JKPT
Vol. 35, No. 3, June 2023
J Kor Phys Ther 2023:35(3):64-70
pISSN 1229-0475 eISSN 2287-156X
Original Article
https://doi.org/10.18857/jkpt.2023.35.3.64

Difference in Gait Characteristics During Attention-Demanding Tasks in Young and Elderly Adults

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Purpose: This study investigated the influence of attention-demanding tasks on gait and measured differences in the temporal, spatial and kinematic characteristics between young healthy adults and elderly healthy adults.
Methods: We recruited 16 healthy young adults and 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, knee and hip-joint kinematic data during stance and swing phase and spatiotemporal parameter data were assessed in this study.
Results: In the elderly adult group, attention-demanding tasks with gait showed a significant decrease in hip-joint motion during the stance phase, compared to the normal gait. Step length, stride length and stride velocity of the elderly adult group were significantly decreased in WMDT gait compared to normal gait ($p < 0.05$). In the young adult group, kinematic data did not show any significant difference. However, stride velocity and cadence during SDT and WMDT gaits were significantly decreased compared to those of normal gait ($p < 0.05$).
Conclusion: We determined that attention-demanding tasks during gait in elderly adults can induce decreased hip-joint motion during stance phase and decreased gait speed and stride length to maintain balance and prevent risk of falling. We believe that understanding the changes during gait in older ages, particularly during attention-demanding tasks, would be helpful for intervention strategies and improved risk assessment.

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

INTRODUCTION

Human gait is a well-recognized biometric feature and refers to systematic, rhythmic and coordinated movements of limb and trunk during locomotion.[1,2] Gait control requires complex interactions between the nervous system and musculoskeletal system to maintain balance and stability during bipedal forward propulsion of the human body.[1-3] Many regions of the brain are concerned with gait function, such as the premotor cortex, basal ganglia, and cerebellum.[4-7] In addition, there are several brainstem locomotor centers, including the subthalamic nuclei, the mesencephalic, and pontine locomotor regions, which produce autorhythmic lower limb patterns during gait.[4-8] The basic gait pattern is generated by an automatic process of the central pattern generator.[5,9] However, various gait conditions also need attentional performance and cognitive processing.[10-12]

Neuromuscular system changes resulting from advanced age commonly cause decreased mobility and daily activity.[2,13] In particular, age-related changes in gait have been reported by many previous studies.[2,13-17] It is well known that decreased muscle activation and lower limb range of motion (ROM) during gait are commonly induced by decreased muscle strength, stability and flexibility of joint motion as a result of aging.[2,14-17] On the other hand, there is association between the decline in cognitive function and the changes in gait pattern in elderly adults.[10,18,19] Abbott et al.[19] suggested that limited gait function was significantly associated with preclinical dementia in older adults. Consequently, decline of gait function in

Received May 15, 2023 **Revised** June 15, 2023
Accepted June 16, 2023
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older adults can occur from difficulty associated with attention-demanding tasks due to cognitive limitations of aging.

Gait analysis during dual-task conditions is commonly used to assess capabilities during attention-demanding task.[20] It is known that the capability to complete attention-demanding tasks is influenced by changes in cognitive capacities associated with aging.[11,12] Therefore, dual-task conditions during motor task performance can determine the interaction between cognitive processing and motor behavior.[20] Numerous studies have reported on the influence of attention-demanding tasks on temporal and spatial gait parameters in various patient populations and healthy adults.[11,12,20-22] In particular, when performing the gait under dual-task conditions, elderly adults with a history of falls showed decreased gait velocity and increased gait variability, compared to non-fallers.[23-25] Consequently, dual task walking conditions could be a useful method to measure the relationship between cognitive ability and gait.[10,23]

Therefore, the purpose of this study was to investigate the impact on gait and the strategy of gait to maintain balance and prevent risk of falling according to an attention-demanding task on gait by assessing the difference in temporal, spatial and kinematic characteristics and gait variability between healthy young adults and healthy elderly adults.

