Journal of Gerontology: MEDICAL SCIENCES
Cite journal as: J Gerontol A Biol Sci Med Sci
2009. Vol. 64A, No. 9, 975–982
doi:10.1093/gerona/glp063

Advance Access publication on May 8, 2009

Dual-Task Gait Performance Among Community-Dwelling Senior Women: The Role of Balance Confidence and Executive Functions

Teresa Liu-Ambrose,[1,2] Lindsay A. Katarynych,[1] Maureen C. Ashe,[1,3] Lindsay S. Nagamatsu,[1,4] and Chun Liang Hsu[1]

[1]Centre for Hip Health and Mobility, Vancouver Coastal Health Research Institute, British Columbia, Canada.
[2]Department of Physical Therapy, [3]Department of Family Practice, and [4]Department of Psychology, University of British Columbia, Vancouver, Canada.

Background. Exploring factors that contribute to dual-task gait performance among seniors is of particular interest in falls prevention because dual-task–related gait changes are associated with increased falls risk. It is unclear currently which specific executive processes are most relevant to dual-task gait performance and whether "balance confidence" is independently associated with dual-task gait performance.

Methods. A cross-sectional analysis of 140 senior women aged 65–75 years old. Balance confidence was assessed by the Activities-Specific Balance Confidence scale. Three key executive processes were assessed by standard neuropsychological tests: (i) set shifting, (ii) working memory, and (iii) response inhibition. Dual-task gait performance was assessed by the simple and complex versions of the walking while talking (WWT) test. Two linear regression models were constructed to determine the independent association of executive functions and balance confidence with: (i) simple WWT completion time and (ii) complex WWT completion time.

Results. Balance confidence was independently associated with both simple and complex WWT completion times after accounting for age, time to walk 40 ft without talking, and global cognition. Set shifting was independently associated with complex WWT completion time; no executive processes were independently associated with simple WWT completion time.

Conclusions. This study highlights that balance confidence is independently associated with dual-task gait performance. Furthermore, executive functions do not play a significant role in dual-task gait performance when the concurrent cognitive load is low. Clinicians may need to consider balance confidence and executive functions in the assessment and rehabilitation of dual-task gait performance among community-dwelling seniors.

Key Words: Executive functions—Balance confidence—Dual-task gait performance.

ABOUT 30% of community dwellers more than the age of 65 experience one or more falls every year (1). Although the etiology of falls is multifactorial (1), falls occur, at least in part, due to impaired physiological functions, such as muscular weakness (2). Such impaired physiological functions result in impaired gait and balance; both are independent risk factors for falls (1,3,4).

Walking is one of the most repetitive and functional human movements. Traditionally, maintaining postural stability during walking was thought to be an automatic task requiring primarily motor responses to sensory stimuli. However, recent evidence suggests that maintaining postural stability during walking depends on both higher level cognitive function and sensorimotor processes (5–7). Research using dual-task paradigms suggests that walking requires more attention in seniors than younger adults (5,8,9). Divided attention, a key component of attention, is defined as the ability to perform more than one thing at the same time (10) or, more commonly, the ability to dual task. Exploring factors that contribute to dual-task gait performance among seniors is of particular interest in falls prevention because dual-task–related gait changes—for example, reduced gait speed (11,12)—are associated with increased falls risk (13,14).

Executive functions, or higher order cognitive processes (15), are crucial for successful dual-task gait performance (16–19). Specifically, the InCHIANTI study demonstrated that poor and intermediate performance on the Trail Making Test, a standard neuropsychological test of executive function, was associated with reduced gait speed over an obstacle course (17). A follow-up study in this cohort also found associations between Trail Making Test performance and gait speed during various dual-task physical tests (16).

Executive function is not a unitary construct—there are distinct processes. Three key executive processes have been identified; they are (i) set shifting, (ii) working memory, and (iii) response inhibition (20,21). Each of these processes is moderately correlated with one another but has a distinct purpose. To our knowledge, no study has assessed the specific and independent contribution of these three key executive processes to dual-task gait performance among seniors. Thus, it is unclear currently which specific executive processes are most relevant to dual-task gait performance.

Furthermore, investigations of dual-task gait performance have not examined the role of falls-related self-efficacy or "balance confidence." Balance confidence may be an important factor to dual-task gait performance as it significantly contributes to balance performance, gait, and stair climbing among seniors (22–26). Low balance confidence often leads to physical activity restriction (27); we hypothesize that low balance confidence may be associated with impaired dual-task gait performance via physical activity restriction as physical inactivity directly impairs physiological functions (e.g., muscular weakness, slowed reaction time). Physical inactivity also increases the risk for chronic medical conditions (e.g., hypertension, diabetes). Many chronic medical conditions have a detrimental effect on cognition (28–33)—a significant predictor of dual-task gait performance (16–19). Finally, based on Bandura's social cognitive theory (34), which states that perceived capability is more predictive of activity than actual physical ability, low balance confidence may directly impair dual-gait performance.

