Cognitive Function as a Prospective Predictor of Falls

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Objective. This study examined speed of processing, executive functioning, and psychomotor speed as independent prospective predictors of falls and recurrent falls across 3 years.

Method. The participants were 509 community-dwelling older adults. Measures of speed of processing, executive function, psychomotor speed, and known risk factors of falling were included in correlation and logistic regression analyses.

Results. Poor executive function (Trail Making Test), slower speed of processing (Digit Symbol Substitution [DSS] Test), and slower psychomotor speed (Digit Symbol Copy Test) were significantly associated with falls. Poor executive function and speed of processing performance (Stroop Test, Trail Making Test, and DSS Test) as well as slower psychomotor speed were significantly related to recurrent falls. Logistic regression results indicated that only medication use, far visual acuity, and psychomotor speed were significant independent predictors of falls. Regarding recurrent falls, being white, medication use, and balance were significant predictors.

Discussion. Although cognitive measures at baseline were significantly associated with falls and recurrent falls at follow-up, these measures did not predict falling after considering known risk factors of falls and psychomotor speed. Thus, it may be that simple measures of psychomotor speed are more salient predictors of falls than cognitive measures.

Key Words: Falls—Processing speed—Executive function—Psychomotor speed.

Falls have been a pressing issue in our society. Not only can falling lead to physical and psychological traumas (Campbell, Borrie, & Spears, 1989; Malimivaara, Heliovaara, Knekt, Reunanen, & Aromaa, 1993), but it is also one of the leading causes of death due to unintentional injuries among older adults in the United States (Centers for Disease Control and Prevention, National Center for Injury Prevention and Control, & Web–based Injury Statistics Query and Reporting System, 2005). In addition, the medical expense of immediate care and subsequent rehabilitation due to falls has increased exponentially in this segment of the population (Alexander, Rivara, & Wolf, 1992; Englander, Hodson, & Terregrossa, 1996; Kiel, O’Sullivan, Teno, & Mor, 1991; Stevens, Corso, Finkelstein, & Miller, 2006). Previous studies have shown that identifying risk factors of falling followed by proper interventions can successfully reduce the incidence of falling (Chang et al., 2004; Clemson et al., 2004; Davison, Bond, Dawson, Steen, & Kenny, 2005; Tinetti et al., 1994). It is, therefore, important to understand the risk factors for falling in order to promote falls prevention and improve public health.

Previous research has suggested that recurrent falls should be differentiated from single falls. First, recurrent falls are more likely to be caused by intrinsic factors (e.g., vision) instead of extrinsic factors (e.g., environmental hazards; Tromp, Smit, Deeg, Bouter, & Lips, 1998). Second, recurrent falls are more predictable than single falls because of their stronger relationships with risk factors (Nevitt, Cummings, Kidd, & Black, 1989; Tinetti, Speechley, & Ginter, 1988). Finally, people who experience recurrent falls may benefit more from preventive and therapeutic efforts (Graafmans et al., 1996; Tromp et al., 1998). Thus, this study examined risk factors for both falls and recurrent falls.

Recently, much attention has been given to the relationship between cognitive function and falls among older adults. Research has shown that poor performance on cognitive tests is associated with increased likelihood of falling among older adults (Anstey, Von Sanden, & Luszcz, 2006; Anstey, Wood, Kerr, Caldwell, & Lord, 2009; Buracchio et al., 2011; Herman, Mirelman, Giladi, Schweiger, & Hausdorff, 2010; Holtzer et al., 2007; Shumway-Cook, Brauer, & Woollacott, 2000). For example, Holtzer and colleagues (2007) investigated if cognitive function was related to single falls or recurrent falls among older adults without dementia. The results showed that better performance on a speed of processing and executive function factor (Trail Making Test, Digit Symbol Substitution [DSS] Test, and Block Design) was significantly related to reduced risk of both single and recurrent falls. A similar study conducted by Anstey and colleagues (2009) found that better performance as measured by accuracy on reaction time tests requiring the executive function of inhibition was significantly associated with a reduced risk of recurrent falls. Similarly, poor performance on speed of processing and executive function (DSS Test and Trail Making Test) was associated with an increased risk of recurrent falls. However, the researchers found that after introducing body sway in the analyses, only executive function as indicated by inhibition...
was significantly related to recurrent falls. Interestingly, reaction time was not associated with recurrent falls. A limitation of this study is the cross-sectional design.

