Published in final edited form as:

Gait Posture. 2018 June ; 63: 63–67. doi:10.1016/j.gaitpost.2018.04.039.

Differential associations between dual-task walking abilities and usual gait patterns in healthy older adults—Results from the Baltimore Longitudinal Study of Aging

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Abstract

Background: It is well established that facing a cognitive challenge while carrying out a motor task interferes with the motor task performance, and in general the ability of handling a dual-task declines progressively with aging. However, the reasons for this decline have not been fully elucidated. Understanding the association between usual-walking gait patterns and dual-task walking performance may provide new insights into the mechanisms that lead to gait deterioration in normal aging and its link to motor and cognitive function.

Research question: —Our aim was to assess usual gait parameters in kinematics and kinetics to understand how these parameters are related with a specific task in dual-task walking.

Methods: We hypothesized that difficulty in dual-task walking would be associated with gait deteriorations as reflected in range of motion and mechanical work expenditure. We tested this hypothesis by quantifying the gait of 383 participants in the Baltimore Longitudinal Study of Aging (68% of whom successfully completed the dual-task walk, 21% failed the motor task, and 11% failed the cognitive task).

Results: Compared to successful performers, participants who failed the single motor task had slower gait speed, shorter stride length, higher cadence, and lower range of motion in the knee and ankle joints ($p < 0.05$, for all), while the participants who failed the cognitive task while walking had longer double support time ($p = 0.003$), and greater knee absorptive mechanical work ($p = 0.001$) and lower ankle generative mechanical work ($p < 0.001$).

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Conflicts of interest

All the authors declare that no financial or personal relationships were conducted with other people or organizations that could inappropriately influence or bias this work.

Significance: These results suggest that dual-task walking may be useful for monitoring subtle and diverse gait deteriorations in aging and possibly for designing interventions for maintaining and regaining proper gait patterns in older adults.

Keywords

Dual-task walking; Narrow walking; Cognitive task in walking; Gait deterioration in aging

1. Introduction

The ability to maintain normal walking while performing another task declines with age [1,2]. Gait speed and swing time decrease during dual-task walking tests correlate with slower usual gait speed in older adults [3]. It has been suggested that training based on dual-task performance improves balance and speed better compared to single task training [4–6]. Dual-task gait training has also been considered as an effective method to improve foot kinetics, [7] which is known to deteriorate with normal aging [8–10]. In addition, previous studies demonstrated that multimodal intervention approaches that integrate motor and cognitive remediation strategies can enhance the effectiveness of fall risk interventions [11–13].

Along with traditional gait parameters (e.g., stride length and width), evaluation of joint rotations and related energy usage during each gait phase through the advanced technology of 3-dimensional gait assessment provides more detailed objective data on gait characteristics, which may facilitate better understanding of gait mechanics in health and disease as well as aid specific problem identification [14]. Primary rotations are in the sagittal plane and are the most informative rotations when assessing usual gait performance [15]. The 3-dimensional gait assessment allows for assessment of these important kinematic factors such as sagittal plane range of motion for hip, knee and ankle during gait performance. With respect to kinetic measures in gait, mechanical work expenditure (MWE) is more representative of lower extremity performance in the older population compared to either single joint moment or angular acceleration alone as MWE quantifies accumulated (integrated) mechanical power during a specific gait phase in stance period [16,17]. Generative and absorptive mechanical work calculations are also valuable as they respectively represent concentric and eccentric muscle activation during specific gait phases [18].

Dual-task walking has been reported associated with age, fall risk and several factors in cognitive and motor tasks [19–23]. Nonetheless, to date, previous work has largely focused on changes in gait spatio-temporal parameters (i.e., gait speed, stride length, step width, and cadence) in dual-task abilities and only a few studies, with relatively small numbers of subjects, have attempted to identify lower extremity dynamics that may explain the ability or the lack of ability to perform efficiently both tasks at the same time [24–26]. Therefore, we aimed to conduct a larger-scale study to assess lower extremity range of motion and mechanical work expenditure in an elderly population to relate these gait parameters to the specific task abilities in dual-task walking. Understanding specific gait modifications in kinematics and kinetics associated with dual-task walking may elucidate subtle gait

deteriorations in normal aging and could provide appropriate and specific methods for intervening older adults in the aims of maintaining their autonomous lives. We hypothesized that difficulty in dual-task walking would be associated with gait deteriorations as reflected in range of motion and mechanical work expenditure.