A better understanding of the relationship between specific executive processes, balance confidence, and dual-task gait performance could enhance future interventions that aim to promote and maintain safe mobility among seniors. Thus, we examined the independent association of three key executive processes and balance confidence with gait performance under two different dual-task conditions among community-dwelling senior women after accounting for age, time to walk 40 ft without talking, and global cognition.

Methods

Participants

The sample for this cross-sectional analysis consisted of women who consented to participate in a 1-year randomized controlled trial of exercise (NCT00426881) that aims to examine the effect of resistance training on cognitive performance of executive functions. As men and women have different cognitive responses to exercise (35), we restricted our study sample to women.

We recruited women who (i) were aged 65–75 years, (ii) were living independently in their own home, (iii) obtained a score greater than or equal to 24 on the Mini-Mental State Examination (MMSE) (36), and (iv) had a visual acuity of at least 20/40, with or without corrective lenses. We excluded those who (i) had a diagnosed neurodegenerative disease (e.g., Alzheimer's disease) and/or stroke, (ii) were taking psychotropic drugs, (iii) did not speak and understand English, (iv) had moderate to significant impairment with activities of daily living as determined by interview, (v) were taking cholinesterase inhibitors within the last 12 months, (vi) were taking antidepressants within the last 6 months, or (vii) were on estrogen replacement therapy within the last 12 months.

Participants were recruited through newspaper advertisements and articles, television features, and flyers posted at local community centers. Those who were eligible based on the telephone screen were invited to attend an information session. One-hundred and sixty women consented and attended our baseline assessment. During the baseline assessment, one person was excluded by the study physician (Karim M. Khan) and one decided to withdraw. Thus, 158 women completed the baseline assessment but only 140 completed the walking while talking (WWT) tests (13) due to time constraints. The study was approved by the relevant hospital and university ethics boards, and all participants provided written informed consent.

Descriptive Variables

Global cognition was assessed using the MMSE (36). All participants underwent a 15-minute physician assessment to confirm current health status and eligibility for the study.

We used the 15-item Geriatric Depression scale (GDS, 37) to screen for depression. The Functional Comorbidity Index was calculated to estimate the degree of comorbidity associated with physical functioning (38). This scale's score is the total number of comorbidities. Current level of physical activity (i.e., previous 7-day period) was determined by the Physical Activities scale for the Elderly self-report questionnaire (39,40).

We used the short form of the physiological profile assessment (PPA, 41; Prince of Wales Medical Research Institute, Randwick, Sydney, New South Wales, Australia) to assess physiological falls risk. Based on five tests of physiological function—postural sway, dominant quadriceps strength, dominant hand reaction, proprioception, and vision—the PPA computes a global falls risk score that has a 75% predictive accuracy for falls. Global PPA scores less than 0 indicate a low risk of falling, scores between 0 and 1 indicate a mild risk of falling, scores between 1 and 2 indicate a moderate risk of falling, and scores more than 2 indicate a high risk of falling.

Dependent Variable: Gait Performance Under Dual-Task Conditions

We administered the simple and complex versions of the WWT test (13) to assess gait performance under dual-task conditions. Both versions predict falls in community-dwelling nondemented seniors and have good reliability (r = .60) (13). One assessor (L.A.K.) administered these tests to all participants.

Participants were instructed to walk an outlined route of 20 ft, turn, and return 20 ft to the starting position. Prior to the

WWT tests, the time required to walk the 40-ft course without talking was recorded for each participant. For the simple WWT test, we recorded the time in seconds it took each participant to walk 40 ft while reciting consecutive letters of the alphabet aloud. (i.e., a, b, c, …). For the complex WWT test, we recorded the time it took each participant to walk 40 ft while reciting alternate letters of the alphabet (i.e., a, c, e, …). For each WWT test condition, participant completed one warm-up trial, and one actual trial from which data was collected. The participants were instructed to be as accurate as possible when performing the cognitive task (i.e., alphabet recitation) and were reminded to keep walking at all times.

Independent Variables

Balance confidence.—The 16-item Activities-Specific Balance Confidence (ABC) scale (42) assessed balance confidence with each item rated from 0% (no confidence) to 100% (complete confidence); it provides a score out of 100.