One prospective study (Buracchio et al., 2011) examined the relationship between executive function and the risk of falling in older adults for a period of 13 months. For each participant, the researchers used 13 cognitive tests of five domains: executive function (e.g., Trail Making Test B and Category Fluency), working memory (e.g., Digit Span Backward), speed of processing/attention (e.g., DSS Test and Trail Making Test A), memory (e.g., Logical Memory Delayed), and visuospatial function (e.g., Block Design). The results showed that only cognition as indicated by executive function was a risk factor for falls. Of note, psychomotor speed was not assessed.

Another paradigm for examining the relationship between cognition and falls is assessing dual-task performance. For example, Herman and colleagues (2010) examined executive function and gait performance with or without a concomitant cognitive task as prospective predictors of falls among older adults without dementia. They included a cognitive battery of executive function and memory, including the measures of Go-No-Go, Stroop interference test, choice reaction time, verbal fluency, forward and backward digit span, and the Trail Making Test. Older people with poor executive functioning were at higher risk of falling. Only gait performance with a simultaneous cognitive load was associated with future falls, whereas gait alone was not. This could be because older adults with poor cognitive function allocate more resources on the cognitive test instead of walking, and are therefore more prone to falling. A study by Springer and colleagues (2006) also examined the relationship between dual tasks, executive function, and falls among older adults. The dual-task effect was measured when participants performed a walking test under three conditions: (a) listening to speech, (b) listening to speech while counting specific words, and (c) subtracting serial sevens. In addition, the researchers administered three cognitive tests (i.e., verbal memory, Stroop interference, and Go-No-Go). The researchers noted that executive function decline might mediate the relationship between falls and gait variability. However, measures of speed of processing were not included in the analyses of these studies.

Overall, there is expanding information that poor performance on cognitive tests, executive function in particular, is related to an increased likelihood of falling. It is important to note, however, that executive function is a diverse cognitive construct that is often referred to as an umbrella term for multiple abilities (Chan, Shum, Touloupoulo, & Chen, 2008). A large proportion of executive function difficulties among older adults can be attributed to speed of processing decline (Verhaeghen, 2011). Thus, executive function should only be examined as a predictor of falls jointly with measures of speed of processing in order to delineate what cognitive ability is the most important predictor (and potentially a target of intervention). Additionally, psychomotor speed is often a confounding variable when measuring both executive function and speed of processing (Joy, Fein, & Kaplan, 2003; Joy, Fein, Kaplan, & Freedman, 2000; Tun, Wingfield, & Lindfield, 1997). Yet, the previously mentioned studies did not also separately consider psychomotor speed when examining the relationship between cognitive function and falls. One way to measure psychomotor speed is by using the Digit Symbol Copy (DSC) Test (Joy et al., 2000; Tun et al., 1997). Similarly, some researchers use Delta Trail Making Test (DTMT—Trail Making Test B time subtracting Trail Making Test A time) to measure executive function while controlling for psychomotor speed. Although Anstey and colleagues (2009) used this technique, their study was cross-sectional.

Therefore, this study addresses these issues by examining whether baseline speed of processing and executive function can independently predict prospective falls and recurrent falls while concurrently considering psychomotor speed. To this end, we used data from the Staying Keen in Later Life (SKILL) study (Edwards, Wadley, Vance, Roenker, & Ball, 2005), which investigated the impact of health, medication use, and cognitive, sensory, and physical functions on mobility outcomes.

**Method**

**Participants**

Potential study participants included older adults from the SKILL study, who completed a baseline visit at the University of Alabama at Birmingham (n = 675). We attempted to contact these participants for a 3-year follow-up telephone interview: 79 refused further participation, 34 were confirmed deceased, and 51 were unable to be reached. Of the remaining 511 participants, 2 were excluded from these analyses due to a baseline Mini Mental State Exam (MMSE) below a score of 23. The age, sex, and race of participants (n = 509) included in these analyses are 63–90 years (M = 73, SD = 5.22), female (55%), and Caucasian (88%), respectively. Their education level ranged from sixth grade to doctorate level.

**Measures**

**Mini mental state exam.**—The MMSE assesses mental status by measuring skills such as orientation, memory, language, and attention (Folstein, Folstein, & McHugh, 1975). The total score ranges from 0 (poor cognitive function) to 30 (high cognitive function). Participants who scored at least 23 were included in analyses.

