นิพนธ์ต้นฉบับ

การเปรียบเทียบค่าตัวแปรในการเดินระหว่างผู้สูงอายุเพศหญิงที่มีและไม่มีความบกพร่อง ในการทรงตัวขณะเดินข้ามสิ่งกีดขวาง

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บทคัดย่อ

วัตถุประสงค์ เพื่อเปรียบเทียบค่าตัวแปรในการเดินระหว่างผู้สูงอายุเพศหญิงที่มีและไม่มีความบกพร่องในการทรงตัวขณะเดินบนทางราบและเดินข้ามสิ่งกีดขวาง
วิธีการศึกษา ใช้แบบประเมิน Berg Balance Scale (BBS) เป็นเกณฑ์ ในการแบ่งกลุ่มความบกพร่องในการทรงตัว ผู้ถูกทดสอบถูกจัดอยู่ในกลุ่มที่มีความบกพร่องในการทรงตัวจำนวน 15 คน (BBS scale $\leq$ 45 คะแนน) และกลุ่มที่ไม่มีความบกพร่องในการทรงตัวจำนวน 15 คน (BBS scale > 45 คะแนน) ผู้เข้าร่วมการศึกษาได้รับการทดสอบที่มี 3 รูปแบบ คือ เดินบนทางราบ และเดินข้ามสิ่งกีดขวางระดับต่ำและสูง (10 และ 30 เปอร์เซ็นต์ของความยาวขา) โดยผู้เข้าร่วมการศึกษาถูกกำหนดให้เดินด้วยความเร็วปกติของตนเองในทุกรูปแบบการเดิน และใช้การวิเคราะห์การเคลื่อนไหวแบบสองมิติ (2D) ในการหาค่าตัวแปรในการเดินทั้งหมด ตัวแปรในการเดินบนทางราบประกอบด้วย walking speed, step length และ toe-floor clearance และตัวแปรในการเดินข้ามสิ่งกีดขวางประกอบด้วย crossing speed, crossing step length, leading and trailing limb elevations และ pre- and post-obstacle distances
ผลการศึกษา พบว่ากลุ่มที่มีความบกพร่องในการทรงตัวมีค่าตัวแปรในการเดินบนทางราบและการเดินข้ามสิ่งกีดขวางทั้งสองระดับน้อยกว่ากลุ่มที่ไม่มีความบกพร่องในการทรงตัว
สรุปผลการศึกษา ผู้สูงอายุเพศหญิงที่มีความบกพร่องในการทรงตัวมีรูปแบบการเดินที่มีความระมัดระวังทั้งขณะเดินบนทางราบและเดินข้ามสิ่งกีดขวางเพื่อรักษาการความมั่นคงของร่างกายและเพื่อความปลอดภัยมากกว่ากลุ่มที่ไม่มีความบกพร่องในการทรงตัว **วารสารเทคนิคการแพทย์เชียงใหม่ 2553; 43: 39-50.**

คำสำคัญ: ตัวแปรในการเดิน ผู้สูงอายุเพศหญิง ความบกพร่องในการทรงตัว การเดินข้ามสิ่งกีดขวาง

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Abstract : Comparison of gait parameters between elderly women with and without balance impairment during walking over obstacle

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Objective: To compare gait parameters between elderly women with and without balance impairment during walking on level surface, and walking and stepping over obstacle.

Methods: The Berg Balance Scale (BBS) was used as a criterion to assign subjects into the balance-impaired group (BBS scale ≤ 45 points, n=15) and the non-balance-impaired group (BBS scale > 45 points, n=15). Participants were tested on three walking conditions including walking on level surface, and walking and stepping over the low and high obstacles (10% and 30% of individual leg length) with their self-selected walking speed. Two-dimensional (2D) motion analysis system was used to measure all gait parameters. Gait parameters of level walking included walking speed, step length and toe-floor clearance from the floor. Gait parameters of crossing step included crossing speed, crossing step length, leading and trailing limb elevations and pre- and post-obstacle distances.

