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Influence of a Dual Task while Stepping Over an Obstacle in the Fall-experienced Elderly People

MASAYUKI SOMA, PT, MS[1)], HIDEYUKI NAKAE, PT, MS[1)], TEPPEI ABIKO, MS, PT[2)], RYOUTA SHIMAMURA, PT[2)], HISASHI UEMATSU, PT[2)], KENNOSUKE KAWAMA, PhD[3)]

[1)] *Department of Rehabilitation, Faculty of Health Sciences, Tohoku Fukushi University: 1–8–1, Kunimi, Aoba-ku, Sendai-city, 981-8522, Japan. TEL: +81 022-233-3111, FAX: +81 022-233-3113, E-mail: souma@tfu-mail.tfu.ac.jp*
[2)] *Division of Physical Therapy, Tokyo Metropolitan Rehabilitation Hospital*
[3)] *Institute of Disability Sciences, University of Tsukuba*

Abstract. [Purpose] The purpose of this study was to investigate the influence of a dual-task on movements of stepping over an obstacle by elderly people who had a fall experience in the past year. [Subjects] Subjects were 7 people who had a history of falls and 22 people who had no history of falls in the past year. [Methods] Subjects were divided into fallers group while subjects performed and non-fallers group by based on interview results. We measured toe clearance the single and dual tasks. The single task was a solitary motor task. The dual task consisted of a motor task and a concurrent cognitive task. The motor task was stepping over an obstacle during comfortable gait, and the cognitive task was the serial subtraction of seven from 100. [Results] Two-way ANOVA showed that toe-obstacle distance had a significant interaction effect. [Conclusion] These results suggest that fallers and non-fallers may have different strategies for stepping over an obstacle.
Key words: Obstacle , Faller, Dual task

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INTRODUCTION

The fall rate of the elderly is 17.7~19.1% in Japan[1,2)]. Researchers have suggested that tripping is associated with falls by community-dwelling elderly people. It is speculated that tripping by the elderly is caused by a decreased toe clearance associated with aging. There is no consensus concerning aging and toe clearance while stepping over an obstacle, and it is reported that step lengths and gait speeds decrease while stepping over an obstacle[3–9)]. However, the frequency of tripping accidents among the elderly has not been clarified.

Recently, the fall incidence among the elderly has been suggested to be related to the attention function[10–13)]. Lundin-Olsson reported[14)] “The elderly stop walking when talking”, a dual task condition, and it can predict the fall incidence for the elderly. Moreover, studies have clarified that a dual task (DT) influences the motor task performance of the elderly a tendency to fall easily.[15–18)]. However, there are few previous reports on motor tasks such as stepping over an obstacle under DT conditions. Schrodt et al[19)] reported that community-dwelling elderly people with a mean age of 73.4 years performed a DT, in which the motor task was maximal speed walking and the cognitive task was to subtract one from a called out number and orally report the answer. Toe clearance was not changed by decreasing the heel-obstacle distance and increasing the toe-obstacle distance. Moreover, we reported that toe clearance was not changed by decreasing the heel-obstacle distance under a motor task of comfortable walking speed and a cognitive task of serial subtraction of number seven performed by community-dwelling elderly people with a mean age of 69 years[20)]. However, the subjects of these reports were not the elderly who had experienced a fall but rather community-dwelling elderly people. If the motor task performance of the elderly with a tendency to fall easily decreases under DT conditions, it is possible that the elderly who have experienced a fall in stepping over an obstacle. It is thought that it is also important to know the kinematic property to determine the influence to stepping over an obstacle on a person who had experienced a fall.

The purpose of this study was to investigate the influence of a DT on the movement of stepping over an obstacle by the elderly who had a history of falls in the past year.

