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

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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
the rate of one per second. The sequence begins with three random number sequences that the assessor reads aloud at ward tests to index the central executive component of 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.

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.

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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.
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 the model. Significant improvements in the model occurred after adding the executive process of response inhibition to the model resulted in an \( R^2 \) change of 2.5% and significantly improved the regression model \( (F \text{ change } [1,129] = 7.9, p < .01) \). Adding the ABC scale score to the model resulted in an \( R^2 \) change of 3.1% and significantly improved the model \( (F \text{ change } [1,129] = 10.60, p = .001) \). The total variance accounted by the final model was 67.3% (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 \( (F \text{ change } [1,130] = 8.07, p < .01) \). Adding the ABC scale score to the model resulted in an \( R^2 \) change of 3.1% and significantly improved the model \( (F \text{ change } [1,129] = 10.60, p = .001) \). 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 fall-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
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>
<thead>
<tr>
<th>Independent Variable</th>
<th>R^2</th>
<th>R^2 Change</th>
<th>Unstandardized B (SE)</th>
<th>Standardized β</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
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<td>.865</td>
<td>.865</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (yr)</td>
<td></td>
<td></td>
<td>0.02 (0.03)</td>
<td>0.03</td>
<td>.35</td>
</tr>
<tr>
<td>Time to Walk 40 ft (s)</td>
<td></td>
<td></td>
<td>1.02 (0.04)</td>
<td>0.92</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>MMSE score (30 point)</td>
<td></td>
<td></td>
<td>0.03 (0.06)</td>
<td>0.02</td>
<td>.63</td>
</tr>
<tr>
<td>Model 2</td>
<td>.873</td>
<td>.008</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (yr)</td>
<td></td>
<td></td>
<td>0.01 (0.03)</td>
<td>0.02</td>
<td>.66</td>
</tr>
<tr>
<td>Time to walk 40 ft (s)</td>
<td></td>
<td></td>
<td>0.96 (0.04)</td>
<td>0.88</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>MMSE score (30 point)</td>
<td></td>
<td></td>
<td>0.03 (0.06)</td>
<td>0.02</td>
<td>.56</td>
</tr>
<tr>
<td>ABC scale score</td>
<td></td>
<td></td>
<td>−0.02 (0.01)</td>
<td>−0.10</td>
<td>&lt;.01</td>
</tr>
</tbody>
</table>

Note: ABC = Activities-Specific Balance Confidence scale; MMSE = Mini-Mental Status 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 Vergheze 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 cognitive impairments. The mean simple and complex WWT completion times in our study were lower than those reported by Vergheze and colleagues (13); there were also small differences between time to walk 40 ft without talking and simple and complex WWT completion times.

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.

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

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>R² Change</th>
<th>Unstandardized B (SE)</th>
<th>Standardized β</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td>.571</td>
<td>0.10 (0.09)</td>
<td>0.07</td>
<td>.26</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>.571</td>
<td>1.55 (0.12)</td>
<td>0.73</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Time to walk 40 ft (s)</td>
<td>-0.05 (0.20)</td>
<td>-0.01</td>
<td>.82</td>
<td></td>
</tr>
<tr>
<td>MMSE score (30 point)</td>
<td>.596</td>
<td>0.10 (0.09)</td>
<td>0.07</td>
<td>.23</td>
</tr>
<tr>
<td>Time to walk 40 ft (s)</td>
<td>1.48 (0.12)</td>
<td>0.70</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>MMSE score (30 point)</td>
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<td>-0.01</td>
<td>.87</td>
<td></td>
</tr>
<tr>
<td>Model 2</td>
<td>.627</td>
<td>0.05 (0.08)</td>
<td>0.04</td>
<td>.53</td>
</tr>
<tr>
<td>Age (yr)</td>
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<td>1.28 (0.14)</td>
<td>0.60</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Time to walk 40 ft (s)</td>
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<td>-0.004</td>
<td>.94</td>
<td></td>
</tr>
<tr>
<td>MMSE score (30 point)</td>
<td>0.03 (0.01)</td>
<td>0.17</td>
<td>&lt;.01</td>
<td></td>
</tr>
<tr>
<td>ABC scale score</td>
<td>-0.07 (0.02)</td>
<td>-0.21</td>
<td>.001</td>
<td></td>
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</tbody>
</table>

Note: ABC = Activities-Specific Balance Confidence scale; MMSE = Mini-Mental State Examination; WWT = walking while talking.
EXECUTIVE FUNCTIONS, BALANCE CONFIDENCE, AND DUAL TASK

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