Results: The balance-impaired group displayed significant reduced gait parameters during walking on level surface and both obstacle tasks than the non-balance-impaired group.

Conclusions: The balance-impaired group seemed to use a conservative or cautious strategy during walking on level surface and obstacle tasks for maintaining body stability and safety than the non-balance-impaired group. **Bull Chiang Mai Assoc Med Sci 2010; 43: 39-50.**

Keywords: gait parameter, elderly women, balance impairment, walking over obstacle

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Introduction

According to the trend of world population, the proportion of elderly adults who aged over 60 years is increasing at a faster rate than any other age group, as the results of both longer life expectancy and declining fertility rates.[1] Aging is characterized by progressive changes in the tissue or organs of the body, leading to a decline in functional movements.[2] The gait parameters of level walking include walking speed, step length and toe-clearance from the floor. The gait parameters of crossing step include crossing speed, crossing step length, leading and trailing limb elevations and pre- and post-obstacle distance.[3] One of the important problems associated with aging and risk of falls in elderly adults is balance impairment.[4] Good balance is an imperative skill for daily life that requires the complex integration of vision, vestibular sense, proprioception, muscle strength and reaction time, with increasing age, a progressive loss of these systems can contribute to balance deficits.[4, 5] For maintaining dynamic balance, elderly individuals have been reported to use a gait strategy by reducing gait speed, taking shorter steps and increasing double support time.[6] A person's gait must be adjusted when confronted by varying heights of the surface of the physical environment during daily activities such as stepping up and over a door threshold, walking up stairs and stepping down off a walkway curb. Among of cause of falls in the elderly, tripping during obstacle crossing also was one of the most frequent.[7] Obstacle crossing during normal walking is a voluntary movement, it requires a feedforword control and postural responses for maintaining stability during the movement.[5] In appropriate control of locomotor system may contribute to body imbalance that may further lead to tripping over obstacle.

In recent year, previous studies investigated and compared kinematics data during obstacle crossing at different height between elderly and young adults. Healthy elderly adults displayed differently strategy by exhibited a more conservative strategy when crossing obstacle with shorter crossing step lengths, slower crossing velocities, lower foot-obstacle clearance, shorter shorter-obstacle distances, longer pre-obstacle distances than young adults.[8, 9] Therefore, elderly adults are at a greater risk for tripping during obstacle negotiation tasks than young adults as the probability for obstacle contact is enhanced by the low clearance height.[10] However, no information about gait parameters during walking over the obstacle in elderly women with and without balance impairment was reported. Thus, measure and compare the gait parameters of level walking and crossing step between elderly women with and without balance impairment is of interest. Elderly women were of interest in this study because rates of balance impairment and fall-related injury in women was 40–60% higher than men of comparable age.[11] In addition, gender effect on gait characteristics during walking can be eliminated. Helbostad and Moe-Nilssen[12] 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. In this study, the selected obstacle heights were 10% and 30% of individual leg length.[13] These obstacle heights were test to ensure that individuals of different stature made the same qualitative adoption in going over obstacles.[13] The lowest height of obstacle at 10% of leg length is approximately 7 centimeters that represents a tropical door threshold or small step while the greatest height of obstacle at 30% of leg length is approximately 21 centimeters is similar to a high curb or stair.[13]

The purposes of this study were to compare gait parameters during walking on level surface, and walking and stepping over low and high obstacles between elderly women with balance-impaired (BI) and non-balance-impaired (NBI). It was hypothesized that there would be difference of all gait parameters between the BI and the NBI groups.