2. Methods

2.1. Participants

Data were collected in 383 men and women (49%) aged 60 to 94 years participating in the Baltimore Longitudinal Study of Aging (BLSA) who had a clinic visit between January 2008 and April 2013 and underwent evaluation in the gait laboratory. The BLSA is a continuous enrollment cohort study initiated in 1958 to study normative aging and is currently supported by the Intramural Research Program of the National Institute on Aging, National Institutes of Health. The BLSA cohort consists of healthy older adults, thus investigation of early markers of decline can be facilitated [27]. Participants were included if self-report indicated no hip or knee joint replacements; no knee osteoarthritis or history of stroke or Parkinson's disease; and ability to follow instructions and safely walk without using an aid. Participants who have any pain during usual gait were excluded from the study. The BLSA protocol was approved by the National Institute of Environmental Health Science Institutional Review Board. All participants provided written consent to participate.

2.2. Gait laboratory measurements

The procedure for the gait analysis performed in the BLSA gait laboratory has been described previously [18]. Briefly, participants were instrumented with 20 reflective markers placed at anatomical landmarks: anterior and posterior superior iliac spines, medial and lateral knees, medial and lateral ankles, toe (second metatarsal head), heel, and lateral malleoli over the mid-femur and mid-tibia. A Vicon 3D motion capture system with 10 digital cameras (Vicon 612 system, Oxford Metrics Ltd., Oxford, U.K.) measured the 3D locations of all markers on the landmarks of lower extremity segments (60 Hz sampling frequency). After all markers were positioned on the skin and non-reflective, form-fitting spandex pants, participants were asked to walk across a 10 m long gait laboratory walkway at their self-selected usual speed ("like walking in the street"). We standardized the assessment of gait characteristics by using at least three gait cycles of the left and right sides with complete foot landing on the force platform were obtained usual speed walking task [10]. For the narrow base walk test, participants were asked to walk along a 10 m long, narrow path outlined by tape on the walking surface (like heel-to-toe tandem walk). The width of narrow path was standardized to 50% of the distance between the subject's ASIS (Anterior Superior Iliac Spines) [28]. The dual-task walk consisted of a narrow base walk test while reciting the days of the week in reverse order [29,30]. Dual-task failed was specified as those who gave up narrow walking or stepped outside the narrow course (single task, without reciting) who were identified as 'failed single motor' and those who passed the single task narrow walk, but discontinued the narrow walk task with reciting the days of the week in reverse order who were identified as 'failed cognitive'. The raw coordinate data of marker positions were digitally filtered with fourth-order zero-lag Butterworth filter with a cutoff at 6 Hz. For the present study, gait parameters included spatiotemporal factors (gait speed, double support

time, stride length, step width, cadence); kinematics (range of motion (ROM)) during one gait cycle for lower extremity joints (hip, knee, and ankle); and kinetics (weight normalized mechanical work expenditure (MWE)) for the durations of primary gait periods for the hip, knee, and ankle in the stance phase in the sagittal plane [16,31]. To dissect functional differences of MWE in concentric and eccentric, joint mechanical powers in positive (generative or concentric) and negative (absorptive or eccentric) were integrated separately [32].

2.3. Statistical analysis

Participants were classified into three groups based on their dual-task walk performance: 1) able to perform dual-task walking, 2) failed dual-task walking in the cognitive task, and 3) failed in the single motor task. The differences in usual gait parameters between the three dual-task performance groups were examined with generalized linear models (GLM) to identify usual gait parameters related with dual-task performance. All the models were adjusted for gait speed (except gait speed itself), age, sex, height, and weight. Graphical analyses were carried out to confirm linearity of the covariates to outcome variables of interests [33]. Statistical significance was defined with p value less than 0.05. Statistical analysis was performed with SAS 9.1 Statistical Package (SAS Institute, Inc., Cary, NC, USA).

