CHAPTER V

DISCUSSION

The purposes of this study were to determine if differences existed between female older adults with and without balance impairment during common daily tasks including walking on level floor and walking over an obstacle in terms of trunk acceleration and selected gait parameters. Female older adults were of interest in this study because rates of fall-related injury in women was 40–60% higher than men of comparable age (14). In addition, gender effect on gait characteristics during walking can be eliminated. Helbostad and Moe-Nilssen (59) reported that healthy elderly men and women displayed significant differences in several basic gait parameters, i.e., men exhibited faster walking speed, longer step length and larger step width than the women.

Balance impairment of the participants was primarily assessed by the Berg Balance Scale (BBS) and was also confirmed by the Timed up and go test (TUG). Most of the elderly women defined as non-balance-impaired performed the BBS with no or minimal difficulty on the test items. Whereas reduced BBS scores for the balance-impaired group were mainly due to difficulty in performing the particular items challenging balance and reducing base of support such as reaching forward with outstretched arm while standing, standing unsupported with feet together, standing unsupported one foot in front of the other foot and especially in standing on one leg. The BBS score of ten elderly women with balance-impaired in the item of reaching forward with outstretched arm while standing was equal to or less than 2 from 4, the maximum score. In addition, the BBS score of eight elderly women with balance-impaired in the items of standing unsupported with feet together and standing unsupported one foot in front of the other foot were equal to or less than 2, and especially in the item of standing on one leg, the BBS score of twelve elderly women with balance-impaired was equal to or less than 2. Furthermore, it took significantly longer for the balance-impaired group (18 ± 4.1 s) to complete the TUG test compared to the non-balance-impaired group (11 ± 0.9 s). Shumway-Cook and colleagues (39) reported that the TUG score greater than 14 could represent impaired balance and increased risk of fall. Furthermore, it has been shown that the TUG score were highly correlated with the BBS scores (46). The TUG and BBS both assess balance and the ability and fall risk, although measuring different constructs of balance. The BBS assesses balance ability during functionally based activities in sitting and standing, whereas the TUG assesses ability to maintain balance during timed locomotion and ambulatory transfers (46). Therefore, in this study balance-impaired individuals were less stability in both static and dynamic balance compared to the non-balance-impaired individuals.

Gait parameters of level walking

At preferred self-selected pace, average walking speed and step length of non-balance-impaired group were within the range reported in healthy adults (1.2–1.8 m/s and 56.00 ± 11.00 cm, respectively) (60). Average walking speed of the balance-impaired group was similar to walking speed of older people with balance deficit (0.79 ± 0.25 m/s) reported by Menze et al (61). In this study, the balance-impaired group had a decreased walking speed partly due to shorter step length. However, averaged toe-floor clearance of both groups were not different from each other and were found to be similar to the values reported (3 cm) in previous studies (28, 30), indicating that elderly women of both groups sufficiently elevated their limbs during level walking.

The results on gait characteristics implied that during walking on level surface, elderly women with balance-impaired seemed to display more conservative or cautious strategies than the non-balance-impaired group. The cautious gait pattern adopted by many elderly people, characterized by reduced walking speed and shortened step length, is likely to be an adaptation to minimize perturbations to the body and thereby reduce of loosing balance (62).

Gait parameters of crossing step

Unlike walking on level surface, walking over obstacle require an individual to meet several multiple objective functions such as energy efficiency, landing stability and obstacle clearance (50). Compared to level walking, a reduced gait speed while crossing the obstacle was observed in both elderly groups. However, the results indicated that elderly women with balance-impaired used a more conservative strategy while obstacle crossing by slower crossing speed, shorter crossing step length, shorter leading and trailing limb elevation and shorter pre- and post-obstacle distances than the non-balance-impaired group in both low and high obstacle conditions, given that there were no differences in average leg length and average obstacle height in both conditions. In the aspect of leading and trailing limb elevations, the balance-impaired group raised their foot at significantly lower margins than the non-balance-impaired group indicating a greater risk for tripping during obstacle negotiation than the non-balance-impaired group. Our results may imply that balance-impaired group did not bend the knee or hip joints over an obstacle as much as the non-balance-impaired group.