Cognitive performance of executive processes.—As there is no unitary executive function, no single measure can adequately tap the construct in its entirety. In this study, we refer to work by Miyake and colleagues (21) who identified three key executive processes that are moderately correlated with one another, but each has a distinct purpose; they are (i) set shifting, (ii) working memory, and (iii) response inhibition. Set shifting requires one to go back and forth between multiple tasks or mental sets (21). Working memory involves monitoring incoming information for relevance to the task at hand and then appropriately updating the informational content by replacing old, no longer relevant information with new incoming information. Response inhibition involves deliberately inhibiting dominant, automatic, or prepotent responses.

We used the plus–minus task to assess set shifting (20,21). This test consisted of three lists of 30 two-digit numbers. On the first list, participants were instructed to add 3 to each number and write down their answers. On the second list, they were instructed to subtract 3 from each number. On the third list, the participants were required to alternate between adding 3 to and subtracting 3 from the numbers. The participants were instructed to complete each list quickly and accurately. Completion times were recorded for each list. The cost of set shifting between the operation of addition and subtraction was calculated as the difference between the time to complete the alternating list and the average of the times to complete the addition and subtraction lists. Smaller differences in times indicate better set shifting.

We used the verbal digits forward and verbal digits backward tests to index the central executive component of working memory (43). Both tests consist of seven pairs of random number sequences that the assessor reads aloud at the rate of one per second. The sequence begins with three digits and increases by one at a time up to a length of nine digits. The test includes two sequences of each length and testing ceases when the participant fails to recollect any two with the same length. The score recorded, ranging from 0 to 14, is the number of successful sequences. For the verbal digits forward test, the participant's task is to repeat each sequence exactly as it is given. For the verbal digits backward test, the participant's task is to repeat each sequence in the reversed order. Working memory consists of three main components: the phonological loop, the visuospatial sketch pad, and the central executive. Both verbal digit span tests represent a measure of the capacity of the phonological loop. Successful performance on the verbal digits span backward test represents a measure of central executive function due to the additional requirement of manipulation of information within temporary storage (44). Thus, we calculated the difference between the verbal digits forward test score and the verbal digits backward test score to provide an index of the central executive component of updating. Smaller difference scores indicate better working memory.

We used version of Graf and colleagues (45) of the Stroop test (46) to assess response inhibition. For the Stroop test, there were three conditions. First, participants were instructed to read out words printed in black ink (e.g., BLUE). Second, they were instructed to read out the color of colored X's. Finally, they were shown a page color words printed in incongruent colored inks (e.g., the word "BLUE" printed in red ink). Participants were asked to name the ink color in which the words are printed (while ignoring the word itself). There were 80 trials for each condition, and we recorded the time participants took to read each condition. Response inhibition was calculated as the time difference between condition in which the word and the color were incongruent and that condition that consisted of the colored X's. Smaller time differences indicate better response inhibition.

Data Analyses

Data were analyzed using SPSS Windows Version 16.0 (SPSS Inc., Chicago, IL). Descriptive data are reported for variables of interest. The associations between the variables were determined using the Pearson product moment coefficient of correlation. Alpha was set at $p < .05$.

Two linear regression models were constructed to determine the independent association of executive functions and balance confidence with (i) simple WWT completion time and (ii) complex WWT completion time. For each of these analyses, age, time to walk 40 ft without talking, and global cognition were statistically controlled by forcing these three variables into the regression model first. These independent variables were determined from the results of the Pearson product moment coefficient of correlation analyses and based on biological relevance, such age and global cognition were entered into the model regardless of the results of the correlation analyses.

Table 1. Descriptive Statistics for Descriptors and Outcome Measures of Interest (N = 140)

Variable	Mean (SD)	Range
Age (yr)	69.6 (3.0)	65 to 76
Height (cm)	161.4 (8.1)	121 to 181
Weight (kg)	70.1 (15.3)	34 to 134
MMSE score (maximum 30 points)	28.6 (1.3)	24 to 30
Falls in the last 12 mos*	46 (32.9)	N/A
Geriatric Depression scale (maximum 15 points)	0.6 (1.9)	0 to 11
Functional Comorbidity Index (maximum 18 points)	2.1 (1.7)	0 to 8
Physical activity scale for the elderly	117.8 (57.3)	0 to 297
Plus–minus task: List 1 (s)	56.5 (17.6)	32 to121
Plus–minus task: List 2 (s)	75.8 (29.6)	33 to 201
Plus–minus task: List 3 (s)	108.3 (35.6)	43 to 222
Verbal digits span forward test (maximum 14 points)	7.9 (2.3)	3 to 13
Verbal digits span backward test (maximum 14 points)	4.4 (2.4)	0 to 12
Stroop test: black ink word condition (s)	36.0 (6.9)	22 to 69
Stroop test: colored X's condition (s)	51.2 (12.5)	32 to 103
Stroop test: colored word condition (s)	97.1 (25.2)	49 to 208
Global PPA score†	0.27 (1.02)	–1.95 to 3.73
Time to walk 40 ft (s)	10.6 (2.1)	7 to 21
Simple WWT completion time (s)	10.4 (2.3)	7 to 26
Complex WWT completion time (s)	12.5 (4.4)	8 to 45
ABC scale score (maximum 100 points)	87.7 (13.0)	33 to 100