Materials and methods

Participants

Elderly women from local Chiang Mai community aged range 60-75 years were recruited to participate in this study. All participants were self-reported to be free of neurological disorders (e.g. Parkinson disease, stroke and brain injury), uncorrected visual problems, severe deformity (e.g. kyphosis, knock-knee, bow leg) and musculoskeletal disorders (e.g. severe pain, ulcers, joint inflammation) that affect the ability to perform the test. The mental status of subject was assessed using the Thai Mini Mental State Exam (TMSE) and the score of each elderly participant was 24 points or higher (score 0-30).[14] The gait parameters of level walking include walking speed, step length and toe-floor clearance. The gait parameters of crossing step include crossing speed, crossing step length, leading and trailing limb elevations and pre- and post-obstacle distance.[3] The Berg Balance Scale (BBS), an observational test for examining functional balance skills in elderly adults in a clinical setting and research purposes, was used as a criterion to assign subjects into the balance impairment (BI) group (BBS scale $\leq$ 45, n=15) and the non-balance impairment (NBI) group (BBS scale < 45, n=15) (score 0-56).[14] All participants were asked to perform the Timed up and go test (TUG)[15], a test of basic functional mobility and balance for frail elderly persons. It takes time in seconds for the subject to rise from sitting, walk 3 metres, turn, walk back to the chair and sitting down. The Institutional Review Board of the Faculty of Associated Medical Sciences, Chiang Mai University, approved the experimental protocol and the experimental procedures were explained to all subjects prior to testing, and written consent was obtained.

Instrumentation

A height-adjustable obstacle consisted of two upright frames and a 1.00 cm wide x 100.00 cm long wood strip. Two reflective markers were placed on each end of the strip to define the position of the obstacle.[16] The strip was light-weight and rigid so it would drop off the frames when contacted. The strip was placed on the two frames with slots spaced in millimeters allowing the obstacle height to be adjusted relative to individual leg length for preventing the influence of the inter-subject anthropometrics differences.[16] The obstacle with height-adjustable was used in the study to ensure that older adults of different statue made the same qualitative adaptation in going over obstacles.[8] The low and high obstacles were adjusted to be equal to 10% of individual lag length (10%LL) and 30% of individual leg length (30%LL). These heights were selected corresponding to situations often encountered during daily activities such as walking across a floor or door threshold, and stepping up a standard stair step. The obstacle was placed in the middle of a 10-m walkway during the obstacle gait testing.[8, 14] Video camera was placed at a distance of 6 m away from the walking path; parallel to the floor and perpendicular to the plane of motion (see Figure 1).