METHODS

1. Subjects

Thirty-one normal healthy subjects were recruited in the current study: fifteen elderly adults (>60 years of age) and sixteen young adults (20-29 years of age) at Dankook University. This study set the inclusion criteria 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)(Table 1). Exclusion criteria for this study were as follows: 1) participants had MMSE ≤ 23 score, 2) participants who have previously been diagnosed with the musculoskeletal and neurologic problems. There were no participants who were excluded by exclusion criteria in two groups. This study provided informed consent to all participants and the study was approved by the institutional review board in Dankook University.

Table 1. Demographic data of elderly and young adult group

	Old (n=15)	Young (n=16)
Age (yr)	65.9 (4.4)	21.6 (1.7)
Gender (Male/Female)	8/7	8/8
Weight (kg)	64.1 (9.3)	62.6 (12.9)
Height (cm)	161.2 (6.2)	167.8 (10.3)
MMSE (score)	27.1 (0.7)	27.6 (0.9)

Values show mean (± standard deviation).

2. Measurements

(1) Cognitive function evaluation

This study evaluated the cognitive function using MMSE for recruiting participants. MMSE was composed to eleven items under the 5 main titles and assessed as the total score of 30. The current study conducted evaluation using MMSE that translated into Korean. We set that the threshold value was 24 score.

(2) Gait measurement

This study measured the kinematic and spatiotemporal parameters of gait using a LEGSys+wearable device (BioSensics, Cambridge, Massachusetts, USA). Five wearable sensors (5.0cm × 4.2cm × 1.2cm) containing tri-axial gyroscopes, accelerometers, and magnetometers were connected to a computer by Bluetooth.[26-28] Each sensor was attached by Velcro straps as follows: 1) the anterior surface of 3cm above the ankle in both shin, 2) anterior surface of 3cm above the knee in both thigh, 3) the low rear center of the posterior superior iliac spine (PSIS). This study set that sampling frequency was 100Hz. Participants were instructed to walk a 7m walkway, which contained five or more strides. Each stride's characteristics were measured when they performed the gait. This study obtained kinematic data and spatiotemporal data from the mid-three strides and excluded the first and last strides. We measured ROM of knee and hip joints during stance and swing phases respectively, and stride length, stride velocity, step length and cadence during the walking task. These parameters were defined as follows: stance, the entire period while the foot is on the ground, swing, the time which the foot is in the air for advancement, stride length, the distance between one heel contact (starting position) and next same-side heel contact (starting position), stride velocity, the velocity during one heel contact to the next same-side heel contact, step length, the distance from one heel contact to opposite-side heel contact, cadence, the total number of full cycles taken within a given period of time.

3) Dual-task

This study measured the gait while performing two different dual-task conditions for the attention-demanding task. The two dual-task conditions were as follows. First, in a subtraction dual task (SDT), participants performed arithmetic (such as serial subtraction) based on the one of the items in MMSE during the gait.[23] This study instructed to serially subtract by seven or nine from a given number and randomly provided the number 100 and 200 to prevent learning effects. Second, in a working memory dual task (WMDT), participants were instructed to speak the reverse of a date randomly provided by the experimenter while they were walking (e.g., 17 January 2018 → 2018 January 17).[21] All participants were instructed to perform two different dual-task conditions during gait and one normal gait condition at a self-selected comfortable speed. Participants repeated each walking task condition three times.[29]

3. Experimental procedure

Participants were instructed to begin in a standing position at the starting line and then perform gait at a given signal like "start". They were instructed to continually perform the dual-cognitive task until they arrived at the finish line. This study randomly presented numbers and dates for SDT and WMDT to participants during the experiment. At this time, participants were instructed to keep walking while performing the given dual tasks. They were also asked to stop when they arrived at the finish line regardless of signal and remain in a standing position like the starting position. This study measured three trials for every condition. If they gave up the task or stopped the gait during the experiment, the trial of experiment was excluded. Participants went back to starting line and were retested.

4. Statistical analysis

SPSS software (ver. 20.0, SPSS, Inc., Chicago, IL, USA) was used to analyze the data. A Shapiro-Wilk test was used to normality test. This study used one-way analysis of variance (ANOVA) with LSD post-hoc to compare the changes between each of the three conditions per group. Independent t-test was used to compare the difference of kinematic, spatiotemporal parameters and gait variability between the elderly adult and young adult groups. Statistical significance was set at 0.05.