Notes: MMSE = Mini-Mental State Examination; N/A = not available; PPA = physiological profile assessment; ABC scale = Activities-Specific Balance Confidence scale; WWT = walking while talking.

* Number of "yes" cases (% of "yes" cases).

† Global PPA scores less than 0 indicate a low risk of falling, scores between 0 and 1 indicate a mild risk of falling, scores between 1 and 2 indicate a moderate risk of falling, and scores more than 2 indicate a high risk of falling.

The three key executive processes were then entered into regression model, and only those that significantly added to the model were kept in the model (i.e., stepwise regression). The ABC scale score was entered last into each model.

Results

Characteristics of the Participants

Table 1 reports the descriptive statistics. Overall, this cohort of community-dwelling senior women was at mild risk of falling as indicated by the mean global PPA score of 0.27 ± 1.02. This concurs with the finding that 67% of this cohort reported no history of falling in the 12 months prior to study entry.

Correlation Coefficients

Table 2 reports the correlation coefficients between variables of interest. Global cognition was not significantly associated with either simple WWT or complex WWT completion time ($p > .08$). Both set shifting and response inhibition were significantly associated with both simple WWT and complex WWT completion times.

Linear Regression Models

Simple WWT completion time.—In the final model, time to walk 40 ft without talking and the ABC scale score were significantly associated with simple WWT completion time ($p < .01$). None of the three executive processes that significantly improved the model after age, time to walk 40 ft without talking, and global cognition were included in the regression model. Age, time to walk 40 ft without talking, and global cognition together accounted for 86.5% of the variance. Adding the ABC scale score to the model resulted in an R^2 change of 0.8% (F change [1,130] = 7.9, $p < .01$). The total variance accounted by the final model was 87.3% (Table 3).

Complex WWT completion time.—In the final model, time to walk 40 ft without talking, set shifting, and the ABC scale score were significantly associated with complex WWT completion time ($p < .01$). Age, time to walk 40 ft without talking, and global cognition together accounted for 57.1% of the variance. Adding the executive process of set shifting to the model resulted in an R^2 change of 2.5% and significantly improved the regression model (F change [1,130] = 8.07, $p < .01$). Adding the ABC scale score to the model resulted in an R^2 change of 3.1% and significantly improved the model (F change [1,129] = 10.60, $p = .001$). The total variance accounted by the final model was 62.7% (Table 4).

Discussion

We found that balance confidence was independently associated with dual-task gait performance among community-dwelling senior women. To our knowledge, this is the first study that has examined the independent association of balance confidence to dual-task gait performance after accounting for the effects of age, global cognition, time to walk 40 ft without talking, and executive functions. Of particular importance, balance confidence was associated more strongly with each dependent variable of interest than was executive functions. This is in light of the fact that majority of the research to date in dual-task gait performance has focused primarily on the role of executive functions (16–19). We also note that our results are contrary to those recent findings of Hausdorff and colleagues (47); they demonstrated no significant bivariate associations between the ABC scale score and dual-task–related gait changes. Differences in study participants and cognitive dual-tasks are possible explanations for the discrepancy.

Our finding of an independent association between falls-related self-efficacy and simple and complex WWT completion times concur with Bandura's social cognitive theory (34), which states that perceived capability is more predictive of activity than actual physical ability. Our results extend those of previous investigations that highlight the

Table 2. Pearson Product Moment Coefficient Matrix Between Simple WWT Completion Time, Complex WWT Completion Time, Age, Global Cognitive Function, Time to Walk 40 ft, Set Shifting, Working Memory, Response Inhibition, and ABC Scale Score

Variable	Age	MMSE	WNT	Δ Plus–Minus	Δ DS	Δ Stroop	ABC scale
Simple WWT completion time	0.25*	–0.11	0.93‡	0.20†	0.19†	0.15†	–0.55‡
Complex WWT completion time	0.25†	–0.12	0.75‡	0.30‡	0.10	0.20*	–0.54‡

Notes: ABC = Activities-Specific Balance Confidence scale; MMSE = Mini-Mental Status Examination; WNT = time in seconds to walk 40 ft without talking; WWT = walking while talking; Δ plus–minus = time in seconds to complete List 3—average time in seconds to complete Lists 1 and 2; Δ DS = verbal digit span forward test score—verbal digit span backward test score; Δ Stroop = time in seconds to complete the colored word condition—time in seconds to complete colored X's condition; age in years.

