-00S, Medicotest A/S, Denmark) were applied parallel to the muscle fibers of the target muscle at an electrode distance of 25 mm. A ground electrode was secured to the overlying left olecranon. The foot switch as synchronize button between the electromyogram and the pole transducer was attached to the upper part of the cane grip. Furthermore, maximum voluntary contraction (MVC) of each target muscle was measured for 5 s.

Measurement of the load amount on the cane was performed by using a force measuring device (POLE TRANSDUCER PL6, Beltech, Japan) attached to the upper part of the shaft of the T-cane. The walking cycle was divided into two phases; the cane-off phase was the period in which a cane did not contact the floor while in the cane-contact phase, the cane did. In this study, the data of cane-contact phase were used for analysis[9]. All row myoelectric waveform was analyzed by using EMG analysis software (BIMUTAS II, Kissei Comtech, Japan) and were rectified after conducting band-pass filter processing (10-500 Hz). The data in 300 ms, centered on the peak value of the third cane-contact phase, were analyzed. The mean integrated electromyogram value was calculated, then normalized with MVC (%). The electromyogram and the pole transducer were synchronized by applying a load to the cane simultaneously with stimulation to the foot switch. When calculating the mean integrated electromyogram value, the beginning of the gait was defined by the waveform of the foot switch, and the peak value of the third cane-contact phase was measured by the POLE TRANSDUCER. For the load on the cane, the data in 100 ms, centered on the peak value of the third cane-contact phase, was analyzed. The data was obtained by dividing the force (N), which was a measurement unit of the POLE TRANSDUCER by 9.8, then by normalizing with body weight (%BW).

In subjective evaluation, 5-grade assessment was conducted after walking with two conditions. Each grade was defined as 1 (difficult to use), 2 (slightly difficult to use), 3 (neither), 4 (somewhat easy to use) and 5 (easy to use).

2.3 Statistical analysis

For statistical analysis, the normality was confirmed using the Shapiro-Wilk test. Then, a paired t-test was conducted to compare muscle activity of upper limbs, the load on the cane, and subjective evaluation under two conditions when normality was observed. The Wilcoxon signed rank test was used when normality was not found. The significance level was $p<0.05$. SPSS Statistics ver. 20 was used for all statistical analysis.

3. Results

The amount of muscle activity when using the movable cane tip was significantly lower than that when using the fixed cane tip in the posterior part of the deltoid, pectoralis major, and triceps brachialis ($p<0.05$) (Table 1).

The load on the cane with the movable cane tip was significantly lower than that in the cane with the fixed cane tip ($p<0.05$) (Table 2).

For subjective evaluation, the score when using the movable cane tip was significantly higher than that when using the fixed cane tip ($p<0.05$) (Table 3).

Table 1 Comparison of muscle activity of the upper limb between the movable cane tip and the fixed cane tip

	Movable cane tip (n=13)	Fixed cane tip (n=13)
Deltoid (anterior)	7.7 ± 3.8	8.2 ± 4.3
Deltoid (middle)	9.5 ± 5.1	10.1 ± 4.9
Deltoid (posterior)	14.5 ± 5.6	18.2 ± 9.4 *
Pectoraris major	20.6 ± 23.9	27.9 ± 35.1 *
Latissimus dorsi	25.2 ± 9.1	27.8 ± 11.7
Biceps brachialis	7.7 ± 7.4	8.9 ± 5.6
Triceps brachialis	101.9 ± 65.4	118.9 ± 66.8 *

Unit : % Values are mean ± SD * : $p<0.05$

Table 2 Comparison of the load amount of the cane between the movable cane tip and the fixed cane tip

	Movable cane tip (n=13)	Fixed cane tip (n=13)
Load amount on cane	14.8 ± 4.2	17.7 ± 5.2 *

Unit : % BW Values are mean ± SD * : $p<0.05$

Table 3 Comparison of subjective evaluation between the movable cane tip and the fixed cane tip

	Movable cane tip (n=13)	Fixed cane tip (n=13)
Subjective evaluation	3.6 ± 0.7	2.7 ± 0.9 *

Values are mean ± SD * : $p<0.05$

4. Discussion

A cane is an important assistive device for preventing falls and safely increasing walking ability for those who have walking disabilities. It is widely used for elderly people. However, the selection of an appropriate cane for the elderly tends to be determined by the experimental decision of physical therapists and the opinions of the elderly. Thus, no selection criteria exist. Therefore, in this study, we discussed the influence of cane tip mobility on the muscle activity of the upper limb, the load on the cane, and subjective evaluation during walking to obtain basic information for selecting canes.

As a result, the amount of muscle activity in the posterior part of the deltoid, pectoralis major, and triceps brachialis and the load on the cane when using the movable cane tip was significantly lower than that of the fixed cane tip. This indicates that the muscle activities of shoulder adductors, internal rotators, extensors, and elbow extensors are less needed when using a movable cane tip during walking although the load on the cane decreases. Since the ground reaction force vector of a cane during walking points to the direction of the cane shaft[22], the cane rolls forward (in the direction of walking) and the ground reaction force vector faces forward as the load is applied from the cane in contact with the ground. It may indicate that the muscle activity of the posterior part of the deltoid is required to stabilize the load on the cane against the ground reaction force vector. In addition, Yasui et al.[13] reported that as the load on the cane increased, greater force was applied in the direction of shoulder joint abduction. On the other hand, the muscle activity of the pectoralis major muscle is presumed to adduct and rotate the shoulder joint internally to stabilize the cane[20]. Moreover, in addition to stabilizing the elbow joint[18], it may indicate that triceps brachialis increases the load on the cane by the force pushing against the ground when trying to lift the upper limb. Regarding the contact status of the cane during walking, it is considered that the loading moves to the three contacting surfaces of the cane tip. The movable cane tip has a joint structure, and it can take the load even with the cane tilted. In other words, since the load transfer from the cane tip end to the three contact surfaces was performed smoothly by moving the joint, a large amount of muscle activity was not required at the time of loading on the cane.

The amount of load on the cane with the movable cane tip is significantly lower than that with the fixed cane tip. With a fixed cane tip, it tends to be unstable when loading from the cane contact since it does not have joint mobility. Thus, a larger force applied to the floor is required. In contrast, no extra muscle activity to push the floor is needed with a movable cane tip since the load transfer is stable and smooth. This seems to lead to a reduction in the load. In addition, the result of the subjective evaluation indicates that the movable cane tip is more useful than the fixed cane tip since it is possible to walk with less amount of muscle activity in the upper limb.

It is suggested that walking with the movable cane tip requires less muscle activity than the fixed cane tip. This indicates the possibility that the movable cane tip is an effective assistive device for maintaining the walking ability of a user who has upper limb muscle weakness due to aging or dysfunction. However, compared with fixed cane tips, the load on the cane was reduced with the movable cane tip. Neumann reported that the load on the cane during walking in patients after total hip arthroplasty was about 10% of their body weight[23]. Considering the value of 14.8% of their body weight with the movable cane tip in this study, it seems to be not particularly low. If larger load is required, a fixed cane tip may be suitable for them. It is important to understand the feature of each cane tip and to select according to their characteristics.

In order to support the safety of users and to maintain and expand their walking ability, it is necessary to select the cane tip that corresponds to their physical condition. The result of this study will help users to select a proper cane and cane tip based on their physical conditions. The limitation of this study was that they only walked on the flat floor. It is necessary to consider a more practical environmental setting, such as ramps, in future research. Although the peak value is used as the load amount on the cane in this research, it is essential to conduct more detailed analysis of the load pattern.

Conflict of interest

The authors declare that there is no conflict of interest.

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