A KINEMATIC ANALYSIS OF ELDERLY GAIT WHILE STEPPING OVER OBSTACLES OF VARYING HEIGHT

Yeon-Joo Yu[1], In-Sik Shin[2], Ki-Kwang Lee[3], Te-Jin Yoon[4], Chi-Sun Choi [2], and Chul-Soo Chung[2]

[1]School of Sports & Health Management, Woosong University, Daejeon, Korea
[2]Department of Physical Education, Seoul National University, Seoul, Korea
[3]College of Sport Science, Kookmin University, Seoul, Korea
[4]Department of Exercise Science, Marquette University, Milwaukee, U.S.A

The purpose of this study was to investigate the kinematics of elderly people who had experienced a fall stepping over obstacles of varying height. Six elderly non-fallers and six elderly fallers stepped over obstacles of height 0, 2.5, 5.1, 15.2cm. The longest stance duration was found in the highest obstacle 15.2cm, which might reflect relatively fast degrading gait function of the faller group. It was found that fallers took a longer time to cross the obstacles, which resulted in slower crossing speeds than when non-fallers stepped over the obstacles. We concluded that elderly persons who had experienced falling tend to step over obstacles conservatively as characterized.

KEY WORDS: obstacles, falling, kinematic analysis, elderly, gait.

INTRODUCTION:

Falling is a serious problem for elderly people. One out of three adults over 65 years old experienced a fall once a year, as the result of a trip or slip (Berg et al., 1997). As a result of an obstacle in their path, normal people usually estimate the obstacle characteristics via visual receptors and adjust their gait patterns accordingly (Chen et al., 1994). Also it has been shown that the risk of falling increases with age (Chen et al., 1994). Patla et al. (1991) investigated that young subjects changed their gait pattern one or two steps before stepping over the obstacles. The previous studies have demonstrated the relations among age, gender, reaction time, walking speed, and stepping strategy in order to avoid an obstacle (Chen et al., 1991, McFadyen & Prince, 2002). However, it is not clear yet how the elderly, who had experienced a fall before, reacted to an obstacle. The purpose of this study was to investigate the kinematics of elderly gait in fallers and non-fallers while stepping over obstacles of varying height.

METHOD:

Six elderly non-fallers (male:n=3, female:n=3), and six fallers (male:n=3, female:n=3) who had experienced at least one serious fall, participated in this study. Physical characteristics of healthy subjects were as follows: Non-fallers; male- age: 77.00±1.73 yrs, weight: 56.77±11.49 kg, female-age: 76.67±0.57 yrs, weight: 55.70±3.99 kg and Fallers; male-age: 79.00±2.64 yrs, weight: 68.31±6.74 kg, female – age: 80.67±3.06 yrs, weight: 44.28±2.37 kg. The biomechanical instrument used in the study included six video cameras, a trigger device, a reference frame, reflective markers and KWON 3D Motion Analysis Package 3.0(Visol corp) for data collection and processing. Six cameras(60Hz) were set to capture the gait performance and the shutter speed was set at 1/500 sec. Reflective markers were placed on the both side of the body at the acromion, anterior superior iliac spine, greater trochanter, mid thigh, lateral and medial edpicondyle of the knee, mid shank, lateral malleoulus, heel, toe and mid posterior superior iliac spine. Using the KWON 3D system, the recorded images were digitized to obtain coordinates of these markers throughout during the gait. The data were filtered with the 2^{nd} order of lowpass filter(6Hz). A 6m walk way with a firm dark surface was used with obstacles of varying heights of 0, 2.5, 5.1, 15.2 cm. Subjects were asked to wear a harness, walk along a walkway at the comfortable speed, step over the obstacle in their usual manner, and continue walking 2 m past the obstacle before stopping. The orders of subjects and obstacle heights were randomized. We only analyzed

the trials when subjects stepped over the obstacles with the right foot first and then followed by the left foot. In order to determine the characteristics of gait during stepping over the obstacles, variables(the swing and stance duration, crossing speed, toe distance, heel distance, and foot clearance distance) were analyzed. The differences of the variables of the two groups, fallers and non-fallers with the varying obstacle heights were statistically tested using analysis of variance (ANOVA) at .05 significance level. Tukey test was used for post-hoc test.
Definition of variables:
- Swing duration (SWD): the time period taken from the right toe-off just before the obstacle to the heel-strike of the crossing right foot.
- Stance duration (STD) phase: the duration starting from heel-strike to the moment of second toe-off
- Crossing speed (CS): the speed calculated using posterior superior iliac spine horizontal translation from first toe-off to second toe-off (after stepping over the obstacle) of the crossing foot.
- Toe distance (TD): the distance from the left toe to the front edge of the obstacle.
- Heel distance (HD): the distance from the rear edge of the obstacle to the right heel at heel strike.
- Foot clearance distance (FC): the height of minimum vertical clearance between the top of the obstacle and the heel or toe of the right foot.