**Far visual acuity.**—A Good-Lite model 600A light box with the Early Treatment Diabetic Retinopathy Study letter chart was used to assess visual acuity. Participants were in a
darkened room at a distance of 10 ft from the light box and were allowed to wear corrective lenses, if needed. The ACTIVE method (Ball et al., 2002; Jobe et al., 2001) of assigning points for each letter correctly identified was used. Scores may range from 0 (if no letters were identified correctly, equivalent to a Snellen score of 20/125) to 90 (if all letters were identified correctly, equivalent to a Snellen score of 20/16), with higher scores indicating better visual acuity.

**Socio-demographic characteristics.**—Known risk factors for falls such as age, sex, race, and education (Campbell et al., 1989; Friedman, Munoz, West, Rubin, & Fried, 2002) were also included in analyses. Age and education were measured as continuous variables in years. Sex and race were coded as categorical variables, with both female and white coded as 1. All other races were coded as 0.

**Balance.**—The Turn 360 Test requires participants to turn in a complete circle while standing (Steinhagen-Thiessen & Borchelt, 1999). The number of steps used to complete the circle was counted. The average number of steps across two trials was calculated, with fewer steps indicating better balance.

**Falls and recurrent falls.**—The Mobility Questionnaire, a previously validated self-report measure, was administered to collect fall-related information (Owsley & McGwin, 2004). Testers asked whether or not participants experienced one or more falls in the last 2 months. A fall was defined as “accidentally losing your balance and falling on the ground or falling against something such as furniture.” Participants who experienced two or more falls were considered as recurrent fallers. Information on where the fall(s) took place and what circumstance(s) may have contributed to the event(s) was also collected. Both falls (one or more falls, yes or no) and recurrent falls (two or more falls, yes or no) outcomes were coded dichotomously.

**Health.**—Two scales were used to measure participants’ health in terms of chronic conditions and medication use.

**Chronic conditions.** A self-report measure of health status used in prior research (Jobe et al., 2001) was included to ascertain health as indicated by chronic conditions. Participants were asked if they had ever been informed by a doctor or a nurse that they had arthritis, asthma, cancer, diabetes, heart disease, multiple sclerosis, osteoporosis, or Parkinson’s disease.

**Medications.** A take-home questionnaire was completed by participants to indicate all prescription medications they were currently using. The total number of medications was recorded. Previous research found that using four or more medications is a significant risk factor of falls (Leipzig, Cumming, & Tinetti, 1999a, 1999b). Therefore, we coded medications dichotomously, as 0-3 or 4 or more medications.

**Speed of processing.**—Three tests were used to examine participants’ speed of processing, including the Useful Field of View (UFOV) Test, Letter and Pattern Comparison Tests, and DSS Test.

**Useful field of view test.** The UFOV Test is a measure of speed of processing for visual attention tasks (Edwards et al., 2005). This software consists of four subtests (stimulus identification alone, divided attention, selective attention, and selective attention in conjunction with same/different discriminations) that successively increase in difficulty. Scores for each subtest represent the average display duration in which a participant is able to respond correctly on 75% of the trials, but do not reflect motor speed or reaction time. The first subtest requires the participant to identify which of the two objects (a silhouette of a car or a truck) was presented inside a fixation box. The second test includes a central identification task, but in addition, the participant is required to locate an outside car (peripheral target). The location of the peripheral target is varied randomly from trial to trial. The third subtest requires the participant to perform the central identification task and the peripheral localization task; however, the peripheral target is embedded in a field of distractors. The fourth subtest is similar to the third one, with the exception that the center task is more demanding. In the fourth subtest, two targets are presented in the central fixation box (either two cars, two trucks, or one car and one truck) and the participant must indicate if the targets inside the box are the same or different. As in subtest 3, the simultaneous localization of a peripheral target that is embedded within distractors is also required. Each subtest begins with two examples and four practice trials, and then the test trials begin. Scores for each subtest can range from 16.67 to 500 ms with lower numbers indicating better speed of processing.

**Letter and Pattern Comparison Tests.** The Letter and Pattern Comparison Tests are pencil-and-paper tests of speed of processing. Each test contains two columns of paired letters or line patterns sets containing three, six, or nine letters or abstract line drawings (Salthouse & Babcock, 1991). Participants were given 20 s to determine whether the paired sets were the same or different. A total score was calculated by adding up the number of correct comparisons.

**DSS Test.** The DSS Test is a well-known measure of speed of processing (Salthouse, 2000), although others have conceptualized this measure as tapping both speed of processing and executive functioning (Baudouin, Clarys, Vanneste, & Isingrini, 2009). The paper test contains a grid of empty boxes with numbers (1–9) above each box and a key that pairs a particular symbol with each number at the top (Wechsler, 1981). Participants were instructed to correctly substitute, by handwriting, as many symbols associated with each of the numbers as possible within 90 s. The total number of correctly paired symbols was used in analyses.