Stepping over an obstacle was found to be a challenging task appropriate for assessment of the ability to control dynamic balance. The balance-impaired older adults were more affected by this task as the results showed a marked reduction in crossing speed of impaired group as they spent longer time crossing the obstacle. Especially while crossing the highest obstacle, three elderly of the balance-impaired group had their trailing limb contacting the obstacle, though it did not lead to fall. Chou and Draganich (30) reported that tripping over obstacles with the trailing limb might be expected to occur more frequently than the leading limb because of lack of visual feedback.

There has been no prior report regarding the pre- and post-obstacle distances comparing elderly women with balance-impaired and non-balance-impaired. Only information about healthy older adults exist. Previous studies reported that healthy elderly adults reduced both pre- and post-obstacle distances compared to their younger counterparts (53, 63). Similar to the results of this study, balance-impaired group placed their leading and trailing limbs closer to the location of the obstacle than the non-balance-impaired group. Weerdesteyn et al (63) explained that placing a foot at an appropriate distance from the obstacle prior to stepping over the obstacle is crucial for older adults in terms of controlling the body's center of mass within base of support. In other words, if the approaching foot is placed far from the obstacle, the body's center of mass would have to move forward more than placing it close to the obstacle which in turns leading to greater displacement of the body's center of mass.

Similar to the pre-obstacle distance, the precise foot placement of the leading limb after obstacle crossing (the post-obstacle distance) would provide individual an adequate distance for lifting their trailing limb over the obstacle without contacting it. However, crossing step length of both groups was not different from the step length of level walking. This information indicated that both balance-impaired and non-balance-impaired elderly adults did not alter their step length during walking over obstacle. Gait parameters of crossing step alone may not completely explain gait alterations during obstacle crossing as they may have been influenced by other factors such as the joint kinematics of leading and trailing limbs. Previous study reported that compared to young adults, elderly adults exhibited a compensatory strategy involving increased hip adduction and medial rotation rather than hip flexion (50).

Peak trunk acceleration amplitude of level walking

In this study, trunk acceleration values were obtained from direct measurements of a tri-axial accelerometer attached to the trunk to estimate control of the body's center of mass (9). Acceleration reflects the change in velocity over time (35). Having a vector property, acceleration can be altered by either changing in velocity magnitude and/or changing in direction. Therefore, if a subject is moving with less smoothness (i.e. abrupt changing in velocity) or having body sway (i.e. abrupt changing in direction) at any instance during locomotion, this would spontaneously reflects in the acceleration data.

It was found that the average magnitudes of peak trunk acceleration amplitude of balance-impaired and non-balance-impaired groups were relatively higher in vertical and anteroposterior directions than mediolateral directions which were in agreement to those reported in previous studies (7, 9-11, 64). Movement of the body's center of mass in vertical direction during walking reflects the up-and-down movement of lower limbs during stance and swing phases of gait cycle (57), whereas acceleration in the anteroposterior component, reflects the forward progression of the body in the travel path. Zijlstra and Hof (65) reported that the basic pattern of forward acceleration during walking corresponds to the pattern that can be expected based on inverted pendulum models of the center of mass trajectory corresponding to the acceleration and deceleration of the lower limbs during swing phase. Trunk accelerations in mediolateral direction were less pronounced because movement of trunk was not expected to be in the sideway during walking, unless body sway should occur.

Although there has been no report comparing trunk acceleration between elderly women with balance-impaired and non-balance-impaired group, previous studies reported that trunk accelerations of older adults during walking on level surface were smaller than the young adults (11-13). In this study, average peak trunk acceleration amplitude of the balance-impaired group was trend to smaller than non-balance-impaired group in vertical and anteroposterior directions and significant smaller in mediolateral direction. The reduced peak trunk acceleration amplitude of balance-impaired group were associated with reduced walking speed and reduced trunk movement as a result of conservative or cautious gait (35). Walking speed was not controlled during data collection in this study because the purpose was to examine trunk acceleration at preferred self-selected walking speed because smoothness or stability of trunk acceleration is optimal when the usual or preferred walking speed, cadence and step length are used (66). For data analysis, differences in walking speed can not be controlled by using it as a covariate because its relationship with acceleration amplitude is not linear (66). Menze et al (13) reported that when subjects are instructed to walk at a range of speed from very slow to very fast, the acceleration increases in an exponential manner. In addition, Zijlstra and Hof (67) reported that the acceleration patterns were similar at different speeds, but were more pronounced because of increased peak amplitudes due to increased speed.