RESULTS

1. Kinematic parameters

Kinematic analysis of knee and hip joints during gait were shown in Table 2 (Figure 1). In the elderly adult group, SDT gait and WMDT gait showed a significant ROM decrease in the hip joint during stance phase, compared to the normal gait ($p < 0.05$). In contrast, the young adult group did not show any significant difference in knee and hip ROM between attention-demanding tasks (SDT and WMDT) with gait and normal gait ($p > 0.05$). In the normal gait condition, there were significant differences in knee and hip-joint ROM between the young adult and elderly adult groups during stance phase, the elderly adult group showed significant decrement in hip-joint ROM and a significant increment in knee-joint ROM compared to those of the young adult group ($p < 0.05$). However, there were no significant differences in ROM between young and elderly adult groups during swing phase ($p > 0.05$).

Table 2. Comparison of kinematic between elderly and young adult groups

	Old				Young			
	Swing knee (deg)	Swing hip (deg)	Stance knee (deg)	Stance hip (deg)	Swing knee (deg)	Swing hip (deg)	Stance knee (deg)	Stance hip (deg)
Normal	41.15 (7.93)	17.78 (6.21)	14.88 (6.31)	16.55 (2.90)	38.81 (6.04)	20.41 (7.78)	9.82* (3.22)	18.70* (5.01)
SDT	37.86 (11.81)	17.70 (6.40)	13.73 (7.11)	14.67 (3.40)	37.09 (6.74)	18.36 (7.81)	9.06 (3.50)	18.19 (4.98)
WMDT	36.69 (12.42)	17.10 (6.58)	13.65 (7.29)	14.20 (4.05)	37.35 (6.26)	18.22 (7.74)	9.08 (3.51)	17.70 (5.23)
F	1.248	0.146	0.231	3.453	0.685	0.800	0.513	0.310
p	0.292	0.865	0.794	0.036	0.507	0.453	0.601	0.734
N vs. C_1	0.245	0.960	0.520	0.040	0.267	0.296	0.380	0.684
N vs. C_2	0.117	0.682	0.493	0.011	0.345	0.266	0.396	0.430
C_1 vs. C_2	0.679	0.719	0.966	0.602	0.866	0.944	0.977	0.701

Values show mean (±standard deviation), Post-hoc values show p-value ($p<0.05$), N: normal gait, C_1: subtraction dual task (SDT), C_2: working memory dual task (WMDT), *significant difference between elderly adult group and young adult group.

https://doi.org/10.18857/jkpt.2023.35.3.64

2. Spatiotemporal parameters

In the elderly adult group, stride length, stride velocity and step length were significantly decreased in WMDT gait compared to normal gait ($p < 0.05$)(Table 3). However, SDT gait did not show any significant difference in spatiotemporal parameters compared to normal gait ($p > 0.05$). In the young adult group, stride velocity and cadence during SDT and WMDT gaits were significantly decreased compared to normal gait ($p < 0.05$). Comparisons between the young adult and elderly adult groups showed significant differences in stride length, stride velocity and step length ($p < 0.05$), however, there was no difference in cadence between young and elderly adult groups ($p > 0.05$).