**Executive functioning.**—Two tests were used to examine participants’ executive function, including the Stroop Test and Trail Making Test.

**Stroop.** A modified version of the computerized Stroop Test (Trenerry, Crosson, DeBoe, & Leber, 1989) was
administered. This test involves three tasks requiring the execution of impulse control and inhibition (Stern & Prohaska, 1996). For each task, participants were asked to respond as quickly and as accurately as possible, but if they did make errors to correct them and proceed. In the first Stroop task (color patches), participants viewed 36 (presented in four columns of nine) colored blocks (red, green, blue, or yellow) on a computer screen and were required to identify the color of each block. In the second task (color words), participants were required to read 36 color names printed in white on the computer screen. In the third task, participants viewed 36 color names printed in a discordant ink color (e.g., yellow printed in red). Identification of the actual color of the ink was required while ignoring the color word. For each task, participants received scores indicating time in seconds required to identify all the stimuli as instructed. The number of uncorrected errors was also recorded for the interference condition. The Stroop effect measures executive function by indicating the impact of distraction on the ability to inhibit a primary response. This score was derived by calculating the difference among the interference and color patch condition times (which helps to eliminate speed of processing). A correction factor, calculated by dividing the interference condition total time by 36 (to estimate time per item) and multiplying by the number of uncorrected errors made, was added to the score as described by Edwards and colleagues (2005).

Trail Making Test (A and B). The Trail Making Test has been described as measuring complex visual scanning (Trails A) and executive functioning (Trails B; Reitan, 1958; Spreen & Strauss, 1991; Stern & Prohaska, 1996).

In Trails A, participants were instructed to draw a line connecting 25 numbered circles in proper order as quickly as possible. For the Trails B task, participants drew a line connecting 25 circles containing either a number or a letter in alternating sequence as quickly as possible (e.g., 1 – A – 2 – B). The time in seconds required to complete each task was recorded. The DMT score was calculated by subtracting time for Trails A completion from time for Trails B and was used in analysis (to derive a more pure measure independent of psychomotor speed).

Psychomotor speed.—The DSC Test is a pencil-and-paper test of psychomotor speed which includes a grid of empty boxes with symbols above each box (Tun et al., 1997). Participants were instructed to correctly copy the symbol above each box into the empty box below it. Participants were asked to perform this task as quickly and as accurately as they could and were allowed as much time as they needed. The time taken to perform the task was recorded and used in analyses.

Procedure

The SKILL study was designed to investigate the interrelationships among cognitive, functional, and sensory abilities in older adults (Clay et al., 2009). Participants completed a screening visit to determine eligibility. Inclusion criteria were MMSE ≥ 23, visual acuity of 20/80 or better, and a fifth-grade literacy level. A baseline visit to measure cognitive and functional performance was completed by those eligible. Three years later, participants were contacted for a follow-up phone interview. The mobility questionnaire was administered to determine recent fall occurrences. Further details of this study are available elsewhere (Clay et al., 2009; Wood et al., 2005).

Analyses

The dependent variables in the study were the occurrence of falls and recurrent falls at follow-up. In order to decrease the number of cognitive predictors and examine for multicollinearity in regression models, Spearman correlations were conducted to examine the associations between potential cognitive predictors of falls (e.g., UFOV, DSC, DSS, Letter and Pattern Comparison, Stroop, and Trail Making Tests) and the two dichotomous indicators of falling. Significant correlates were then used in logistic regression analyses to examine prospective predictors of falling and recurrent falling. Known risk factors of falls, including balance, chronic conditions, vision, medication status, and socio-demographic characteristics, were included as covariates (Campbell et al., 1989; Friedman et al., 2002; Leipzig et al., 1999a, 1999b; Stolze et al., 2004). Alpha levels less than .05 were considered as statistically significant.

Results

Tables 1 and 2 show the participants’ baseline characteristics and results from Spearman correlations, respectively. Falling was associated with poor executive function and speed of processing as measured by the DMT (p = .02) and the DSS Test (p = .011), as well as slower psychomotor speed as measured by the DSC Test (p = .004). Recurrent falls were associated with poorer executive function and speed of processing performance as indicated by the Stroop Test (p = .034) and DSS Test (p = .006), as well as slower psychomotor speed as measured by the DSC Test (p = .005). These cognitive measures along with previously identified risk factors were examined as predictors in regression analyses.