3. Results

Most subjects (68%, N = 261) were able to perform dual-task walking, however, 21% (N = 80) failed on the motor task, and 11% (N = 42) failed on the cognitive test. Older adults who could perform dual-task walking without errors were younger ($p < 0.001$), heavier ($p = 0.019$), and better cognitive performance ($p = 0.007$) than those who could not perform dual-task walking (see Table 1). Those who failed the motor component were older on average, and had poorer cognitive performance compared to those who could perform dual-task walking without error ($p < 0.010$, for all).

Compared to participants able to perform dual-task walking, participants who failed in the single motor task had slower gait speed ($p < 0.001$, Table 2), shorter stride length ($p = 0.009$), higher cadence ($p = 0.012$), and smaller ROM in knee ($p = 0.020$) and ankle ($p = 0.018$) joints during their usual gait. Participants who failed in the cognitive task had longer double support time ($p = 0.003$), greater knee absorptive MWE during knee flexion ($p = 0.001$), and lower ankle generative MWE during ankle plantar flexion ($p < 0.001$) than participants fully able to perform dual-task walking.

4. Discussion

The dual-task activity used in this study imposed a considerable challenge for motor and cognitive abilities as evidenced by the high failure rate among generally well-functioning older adults. Only 68% completed both tasks simultaneously without an error. As can be expected from the high complexity of this dual-task, participants who could not complete the walking component without errors had poorer usual gait performance than successful participants not only in the speed and range of motion, but also in mechanical energy usage.

Dual-task walking failure rate of 13.9% from present study (without considering participants who failed in the single motor task) is similar with the previous study reporting 14% of failure rate [34]. These high rates of failure demonstrate the burden of dual-task walking in older adults and the significance of considering this factor in older adults.

Different individuals may respond to dual physical and cognitive challenges by prioritizing performance in one of the two tasks and that the choice may manifest as deficits in specific gait characteristics. This paradigm provides one explanation for the compensatory gait modifications that individuals adopt during challenging situations encountered in daily life. Participants who failed the single motor component (i.e., could not perform the narrow walking test) showed significantly poorer usual gait performances in spatiotemporal parameters and ROMs of knee and ankle joint in the sagittal plane than participants who passed the dual-task walking test. Slower gait speed and shorter stride length with smaller ROM in the knee and ankle joints during usual speed walking can be considered early signs of limited performance in challenging walks, such as walking in a narrow corridor, which requires advanced control [35].

Interestingly, participants who failed dual-task in the cognitive portion showed abnormal gait patterns in double support time and knee and ankle MWE that were not seen in participants who passed dual-task walking. This may represent a specific pattern of gait disorders in normal aging reflected in or revealed through temporal change and mechanical energy usage [36,37]. Thus, older people may be unable to handle dual-task challenges due to already existing burdens and consequent compensatory gait strategies in normal aging. Confirming prior findings, cognitive task related longer double support time in this study may contribute to the source of mediolateral instability due to both greater mediolateral momentum and/or insufficient forward momentum [38]. Modified knee and ankle kinetic characteristics during usual walking in participants who failed the narrow walk test when faced with a cognitive challenge are similar to those previously observed in pathologic gait characteristics in individuals with higher and lower mechanical work consumptions from knee and ankle, respectively during usual walking [18]. While traditional spatiotemporal gait parameters and kinematics of lower extremities from usual gait were related with challenging single motor task, modified kinetics from knee and ankle joints were found uniquely associated with dual-task walking in this study. Lower kinematics shown from the joints of knee and ankle, associated with single motor task, can be inferred as limited rotations which simply resulted in lower spatial gait patterns, like slower speed and shorter stride. Dual-task walking associated modifications of kinetics from the joints of knee and ankle can be presumed as kind of compensational efforts for the reduced forward momentum due to the elongated double support time.

Relatively small difference in double support time (9.52%) coexists with larger differences in the knee and ankle energy consumptions (MWE; 33.54%, and 33.61% respectively) in older adults with dual-task walking problem. This dual-task related pattern suggests the significance of temporal gait pattern modification, even in small amount, because this can be resulted in or related with relatively bigger kinetic modifications. These modifications of MWE from knee and ankle joints may be critical early indicators of gait deterioration revealed through dual-task gait assessment. Greater eccentric energy use from knee joint

during knee flexion may accelerate joint degeneration through increased energy absorption and hence more stress on the knee joint [31]. Less concentric energy use from the ankle joint during ankle plantar flexion may cause instability through stunted forward momentum and ankle propulsion [39]. These results also confirm previous work that demonstrated the importance of dual-task gait training in improving foot kinetics [7], and suggest a possible strategy for identifying older adults who may benefit from kinetics training to avoid deterioration in usual gait. These results should help inform further consideration of underlying mechanism and conceptual models regarding the connection between cognitive and motor function tasks.