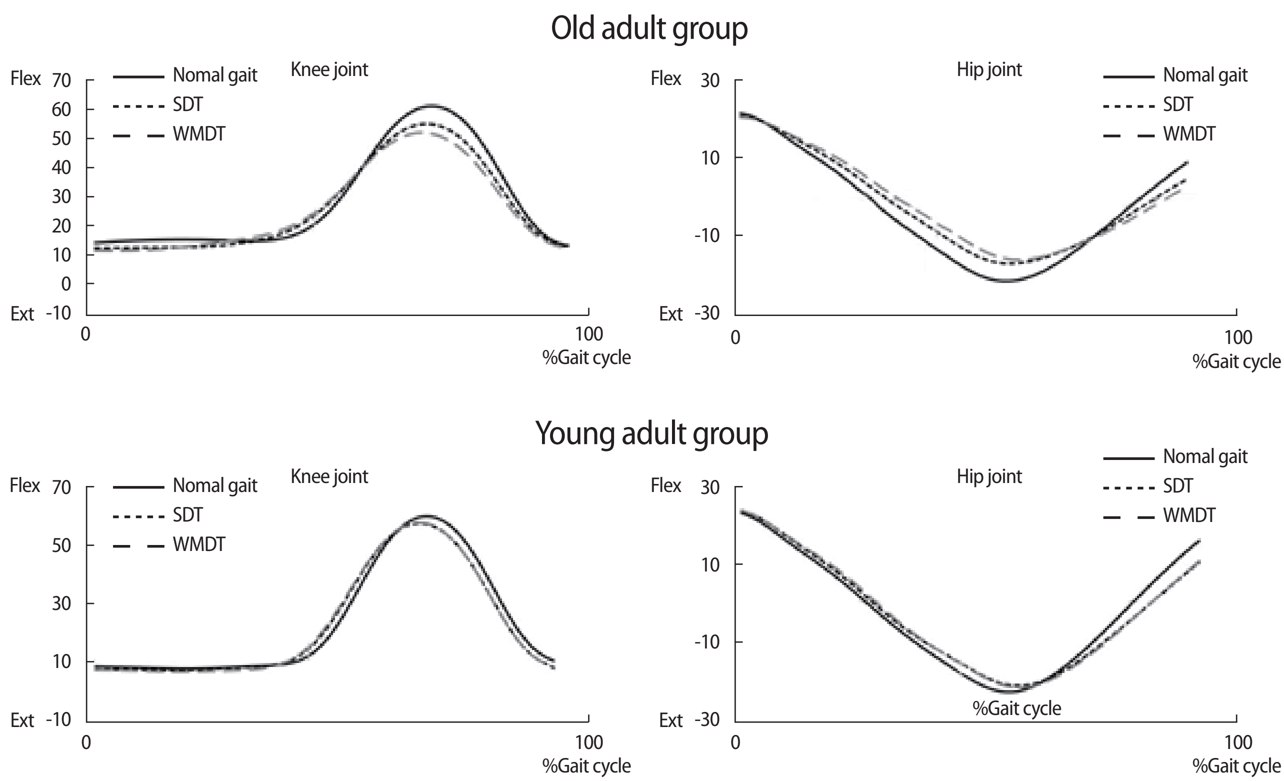

Figure 1. Knee and hip-joint angles of normalized gait cycle for participants in elderly and young adult groups according to attention-demanding tasks: subtraction dual task (SDT) and working memory dual task (WMDT), Positive values indicate joint flexion, negative values indicate joint extension.

Table 3. Comparison of spatiotemporal parameter between elderly and young adult groups

	Old					Young				
	Step length (m)		Stride length (m)	Stride velocity (m/s)	Cadence	Step length (m)		Stride length (m)	Stride velocity (m/s)	Cadence
	Left	Right				Left	Right			
Normal	0.62 (0.09)	0.64 (0.06)	1.26 (0.13)	1.17 (0.20)	111.09 (11.65)	0.72* (0.08)	0.71* (0.10)	1.43* (0.17)	1.39* (0.18)	117.06 (4.94)
SDT	0.55 (0.13)	0.59 (0.08)	1.14 (0.19)	1.00 (0.29)	102.89 (19.27)	0.68 (0.08)	0.67 (0.08)	1.34 (0.15)	1.23 (0.19)	109.41 (9.40)
WMDT	0.52 (0.12)	0.58 (0.09)	1.10 (0.19)	0.93 (0.28)	99.52 (18.85)	0.67 (0.06)	0.67 (0.07)	1.34 (0.12)	1.24 (0.14)	110.83 (6.86)
F	2.728	2.627	3.548	3.463	1.847	1.831	1.281	4.770	4.770	4.966
p	0.077	0.084	0.038	0.041	0.170	0.172	0.288	0.178	0.013	0.011
N vs. C_1	0.117	0.113	0.068	0.075	0.192	0.119	0.151	0.096	0.006	0.008
N vs. C_2	0.028	0.035	0.014	0.014	0.069	0.082	0.157	0.081	0.008	0.029
C_1 vs. C_2	0.504	0.578	0.487	0.473	0.590	0.849	0.983	0.931	0.897	0.612

Values show mean (±standard deviation), Post-hoc values show p-value ($p < 0.05$), N: normal gait, C_1: subtraction dual task (SDT), C_2: working memory dual task (WMDT), *significant difference between elderly adult group and young adult group.