Therefore, the reduced peak trunk acceleration amplitude patterns found in the balance-impaired group implied that trunk motion during walking on level surface of impaired group were smaller than non-balance-impaired group and associated with their conservative or cautious gait for maintaining their stability during walking. In addition, a short step length of balance-impaired group was employed for maintaining their mediolateral trunk stability as it has been shown that stability of trunk acceleration in mediolateral direction is best when short steps and usual cadence are combined (66).

Peak trunk acceleration amplitude of crossing step

Similar to level walking, during walking over obstacle, average peak trunk acceleration amplitudes of the balance-impaired group remained also lower than non-balance-impaired group in all three directions except in mediolateral direction during obstacle crossing at the high obstacle condition. In vertical direction, peak trunk acceleration amplitude of both groups was increased linearly as obstacle height increased which might associate with increased trunk and lower limb movements in vertical direction. Peak trunk acceleration amplitude in the anteroposterior direction did not change from the low to high obstacles. Possible explanation is that forward acceleration reached its peak value during foot contact (68). During crossing the obstacle, subjects approached the obstacle similar in fashion for both obstacle heights, therefore peak forward acceleration did not changed with height.

In the sideway direction, peak trunk acceleration amplitude of balance-impaired group during obstacle crossing at the low obstacle condition was smaller than the non-balance-impaired group, however, at the high obstacle peak trunk acceleration amplitude of balance-impaired group was greater than non-balance-impaired group (see Figure 16). This information indicated that at the low obstacle the balance-impaired group could sufficiently control their trunk stability in the sideway while negotiating a low obstacle. In contrast, at the high obstacle condition, it was more difficult for the balance-impaired group to control their trunk stability that they reduced crossing speed. As shown by the significant group x height interaction effect, the balance-impaired group displayed greater changes in trunk sway in the sideway than the non-balance-impaired group. This result indicated that the balance-impaired group had greater lateral body sway more than the non-balance-impaired group. During a single support phase of obstacle crossing, it was a difficult task due to the reduced base of support while a precise control of the motion of the whole body's center of mass was still required. The increased leading limb elevation as obstacle height increased resulted in greater movement of the whole body's center of mass and perturb balance maintenance. This result was supported by Chou et al's study (32). They reported that elderly adults with balance-impaired demonstrated significantly greater and faster mediolateral motion of the center of mass when obstacle crossing associated with an increased mediolateral range of motion of the leading limb trajectory. Therefore, the results of this study were implied that reduced trunk stability of the balance-impaired group during crossing step might be correlate with the BBS score. The balance-impaired group was difficult to perform the BBS in the items which were challenged balance and reduced base of support. Moreover, inability to adequately control the motion of the center of mass in the frontal plane might lead to a loss of balance resulting in a sideways fall, which has been reported as one of the causes of hip fractures among frail elderly nursing home fallers (69).

For the limitation of this study, although peak trunk acceleration amplitude can provide the magnitude of trunk motion during gait, peak trunk acceleration amplitude alone may not provide complete information about stability of trunk. Menze et al (12) reported that despite walking more slowly, older people with a high risk of falling exhibited more variable step timing, and less rhythmic or smoothness of trunk acceleration patterns. Rhythmic or smoothness of trunk acceleration, represented in Harmonic ratio (HR) (11-13), can represent the stability of trunk during walking. However, harmonic ratio (HR) was beyond the scope of this study. Therefore, for more understanding of the trunk acceleration patterns in relation to balance control, the study about rhythmic and smoothness of trunk acceleration is warranted.

CONCLUSION

The finding of this study showed that elderly women with balance-impaired exhibited more cautious strategies in both walking on level and obstacle crossing than the non-balance-impaired group. On level walking the balance-impaired group significantly reduced their walking speed, step length and peak trunk acceleration amplitude in mediolateral direction than the non-balance-impaired group. For walking over obstacle tasks, the balance-impaired group were also significantly reduced their crossing speed, crossing step length, leading and trailing limb elevations, pre- and post-obstacle distances and peak trunk acceleration amplitude than the non-balance-impaired group and except in the high obstacle condition. Only peak trunk acceleration amplitude in mediolateral direction of the balance-impaired group was significantly greater than the non-balance-impaired group. This information suggested that peak trunk acceleration amplitude in mediolateral direction during crossing a high obstacle could be used as a criterion to distinguish elderly women with balance-impaired from non-balance-impaired.