SUBJECTS AND METHODS

Subjects

The subjects were 30 healthy community-dwelling elderly females aged more than 65 years old with no

Table 1. Characteristics of subjects (n=29)

	Non-faller group	Faller group
Subjects (n)	22	7
Age (years)	70.0±3.5	67.6±3.1
Height (cm)	152.0±4.5	148.3±5.8
Weight (kg)	52.8±8.2	50.0±5.0
Foot distance (cm)	22.6±0.7	22.0±1.1

(Mean±SD)

orthopedic impairments. Moreover we asked the participants about whether or not they had fallen in the past year, and then examined the experiences of participants who answered, "yes". In the present study, we judged a fall by the definition of Gibson[21]: "falling down to the ground, or to a lower level against one's will". We divided the subjects into two groups, one included 7 people who had experienced a fall (fallers group), the other were 23 people who had not experienced a fall (non-fallers group) in the past year. Concerning the reason for the fall, five respondents answered that they had "Stumbled on an obstacle", two answered that they had "Fallen from stairs", and one person answered "My foot got caught while I was hurrying", and "I lost my balance while walking on uneven ground". Subjects' characteristics are presented in Table 1. Subjects had no exercise habit. Prior to the study, each subject was informed about the detail of the design, and agreed to be participate in the study.

Methods

The tasks were a DT condition, in which a cognitive task was concurrently imposed on a motor task, and a single task (ST), in which there was just a solitary motor task. Each task was performed five times. The motor task was stepping over a 2 cm high wooden obstacle that was 80 cm wide, and 15 cm deep, which was set up in the middle of a 9 m walkway. The participants were asked to walk at a comfortable speed. The cognitive task consisted of repetitively subtracting 7 starting from 100 (serial subtraction of sevens). For the ST subjects were instructed to "Walk at a comfortable speed, and step over the obstacle". For the subjects were instructed to "Walk at a comfortable speed, and step over the obstacle. During walking, repetitively subtract 7 starting from 100, and answer our questions. Continue both tasks while walking". To exclude the influence of a learning effect, the subjects were not allowed to practice stepping over the obstacle. We recorded the subjects performing the DT regardless of whether or not they subtracted correctly.

Movement was recorded using a LOCUS-III D MA-2250 three-dimensional motion analysis (ANIMA Corp) and a G1812 force platform (ANIMA Corp). The positions of the force platform and infrared camera are shown in Figure 1. Three-dimensional motion analysis was synchronized with the force platform, and it was started when the force platform perceived a mass of 2.5 kg or more in the Z axis. Infrared light emitting diodes (LED) were attached to the dorsal big-toe to measure toe clearance, toe-obstacle distance and heel-obstacle distance while stepping over the obstacle. The LED was adjusted to be positioned an equal distance from both the floor and the tip of the big toe to the LED in the static standing position. So that the tip of the big toe and the sole of the foot could be considered on the same arc of the circle with the LED at its center, so