RESULTS AND DISCUSSION:

A significant difference was evident in SWD (F=92.77, p=0.00) between obstacle heights. However SWD did not show any significant difference between fallers and non-fallers. SWD in fallers showed significant differences in the obstacle heights between 2.5 and 5.1cm(p=.01) and between 5.1 and 15.2cm(p=.04). STD did not show any significant difference in falling experience and obstacle heights. STD was gradually increased with obstacle heights for the non-fallers, however the faller group did not show same trend as the non-faller group. It was noticed that the longest STD was found in the highest obstacle 15.2cm, which might reflect relatively fast degrading gait function of the faller group.

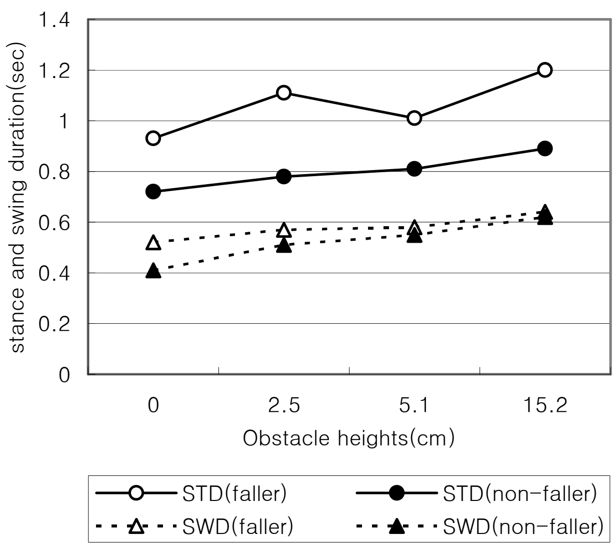

Figure1 The changes of stance duration (STD) and swing duration (SWD) in fallers and non-fallers.

CS showed significant difference in obstacle heights(F=42.9, p=.00). As the height of obstacle increased, elders stepped over the obstacle slowly. The fallers showed lower CS than non-fallers in the same height of obstacle, which might indicate that fallers were too cautious when they stepped over an obstacle. Fallers seemed to show a more conservative strategy to reduce the risk of falling when they are stepping over obstacles. The TD appeared consistently longer in fallers compared to that of non-fallers (Table1), but no significant difference was found. These result partially agreed with Chen et al. (1991), reporting that old adults had a 5% longer TD than young adults. This could be a strategy to reduce the risk of toe contact with the obstacle and the chance of toe contact causing a trip. HD did not show any significant difference in falling experience and obstacle heights. However, fallers had shorter HD than non-fallers at the same height. No significant height and falling experience effects on FC were found, but FC increased as obstacle height increased except 15.2cm.

Table 1 Variables of elderly gait while stepping over at obstacle

Variables	0cm		2.5cm		5.1cm		15.2cm	
	faller	non-faller	faller	non-faller	faller	non-faller	faller	non-faller
Crossing Speed (m/s)	0.8±0.3	1.0±0.2	0.78±0.4	0.89±0.2	0.83±0.4	0.86±0.1	0.66±0.2	0.79±0.2
Toe Distance (cm)	20.±10.7	15.0±3.4	20.0±9.6	13.0±6.8	17.5±4.7	14.7±5.9	14.7±3.9	14.9±6.0
Heel Distance (cm)	11.3±11.8	14.9±3.6	8.0±7.0	14.47±5.0	9.2±5.5	16.5±5.8	12.9±6.1	15.6±4.3
Foot Clearance Distance (cm)	6.4±1.6	3.9±1.8	12.4±9.1	11.9±4.4	18.2±5.4	14.8±4.1	15.3±3.5	13.4±5.4

CONCLUSION:

The fallers stepped over the obstacle with the lower speed. They put their trailing foot far from the front edge of the obstacle and placed their leading foot close to the rear edge of the obstacle. The elderly who have experienced a fall while stepping over obstacles seem to take a somewhat conservative strategy. The fallers lifted their feet from the obstacle higher than non-fallers while crossing the obstacle. It may be caused by the fear of falling and/or a reduced gait function. This study confirmed that the height of 15.2 cm obstacle might be a difficult task to cross over for the elderly. This information can be used as a good source for designing senior facilities.

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