* $p \leq 0.01$.

† $p \leq 0.05$.

‡ $p \leq 0.001$.

importance of self-efficacy to gait performance (23,24,26,48) and overall to healthy aging (49–52). Specifically, we previously demonstrated that balance confidence was independently associated with gait speed among senior women with low bone mass, at usual pace and fast pace, after accounting for age, current physical activity level, and performances in relevant physiological domains (23). Also, instrumental self-efficacy beliefs significantly affected perceived functional disability, independent of actual physical abilities among seniors (50). Furthermore, higher baseline self-efficacy had a buffering effect on subsequent functional decline in both high-functioning seniors (51) and those with knee osteoarthritis (52).

An independent association between balance confidence and dual-task gait performance may be expected among seniors at high risk of falls, such as those with a history of falls and/or with significant impairment in physiological functions. However, only one third of our cohort reported a history of falling in the previous 12 months and as a group did not demonstrate significant impairment in physiological functions as indicated by the mean global PPA score. Furthermore, the mean ABC scale score for this cohort of senior women was 88, which is similar to that previously reported for healthy seniors (mean = 91) (53). Thus, the significant independent association between balance confidence and dual-task gait performance observed in this study may be evident in the general population of healthy community-dwelling senior women.

This cross-sectional study also demonstrated that within the cognitive domain of executive functions, the specific executive process of set shifting was independently associated with gait performance under the complex WWT condition. Thus, our finding extends previous findings that set shifting plays a significant role in dual-task gait performance (16,17,54). Specifically, van Lersel and colleagues (54), who assessed two of the three key executive processes identified by Miyake and colleagues (21), demonstrated that set shifting, but not response inhibition, was significantly associated with dual-task stride length variability and mediolateral trunk sway. We also found that executive functions were not significantly associated with simple WWT condition completion time. Thus, our results suggest that executive functions do not play a significant role in dual-task gait performance among seniors when the concurrent cognitive load is low. This concurs with previous studies that found executive functions are important primarily in challenging and attention demanding locomotion tasks (17,18,54,55).

A clinical implication of these results is clinicians may need to consider the specific executive process of set shifting and balance confidence in the assessment and rehabilitation of gait among community-dwelling seniors. Our data suggest that these individuals may exhibit impaired dual-task gait performance secondary to both reduced set shifting—the cognitive ability to go back and forth between multiple tasks—and reduced balance confidence. Thus, successful rehabilitation of impaired

Table 3. Linear Regression Model Summary for Simple WWT Completion Time

	Simple WWT Completion Time (s)				
Independent Variable	R^2	R^2 Change	Unstandardized B (*SE*)	Standardized β	*p* Value
Model 1	.865	.865			
Age (yr)			0.02 (0.03)	0.03	.35
Time to Walk 40 ft (s)			1.02 (0.04)	0.92	<.001
MMSE score (30 point)			0.03 (0.06)	0.02	.63
Model 2	.873	.008			
Age (yr)			0.01 (0.03)	0.02	.66
Time to walk 40 ft (s)			0.96 (0.04)	0.88	<.001
MMSE score (30 point)			0.03 (0.06)	0.02	.56
ABC scale score			–0.02 (0.01)	–0.10	<.01

Note: ABC = Activities-Specific Balance Confidence scale; MMSE = Mini-Mental State Examination; WWT = walking while talking.

Table 4. Linear Regression Model Summary for Complex WWT Completion Time

	Complex WWT Completion Time (s)				
Independent Variable	R^2	R^2 Change	Unstandardized B (*SE*)	Standardized β	*p* Value
Model 1	.571	.571			
Age (yr)			0.10 (0.09)	0.07	.26
Time to walk 40 ft (s)			1.55 (0.12)	0.73	<.001
MMSE score (30 point)			–0.05 (0.20)	–0.01	.82
Model 2	.596	.025			
Age (yr)			0.10 (0.09)	0.07	.23
Time to walk 40 ft (s)			1.48 (0.12)	0.70	<.001
MMSE score (30 point)			–0.03 (0.20)	–0.01	.87
Set shifting			0.03 (0.01)	0.16	<.01
Model 3	.627	.031			
Age (yr)			0.05 (0.08)	0.04	.53
Time to walk 40 ft (s)			1.28 (0.14)	0.60	<.001
MMSE score (30 point)			–0.01 (0.19)	–0.004	.94
Set shifting			0.03 (0.01)	0.17	<.01
ABC scale score			–0.07 (0.02)	–0.21	.001

Note: ABC = Activities-Specific Balance Confidence scale; MMSE = Mini-Mental State Examination; WWT = walking while talking.

dual-task gait performance in this population of seniors may require strategies that target the specific executive process of set shifting and balance confidence. Our results also suggest that usual gait speed may be used as a simple screening tool for impaired dual-task gait performance as the time to walk 40 ft without talking alone explained a large portion of the variance for both simple and complex WWT completion times.