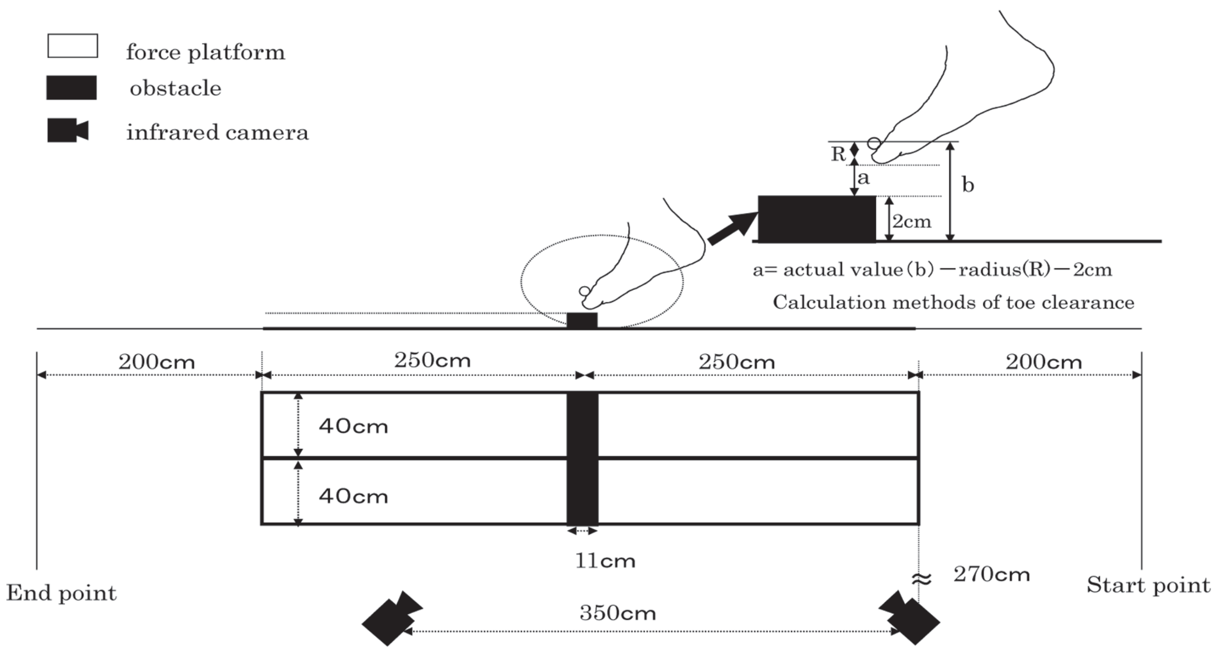

Fig. 1. The position of the force platform and infrared camera and the calculation methods of toe clearance

that the toe clearance and toe-obstacle distances could be calculate from the position of the LED by subtracting the radius of the circle (Fig. 1).

We measured gait speed, step length, and cadence, the stepping-over the obstacle parameters of leading toe clearance, trailing toe clearance, toe-obstacle distance, and heel-obstacle distance. Toe-obstacle distance was calculated as the horizontal distance between the tip of the big-toe on the trailing foot to the front edge of the obstacle while subtracting the obstacle. Heel-obstacle distance was calculated as the horizontal distance between the rear edge of the obstacle and the heel on the leading foot measured at heel strike after crossing the obstacle. Toe clearance was defined as the vertical distance between the tip of the big toe and the obstacle as it passed over the foremost edge of the obstacle. Gait speed was measured over 5 m walking, step length and cadence were calculated the force plate. We calculated toe clearance by subtracting obstacle height and big-toe back side LED height in static standing from the actual stepping-over the obstacle value of the LED height (Fig. 1). Toe-obstacle distance was the addition of the LED actual value and the radius of the circle just before stepping over the obstacle. Heel-obstacle distance obtained by was subtracting foot distance from the actual value of the LED, and adding the result to the radius of the circle just after stepping over the obstacle.

The data used for the analysis was the first trial in the ST condition, and the first trial in the DT condition in which the same leg was used to step over the obstacle. The comparison between gait and stepping-over the obstacle parameters for the group and gait conditions was performed with two-way repeated analysis of variance (ANOVA) .For the comparison of the cognitive task, the number of correct answers was evaluated using the Mann-Whitney U test. All data were analyzed using SPSS15.0J statistical software. An alpha level of 0.05 was chosen for determining the statistical significance.

RESULTS

The data of 22 non-fallers and 7 of 8 fallers were used for the final analysis (Table 1). The data for one person were excluded, because he did not step over the obstacle using the same leg as used in the first trial of the ST condition in the DT condition.

The legs used to step over the obstacle were 15 left and 7 right legs in the non-faller group, and 4 and 3 right in faller groups.

In the DT trials, the same legs as used in the first ST trial was used by 18 subjects in the first trial, 3 subjects in the second trial, 1 subject in the third trial in the non-faller group, and by 7 subjects in the first trial in the faller group.

Regarding the characteristics of the subjects, there were no significant differences between the two groups (Table 1).

Two-way ANOVA showed a significant difference, and between the groups significant main effects were found for gait speed($F(1,27)=34.6$, $p<0.05$), step length ($F(1,27)=34.6$, $p<0.05$) and cadence ($F(1,27)=34.2$, $p<0.05$). Furthermore, significant interaction was detected for cadence($F(1,27)=6.2$, $p<0.05$). A significant interaction was found for toe-obstacle distance found interaction ($F(1,27)=4.8$,$p<0.05$) between the group and condition (Table 2).

In the cognitive task, the faller group provided 2.7±1.5 correct answers, and the non-faller group provided 3.4±1.5 correct answers with no significant difference.

