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Research paper

Effects of balance recovery after square and semicircular turns on gait velocity and center of mass acceleration in older adults with differing visual acuity[☆]



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ABSTRACT

Objectives: To investigate the effects of square turning (ST) and semicircular turning (SCT) on gait velocity and center of mass (COM) acceleration while ambulating in elderly women with good binocular visual acuity (GBVA) and poor binocular visual acuity (PBVA). We also compared balance recovery after turning within visual acuity groups.

Methods: The present study enrolled 22 community-living elderly Korean women. The BVA of 11 participants were less than or equal to 0.4 logarithm of the minimum angle of resolution (logMAR), and the others were better than or equal to 0.3 logMAR. Participants walked at a self-selected speed along a marked path that included two types of turns (consist of three segment: straight, turning, return straight) while fitted with an accelerometer over the L3 spinal process. Gait velocity and COM acceleration were measured using a tri-axial accelerometer. Balance recovery after turning was indexed by comparison of the gait velocity and normalized COM acceleration of the straight and return-straight stages of sharp (ST) and less-sharp (SCT) turns.

Results: The velocity was significantly faster and normalized medial–lateral (ML) COM acceleration was lower during the three segments of the ST and SCT courses in the GBVA group compared with that of PBVA group. In addition, the velocity in both groups during turning segment significantly decreased and velocity of GBVA group was significantly recovered after turning only SCT course whereas velocity of PBVA was not recovered on both courses. Normalized anterior–posterior (AP) COM in GBVA group significantly decreased during turning and return straight segment compare to straight segment on ST course. PBVA group showed different AP COM between straight and return straight segments on ST course. Normalized (ML) COM acceleration of the both groups during turning and return straight segment on SC course was significantly decreased compare to straight segment.

Conclusions: We found that visual acuity affected gait velocity and balance in older adults. Those with PBVA exhibited more cautious walking strategies, including slower gait velocity and fluctuated ML COM motion, to overcome the difficulty posed by turning while walking. Those with GBVA recovered balance more quickly after less sharp turns. Changing direction while walking is one of the biggest challenges for elderly, even those with good visual acuity and especially, older adults with PBVA require balance and gait training using a variety of turns to prevent falls.

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[☆] Each subject provided his informed consent before participating in the study. This study was approved by the Inje University Faculty of Health Sciences Human Ethics Committee. 2014-07-26.

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1. Introduction

Walking is a requirement to independently perform activities of daily living (ADLs) and for quality of life in elderly individuals. Walking requires sustaining forward movement, maintaining balance, and adapting to challenges, such as avoiding obstacles or navigating curved paths [1,2]. Changing directions while walking is commonly required, and turning is necessary to

perform many ADLs [3,4]. Square turning (ST), for example, is used to walk around buildings, and semicircular turning (SCT) is useful to avoid obstacles. Turning during ambulation is a complex and challenging maneuver for older adults, as it demands constant body reorientation [5,6]. Turning requires head yaw, trunk and foot rotation, and accurate limb control [7,8]. Balance must be maintained in older adults to decrease the risk of falling [2,9,10].

Previous studies investigated the biomechanical strategies used in a variety of ST and circular turning (CT) maneuvers in young adults [9,11,12]. Glaister et al. [9] investigated ground reaction forces and impulses during three stages of a 90° turning maneuver. Turn initiation and termination were both characterized by medial spanning impulses, while apex steps were characterized by a large lateral impulse. In the anterior–posterior direction, initiation steps involved a greater degree of braking; apex and termination steps were characterized by greater propulsive impulses vs straight steps. These results imply that walking in a straight line exerts equal force on the body from both limbs, whereas turning requires kinetic asymmetry. In addition, medial and lateral impulses during turning were greater compared with walking in a straight line. The outer leg exerts greater plantar-flexor forces to propel the body, because it must travel a greater distance during the turn. More muscles are activated around the knee of the inner limb during the stance phase to enable body support and control while turning. Maintaining balance becomes more challenging when the body's center of mass (COM) moves in a medial–lateral direction during turning due to asymmetric movement of the inner and outer limbs. In addition, self-selected turning was significantly slower vs walking in a straight line due to braking impulses; however, younger adults attempt to optimize forward progression, mobility and efficiency during turning. Ventura et al. [12] investigated the compensatory mechanisms employed by transtibial amputees during a simple turning task, demonstrating that amputees and non-amputees employ different joint strategies during turning. Amputees depend primarily on sagittal plane hip joint exertion, whereas non-amputees depend primarily on ankle exertion in the sagittal plane, and hip joint exertion in the coronal plane. These results suggest that when ankle plantar-flexor forces propel the body, physically weaker subjects may compensate by employing hip joint strategies during turning.