Interestingly, MMSE scores did not differ between those who failed the cognitive component and those who passed dual-task walking. This was a relatively high functioning sample and the cognitive challenge in the dual-task may detect more subtle, earlier decline than that which can be assessed with the MMSE. Moreover, it may help to keep in mind that the MMSE focuses on memory, while dual tasking ability are generally more closely related to executive function and attention abilities. Those who failed the dual-task walking in the cognitive task may have failed either the narrow walk component by stepping outside the path or reciting the days of the week in reverse order incorrectly. One limitation of these analyses is the inability to consider the sources of failure separately. This distinction should be evaluated in future work. Further research is needed to better understand the multiple physical and cognitive factors that may underlie aberrant gait mechanics and the potential for modification or reversal of deleterious practices.

In conclusion, the present study confirms previous work demonstrating the importance of cognitive features in determining usual gait features [19,40,41] and suggests that dual-task walking can be a possible tool for monitoring subtle and diverse gait deteriorations in aging and for identifying older adults that may benefit from appropriately designed interventions for maintaining and regaining proper gait patterns. In the absence of sophisticated gait monitoring equipment, perhaps just the ability to complete a relatively simple dual-task walking paradigm, i.e., narrow path walking while reciting days of the week in reverse order, can be used as a screen tool and simple indicator of diminished walking and cognition abilities, which is indispensable for monitoring age-related mobility decline [42]. The present findings should be confirmed in longitudinal studies to better understand causal relationships between usual gait patterns and dual-task walking performance and the prognostic potential of this task.

Acknowledgements

This research was supported entirely by the Intramural Research Program of the NIH, National Institute on Aging and Chonnam National University. Data for these analyses were obtained from the Baltimore Longitudinal Study of Aging, a study performed by the National Institute on Aging.

References

- [1]. Malcolm BR, Foxe JJ, Butler JS, De Sanctis P, The aging brain shows less flexible reallocation of cognitive resources during dual-task walking: a mobile brain/body imaging (MoBI) study, *Neuroimage* 117 (2015) 230–242. [PubMed: 25988225]

