The Relation Between Psychometric Test Performance and Physical Performance in Older Adults

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Background. The relationship between cognitive function and physical disability in nondemented older adults is not well characterized. The purpose of this study was to examine the relationship between performance on psychometric measures and a modified Physical Performance Test (modified PPT) in older men and women.

Methods. One hundred twenty-five men and women aged 75 years and older, who were enrolled in randomized, controlled trials of exercise or hormone replacement therapy, were recruited from the community-at-large and from congregate living sites. Measures obtained included Trailmaking A and B tests, Cancellation Random Figure tests, Weschler Associate Learning and 20-minute Delayed Recall, Verbal Fluency test, a modified PPT, and self-reports about performance of activities of daily living, medication use, and hospitalization in the previous year.

Results. Simple regression analysis demonstrated that speed of performance on the Trailmaking B and Cancellation Random Figure tests was significantly associated with total modified PPT score ($r = .29, p < .001$ and $r = .36, p < .001$, respectively). A factor analysis of the psychometric test battery demonstrated that two factors, a cognitive speed factor and a memory factor, accounted for 55% of the variance in cognitive test performance. Hierarchical multiple regression analyses demonstrated that age, number of medications, and the cognitive speed factor were independent predictors of total modified PPT score.

Conclusions. Cognitive processing speed is a significant component of physical frailty in this population, although it accounts for a small percentage of variance on a standardized physical performance test.

Declines in cognitive function associated with aging have been well described by a number of investigators. Cross-sectional studies have demonstrated that younger adults perform better than older adults on tests of short-term memory, psychomotor speed, visual–spatial praxis, concept formation, and visual–perceptual function (1,2). It has been postulated that the age-related declines in cognitive performance are due to more global declines in speed of information processing and ability to use short-term memory while information is being processed (3). It is also recognized that factors such as education (4,5) and physical fitness (6,7) interact with age-associated declines in cognitive function.

There is a paucity of information about the relationship between cognitive performance and physical functioning in older adults. Because aging of the central nervous system may limit adaptive responses that are necessary for independent functioning, it is important that we understand the contribution of cognitive impairments to declines in physical functioning. Poor performance on global measures of cognition is associated with disability in demented and nondemented populations (8–10). For example, Ferrucci and associates (8) reported that performance on the Block Design subtest of the Weschler Adult Intelligence Scale–Revised (WAIS–R) was associated with self-reported disability in an elderly sample without overt dementia, although the relationship was not significant in a multivariate model that included measures of health. Nevitt and coworkers (11) evaluated a cohort of elderly community-dwelling adults with a history of falls and found that slower performance on the Trailmaking B test increased the risk of injurious falls. This finding would suggest that impairment of cognitive processing speed may be an important component of postural stability which, in turn, may impair other measures of physical performance. Neither study included measures of other cognitive domains. The relationship between cognitive decline and physical disability is not well understood, in part because studies of disability have included a limited number of cognitive performance tests.

The aim of this study was to examine the relationship between performance on a number of cognitive measures assessing several domains of function and performance on a standardized multidimensional test of physical performance in a sample of older men and women. We tested the hypothesis that poor performance on tests of cognitive processing speed would be associated with poor physical performance.

Methods

Participants

The participants for this study were 125 men and women aged 75 years and older who did not engage in regular exercise and were enrolled in intervention trials of exercise or hormone replacement therapy. Participants provided written informed consent to participate in the study, which was approved by the Human Studies Committee of the Washington University School of Medicine, St. Louis.

Preliminary screening tests included a medical history, physical examination, the Short Blessed Test of memory, concentration, and orientation (12), blood and urine chemistries, and a chest x-ray. Self-report regarding medical diseases and hospitalization in the previous 12 months was validated by ascertaining medications used and by review of medical records.
Individuals were excluded from participation in the study if they: (a) were unable to walk 50 feet independently; (b) had any active medical problems that would contraindicate performance of a graded exercise stress test (e.g., unstable angina, clinically significant aortic stenosis, ventricular arrhythmias); (c) were unable to complete the graded exercise stress test or the modified PPT; (d) had a score greater than 8 on the Short Blessed Test or were unable to provide informed consent due to cognitive impairment; or (e) were unable to follow the directions for the psychometric tests due to visual or auditory impairments.

