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Original Article

The Mediolateral CoP Parameters can Differentiate the Fallers among the Community-dwelling Elderly Population

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Abstract. [Purpose] Age-related mediolateral (ML) instability of static postural control in the elderly has been well studied. Recent studies have provided evidence that ML center of pressure (CoP) parameters during dynamic postural control are more sensitive for differentiation of the fallers in the elderly. However, very limited studies have been done in which ML stability differences between fallers and non-fallers were investigated. The purpose of this study was to investigate the differences in ML CoP parameters between elderly fallers and elderly non-fallers during dynamic postural control. [Subjects and Methods] Twenty-nine community-dwelling older adults were divided into either fallers or non-fallers according to a self-report related to falling history within a year. Every participant performed 4 different tasks (static postural control tasks comprising quiet stance with eyes open and eyes closed and dynamic postural control tasks comprising stance with arm lifting and with trunk flexion) on force plates. [Results] The fallers demonstrated decreased AP and ML CoP parameters, and ML CoP distance was significantly smaller than in the non-fallers during both dynamic postural control tasks. [Conclusions] ML CoP parameters were able to differentiate the fallers from the non-fallers in a community-dwelling elderly population.

Key words: Fall predictors, Mediolateral stability, CoP parameters

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INTRODUCTION

Postural control is the essential component for performance of a wide range of activities of daily living, but its capacity decreases with aging. Decreased postural control with aging increases the fall risk[1)], which also gets higher with aging. Falls lead to the fall-related injuries, and hip fracture in the elderly is a common fall-related injury[1, 2)]. Falls themselves also decrease the activity level of the elderly secondary to fear of falling with/without a history of falls[3, 4)]. So, many investigations have been done to identify potential fallers for the purpose of fall prevention[5, 6)]. The majority of the research has investigated the anterioposterior (AP) stability differences during sagittal plane movements like walking, even though falls seem to happen in the frontal plane[7)]. In addition, many researchers have provided redundant evidence indicating that mediolateral (ML) stability was decreased both in healthy elderly groups[6, 8, 9)] compared with healthy young groups and in Parkinson's groups[10, 11)] compared with healthy elderly and healthy young groups.

Age-related ML instability was found in both static[8, 11–15)] and dynamic postural control[2, 7, 13)]. The elderly showed increased ML postural sway compared with the young in static postural control tasks like near-tandem standing[8)], quiet standing on firm surface[12)], quiet standing with different task conditions[13)], and standing on different bases of support[15)]. During dynamic postural control tasks like turning around[7)], walking[13)], or walking on a split-belt treadmill[2)], the elderly showed increased reliance on stepping, larger lateral stepping, or multiple stepping. Decreased sensory inputs, decreased muscle strength, decreased joint flexibility, and increased fear of falling seem to cause decreased postural control in the elderly[4, 16)]. In particular, age-related increases in muscle co-activation during dynamic postural control are presented as a reason for the decreased capacity of voluntary movements or compensatory postural control[1, 4, 14, 17–19)].

Most ML stability studies have provided evidence of age-related ML instability compared with a young population, and there have been limited studies investigating the differences in ML stability between elderly fallers and elderly non-fallers. Also, most ML stability studies have examined ML stability during static postural control[8, 20)]. Therefore, the purpose of this study was to investigate the differences in ML stability between elderly fallers and elderly non-fallers during dynamic postural control.

SUBJECTS AND METHODS

Twenty-nine community-dwelling older adults (3 men,

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Table 1. Means and standard deviations of CoP parameters during static postural control

	Eyes Open				Eyes Closed			
	CPx_r	Cpy_r	CPx_d	CPy_d	CPx_r	Cpy_r	CPx_d	CPy_d
Non-Faller	2.11±0.70	2.24±0.50	20±5.23	24±5.25	2.16±0.70	2.61±0.66	24.9±7.60	32.6±8.69
Faller	2.44±0.81	2.21±0.62	21.86±4.27	24.49±12.03	2.11±0.58	2.63±0.62	23.05±6.69	30.85±15.22

In the eyes open condition, the fallers demonstrated increased CoP parameters in both the ML and AP directions. In the eyes closed condition, the fallers demonstrated a decreased trend in the ML direction. However, the differences between the groups were not significant (p>0.05).