- [2]. Malone LA, Bastian AJ, Age-related forgetting in locomotor adaptation, *Neurobiol. Learn. Mem* 128 (2015) 1–6. [PubMed: 26589520]
- [3]. Hausdorff JM, Schweiger A, Herman T, Yogev-Seligmann G, Giladi N, Dual-task decrements in gait: contributing factors among healthy older adults, *J. Gerontol. A. Biol. Sci. Med. Sci* 63 (2008) 1335–1343. [PubMed: 19126846]
- [4]. Pichierri G, Murer K, de Bruin ED, A cognitive-motor intervention using a dance video game to enhance foot placement accuracy and gait under dual task conditions in older adults: a randomized controlled trial, *BMC Geriatr* 12 (2012) 74. [PubMed: 23241332]
- [5]. Theill N, Schumacher V, Adelsberger R, Martin M, Jancke L, Effects of simultaneously performed cognitive and physical training in older adults, *BMC Neurosci* 14 (2013) 103. [PubMed: 24053148]
- [6]. Hagovska M, Olekszyova Z, Relationships between balance control and cognitive functions, gait speed, and activities of daily living, *Z. Gerontol. Geriatr* 49 (2016) 379–385. [PubMed: 26458911]
- [7]. Kim SG, Park JH, The effects of dual-task gait training on foot pressure in elderly women, *J. Phys. Ther. Sci* 27 (2015) 143–144. [PubMed: 25642059]
- [8]. Silder A, Heiderscheit B, Thelen DG, Active and passive contributions to joint kinetics during walking in older adults, *J. Biomech* 41 (2008) 1520–1527. [PubMed: 18420214]
- [9]. Schmitz A, Silder A, Heiderscheit B, Mahoney J, Thelen DG, Differences in lower-extremity muscular activation during walking between healthy older and young adults, *J. Electromyogr. Kinesiol* 19 (2009) 1085–1091. [PubMed: 19081734]
- [10]. Ko SU, Hausdorff JM, Ferrucci L, Age-associated differences in the gait pattern changes of older adults during fast-speed and fatigue conditions: results from the Baltimore Longitudinal Study of Ageing, *Age Ageing* 39 (2010) 688–694. [PubMed: 20833863]
- [11]. MacAulay RK, Allaire TD, Brouillette RM, Foil HC, Bruce-Keller AJ, Han H, et al., Longitudinal assessment of neuropsychological and temporal/spatial gait characteristics of elderly fallers: taking it all in stride, *Front. Aging Neurosci* 7 (2015) 34. [PubMed: 25852548]
- [12]. Muir-Hunter SW, Wittwer JE, Dual-task testing to predict falls in community-dwelling older adults: a systematic review, *Physiotherapy* 102 (2016) 29–40. [PubMed: 26390824]
- [13]. Srygley JM, Mirelman A, Herman T, Giladi N, Hausdorff JM, When does walking alter thinking: age and task associated findings, *Brain Res* 1253 (2009) 92–99. [PubMed: 19084511]
- [14]. Miranda H, Viikari-Juntura E, Martikainen R, Riihimäki H, A prospective study on knee pain and its risk factors, *Osteoarthritis Cartilage* 10 (2002) 623–630. [PubMed: 12479384]
- [15]. Grodzinsky AJ, Levenston ME, Jin M, Frank EH, Cartilage tissue remodeling in response to mechanical forces, *Annu. Rev. Biomed. Eng* 2 (2000) 691–713. [PubMed: 11701528]
- [16]. Ko S, Ling SM, Winters J, Ferrucci L, Age-related mechanical work expenditure during normal walking: the Baltimore Longitudinal Study of Aging, *J. Biomech* 42 (2009) 1834–1839. [PubMed: 19646705]
- [17]. Teixeira-Salmela LF, Nadeau S, Milot MH, Gravel D, Requia LF, Effects of cadence on energy generation and absorption at lower extremity joints during gait, *Clin. Biomech. (Bristol, Avon)* 23 (2008) 769–778.
- [18]. Ko SU, Stenholm S, Chia CW, Simonsick EM, Ferrucci L, Gait pattern alterations in older adults associated with type 2 diabetes in the absence of peripheral neuropathy—results from the Baltimore Longitudinal Study of Aging, *Gait Posture* 34 (2011) 548–552. [PubMed: 21873064]
- [19]. Bridenbaugh SA, Kressig RW, Motor cognitive dual tasking: early detection of gait impairment, fall risk and cognitive decline, *Z. Gerontol. Geriatr* 48 (2015) 15–21. [PubMed: 25633391]
- [20]. Ansai JH, Aurichio TR, Rebelatto JR, Relationship between dual task walking, cognition, and depression in oldest old people, *International. Psychogeriatr./IPA* 28 (2016) 31–38.
- [21]. Smith E, Cusack T, Blake C, The effect of a dual task on gait speed in community dwelling older adults: a systematic review and meta-analysis, *Gait Posture* 44 (2016) 250–258. [PubMed: 27004667]
- [22]. Ling SM, Fried LP, Garrett ES, Fan MY, Rantanen T, Bathon JM, Knee osteoarthritis compromises early mobility function: The women's health and aging study II, *J. Rheumatol* 30 (2003) 114–120. [PubMed: 12508399]