Psychometric Measures
Participants received a battery of psychometric tests administered by a trained interviewer. The cognitive tasks were chosen because of their ease of administration, brevity, and sensitivity to age-related changes in psychomotor speed and memory. In an effort to differentiate among people with varying degrees of impairment, we chose measures that would minimize ceiling effects. The following measures were included:

(a) Associate learning and 20-minute delayed recall.—This test (13) evaluates the individual’s ability to acquire and retain new verbal information. A set of 10 monosyllabic word pairs is presented at a rate of one pair every 2 seconds in each of three trials. After every trial the person is asked to reproduce the second word of the pair. The task is scored as the sum of the number of correct “easy” word pairs divided by 2 and added to the number of “hard” word pairs. Twenty minutes after the last trial the word pair list is read again, and the person is asked to reproduce the second word of each pair. Scoring is the same as for the initial trial.

(b) Word fluency (animal category).—The participant is asked to say as many unique animal names as possible in 60 seconds. The test (14) is scored as the total number of unique animal names produced.

(c) Trailmaking A.—This is a paper-and-pencil task that requires the person to connect numbered circles in numeric order (15,16). The task is timed with a maximal allowed time of 180 seconds, and the number of correctly drawn lines is recorded.

(d) Trailmaking B.—This is a paper-and-pencil task that requires the person to connect circles alternating between numbers and letters in numeric and alphabetical order (15,16). The task is timed with a maximal allowed time of 180 seconds, and the number of correctly drawn lines is recorded.

(e) Cancellation Random Letter Test and Random Figure Test.—Two visual target cancellation tests (17) were administered (random letter array and random figure array). For each test, 60 targets are displayed on a sheet of paper (21.6 × 27.8 cm). The midline of the participant’s body is aligned with the midline of the test sheet. Participants are instructed to locate and mark the appropriate targets (the letter “A” or an open circle with radiations and a single slanted line). The number of correctly identified targets is counted, and the task is timed.

(f) Geriatric Depression Scale—Short Form (GDS).—Because depression can affect cognitive performance, this measure (18) was included to assess for the presence of dysthymia.

Modified Physical Performance Test
We used an objective evaluation of physical function that was a modification of the Physical Performance Test (PPT) developed by Reuben and Siu (19,20) that correlates well with degree of disability, loss of independence, and mortality. Our modification, which focuses on gross motor function, substitutes the writing and eating tasks for two tasks (chair rise and a Romberg balance test) developed by Guralnik and colleagues (21,22). This modified PPT includes seven standardized tasks that are timed (50-foot floor walk, put on and remove a lab coat, pick up a penny from the floor, stand up five times from a 16-inch chair, lift a 7-pound book to a shelf, climb one flight of stairs, stand with feet in side-by-side, semi-tandem, and full-tandem positions), and two additional tasks (climb up and down four flights of stairs, performance of a 360° turn). The score for each item ranges between 0 and 4, with 36 representing a perfect total score for the test. Test–retest reliability of the total modified PPT score in our laboratory for this sample was 0.96 (intraclass coefficient).

Activities of Daily Living
The Older American Resource Services (OARS) instrument (23) was used to collect information about the use of human assistance or assistive technology for current task performance for basic (BADL) and instrumental (IADL) activities of daily living (ADLs). The Physical Function subscale of the Functional Status Questionnaire [FSQ; (24)] was used to collect information about difficulty with task performance over the previous month. The OARS BADL and IADL scales each have a maximum score of 14; the FSQ subscale has a maximum score of 36.

Statistical Analysis
The data were analyzed using SAS statistical software (SAS; Cary, NC) and SigmaPlot (SPSS Inc.; Chicago, IL). Pearson product correlations were calculated to evaluate the relationship between total modified PPT score and the demographic, ADL, health, and cognitive measures. Alpha was set at 0.05.

Factor analysis.—To reduce the number of independent variables and improve the robustness of the underlying cognitive constructs, a factor analysis of the psychometric data was performed using a principal components analysis with varimax rotation. The results of the factor analysis were interpreted using both the Kaiser-Guttman rule of retaining components with eigenvalues greater than 1.0 and examining the scree plots of eigenvalues versus their ordinal positions.