Logistic regressions were conducted for the dichotomous outcomes of falls and recurrent falls. The results of the two logistic regression models are shown in Table 3. Taking four or more medications (OR = 3.51, 95% CI = 1.98–6.23, p ≤ .001) and far visual acuity (OR = .97, 95% CI = .95–.99, p = .008) were significant predictors of falling in step 1. After considering cognitive function and psychomotor speed, taking four or more medications (OR = 3.43, 95% CI = 1.93–6.12, p ≤ .001) and far visual acuity (OR = .98, 95% CI = .96–.99, p = .03) remained significant.
Additionally, psychomotor speed as indicated by the DSC Test ($OR = 1.01, 95\% CI = 1.00–1.02, p = .03$) was a significant predictor of falling. Specifically, participants who took four or more medications and those who had slower psychomotor speed at baseline were more likely to report a fall 3 years later. Those who had better vision were less likely to report a fall at follow-up.

In the regression model of recurrent falls, higher education ($OR = .82, 95\% CI = .67–1.00, p = .046$), taking four or more medications ($OR = 3.96, 95\% CI = 1.23–12.70, p = .02$), and balance as measured by the Turn 360 Test ($OR = 1.55, 95\% CI = 1.19–2.02, p = .001$) were found as significant factors in step 1. After considering cognitive function and psychomotor speed, being white ($OR = 6.19, 95\% CI = 1.03–37.12, p = .046$), taking four or more medications ($OR = 3.96, 95\% CI = 1.23–12.70, p = .02$), and balance as measured by the Turn 360 Test ($OR = 1.38, 95\% CI = 1.05–1.81, p = .02$) were significant. Specifically, participants who used four or more medications and those with poor balance were more likely to experience recurrent falls. Those who were white were more likely to experience recurrent falls at follow-up.

**Discussion**

This study examined if speed of processing and executive function can prospectively predict falls and recurrent falls while considering psychomotor speed (measured by the DSC Test) and other known risk factors of falling. Among

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total ($n = 509$)</th>
<th>Fallers ($n = 87$)</th>
<th>Recurrent fallers ($n = 25$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>72.65 ± 5.22</td>
<td>73.03 ± 4.78</td>
<td>72.33 ± 5.04</td>
</tr>
<tr>
<td>Sex: female (%)</td>
<td>55.6</td>
<td>54.02</td>
<td>64</td>
</tr>
<tr>
<td>Race: white (%)</td>
<td>87.6</td>
<td>86.21</td>
<td>92</td>
</tr>
<tr>
<td>Education (years)</td>
<td>14.16 ± 2.68</td>
<td>14.05 ± 2.71</td>
<td>12.84 ± 2.63</td>
</tr>
<tr>
<td>Medications (≥4; %)</td>
<td>49.7</td>
<td>68.97</td>
<td>80</td>
</tr>
<tr>
<td>Chronic conditions (%)</td>
<td>78.4</td>
<td>80.46</td>
<td>88</td>
</tr>
<tr>
<td>Turn 360 Test (average steps)</td>
<td>6.82 ± 1.55</td>
<td>7.13 ± 1.91</td>
<td>7.9 ± 2.75</td>
</tr>
<tr>
<td>Far Visual Acuity</td>
<td>72.76 ± 11.37</td>
<td>70.45 ± 13.16</td>
<td>72.3 ± 14.48</td>
</tr>
<tr>
<td>Stroop (correct)</td>
<td>31.49 ± 15.64</td>
<td>33.69 ± 18.02</td>
<td>36.18 ± 14.17</td>
</tr>
<tr>
<td>DMTT (s)</td>
<td>77.33 ± 66.43</td>
<td>86.43 ± 62.56</td>
<td>95.47 ± 61.57</td>
</tr>
<tr>
<td>UFOV-P</td>
<td>25.09 ± 34.41</td>
<td>31.33 ± 58.04</td>
<td>54.88 ± 104.83</td>
</tr>
<tr>
<td>UFOV-D</td>
<td>99.01 ± 110.28</td>
<td>115.55 ± 130.15</td>
<td>112.88 ± 139.04</td>
</tr>
<tr>
<td>UFOV-S</td>
<td>281.44 ± 129.83</td>
<td>298.67 ± 142.25</td>
<td>292.12 ± 140.78</td>
</tr>
<tr>
<td>UFOV-S/D</td>
<td>443 ± 77.85</td>
<td>448.05 ± 78.71</td>
<td>446.16 ± 81.31</td>
</tr>
<tr>
<td>LPC (correct)</td>
<td>67.7 ± 13.98</td>
<td>65.56 ± 15.23</td>
<td>62.2 ± 16.66</td>
</tr>
<tr>
<td>DSC Test (s)</td>
<td>101.49 ± 31.51</td>
<td>113.02 ± 40.85</td>
<td>124.19 ± 44.97</td>
</tr>
<tr>
<td>DSS Test (correct)</td>
<td>40.82 ± 10.43</td>
<td>38.29 ± 10.29</td>
<td>35 ± 10.81</td>
</tr>
</tbody>
</table>