We highlight that the cross-sectional design of this study does not allow ascertainment of the temporal relationship between measures of interest. However, a number of large population-based, prospective studies (50,51) support Bandura's tenet that self-efficacy is more predictive of activity than actual ability. We also note that our small study sample consisted exclusively of independent community-dwelling senior women who were without significant physical and cognitive impairments. The mean simple and complex WWT completion times in our study were lower than those reported by Verghese and colleagues (13); there were also small differences between time to walk 40 ft without talking and simple and complex WWT completion times. This may indicate a minimal dual-task effect on our participants. Thus, the results of this study may not generalize to senior women with significant physical and/or cognitive impairments, and we may have underestimated the contribution of executive functions to dual-task gait performance. Also, the relationship between efficacy and performance is different between men and women (50). Specifically, Myers and colleagues (53) demonstrated that men have higher balance confidence compared with women. Thus, our results may also not generalize to senior men. Future population-based, prospective studies are needed to test whether the present findings also apply in larger, more heterogeneous populations. Future studies of dual-task gait performance should also assess changes in gait variability, not just gait speed, as gait variability may provide additional in-depth understanding of dual-task decrement in gait. Also, because the overall effect of set shifting and balance confidence on dual-gait performance observed in this study was small, future studies are also needed to determine the clinical significance, if any, of the additional and unique variance accounted for by each factor. Finally, although the neuropsychological tests used in this study are standardized and widely used (56), they have limitations. Thus, more sensitive measures of executive functions should be used in future studies to better examine the differential impact of key executive processes on dual-task gait performance.

In conclusion, this study highlights that balance confidence is independently associated with dual-task gait performance. Furthermore, executive functions do not play a significant role in dual-task gait performance when the concurrent cognitive load is low. Clinicians may need to consider balance confidence and executive functions in the assessment and rehabilitation of dual-task gait performance among community-dwelling seniors.

Funding

Vancouver Foundation (British Columbia Medical Services Foundation Operating Grant: BCM06-0035) and the Michael Smith Foundation for Health Research (Establishment Grant: CI-SCH-063(05-1)CLIN) to T.L-A. supported this study.

Conflict of Interest

None for all authors.

Acknowledgments

We are grateful to the study participants for their time and commitment to this research study. We also thank Dr Karim Khan, MD, PhD, Professor, Department of Family Practice, University of British Columbia, in his role as the study physician. T.L-A. and M.C.A. are Michael Smith Foundation for Health Research Scholars. Author contributions: T.L-A.: Study concept and design, acquisition of data, analysis and interpretation of data, preparation of manuscript, and critical review of manuscript. M.C.A., L.A.K., L.C.N., and L.H.: Acquisition of data, interpretation of data, and critical review of manuscript.

Correspondence

Address correspondence to Teresa Liu-Ambrose, PhD, PT, University of British Columbia, 357-2647 Willow Street, Vancouver, British Columbia, Canada V5Z 1M9. Email: teresa.ambrose@ubc.ca