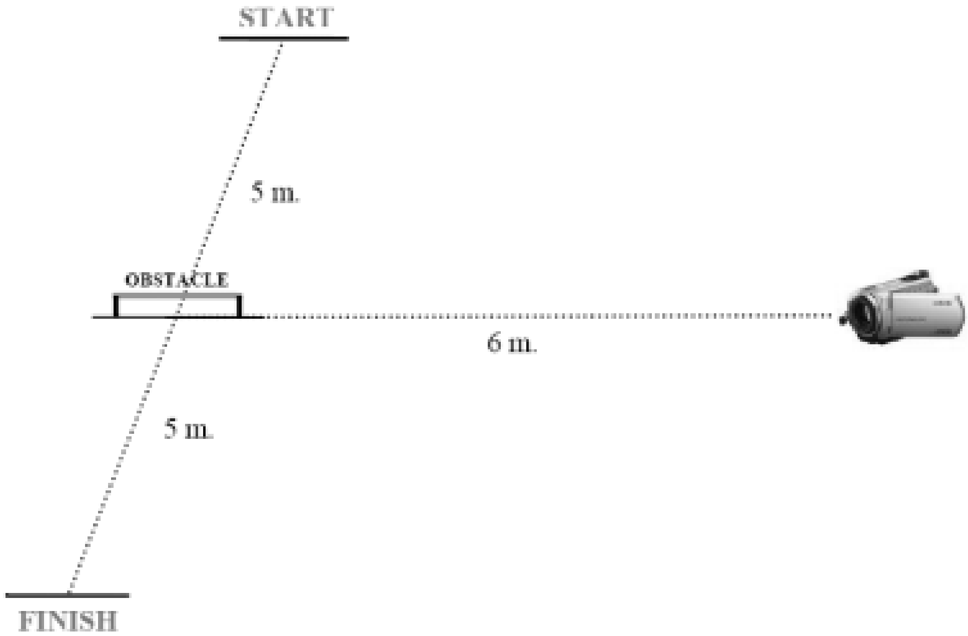

Figure 1. Instrument walkway

Data acquisitions

Gait parameters of the level walking and crossing step were analyzed from the 2-dimensional coordinates of the shoe markers. The reflective markers were placed on the tip of toe and heel of the participant's shoe in both right and left sides. All video images of the successful walking trials were imported to a computer installed with a Silicon Coach 6.0 program (Silicon Coach Ltd., Dunedin, New Zealand). Video images were captured and digitized to obtain the x-y coordinates for each reflective marker using a Silicon Coach 6.0 program with a sampling rate at 50 frames per second. The video image in each walking condition was digitized separately in three frames for collected gait parameters of level walking and crossing step. All digitized frames were transferred to ratio scale for calculation using Microsoft excel. Gait parameters of this study were determined using the following criteria.

Gait parameters of level walking

- **Walking speed** (m/s) was defined as the rate of walking distance per time.
- **Step length** (cm) was defined as the distance from between successive foot-floor contacts with opposite feet.
- **Toe-floor clearance** (cm) was defined as the maximal height of the toe elevated from the floor at the mid swing phase.

Gait parameters of crossing step (see Figure 2)

- **Crossing speed** (m/s) was defined as the rate of change of crossing distance per time that the leading and trailing limbs completely spent to cross the obstacle.
- **Crossing step length** (cm) was defined as the horizontal distance of the leading limb along the direction of progression in the crossing step using the heel marker.
- **Leading limb elevation** (cm) was defined as the vertical distance between the toe marker of the leading limb and the floor when the toe was directly above the obstacle.
- **Trailing limb elevation** (cm) was defined

as the vertical distance between the toe marker of the trailing limb and the floor when the toe was directly above the obstacle.

- **Pre-obstacle distance** (cm) was defined as the shortest horizontal distance between the toe marker of the trailing limb and the obstacle.

- **Post-obstacle distance** (cm) was defined as the shortest of the horizontal distance between the heel marker of the leading limb and the obstacle.

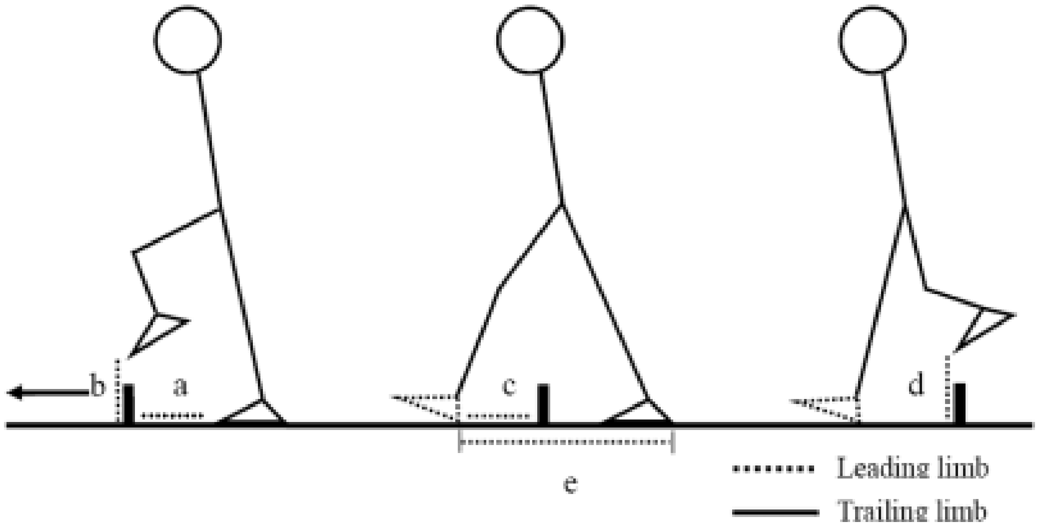

Figure 2. Gait parameters of crossing step ((a) pre-obstacle distance, (b) leading limb elevation, (c) post-obstacle distance, (d) trailing limb elevation and (e) crossing step length

Test procedure

Participants wore their own shoes and performed the tests without any personal assistance or walking aids during walking. All participants were asked to walk at a self-selected pace during walking on level surface (unobstructed) and obstacle tasks (10%LL and 30%LL), respectively. Before data collection, participants were practiced the task for familiarity and safety. Participants performed two trials for each condition with 2 minutes for rest between trial and 5 minutes of rest between conditions.