Note. DSC = Digit Symbol Copy; DSS = Digit Symbol Substitution; DTMT = Delta Trail Making Test; LPC = total Score of the Letter Comparison Test and the Pattern Comparison Test; UFOV-D = Useful Field of View Divided Attention; UFOV-P = Useful Field of View Processing Speed; UFOV-S = Useful Field of View Selective Attention; UFOV-S/D = UFOV Same/different Discriminations.

*p < .05. ** p ≤ .01.

**Table 2.** Spearman Correlation Matrix Among Falls, Recurrent Falls, and Cognitive Variables

<table>
<thead>
<tr>
<th></th>
<th>Falls</th>
<th>Recurrent falls</th>
<th>Stroop (correct)</th>
<th>DMTT (s)</th>
<th>UFOV-P</th>
<th>UFOV-D</th>
<th>UFOV-S</th>
<th>UFOV-S/D</th>
<th>LPC (correct)</th>
<th>DSC (s)</th>
<th>DSS (correct)</th>
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</thead>
<tbody>
<tr>
<td>Falls</td>
<td>–</td>
<td>.52**</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Recurrent falls</td>
<td>.05</td>
<td>.10**</td>
<td>.07</td>
<td>.43**</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>DMTT (s)</td>
<td>.10*</td>
<td>.43**</td>
<td>–</td>
<td>.26**</td>
<td>.26**</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>UFOV-P</td>
<td>.09</td>
<td>.06</td>
<td>.26**</td>
<td>.31**</td>
<td>.40**</td>
<td>.38**</td>
<td>.55**</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>UFOV-D</td>
<td>.03</td>
<td>–.02</td>
<td>.33**</td>
<td>.02</td>
<td>.24**</td>
<td>.17**</td>
<td>.35**</td>
<td>.51**</td>
<td>–</td>
<td>–</td>
<td>–</td>
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<tr>
<td>UFOV-S</td>
<td>.04</td>
<td>.21**</td>
<td>.24**</td>
<td>.21**</td>
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<td>.27**</td>
<td>.35**</td>
<td>.39**</td>
<td>.24**</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>UFOV-S/D</td>
<td>.05</td>
<td>.02</td>
<td>.08</td>
<td>.42**</td>
<td>.42**</td>
<td>.27**</td>
<td>.45**</td>
<td>.45**</td>
<td>.35**</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>LPC (correct)</td>
<td>-.07</td>
<td>-.08</td>
<td>-.42**</td>
<td>-.42**</td>
<td>-.27**</td>
<td>-.45**</td>
<td>-.45**</td>
<td>-.35**</td>
<td>–</td>
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<td>–</td>
</tr>
<tr>
<td>DSC (s)</td>
<td>.13**</td>
<td>.12**</td>
<td>.36**</td>
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<td>.61**</td>
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<td>–</td>
</tr>
<tr>
<td>DSS (correct)</td>
<td>-.11*</td>
<td>-.12**</td>
<td>-.40**</td>
<td>-.51**</td>
<td>-.35**</td>
<td>-.46**</td>
<td>-.45**</td>
<td>-.32**</td>
<td>.70**</td>
<td>-.69**</td>
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</tbody>
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Note. DSC = Digit Symbol Copy; DSS = Digit Symbol Substitution; DTMT = Delta Trail Making Test; LPC = total Score of the Letter Comparison Test and the Pattern Comparison Test; UFOV-D = Useful Field of View Divided Attention; UFOV-P = Useful Field of View Processing Speed; UFOV-S = Useful Field of View Selective Attention; UFOV-S/D = UFOV Same/different Discriminations.
the cognitive measures included in the study, we found that both executive function and speed of processing were significantly associated with falls and recurrent falls. However, neither executive function nor speed of processing was a significant predictor of falls or recurrent falls when simultaneously considering a simpler measure of psychomotor speed and other risk factors. We found that taking four or more medications, vision, and psychomotor speed were significant predictors of single falls. Regarding recurrent falls, being white, taking four or more medications, and balance were significant predictors.