References

1. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. *N Engl J Med*. 1988;319:1701–1707.
2. Carter ND, Kannus P, Khan KM. Exercise in the prevention of falls in older people: a systematic literature review examining the rationale and the evidence. *Sports Med*. 2001;31:427–438.
3. Lord S, Clark R. Simple physiological and clinical tests for the accurate prediction of falling older people. *Gerontology*. 1996;42:199–203.
4. Campbell AJ, Borrie MJ, Spears GF. Risk factors for falls in a community-based prospective study of people 70 years and older. *J Gerontol*. 1989;44:M112–M117.
5. Woollacott M, Shumway-Cook A. Attention and the control of posture and gait: a review of an emerging area of research. *Gait Posture*. 2002;16:1–14.
6. Yogev-Seligmann G, Hausdorff JM, Giladi N. The role of executive function and attention in gait. *Mov Disord*. 2008;23:329–342; quiz 472.
7. Malouin F, Richards CL, Jackson PL, Dumas F, Doyon J. Brain activations during motor imagery of locomotor-related tasks: a PET study. *Hum Brain Mapp*. 2003;19:47–62.
8. Lindenberger U, Marsiske M, Baltes PB. Memorizing while walking: increase in dual-task costs from young adulthood to old age. *Psychol Aging*. 2000;15:417–436.
9. Hollman JH, Kovash FM, Kubik JJ, Linbo RA. Age-related differences in spatiotemporal markers of gait stability during dual task walking. *Gait Posture*. 2007;26:113–119.
10. Baddeley AD, Baddeley HA, Bucks RS, Wilcock GK. Attentional control in Alzheimer's disease. *Brain*. 2001;124:1492–1508.
11. Beauchet O, Annweiler C, Allali G, Berrut G, Herrmann FR, Dubost V. Recurrent falls and dual task-related decrease in walking speed: is there a relationship? *J Am Geriatr Soc*. 2008;56:1265–1269.
12. Faulkner KA, Redfern MS, Cauley JA, et al. Multitasking: association between poorer performance and a history of recurrent falls. *J Am Geriatr Soc*. 2007;55:570–576.
13. Verghese J, Buschke H, Viola L, et al. Validity of divided attention tasks in predicting falls in older individuals: a preliminary study. *J Am Geriatr Soc*. 2002;50:1572–1576.
14. Lundin-Olsson L, Nyberg L, Gustafson Y. "Stops walking when talking" as a predictor of falls in elderly people. *Lancet*. 1997;349:617.
15. Stuss DT, Alexander MP. Executive functions and the frontal lobes: a conceptual view. *Psychol Res*. 2000;63:289–298.
16. Coppin AK, Shumway-Cook A, Saczynski JS, et al. Association of executive function and performance of dual-task physical tests among older adults: analyses from the InChianti study. *Age Ageing*. 2006;35:619–624.
17. Ble A, Volpato S, Zuliani G, et al. Executive function correlates with walking speed in older persons: the InCHIANTI study. *J Am Geriatr Soc*. 2005;53:410–415.
18. Springer S, Giladi N, Peretz C, Yogev G, Simon ES, Hausdorff JM. Dual-tasking effects on gait variability: the role of aging, falls, and executive function. *Mov Disord*. 2006;21:950–957.
19. Holtzer R, Verghese J, Xue X, Lipton RB. Cognitive processes related to gait velocity: results from the Einstein Aging Study. *Neuropsychology*. 2006;20:215–223.
20. Miyake A, Emerson MJ, Friedman NP. Assessment of executive functions in clinical settings: problems and recommendations. *Semin Speech Lang*. 2000;21:169–183.
21. Miyake A, Friedman NP, Emerson MJ, Witzki AH, Howerter A, Wager TD. The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: a latent variable analysis. *Cogn Psychol*. 2000;41:49–100.
22. Maki BE, Holliday PJ, Topper AK. Fear of falling and postural performance in the elderly. *J Gerontol*. 1991;46:M123–M131.
23. Liu-Ambrose T, Khan KM, Donaldson MG, Eng JJ, Lord SR, McKay HA. Falls-related self-efficacy is independently associated with balance and mobility in older women with low bone mass. *J Gerontol A Biol Sci Med Sci*. 2006;61:832–838.
24. Myers A, Powell L, Maki B, Holliday P, Brawley L, Sherk W. Psychological indicators of balance confidence: relationship to actual and perceived abilities. *J Gerontol*. 1996;51A:M37–M43.
25. Hamel KA, Cavanagh PR. Stair performance in people aged 75 and older. *J Am Geriatr Soc*. 2004;52:563–567.
26. Maki BE. Gait changes in older adults: predictors of falls or indicators of fear. *J Am Geriatr Soc*. 1997;45:313–320.
27. Tinetti ME, Mendes de Leon CF, Doucette JT, Baker DI. Fear of falling and fall-related efficacy in relationship to functioning among community-living elders. *J Gerontol*. 1994;49:M140–M147.
28. Oyama H, Kida Y, Tanaka T, Iwakoshi T, Niwa M, Kobayashi T. Incidental white matter lesions identified on magnetic resonance images of normal Japanese individuals—correlation with age and hypertension. *Neurol Med Chir (Tokyo)*. 1994;34:286–290.
29. Bokura H, Yamaguchi S, Iijima K, Nagai A, Oguro H. Metabolic syndrome is associated with silent ischemic brain lesions. *Stroke*. 2008;39:1607–1609.
30. Gatto NM, Henderson VW, St John JA, McCleary C, Hodis HN, Mack WJ. Metabolic syndrome and cognitive function in healthy middle-aged and older adults without diabetes. *Neuropsychol Dev Cogn B Aging Neuropsychol Cogn*. 2008;15:627–641.
31. Arvanitakis Z, Wilson RS, Bennett DA. Diabetes mellitus, dementia, and cognitive function in older persons. *J Nutr Health Aging*. 2006;10:287–291.
32. Obisesan TO, Obisesan OA, Martins S, et al. High blood pressure, hypertension, and high pulse pressure are associated with poorer cognitive function in persons aged 60 and older: the Third National Health and Nutrition Examination Survey. *J Am Geriatr Soc*. 2008;56: 501–509.
33. Waldstein SR, Brown JR, Maier KJ, Katzel LI. Diagnosis of hypertension and high blood pressure levels negatively affect cognitive function in older adults. *Ann Behav Med*. 2005;29:174–180.
34. Bandura A. Self-efficacy: toward a unifying theory of behavioral change. *Psychol Rev*. 1977;84:191–215.
35. Colcombe S, Kramer AF. Fitness effects on the cognitive function of older adults: a meta-analytic study. *Psychol Sci*. 2003;14:125–130.
36. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res*. 1975;12:189–198.
37. Yesavage JA. Geriatric Depression Scale. *Psychopharmacol Bull*. 1988;24:709–711.
38. Groll DL, To T, Bombardier C, Wright JG. The development of a comorbidity index with physical function as the outcome. *J Clin Epidemiol*. 2005;58:595–602.
39. Washburn RA, Smith KW, Jette AM, Janney CA. The physical activity scale for the elderly (PASE): development and evaluation. *J Clin Epidemiol*. 1993;46:153–162.
40. Washburn RA, McAuley E, Katula J, Mihalko SL, Boileau RA. The physical activity scale for the elderly (PASE): evidence for validity. *J Clin Epidemiol*. 1999;52:643–651.
41. Lord SR, Menz HB, Tiedemann A. A physiological profile approach to falls risk assessment and prevention. *Phys Ther*. 2003;83:237–252.
42. Powell L, Myers A. The Activities-Specific Confidence (ABC) Scale. *J Gerontol*. 1995;50A:M28–M34.
43. Wechsler D. *Wechsler Adult Intelligence Scale—Revised Manual*. New York: The Psychological Corporation; 1981.
44. Baddeley A. Working memory. *Science*. 1992;255:556–559.