Table 4. Comparison of gait variability between elderly and young adult groups

Gait Variability (%)	Old			Young		
	Stride time	Stride length	Stride speed	Stride time	Stride length	Stride speed
Normal	2.30 (1.29)	3.17 (2.68)	4.86 (3.39)	2.58 (1.53)	3.05 (2.10)	4.56(2.61)
SDT	3.34 (2.12)	5.08 (4.72)	7.43 (5.28)	3.98 (3.80)	3.71 (1.62)	6.65 (4.00)
WMDT	5.42 (3.82)	5.13 (2.43)	9.06 (5.11)	3.54 (1.37)	4.07 (2.22)	5.63 (2.62)
F	5.483	1.594	3.094	1.312	1.074	1.761
p	0.008	0.215	0.056	0.279	0.350	0.183
N vs. C_1	0.288	0.134	0.138	0.120	0.353	0.067
N vs. C_2	0.002	0.125	0.018	0.282	0.156	0.344
C_1 vs. C_2	0.035	0.973	0.345	0.624	0.616	0.363

Values show mean (±standard deviation), Post-hoc values show p-value ($p<0.05$), N: normal gait, C_1: subtraction dual task (SDT), C_2: working memory dual task (WMDT), *significant difference between elderly adult group and young adult group.

3. Gait variability

The results of gait variabilities during the normal gait and attention-demanding tasks with gait were shown in Table 4. In the elderly adult group, stride time and stride speed variabilities during WMDT with gait showed significant increment compared with those of the normal gait ($p<0.05$). In addition, there was significant increment in the stride time during WMDT with gait than those of the SDT with gait ($p<0.05$). However, there were not any significant differences between SDT with gait and normal gait in all gait variabilities ($p>0.05$). In the case of the stride length variability, there were no significant differences between the normal gait, SDT and WMDT with gait ($p>0.05$). In addition, stride speed variability did not show the significant differences except for the result between WMDT with gait and the normal gait ($p>0.05$).

DISCUSSION

The purpose of this study was to demonstrate the difference in gait characteristics between healthy elderly and young adults when performing attention-demanding tasks. The main findings of this study are as follows. In the elderly adult group, 1) Kinematic analysis showed that the angle of the hip joint during stance phase was significantly decreased in SDT and WMDT gaits compared to normal gait. 2) In terms of spatiotemporal parameters, significant decreases in stride length, stride velocity and step length were observed in WMDT gait compared to normal gait. 3) In contrast, there were no significant changes in spatiotemporal parameters during SDT gait compared to normal gait. In the young adult group, 1) Kinematic analysis showed no significant difference in SDT and WMDT gaits compared to normal gait. 2) In the analysis of spatiotemporal parameters, stride velocity and cadence were significantly decreased by SDT and WMDT during gait compared to normal gait. 3) There was no difference in stride length and step length between gait with attention-demanding tasks and normal gait.

These findings suggest that the attention-demanding task in healthy young adults did not affect the kinematic parameters (such as hip and knee-joint angle) during gait, however, the attention-demanding task may have reduced gait speed without causing a change in step and stride length. In contrast, healthy elderly adults were affected in both kinematic and spatiotemporal gait parameters by the attention-demanding task. In particular, decreased hip-joint motion was observed during the stance phase. Previous study suggested that the temporo-spatial parameters of older adults were affected in the gait that require high cognitive demand compared to normal gait.[17] Therefore, the result of previous study was consistent with the results of this study and these results could be useful in the development of strategies for maintaining balance while walking and performing an attention-demanding task.[2,17] In addition, we regard that the speed and length of gait in elderly adults can be influenced by attention-demanding tasks. The task concerned with calculation (SDT) did not affect gait speed and length. However, the task related to working memory (WMDT), caused decreased gait speed and length. These results are different from those of the young adults group where in both SDT and WMDT during gait influenced gait speed. This is probably due to the fact that the elderly adult group had already reduced gait and stride speed due to aging.[2,17] The capacity of working memory in the human brain is generally considered to have limitations. In addition, it is well known

https://doi.org/10.18857/jkpt.2023.35.3.64

that decline of working memory in older adults is most sensitive and faster compared to the loss of other cognitive functions.[30-32] Qu[30] therefore suggested that cognitive tasks involving working memory can be a severe obstacle in maintaining walking balance. Especially, gait variability was increased in older adults during the gait with cognitive tasks compared to young adult and normal gait. Consequently, we suggested that the attention-demanding task associated with working memory would have more influence on the walking than the simple calculation task.

