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Original Article

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Changes of Gait Variability by the Attention Demanding Task in Elderly Adults

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Purpose: Gait variability is defined as the intrinsic fluctuations which occur during continuous gait cycles. Increased gait variability is closely associated with increased fall risk in older adults. This study investigated the influence of attention-demanding tasks on gait variability in elderly healthy adults.
Methods: We recruited 15 healthy elderly adults in this study. All participants performed two cognitive tasks: a subtraction dual-task (SDT) and working memory dual-task (WMDT) during gait plus one normal gait. Using the LEGSys+ system, we measured the coefficient of variation (CV % = 100 × [standard deviation/mean]) for participants' stride time, stride length, and stride velocity.
Results: SDT gait showed significant increment of stride time variability compared with usual gait ($p < 0.05$), however, stride length and velocity variability did not difference between SDT gait and usual gait ($p > 0.05$). WMDT gait showed significant increment of stride time and velocity variability compared with usual gait ($p < 0.05$). In addition, stride time variability during WMDT gait also significantly increased compared with SDT gait ($p < 0.05$).
Conclusion: We reported that SDT and WMDT gait can induce the increment of the gait variability in elderly adults. We assume that attention demanding task based on working memory has the most influence on the interference between cognitive and gait function. Understanding the changes during dual task gait in older ages would be helpful for physical intervention strategies and improved risk assessment.

Keywords: Dual task, Attention demanding task, Working memory, Gait analysis, Aging

INTRODUCTION

Human gait is defined as systematic, rhythmic, and coordinated movement of limb and trunk during locomotion.[1,2] Walking requires coordination of many neural structures, including the cerebral cortex, cerebellum, basal ganglia, and brainstem locomotor centers.[3-5] There are several brainstem locomotor centers, including subthalamic, mesencephalic, and pontine locomotor regions.[3-5] For the mesencephalic locomotor center, pedunculopontine nucleus (PPN) and cuneiform nucleus are known to be involved in the control of rhythmic gait function. Systematic and rhythmic walking pattern is generated by an automatic process of locomotor centers also known as central pattern generator or stepping pattern generator.[5,6] However, various gait conditions also need attentional performance and cognitive processing.[7-9]

Decreased mobility and daily activity in older adults are commonly caused by neuromuscular system changes or decreased muscle activation and muscle strength.[2,10-13] Decline in cognitive function is also associated with changes in gait pattern in older adults.[7,14,15] When assessing gait under dual-task conditions, older adults with a history of falls have shown decreased gait velocity but increased gait variability compared to non-fallers.[16-18] Gait variability is defined as inherent natural fluctuations that occur during continuous gait cycles. Increased gait variability is closely associated with increased fall risk in older adults. Dual tasks while walking are commonly reported to increase gait variability. The objective of this study was to determine the influence of attention-demanding task on gait variability in healthy elderly adults.

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METHODS

1. Subjects

Fifteen normal elderly adults participated in this study (8 males, 7 females, mean age: 65.93 ± 4.35 years, range: 60 to 70). Inclusion criteria for this study were as follows: 1) no history of musculoskeletal and neurologic problems, 2) independently performing activities of daily living (ADL) and gait, 3) no cognitive problems like dementia (mini mental state examination, MMSE > 23 score). All participants provided informed consent and the study was approved by the institutional review board in Dankook University.

2. Measurements

1) Gait Measurement

Kinematic and spatiotemporal parameters of gait were collected using a LEGSys+ wearable device (BioSensics, Cambridge, Massachusetts, USA). Five wearable sensors (5.0 cm × 4.2 cm × 1.2 cm) were connected to a computer by Bluetooth and contained tri-axial gyroscopes, accelerometers, and magnetometers.[19-21] Each sensor was attached by Velcro straps to the anterior surface of both shins 3 cm above the ankle, anterior surface of both thigh 3 cm above the knee, and the low rear center of the posterior superior iliac spine (PSIS). Sampling frequency of sensors used in this study was 100 Hz. Subjects were instructed to walk a 7 m walkway, which required five or more strides.[22] The experiment measured each stride's characteristics as they emerged during the gait task. We measured the coefficient of variation (CV % = 100 × [Std/mean]) for participants' stride time, stride length, and stride velocity.