Previous research has documented that executive function is a predictor of falls and fall-related risk factors (Ble et al., 2005; Holtzer et al., 2007; Rapport, Hanks, Millis, & Deshpande, 1998; Springer et al., 2006). For example, Ble and colleagues (2005) found that the adjusted DTMT is significantly associated with walking speed while stepping over obstacles. A study by Rapport and colleagues (1998), among inpatients aged 17–73 years, found that executive function at admission (Stroop and Wisconsin Card Sorting Tests) accounted for higher variance in inpatient falls than functional abilities during hospitalization. The results of Holtzer and colleagues (2007) also support the idea that executive function predicts future falling. Holtzer and colleagues did point out, however, that executive processes depend on speed of processing, and therefore speed of processing might also be a predictor of falls. A limitation to these findings is that the studies by Ble and colleagues and Holtzer and colleagues were cross-sectional. Although the study by Rapport and colleagues examined falls prospectively, the total number of falls may have been underestimated due to increased supervision of activities among the inpatients.

In our study, we found that some speed of processing and executive function measures at baseline were significantly associated with falls and recurrent falls at follow-up, but these measures did not predict falling after considering previously known risk factors of falls and a simpler measure of psychomotor speed. It should be acknowledged that there are no pure measures of cognitive function. While measuring executive function, speed of processing and psychomotor speed are likely to contribute to performance. Moreover, psychomotor speed is often a confounder in speed of processing measures (Joy et al., 2003). Most studies of falling, however, do not take psychomotor speed into account. Interestingly, the UFOV Test, which does not confound psychomotor speed with speed of processing, was not a significant predictor of falling in this study. Although DSS performance did significantly predict falling and may be considered a measure of speed of processing and executive functioning (Baudouin et al., 2009; Salthouse, 2000), this measure was not significant when considering the simpler measure of DSC, which is indicative of psychomotor speed. Overall, the results of this study indicate that simple measures of psychomotor speed are more salient predictors of falls than either executive function or speed of processing measures. Further research is needed to examine if more simple measures of motor speed, such as finger tapping, are more or less predictive of prospective falls when considered concurrently with psychomotor speed and indices of cognitive function. The present results highlight the importance of considering the role of psychomotor speed when examining cognitive predictors.

We also found that using four or more medications and visual acuity are predictors of falls, and being white, using four or more medications and balance are predictors of recurrent falls, which is comparable to the findings of previous studies (Lord & Dayhew, 2001; Stel, Smit, Pluijm, & Lips, 2003). Unlike previous research (Campbell et al., 1989; Friedman et al., 2002), several known risk factors did not consistently predict falls or recurrent falls, such as sociodemographic characteristics. Although these results could

### Table 3. Logistic Regression Analysis Examining if Cognitive Function Predicted Incidence of Falls and Recurrent Falls at Follow-up

<table>
<thead>
<tr>
<th>Variables</th>
<th>Odds ratio(95% CI)</th>
<th>Odds ratio(95% CI)</th>
<th>Odds ratio(95% CI)</th>
<th>Odds ratio(95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age: female (%)</td>
<td>0.99(0.94–1.04)</td>
<td>0.95(0.86–1.04)</td>
<td>0.92(0.83–1.01)</td>
<td></td>
</tr>
<tr>
<td>Sex: white (%)</td>
<td>0.14(0.06–0.31)</td>
<td>0.06(0.01–0.28)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Race: white (%)</td>
<td>1.14(1.05–1.23)</td>
<td>0.63(0.54–0.74)</td>
<td>0.79(0.71–0.88)</td>
<td></td>
</tr>
<tr>
<td>Education (years)</td>
<td>1.04(1.01–1.10)</td>
<td>1.02(0.99–1.06)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medications (≥4; %)</td>
<td>3.51(1.98–6.23)</td>
<td>3.43(1.93–6.12)</td>
<td>3.99(1.26–12.60)</td>
<td>3.96(1.23–12.70)</td>
</tr>
<tr>
<td>Chronic condition</td>
<td>0.69(0.36–1.35)</td>
<td>0.63(0.32–1.24)</td>
<td>1.38(0.29–6.55)</td>
<td>1.37(0.28–6.64)</td>
</tr>
<tr>
<td>Turn 360 Test (average steps)</td>
<td>1.11(0.95–1.29)</td>
<td>1.05(0.89–1.23)</td>
<td>1.55(1.19–2.02)</td>
<td>1.38(1.05–1.81)</td>
</tr>
<tr>
<td>Far Visual Acuity Test</td>
<td>0.97(0.95–0.99)</td>
<td>0.98(0.96–0.99)</td>
<td>1.02(0.97–1.07)</td>
<td>1.03(0.98–1.07)</td>
</tr>
<tr>
<td>DSC Test (s)</td>
<td>1.01(1.00–1.02)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DSS Test (correct)</td>
<td>1.00(0.96–1.03)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DTMT (s)</td>
<td>1.00(0.99–1.00)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroop (correct)</td>
<td></td>
<td></td>
<td>1.01(0.98–1.04)</td>
<td></td>
</tr>
</tbody>
</table>