26 female, mean age: 78.9±4.69years, mean weight of 56.16±8.55 kg) participated from 4 local senior welfare centers. The inclusion criteria were (1) ability to maintain standing for 2 minutes without assistance, (2) ability to walk 5 m with or without assistive devices (e.g., walker or cane), (3) no peripheral or central nervous system lesion, (4) no severe musculoskeletal injury within a year, (5) no vestibular disorder affecting balance ability and (6) no cognitive problem (Mini-Mental State Examination > 24 points). According to a self-report related to falling history within a year, all participants were divided into two groups, a non-faller group (n: 21) and a faller group (n: 8). Fall was defined as an event causing a person to rest unintentionally on the ground or other lower level not due to any intentional movement, a major intrinsic event, or extrinsic force[21]. All participants understood the study's purpose and provided written informed consent prior to participation in accordance to the ethical standards of the Declaration of Helsinki. This protocol was approved by the local ethics committee. Each participant carried out four different tasks for center of pressure (CoP) data acquisition. All measurements were completed in random order, after three practical trials for familiarization of each task. To prevent fatigue, the participants had a resting time of at least 5 minutes between each CoP data acquisition task, with the length of the rest adjustable depending on their condition. To obtain CoP data, four different tasks were performed on a force plate (AMTI, Watertown, MA, USA). These tasks are part of the Dynamic Balance Measures (DBM) invented by Desai et al.[22] and were as follows: (1) quiet standing on a firm surface with the eyes open (EO); (2) quiet standing on a firm surface with the eyes closed (EC); (3) standing while performing a cyclic, rhythmic arm lifting (AL) and lowering task in which a lightweight 70-cm pole, 1.5 cm in diameter, held with both hands was raised to shoulder level and then lowered to the legs while keeping the hands shoulder-width apart and the elbows extended; and (4) standing while performing cyclic, rhythmic forward trunk bending and extension to return to the upright standing position (TF). The amplitude of the trunk bending was about 30 degrees. Except the arm lifting task, the participants were instructed to keep their arms at their sides. The cyclic movements of tasks 3 and 4 were paced by a sound. A beep was sounded every two seconds. Four different tasks were performed for 30 seconds with a 200-Hz sampling rate, and the tasks were repeated 3 times, to prevent a learning effect, the four tasks were performed in random order. The acquired CoP data were subjected to some post-processing using MATLAB ver 7.0. Considering the start and end of each task, the first 6 seconds (20% of data) and the last 3 seconds (10% of data) were discarded. To reducing the measurement noise, 15-Hz low-pass filtering was carried out[23]. Based on this data, CoP range and CoP distance were calculated for each axis (Anteroposterior and mediolateral). All data were analyzed using the Mann-Whitney U test to compare the differences between the two groups, in terms of CoP parameters. All statistical analyses were performed using the PASW 18.0 (SPSS Inc., Chicago, IL, USA), and $p<0.05$ was set as the criterion for statistical significance.

RESULTS

Prior to CoP data acquisition, all participant's general characteristics (age, weight, and sex) and falling history were recorded. There were no statistical differences in general characteristics between the two groups. During statistic postural control tasks (EO and EC), both groups demonstrated increased AP and ML CoP parameters with EC compared with EO. Between-group comparisons revealed that the fallers demonstrated increased ML CoP parameters with EO and decreased ML CoP parameters with EC. However, the differences were not significant ($p > 0.05$, Table 1). During dynamic postural control tasks (AL and TF), both groups demonstrated increased AP and ML CoP parameters compared with static postural control tasks. Between-group comparisons revealed that the fallers demonstrated decreased AP and ML CoP parameters compared with the non-fallers in both AL and TF (Table 2). The ML CoP parameters, in particular the ML CoP distance, in both AL and TF were significantly different ($p < 0.05$). The AP CoP parameters of the fallers were significantly different only in AF compared with the non-fallers.

DISCUSSION

The results of this study showed that the elderly with a history of falls compensated for postural challenges with restricted postural sway in dynamic postural control tasks compared with the non-faller elderly. Contrary to the dynamic postural control tasks, the faller group demonstrated increased postural sway in static postural control tasks compared with the non-faller group, which was consistent with the result of a previous study[20]. In addition, the ML CoP parameters were more sensitive than the AP CoP parameters for the purpose of differentiating the fallers from the non-fallers in a community-dwelling elderly population.