- [23]. Liston MB, Bergmann JH, Keating N, Green DA, Pavlou M, Postural prior-ization is differentially altered in healthy older compared to younger adults during visual and auditory coded spatial multitasking, *Gait Posture* 39 (2014) 198–204. [PubMed: 23891026]
- [24]. Lundin-Olsson L, Nyberg L, Gustafson Y, Stops walking when talking as a predictor of falls in elderly people, *Lancet* 349 (1997) 617.
- [25]. Hyndman D, Ashburn A, Stops walking when talking as a predictor of falls in people with stroke living in the community, *J. Neurol. Neurosurg. Psychiatry* 75 (2004) 994–997. [PubMed: 15201358]
- [26]. Beauchet O, Annweiler C, Dubost V, Allali G, Kressig RW, Bridenbaugh S, et al., Stops walking when talking: a predictor of falls in older adults, *Eur. J. Neurol* 16 (2009) 786–795. [PubMed: 19473368]
- [27]. Simonsick EM, Glynn NW, Jerome GJ, Shardell M, Schrack JA, Ferrucci L, Fatigued, but not frail: perceived fatigability as a marker of impending decline in mobility-intact older adults, *J. Am. Geriatr. Soc* 64 (2016) 1287–1292. [PubMed: 27253228]
- [28]. Schrage MA, Kelly VE, Price R, Ferrucci L, Shumway-Cook A, The effects of age on medio-lateral stability during normal and narrow base walking, *Gait Posture* 28 (2008) 466–471. [PubMed: 18400500]
- [29]. Hamrick I, Hafiz R, Cummings DM, Use of days of the week in a modified mini-mental state exam (M-MMSE) for detecting geriatric cognitive impairment, *J. Am. Board Fam. Med.: JABFM* 26 (2013) 429–435. [PubMed: 23833158]
- [30]. Montero-Odasso M, Oteng-Amoako A, Speechley M, Gopaul K, Beauchet O, Annweiler C, et al., The motor signature of mild cognitive impairment: results from the gait and brain study, *J. Gerontol. A. Biol. Sci. Med. Sci* 69 (2014) 1415–1421. [PubMed: 25182601]
- [31]. Ko SU, Ling SM, Schreiber C, Nesbitt M, Ferrucci L, Gait patterns during different walking conditions in older adults with and without knee osteoarthritis—results from the Baltimore Longitudinal Study of Aging, *Gait Posture* 33 (2011) 205–210. [PubMed: 21145241]
- [32]. Ko SU, Stenholm S, Ferrucci L, Characteristic gait patterns in older adults with obesity—results from the Baltimore Longitudinal Study of Aging, *J. Biomech* 43 (2010) 1104–1110. [PubMed: 20080238]
- [33]. Ko SU, Gunter KB, Costello M, Aum H, MacDonald S, White KN, et al., Stride width discriminates gait of side-fallers compared to other-directed fallers during overground walking, *J. Aging Health* 19 (2007) 200–212. [PubMed: 17413131]
- [34]. Hegeman J, Weerdesteijn V, van den Bemt B, Nienhuis B, van Limbeek J, Duysens J, Dual-tasking interferes with obstacle avoidance reactions in healthy seniors, *Gait Posture* 36 (2012) 236–240. [PubMed: 22565318]
- [35]. Schrack JA, Zipunnikov V, Simonsick EM, Studenski S, Ferrucci L, Rising energetic cost of walking predicts gait speed decline with aging, *J. Gerontol. A. Biol. Sci. Med. Sci* 71 (2016) 947–953. [PubMed: 26850913]
- [36]. Tseng SC, Stanhope SJ, Morton SM, Impaired reactive stepping adjustments in older adults, *J. Gerontol. A. Biol. Sci. Med. Sci* 64 (2009) 807–815. [PubMed: 19351694]
- [37]. Ko SU, Simonsick EM, Ferrucci L, Gait energetic efficiency in older adults with and without knee pain: results from the Baltimore Longitudinal Study of Aging, *Age (Dordr)* 37 (2015) 9754. [PubMed: 25666574]
- [38]. LaRoche DP, Greenleaf BL, Croce RV, McGaughy JA, Interaction of age, cognitive function, and gait performance in 50–80-year-olds, *Age (Dordr)* 36 (2014) 9693. [PubMed: 25073454]
- [39]. Ko SU, Stenholm S, Metter EJ, Ferrucci L, Age-associated gait patterns and the role of lower extremity strength—results from the Baltimore Longitudinal Study of Aging, *Arch. Gerontol. Geriatr* 55 (2012) 474–479. [PubMed: 22564361]
- [40]. Hausdorff JM, Yogev G, Springer S, Simon ES, Giladi N, Walking is more like catching than tapping: gait in the elderly as a complex cognitive task, *Exp. Brain Res* 164 (2005) 541–548. [PubMed: 15864565]
- [41]. Alexander NB, Hausdorff JM, Guest editorial: linking thinking, walking, and falling, *J. Gerontol. A. Biol. Sci. Med. Sci* 63 (2008) 1325–1328. [PubMed: 19126844]