*Note. DSC = Digit Symbol Copy; DSS = Digit Symbol Substitution; DTMT = Delta Trail Making Test.
*p < .05. **p ≤ .01. ***p ≤ .001.*
potentially indicate that performance-based measures of balance, vision, and psychomotor speed may be better predictors than socio-demographic characteristics, the sample of this study is not diverse enough to support this conclusion.

**Limitations of the Study**

We acknowledge that there are limitations to this study. Although research shows that psychotropic, cardiac, and analgesic drug use place older adults at greater risk of falling (Leipzig et al., 1999a, 1999b), we only examined total number of medications. Therefore, we were unable to account for the potential relationship of specific medication use and falls.

Another limitation is that the observed rate of falling in our study is smaller than the rates in previous research. This may be due to the sample that included participants who were highly educated (M = 14 years) and who were mostly white (87%). Although studies have shown that whites have significantly higher frequency of falls and recurrent falls compared with other racial groups (Friedman et al., 2002; Nevitt et al., 1989), they also show that people with higher education are more likely to pursue a healthier lifestyle (Kim, Symons, & Popkin, 2004) that consequently prevent falls (Graafmans, Lips, Wijlhuizen, Puijim, & Bouter, 2003). Another limitation is that this study did not account for incidence of stroke, depression, or pain, which have been indicated as significant risk factors of falling in previous research (Hyndman, Ashburn, & Stack, 2002; Jorgensen, Engstad, & Jacobsen, 2002; Leveille et al., 2009; Rubenstein, 2006).

Finally, the method of falls data collection was not ideal and alternate statistical analyses could have been used. International experts recommend that the best way to collect falls data is using diaries with monthly reporting and follow-up phone interviews, if required (Lamb, Jørstad-Stein, Hauer, & Becker, 2005). In our study, we asked participants to recall fall events from the past 2 months. We might, hence, underestimate the incidence of falling. Given that falls are relatively rare events, coding and distribution of falls data can be challenging for statistical analyses. Our falls outcomes were coded dichotomously and analyzed with logistic regression. Other studies have used coded falls data using total number of falls; total number of fallers, non-fallers, and frequent fallers; fall rate per person year; and time to first fall (Hauer, Lamb, Jorstad, Todd, & Becker, 2006; Lamb et al., 2005). Similarly, other statistical techniques such as negative binomial or Cox Hazard logistic regression have been used to analyze falls data. There are, of course, limitations to logistic regression. One limitation of logistic regression analyses is that the predictor variables should not be highly correlated. For this reason, we did not include predictors that were correlated at r > .7 in the model. Another limitation is that sample sizes of 400 or larger are required for this technique, but our sample size of 509 is sufficient (Bewick, Cheek, & Ball, 2005). Benefits of using logistic regression include that the results are easy to interpret, and, in general, use of other transformations typically yields similar results (Bewick et al., 2005). Nevertheless, data from the SKILL study provided a unique opportunity to simultaneously examine indices of cognitive performance and psychomotor speed as prospective predictors of falling.

In conclusion, simple measures of psychomotor speed may be better prospective predictors of falling than more complex cognitive measures of executive function or speed of processing. These findings suggest that people with better psychomotor speed might take actions quicker in reacting to postural or environmental perturbation, such as grabbing handrail at bathroom when slipping or finding enough space and direction for stepping out when losing balance in a crowd. However, although psychomotor speed as measured by performance on the DSC Test was a significant independent predictor of falling, when considered in concert with other risk factors neither psychomotor speed nor cognitive function independently predicted recurrent falls. The implications of these findings are that focusing interventions on modifiable falls risk factors other than cognition may be the most effective methods of decreasing falls risk. However, direct study and comparison of differing intervention types is needed to confirm this possibility. Overall, research on cognitive predictors of falling must also consider the role of psychomotor speed.

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**References**


COGNITIVE FUNCTION AND FALLS