Statistics

Data were tested for normality using Shapiro-Wilks test. For group comparison of variables pertaining to the level walking condition, if group data were parametric independent samples t-test was used and if data were non-parametric data Mann-Whitney U tests was used.

For the effect of obstacle height, a 2 (group) x 2 (obstacle height) analysis of variance mixed model with obstacle height as a within-subject factor and group as a between-subjects factor was performed to determine the differences between the two groups for gait parameters of a crossing step during the stepping over an obstacle tasks (10%LL and 30%LL). A level of significance for all variable were set at $p<0.05$.

Results

Demographic data

Elderly women aged range 60-75 years from several gerontology groups in local Chiang Mai community were recruited to participate in the study. Age and average leg length of the BI and the NBI groups were not different. Demographic data of the NBI (n=15) and the BI (n=15) groups are presented in Table 1.

Table 1. Demographic data of the BI and the NBI groups

Demographic data	BI	NBI	Independent-test	Mann-Whitney test
Age (y)	71.9±3.5	69.9±4.2		0.096
Weight (kg)	58.2±8.2	47.6±8.9	0.002*	
Height (cm)	151.6±5.0	145.4±9.3	0.030*	
Leg length (cm)	78.2±6.3	80.4±4.3	0.289	
TMSE (0-30)	26.4±1.9	27.0±1.8		0.309
BBS (0-56)	44.0±1.2	53.4±2.7		0.000**
TUG (sec)	18.0±4.1	11.2±0.9	0.000**	

Note: Values are means ± S.D. *Significant difference at $p<0.05$, **$p<0.001$.

Gait parameters of level walking

For walking on level surface, walking speed and step length of the BI group were significantly slower and shorter than the NBI group while toe-clearance of both groups was not different. Gait parameters of level walking are presented in Table 2.

Table 2. Gait parameters of level walking

Gait parameters	BI	NBI	Independent t-test	Mann-Whitney test
Walking speed (m/s)	0.60 ± 0.15	1.36 ± 0.69		p=0.000**
Step length (cm)	42.29 ± 7.23	55.20 ± 7.23	P=0.000**	
Toe-floor clearance (cm)	3.34 ± 0.99	4.78 ± 2.96	P=0.086	

Note: Values are means ± S.D. *Significant difference at $p<0.05$, **$p<0.001$.

Gait parameters of crossing step

The obstacle height of the BI and NBI groups were not different in both conditions. The obstacle height in 10%LL and 30%LL conditions of the BI were 7.80 ± 0.63 and 23.48 ± 1.90 cm, respectively, while the obstacle height in 10%LL and 30%LL conditions of the NBI were 8.04 ± 0.43 and 24.12 ± 1.29 cm, respectively. Most of the participants of both groups completed the entire obstacle testing without difficulty, except three of the BI group, their trailing limb contacted the obstacle during performing the 30%LL condition. Gait parameters of crossing step of both groups are presented in Table 3.