2) Dual-Task

This study used two different dual-task conditions for the attention-demanding task during gait. The two dual-task conditions were as follows. First, in a subtraction dual task (SDT), participants performed arithmetic (such as serial subtraction) when they were walking.[16] Participants were instructed to serially subtract by the value of seven or nine from a given number between 100 and 200 to prevent learning effects. Second, in a working memory dual task (WMDT), subjects were instructed to speak the reverse of a date randomly offered by the experimenter, during gait (e.g., 8 June 2017 → 2017 June 8).[23] All subjects performed two different dual-task conditions during gait and one usual gait condition at a self-selected comfortable speed. Each walking task condition was repeated three times.[24]

3. Experimental Procedure

Subjects were asked to begin in a standing position at the starting line and then perform gait at a given signal like "start". This study measured three trials for every condition. Subjects were instructed to stop when they arrived at the finish line regardless of signal and remain in a standing position like the starting position. They were asked to continually perform the dual-cognitive task and stopped when they arrived at the finish line. If they gave up the task or stopped the gait during the experiment, the experiment was excluded. Subjects went back to starting line and were retested.

4. Statistical Analysis

Data analysis was performed using SPSS software (ver. 20.0; SPSS, Inc., Chicago, IL, USA). One-way analysis of variance (ANOVA) with LSD post-hoc was used to compare the difference between each of the three conditions. Statistical significance was set at 0.05.

RESULTS

Results of comparison of gait variability among usual gait, SDT gait, and WMDT gait are shown in Table 1. During SDT gait, stride length variability or stride velocity variability did not show significant difference with that of usual gait ($p > 0.05$). In contrast, stride time variability was significantly increased compared to that of usual gait ($p < 0.05$). WMDT gait did not show significant increment of stride length variability compared to usual gait ($p > 0.05$). In contrast, stride time variability and stride velocity variability were significantly increased during WMDT gait compared to those of usual gait ($p < 0.05$). WMDT gait also showed significant increment

Table 1. Difference of gait variability according to the attention demanding task.

	Gait variability (%)		
	Stride length	Stride time	Stride velocity
Usual gait	3.17 ± 2.68	2.03 ± 1.29	4.86 ± 3.39
Subtraction dual task gait	5.08 ± 4.72	3.34 ± 2.12*	7.43 ± 5.28
Working memory dual task gait	5.13 ± 2.43	5.42 ± 3.82*,†	9.06 ± 5.11*

Values represent mean ± standard deviation.
SDT: subtraction dual task, WMDT: working memory dual task.
One-way ANOVA with LSD post hoc test was used to compare the difference of gait variability between *usual gait and each dual task gait, and between †subtraction dual task gait and working memory dual task gait.
*$p < 0.05$.

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of stride time variability compared to SDT gait.

DISCUSSION

The purpose of this study was to determine the effect of two types of cognitive dual tasks on gait variability in healthy elderly adults. Main findings of this study were as follows. Gait variability of stride length did not show significant difference among usual gait, SDT gait, and WMDT gait. In contrast, gait variability of stride time showed significant increment during SDT gait and WMDT gait compared to that of usual gait. WMDT gait also showed significant increment of stride time variability compared to SDT gait. In terms of stride velocity variability, WMDT only showed significant increment compared to usual gait. However, SDT gait did not show significant difference in stride velocity compared to usual gait. Therefore, WMDT gait had the most influence on gait variability of stride time and stride velocity. Capacity of working memory in human brain is generally considered to have limitations. Decline of working memory in older adults is known to be more sensitive and faster compared to loss of other cognitive functions.[25-27]

Interferences between gait-related variables and cognitive dual tasks in elderly adults are known to be more severe compared to those in young adults. Many studies have reported that gait-related variables during walking with attention-demanding dual tasks or motor dual tasks are decreased. In 2012, Holtzer et al.[28] reported the relationship between cognitive function and gait parameters in elderly adults. Their resukts have suggested that the decline in cognitive function has significant correlation with decrement in gait ability.[28] In 2014, Qu[27] reported that cognitive tasks involving visuospatial sketchpad interfered with gait more severely in older adults than those in young adults. In terms of gait variability, it is well-known that increased gait variability is closely associated with increased fall risk in older adults. It has been commonly reported that dual tasks while walking will increase gait variability.[29,30] In 2008, Laessoe et al.[29] reported that stride-to-stride variability with motor dual tasks was increased in elderly adults. Subsequently, Schniepp et al.[30] have also reported that elderly adults with history of fall show significant increment of gait variability during cognitive dual task gait. Consequently, we believe that increased gait variability during attention demanding task with gait could be caused by cognitive decline in elderly adults. However, limitations of this study should be considered. Age group of our participants was narrow. Therefore, it might be difficult to generalize results of this study. In future research, different age groups should be included.

In conclusion, results of this study demonstrate that SDT and WMDT gaits can influence gait variability in elderly adults. Attention demanding task based on working memory has the most influence on the interference between cognitive and gait function.[31,32] Therefore, changes in gait variability by attention demanding task with gait might be useful as intervention strategies to rehabilitate or train people who are at risk for falling.

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