The decreased CoP parameters of the fallers during dynamic postural control tasks may be, in part, due to in-

Table 2. Means and standard deviations of CoP parameters during dynamic postural control

	Arm Lifting				Trunk Flexion			
	CPx_r	Cpy_r	CPx_d	CPy_d	CPx_r	Cpy_r	CPx_d	CPy_d
Non-Faller	4.56±1.78	3.24±0.79	53.79±13.59	44.39±9.81	4.57±0.93	5.49±1.32	52.37±13.51	77.96±26.06
Faller	3.34±0.62*	2.71±0.58*	37.92±8.62*	35.63±11.77*	4.14±0.60	5.38±0.78	40.75±9.44*	67.49±23.29

During arm lifting, the fallers demonstrated significantly decreased CoP parameters in both the ML and AP directions ($p<0.05$). During trunk flexion, the fallers showed decreased trends for the CoP parameters in both the ML and AP directions but only the CoP distance in the ML direction decreased significantly compared with the non-faller ($p<0.05$). * $p<0.05$

creased stiffness of the whole body to reduce joint mobility and flexibility[1, 17, 24, 25] and may be caused by increased muscle co-activation, which has been commonly found in elderly populations[1, 4, 19]. Allum et al. suggested that the reduced degrees of freedom to be controlled by the postural control system are the benefit of increased body stiffness[25]. Increased muscle co-activation plays double roles, but each role has an opposite effect on dynamic postural control. Increased muscle co-activation in the elderly is often considered a compensatory strategy to increase joint stiffness, resulting in enhanced joint and postural stability[14, 19]. On the other hand, excessive muscle co-activation limits postural flexibility and might decrease dynamic postural control[17] and increase the risk of falling[18]. Increased muscle co-activation of the ankle joints is used by the elderly for postural control[1, 4, 19], which induces reliance on a hip strategy for static postural control[15, 26] and stepping strategy for dynamic postural control with unconstrained feet[7, 27]. Instead of using a hip strategy or stepping strategy, the fallers in this study seemed to excessively increase muscle co-activation of not only the ankle joint but also the hip joints. Even though the muscle co-activation of the hip joints has a positive effect on postural control[25], the faller group seemed to decrease the postural sway on the frontal plane rather than on the sagittal plane. The ML CoP distance of the fallers was significantly decreased compared with the non-fallers. However, hip muscle activations were not examined in this study. So, the results of further studies that investigate the muscle activation differences of the hip joints between fallers and non-fallers would be beneficial.

The decreased CoP parameters, especially the ML CoP distance, can be also explained by postural control with a long-term mechanism[10, 20, 28]. Laughton et al. found increased postural sway during short-term postural control and diminished postural sway during long-term postural control in the elderly with a quiet stance[20]. During short-term postural control, the open-loop mechanism without sensory feedback is utilized, while the closed-loop mechanism with sensory feedback is used during long-term postural control[10, 20, 28]. Short term refers to the period less than 2 seconds after the initiation of postural control, and long term refers to the period after 2 seconds[28]. In this study, CoP data for 30 seconds were collected, and the first 6 seconds of data were discarded prior to analysis. Therefore, the analysis was done with CoP data controlled by the closed-loop mechanism, which might have adjusted and diminished the postural sway and resulted in decreased CoP parameters. In particular, fallers with decreased proprioception[8] might use an excessive long-term mechanism compared with non-fallers. If so, this suggests that the elderly at least seem to use postural control strategies that differ between static and dynamic postural control and that the fallers in this study demonstrated increased postural sway during static postural control. CoP data for static postural control were also collected for 30 seconds, and the first 6 seconds of data were discarded.

The limitations of this study were the small number of subjects in the faller group and the larger number of women than men in both groups. Even though a small number of subjects in the faller group was included in this study, the results of this study were consistent with those of previous studies. The demographic data also did not differ between the groups. Sullivan et al. found that women and men performed similarly in a study using balance platform testing[28] except that modestly greater sway was found in men during standing with the eyes-closed. Therefore, the effect of sex imbalance on dynamic postural control might be minimal.

This study showed that the elderly fallers demonstrated a significantly decreased ML CoP distance for dynamic postural control compared with static postural control. Based on these results, the parameters of ML stability seem to be better predictors of fallers[6, 8, 9]. However, performance of a prospective cohort would provide more solid evidence concerning which parameters of ML stability can be used to determine who would have a tendency to fall among a community-dwelling elderly population. Also, further studies to investigate muscle activations of the hip joints during dynamic postural control and the relationship between onset time of muscle activation and postural sway would provide details regarding whether the decreased CoP distance is an excessive compensatory strategy or an excessive effect of a long-term mechanism. Lastly, future studies with a larger number of subjects and a more even distribution for sex will also enhance the results of this study.

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