DISCUSSION

Our present study found interaction effects of toe-obstacle distance while stepping over the obstacle in the non-faller group and the faller group under the DT condition. This result suggests that fallers and non-fallers may have different strategies for toe-obstacle clearance when stepping over an obstacle. In other words, although the non-fallers group did not change toe-obstacle distance in both conditions, the faller group decreased the toe-obstacle distance in DT condition, and the toe-obstacle distance while stepping over the obstacle was nearer to the obstacle. We speculate there are two reasons for this. One is that the faller group subjects would normally give more attention resources to gait, but the cognitive task would have the decreased amount of attention paid to gait. Consequently, we think that the toe-obstacle distance being

Table 2. Gait parameter and stepping over obstacle parameters of the ST and DT conditions

	Non-faller group		Faller group		Interaction group×condition
	Single task	Dual task	Single task	Dual task	
Gait speeds (m/min)	64.6±10.4*	54.3±8.2*	66.4±10.1*	47.8±9.1*	
step length (cm)	56.2±7.1*	51.7±6.3*	55.5±7.2*	49.6±4.5*	
cadence (steps/min)	114.7±9.1*	105.4±11.7*	119.5±7.5*	96.2±15.5*	**
Leading clearance (cm)	4.6±1.0	4.3±1.8	4.8±1.1	4.3±2.4	
Trailing clearance(cm)	2.9±1.4	3.1±1.8	3.1±0.7	3.5±1.4	
Toe-obstacle distance (cm)	22.2±7.5	23.3±5.8	26.5±10.4	18.0±4.9	**
Heel-obstacle distance (cm)	9.9±6.4	7.5±4.3	9.2±7.3	10.3±5.2	

(Mean±SD)
Gait condition: *p<0.05

paid to the tip of the toe decreased, due to the decreased amount of attention, which is a peripheral part of the body. It is also possible that the faller group decreased the toe-obstacle distance intentionally in order to step over the obstacle safely, since Shumway-Cook et al.[22]reported that the frail elderly use the posture-first strategy which prioritizes the posture and motion under the DT condition. It will be necessary to further examine which strategy is used in the future.

The mean comfortable gait parameters in the ST of both groups were not different from those reported in previous studies[23,24]. Moreover, Toe-obstacle distance, Heel-obstacle distance in stepping over the obstacle were not different from those reported in the literature[7,19,20,25] However, both groups stepped over the obstacle with a leading toe clearance of 4.8 –5.0 cm, and a trailing toe clearance of 2.9 –3.2 cm in the ST. This clearance was smaller than those reported in previous studies[7,19]. A previous report found a leading toe clearance of 6.5–11.4 cm using an equivalent obstacle height. Trailing toe clearance has not been reported in equivalent obstacle height. However it was reported as 14.1 cm for an obstacle height of 5.1 cm[8]. In previous studies, toe clearance was defined as the minimum vertical clearance between the top of the obstacle and the lowest point of the toe as it passed over the center of the top of the obstacle. However, in tripping during walking, the tip of the toe usually collides with the foremost edge of the obstacle. Therefore, in this study, toe clearance was defined as the vertical distance between the tip of the big toe and the obstacle as it passed over its foremost edge. Consequently, toe clearance was measured as the foot was raised halfway above the obstacle.

Gait parameters showed a decrease in gait speed, step lengths and cadence, by both fallers and non-fallers in the DT. This result is similar to that of Beauchet et al.[16] who reported an extended walking time and an increase in the number of steps under DT conditions. Concerning step length, it is thought that the step length influences gait speed and cadence, because step length has a close relation to gait speed and cadence. Both groups had similar gait parameters and this result may be associated with safety either through adjusting the position before stepping over the obstacle, by both the faller group and non-faller group, or by decreasing gait speed, step lengths and cadence. It is interesting to note that the fallers, who were at risk of falling, had similar gait control to the non-fallers. In other words, we suggest toe-obstacle distance is important.

The DT of stepping over the obstacle at a comfortable gait while concurrently performing the serial subtraction of seven clarified that the movement of stepping over an obstacle has some influence on both fallers and non-fallers. In the DT condition, we consider that the level of difficulty of the motor task and the cognitive task are different, because the cognitive function in the motor function. The number of correct answers in the DT in this study showed no significant difference between the faller and non-faller groups, and we think that each group was able to reduce the amount of attention to walking within their limited attention resources. In the future, it will be necessary to investigate how the difficulty level of cognitive tasks influence motion.

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