Previous studies also have demonstrated the strategies used to turn while walking in older adults. Baird and Van Emmerik [13] investigated age-related differences in segment and joint coordination affecting postural stability during a standing turn. Fuller et al. [14] examined control strategies used by older adults to initiate a voluntary change in the direction of travel. Paquette et al. [15] studied the effects of changing the base of support (BOS) at the turning point on anticipatory locomotor modifications during voluntary changes in direction in older adults. Studies suggest that older adults use more cautious foot placement and hip orientation to turn while ambulating. A slower walking speed and increase in step width just prior to turning, combined with a delay in COM motion, contribute to postural instability in older adults [13–15].

Many older adults have decreased postural stability and substantial visual impairment from conditions such as cataracts, glaucoma, and macular degeneration [16,17]. Vision plays a key role in maintaining balance. Vision provides information regarding the environment (visual exteroception), such as the curve of a path [7]. Visual cues before and during ambulation help determine the speed of locomotion. Also, vision provides constant information to the central nervous system about body orientation (visual exproprioception) in space and relative to other body parts [2,18]. Thus, visual cues influence body alignment with reference to gravity and to the environment during ambulation.

Although turning while walking is a complex and challenging maneuver, the main factor preventing a fall in elderly individuals is

balance recovery. To compare the effects of velocity and COM motion before and after turning, parameters must be evaluated that quantify the pattern of movement and balance [19–21].

Few studies have investigated the effects of balance recovery in relation to gait velocity and shift in COM while turning in older people or in relation to poor binocular visual acuity (PBVA). The present study investigated the effects of gait velocity and COM acceleration during ST and SCT while walking in older adults with good binocular visual acuity (GBVA) and poor BVA (PBVA) subjects walked path that included straight and turning segments. This study also compared the measured parameters within groups.

2. Methods

2.1. Subjects

A total of 22 elderly women living in Gyeongsangnam-do, South Korea, participated in this study. Each participant's BVA was evaluated with and without their own spectacles for classification into two groups: PBVA and GBVA. The PBVA group ($n = 11$) consisted of individuals with BVA less than or equal to 0.4 logMAR; the GBVA group ($n = 11$) consisted of individuals with BVA or better than or equal to 0.3 logMAR. The inclusion criteria were as follows: (1) older than 65 years of age with BVA of 0.4 logMAR or worse (2) older than 65 years of age with BVA of 0.3 logMAR or better; (3) the ability to walk independently without any assistive device; and (4) a score of at least 24 on the Korean version of the Mini-Mental State Exam. The exclusion criteria were as follows: (1) a past or present neurologic disorder, (2) a musculoskeletal disease that may interfere with daily activities, (3) significant visual, auditory and vestibular impairments, (4) treatment with drugs that would influence the study results, or (5) participation in a regular exercise program within the last 6 months. Table 1 shows study participant characteristics.

2.2. Materials

2.2.1. Tri-axial accelerometer

Gait velocity and COM acceleration during ambulation on ST and SCT courses were measured using a tri-axial accelerometer (Fit Dot Life, Suwon, Korea). The accelerometer was 35 × 35 × 13 mm in size and weighed 13.7 grams. A sensor range of −8 g to +8 g could be selected in the acquisition software (Fitmeter manager 2, ver. 1.2.0.14, Korea). The raw data were measured using x, y, and z acceleration variables. The data were automatically transferred to a computer using a USB cable connection. The present study used a sensor range of ±2 g. The accelerometer was attached over the L3 spinous process using double-sided adhesive tape [22]. Another accelerometer with a hand switch was used by the investigator to divide the path into three phases (straight, turning, and straight return). Data were collected with a sampling rate of 32 Hz. The

Table 1
General characteristics of the participants ($n = 22$).

Variables	PBVA group ($n = 11$)	GBVA group ($n = 11$)	<i>P</i>
	Mean ± SD	Mean ± SD	
Age (years)	77.00 ± 5.62	75.55 ± 7.27	.605
Height (cm)	149.51 ± 4.21	149.11 ± 3.86	.819
Weight (kg)	51.15 ± 5.22	50.35 ± 6.79	.762
BVA left side	0.5 ± 0.09	0.22 ± 0.10	.000*
BVA right side	0.5 ± 0.11	0.21 ± 0.09	.000*

PBVA: poor binocular visual acuity; GBVA: good binocular visual acuity; BVA: binocular visual acuity (logMAR).

* $P < 0.05$.

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