Table 3. Gait parameters of crossing step

Variables	group	Obstacle heights		p-values	
		10%LL	30%LL		
Crossing speed (m/s)	BI	0.41 ± 0.10	0.33 ± 0.13	p_g = 0.000**	p_h = 0.000**
	NBI	0.74 ± 0.19	0.65 ± 0.13	p_{gh} = 0.696	
Crossing step length (cm)	BI	44.04 ± 5.14	44.30 ± 5.42	p_g = 0.000**	p_h = 0.134
	NBI	57.83 ± 6.57	54.54 ± 5.30	p_{gh} = 0.082	
Leading limb elevation (cm)	BI	18.46 ± 3.69	33.42 ± 4.25	p_g = 0.006*	p_h = 0.000**
	NBI	24.52 ± 8.71	36.32 ± 4.01	p_{gh} = 0.259	
Trailing limb elevation (cm)	BI	18.03 ± 3.58	32.50 ± 4.25	p_g = 0.002*	p_h = 0.000**
	NBI	25.15 ± 8.63	37.38 ± 6.02	p_{gh} = 0.447	
Pre-obstacle distance (cm)	BI	8.16 ± 4.40	10.02 ± 4.09	p_g = 0.000**	p_h = 0.420
	NBI	19.55 ± 8.16	16.08 ± 4.05	p_{gh} = 0.011*	
Post-obstacle distance (cm)	BI	13.88 ± 3.97	11.43 ± 4.81	p_g = 0.032*	p_h = 0.148
	NBI	16.12 ± 5.40	16.21 ± 4.81	p_{gh} = 0.120	

Note: Values are means ± S.D. p values: p_g represents group effect; p_h represents obstacle height effect; p_{gh} represents group x obstacle height interaction. *Significant difference at $p<0.05$, **$p<0.001$.

Discussion

The purposes of this study were to determine if there were differences between female older adults with and without balance impairment during common daily tasks including walking on level floor and walking and stepping over an obstacle. Balance impairment of the participants was primarily assessed by the Berg Balance Scale and was confirmed by the TUG test. Most of the elderly defined as no balance impairment performed the BBS with no difficulty. Whereas reduced BBS scores for the balance-impaired group were mainly due to difficulty in performing the particular items challenging dynamic balance such as reaching forward with outstretched arm and standing on one leg. 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[17] reported that the TUG score greater than 14 could represent impaired balance and risk of fall. Furthermore, it has been shown that the TUG score were highly correlated with the BBS scores.[18] The TUG and BBS both assess balance and the ability and fall risk, but they do so by 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.[18] Therefore, balance-impaired group were assumed that they were less stability in both static and dynamic balance.

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).[19] Average walking speed of the balance-impaired group was similar to walking speed of elderly people with balance-impaired (0.79 ± 0.25 m/s) reported by Menze et al.[20] In this study, the balance-impaired group had a decreased walking speed (42.29 ± 7.23 cm) because of 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,[21, 22] indicating that elderly women of both groups sufficiently elevated their limbs to prevent tripping during walking. Although elderly women of non-balance-impaired group seemed to overweight,[23] their gait parameters of level walking were similar to healthy older adults. This information was implied that in this study body anthropometry did not effect to gait parameters. In contrast, 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 the risk of falls.[24]

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.[16] 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-impaired group in both 10%LL and 30%LL conditions, given that there were no differences in average leg length and average obstacle height in both conditions for both groups. 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. Therefore, a greater risk for tripping during obstacle negotiation tasks than the non-balance-impaired group. Our results may imply that balance-impaired group did not flex the knee or hip joints over an obstacle as high as the non-balance-impaired group.

Stepping over an obstacle was found to be a challenging task for assessment of the ability to control 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 individuals of the balance-impaired group had their trailing limb contacting the obstacle, though it did not lead to fall. Chou and Draganich[21] 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 balance. Only information about healthy older adults was reported. Previous studies reported that healthy elderly adults reduced both of pre- and post-obstacle distances compared to their younger counterparts.[25, 26] Similar to this study, balance-impaired group placed their leading and trailing limbs closer to the edge of an obstacle than the non-balance-impaired group. Weerdesteyn et al[25] 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 COM within base of support. In other words, if the approaching foot is placed far from the obstacle, the body's COM would have to move forward more than placing it close to the obstacle which in turn, leading to greater displacement of the body's COM. 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 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 internal rotation rather than hip flexion.[16]

In conclusion, gait parameters of level walking and crossing step between elderly women with and without balance impairment were significantly different. Elderly women with balance impairment used a cautious strategy for maintaining their stability during walking on level surface and obstacle tasks, and had a greater risk for tripping during obstacle negotiation tasks than the elderly women without balance impairment.

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