The result of many previous studies was consistent with the results of this study, which showed significant effects of the dual-task condition on gait parameters such as increased number of stops, lateral deviations, stride length, and walking time.[18,20,23,30,33] In this regard, the deficits in the dual-task performance of elderly adults showed faster decline compared to the basic functional performance deficits.[33] Furthermore, several studies have reported that attention-demanding dual-task training has significant effects on the improvement of gait function.[13] In 2016, Azadian et al.[13] reported on the effectiveness of dual-task and executive training in older adults with a balance impairment. They suggested that spatiotemporal parameters during gait were improved after both dual-task training and executive training.

Consequently, as far as we are aware, this is the first study to identify changes in kinematic and spatiotemporal parameters of gait due to attention-demanding tasks in elderly and young adults. However, several limitations of this study should be considered. First, the educational level of every participants was different, which might affect the ability to perform dual tasks such as arithmetic operation. Second, cognitive dual-tasks used for this study only showed results of particular types of dual-tasks during gait. Third, we could not acquire ankle-joint angles that affected the gait. In future research, ankle-joint measurements should be included.

In conclusion, our results indicate that attention-demanding tasks during gait in elderly adults can induce decreased hip-joint motion during stance phase and reduced gait speed and stride length to maintain balance and prevent risk of falling. Conversely, attention-demanding tasks during gait did not affect kinematic parameters in young adults. We believe that the changes in kinematic and spatiotemporal parameters during gait in advanced ages, particularly under attention-demanding task conditions, would be provided as the standard data to intervention strategies and fall risk assessment for improving the gait function in elderly adults. Furthermore, the results of this study can provide fundamental data for the application of interventions to improve the gait function of patients with neurological injury and better strategies for patients to return to society.

REFERENCES

1. Kusakunniran W, Wu Q, Li H et al. Automatic gait recognition using weighted binary pattern on video. 2009 sixth IEEE international conference on advanced video and signal based surveillance. 2009:49-54.
2. Boyer KA, Johnson RT, Banks JJ et al. Systematic review and meta-analysis of gait mechanics in young and older adults. Exp Gerontol. 2017;95:63-70.
3. Kang HG, Dingwell JB. Dynamics and stability of muscle activations during walking in healthy young and older adults. J Biomech. 2009;42(14):2231-7.
4. MacKay-Lyons M. Central pattern generation of locomotion: a review of the evidence. Phys Ther. 2002;82(1):69-83.
5. Takakusaki K. Forebrain control of locomotor behaviors. Brain Res Rev. 2008;57(1):192-18.
6. Jahn K, Zwergal A. Imaging supraspinal locomotor control in balance disorders. Restor Neurol Neurosci. 2010;28(1):105-14.
7. Shik ML, Orlovsky GN. Neurophysiology of locomotor automatism. Physiol Rev. 1976;56(3):465-501.
8. York DH. Review of descending motor pathways involved with transcranial stimulation. Neurosurgery. 1987;20(1):70-3.
9. Marder E, Bucher D. Central pattern generators and the control of rhythmic movements. Curr Biol. 2001;11(23):R986-96.
10. Martinez-Ramirez A, Martinikorena I, Lecumberri P et al. Dual task gait performance in frail individuals with and without mild cognitive impairment. Dement Geriatr Cogn Disord. 2016;42(1-2):7-16.
11. Hagner-Derengowska M, Kaluzny K, Hagner W et al. The effect of two different cognitive tests on gait parameters during dual tasks in healthy postmenopausal women. Biomed Res Int. 2016;2016:1205469.
12. Asai T, Misu S, Doi T et al. Effects of dual-tasking on control of trunk movement during gait: respective effect of manual- and cognitive-task. Gait Posture. 2014;39(1):54-9.
13. Azadian E, Torbati HR, Kakhki AR et al. The effect of dual task and executive training on pattern of gait in older adults with balance impairment: a randomized controlled trial. Arch Gerontol Geriatr. 2016;62:83-9.
14. Gillain S, Boutaayamou M, Dardenne N et al. Data set of healthy old people assessed for three walking conditions using accelerometric and optoelectronic methods. Aging Clin Exp Res. 2017;29(6):1201-9.
15. Cadore EL, Casas-Herrero A, Zambom-Ferraresi F et al. Do frailty and cognitive impairment affect dual-task cost during walking in the oldest old institutionalized patients? Age (Dordr). 2015;37(6):124.
16. Anderson DE, Madigan ML. Healthy older adults have insufficient hip range of motion and plantar flexor strength to walk like healthy young adults. J Biomech. 2014;47(5):1104-9.
17. Vieira ER, Lim HH, Brunt D et al. Temporo-spatial gait parameters dur-