- [42]. Rosso AL, Studenski SA, Chen WG, Aizenstein HJ, Alexander NB, Bennett DA, et al., Aging, the central nervous system, and mobility, J. Gerontol. A. Biol. Sci. Med. Sci 68 (2013) 1379–1386. [PubMed: 23843270]

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Table 1

Participant Characteristics.

Characteristics for participants	mean (SE) [†]	<i>p</i> -values for the comparisons between				
		Dual-task passed (N = 261)	Dual-task failed (N = 122)		Dual-task failed vs. Dual-task passed	Failed cognitive vs. Dual-task passed
			Failed cognitive ^a (N = 42)	Failed single motor (N = 80)		Failed single motor vs. Dual-task passed
Age, years	70.21 (0.45)		72.25 (1.11)	79.44 (0.81)	< 0.001	0.206
Height, m	1.69 (0.01)		1.68 (0.01)	1.68 (0.01)	0.395	0.981
Weight, kg	78.22 (1.02)		75.32 (2.51)	73.45 (1.76)	0.019	0.535
Women, N(%)	48.66 (3.11)		50.00 (7.74)	47.50 (5.61)	0.957	0.986
MMSE ^b , score	28.74 (0.10)		28.77 (0.26)	27.97 (0.19)	0.007	0.993

[†]SE = Standard error.^aFailed cognitive: narrow walking was done, but not with cognitive performing.^bMini-Mental-State-Examination.

Table 2

Gait parameters for usual walking in groups with different dual task performances in narrow walking test.

Characteristics for participants	mean (SE) [‡]	<i>p</i> -values for the comparisons between				
		Dual-task failed (N = 122)	Dual-task failed vs. Dual-task passed	Failed cognitive vs. Dual-task passed	Failed single motor vs. Dual-task passed	
	Dual-task passed (N = 261)	Failed cognitive (N = 42)	Failed single motor (N = 80)			
<i>Spatiotemporal</i>						
Gait speed, m/s	1.15 (0.01)	1.09 (0.03)	1.04 (0.02)	< 0.001	0.123	< 0.001
Double support time, second	0.21 (0.00)	0.23 (0.01)	0.22 (0.00)	0.001	0.003	0.063
Stride length, meter	1.22 (0.01)	1.21 (0.02)	1.17 (0.01)	0.025	0.958	0.009
Stride width, centimeter	10.26 (0.20)	10.88 (0.47)	11.17 (0.38)	0.033	0.362	0.081
Cadence, steps/minutes	110.30 (0.61)	110.78 (1.44)	114.25 (1.15)	0.029	0.948	0.012
<i>Kinematics</i>						
Range of rotation (ROM) in AP, degree						
Hip	38.43 (0.30)	38.89 (0.71)	38.52 (0.56)	0.663	0.820	0.991
Knee	55.08 (0.32)	53.96 (0.76)	53.14 (0.60)	0.008	0.359	0.020
Ankle	24.97 (0.27)	23.87 (0.64)	23.29 (0.51)	0.005	0.256	0.018
<i>Kinetics</i>						
MWE in AP, 1000*J/kg						
Hip generative MWE during HF	103.10 (2.30)	99.07 (5.44)	109.13 (4.40)	0.674	0.774	0.478
Knee absorptive MWE during KF	133.62 (4.87)	178.44 (11.55)	141.18 (9.21)	0.012	0.001	0.772
Ankle Generative MWE during AF	242.33 (4.84)	160.89 (11.46)	227.67 (9.14)	< 0.001	< 0.001	0.374

MWE = mechanical work expenditure.

AP = anterior-posterior plane.

HF = hip flexion period in stance phase; KF = knee flexion in late stance phase. AF = ankle plantar flexion period in late stance phase.

[‡]Speed is adjusted by age, sex, height, and weight; others are adjusted by speed, age, sex, height, and weight.