45. Graf P, Uttl B, Tuokko H. Color- and picture-word Stroop tests: performance changes in old age. *J Clin Exp Neuropsychol*. 1995;17:390–415.
46. Trenerry M, Crosson B, DeBoe J, Leber W. Stroop neuropsychological screening test. Odessa, FL: Psychological Assessment Resources; 1988.
47. 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*. 2008;63:1335–1343.
48. Rosengren KS, McAuley E, Mihalko SL. Gait adjustments in older adults: activity and efficacy influences. *Psychol Aging*. 1998;13: 375–386.
49. Seeman T, McAvay G, Merrill S, Albert M, Rodin J. Self-efficacy beliefs and change in cognitive performance: MacArthur studies of successful aging. *Psychol Aging*. 1996;11:538–551.
50. Seeman TE, Unger JB, McAvay G, Mendes de Leon CF. Self-efficacy beliefs and perceived declines in functional ability: MacArthur studies of successful aging. *J Gerontol B Psychol Sci Soc Sci*. 1999;54:P214–P222.
51. Mendes de Leon CF, Seeman TE, Baker DI, Richardson ED, Tinetti ME. Self-efficacy, physical decline, and change in functioning in community-living elders: a prospective study. *J Gerontol B Psychol Sci Soc Sci*. 1996;51:S183–S190.
52. Sharma L, Cahue S, Song J, Hayes K, Pai YC, Dunlop D. Physical functioning over three years in knee osteoarthritis: role of psychosocial, local mechanical, and neuromuscular factors. *Arthritis Rheum*. 2003;48:3359–3370.
53. Myers A, Fletcher P, Myers A, Sherk W. Discriminative and evaluative properties of the activities-specific balance confidence (ABC) scale. *J Gerontol*. 1998;53:M287–M294.
54. Iersel MBv, Kessels RPC, Bloem BR, Verbeek ALM, Olde Rikkert MGM. Executive functions are associated with gait and balance in community-living elderly people. *J Gerontol A Biol Sci Med Sci*. 2008;63:1344–1349.
55. Persad CC, Giordani B, Chen HC, et al. Neuropsychological predictors of complex obstacle avoidance in healthy older adults. *J Gerontol B Psychol Sci Soc Sci*. 1995;50:P272–P277.
56. Spreen O, Strauss E. 1998. *A Compendium of Neurological Tests*., 2nd ed. New York: Oxford University Press.

Received November 5, 2008
Accepted March 29, 2009
Decision Editor: Luigi Ferrucci, MD, PhD