ing street crossing conditions: a comparison between younger and older adults. Gait Posture. 2015;41(2):510-5.
18. Beauchet O, Kressig RW, Najafi B et al. Age-related decline of gait control under a dual-task condition. J Am Geriatr Soc. 2003;51(8):1187-8.
19. Abbott RD, White LR, Ross GW et al. Walking and dementia in physically capable elderly men. JAMA. 2004;292(12):1447-53.
20. Plummer-D'Amato P, Altmann LJ, Saracino D et al. Interactions between cognitive tasks and gait after stroke: a dual task study. Gait Posture. 2008; 27(4):683-8.
21. Catena RD, van Donkelaar P, Chou LS. Cognitive task effects on gait stability following concussion. Exp Brain Res. 2007;176(1):23-31.
22. Madehkhaksar F, Egges A. Effect of dual task type on gait and dynamic stability during stair negotiation at different inclinations. Gait Posture. 2016;43:114-9.
23. Soangra R, Lockhart TE. Dual-task does not increase slip and fall risk in healthy young and older adults during walking. Appl Bionics Biomech. 2017;2017:1014784.
24. Muhaidat J, Kerr A, Evans JJ et al. Exploring gait-related dual task tests in community-dwelling fallers and non-faller: a pilot study. Physiother Theory Pract. 2013;29(5):351-70.
25. LaRoche DP, Greenleaf BL, Croce RV et al. Interaction of age, cognitive function, and gait performance in 50-80-year-olds. Age (Dordr). 2014; 36(4):9693.
26. Gill SV, Walsh MK, Pratt JA et al. Changes in spatiotemporal gait patterns during flat ground walking and obstacle crossing 1 year after bariatric surgery. Surg Obes Relat Dis. 2016;12(5):1080-5.
27. Najafi B, Helbostad JL, Moe-Nilssen R et al. Does walking strategy in older people change as a function of walking distance? Gait Posture. 2009; 29(2):261-6.
28. Zukowski LA, Martin JM, Scronce G et al. The influence of cognitive load on metabolic cost of transport during overground walking in healthy, young adults. Eur J Appl Physiol. 2017;117(4):679-86.
29. Hollman JH, Kovash FM, Kubik JJ et al. Age-related differences in spatiotemporal markers of gait stability during dual task walking. Gait Posture. 2007;26(1):113-9.
30. Qu X. Age-related cognitive task effects on gait characteristics: do different working memory components make a difference? J Neuroeng Rehabil. 2014;11:149.
31. Hertzog C, Dixon RA, Hultsch DF et al. Latent change models of adult cognition: are changes in processing speed and working memory associated with changes in episodic memory? Psychol Aging. 2003;18(4):755-69.
32. Park DC, Lautenschlager G, Hedden T et al. Models of visuospatial and verbal memory across the adult life span. Psychol Aging. 2002;17(2):299-320.
33. Lemke NC, Wiloth S, Werner C et al. Validity, test-retest reliability, sensitivity to change and feasibility of motor-cognitive dual task assessments in patients with dementia. Arch Gerontol Geriatr. 2017;70:169-79.

https://doi.org/10.18857/jkpt.2023.35.3.64