Regression analyses.—Simple linear regression was used to evaluate the relationship between each of the cognitive test scores and total modified PPT score. Multiple linear regression was used to determine the relationship between the cognitive factor scores, demographic variables, health variables, and total modified PPT score. Demographic variables included age, education, gender, race, and living arrangement. Health-related variables included GDS score, mean number of medications, and occurrence of hospitalization in the previous year. Exploratory models were constructed to analyze the relationship between each dependent variable and total modified PPT score. Variables were included in the final model only if they had a significant relation with PPT score after controlling for age.
RESULTS

Baseline characteristics of the participants are presented in Table 1. Participants were aged 75 to 94 years (mean 82.3 ± 4.5 years) and were predominately female (75%) and white (87%). Seventeen percent of the participants required assistance in two or more IADLs. Hypertension, degenerative joint disease, and coronary artery disease were the most frequently reported conditions. Twenty percent of the participants had been hospitalized in the previous 12 months. The mean GDS score (1.8 ± 1.8) was well within the normal range, and only 4% of the subjects were taking a benzodiazepine, minor sedative, or antidepressant medication. Pearson correlation analyses revealed that after controlling for age, OARS IADL and BADL score, FSQ score, number of routine medications, Trailmaking A time and number of lines completed, Trailmaking B time, and Cancellation Random Figure test (no.correct/s) was significantly related to total PPT score. Simple regression analysis also demonstrated that speed of performance on the Trailmaking B test (lines/s) and Cancellation Random Figure test (no.correct/s) was significantly associated with total modified PPT score (r = .29, p < .001 and r = .36, p < .001, respectively).

The principal components analysis revealed that two factors had eigenvalues above 1.0. The rotated factor scores accounted for 55% of the variance in cognitive test performance (Table 2). The six variables that loaded on Factor 1 were all components of the timed measures (Trailmaking A and B, Cancellation tests), whereas the three measures that loaded on Factor 2 included two memory tasks and the Short Blessed Test.

Results from the multiple regression analyses are presented in Table 3. Age accounted for 30% of the variance in PPT performance. When mean number of medications were included in the model, the explained variance in PPT score increased to 33%. In a hierarchical model that included age, number of medications, and the cognitive factor scores, the Factor 1 score (cognitive speed) was a significant independent predictor of total PPT score. The model R² value increased to 38%.

DISCUSSION

To the best of our knowledge, this is the first study examining the relationship between performance on a range of cognitive tests and a physical performance battery in a sample of older adults without overt dementia. Poorer performance on measures of cognitive processing speed was associated with worse performance on a modified PPT after adjustment for age and measures of health. Performance on tasks of memory did not predict physical performance. Our results indicate that cognitive processing speed is an independent predictor of physical performance and therefore may represent a factor contributing to physical frailty in this population. The amount of variance in PPT score explained by the Factor 1 score (cognitive speed measures) was only 5%, suggesting that other factors may play a larger role in predicting physical performance.

This study demonstrated significant associations between two timed cognitive measures and a PPT score. The Trailmaking tests and the Cancellation tests are both measures of cognitive processing and psychomotor speed. Both tests, however, also require other types of cognitive skills including visual scanning, attention, and learning. Because of the restricted number of tests that we were able to administer, we cannot differentiate between all the cognitive domains that may predict physical frailty in this population.

Table 1. Baseline Characteristics of the Sample (N = 125)

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
<th>Range</th>
<th>r</th>
<th>Partial r†</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPT score</td>
<td>27.9 ± 5.0</td>
<td>6-36</td>
<td>- .55***</td>
<td></td>
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<tr>
<td>Age</td>
<td>82.3 ± 4.4</td>
<td>75-95</td>
<td>.08</td>
<td>.05</td>
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<tr>
<td>Education (yr)</td>
<td>13.5 ± 3.0</td>
<td>6-17</td>
<td>- .02</td>
<td>-.03</td>
</tr>
<tr>
<td>Race (% Caucasian)</td>
<td>87</td>
<td>-</td>
<td>- .06</td>
<td>.04</td>
</tr>
<tr>
<td>Sex (% female)</td>
<td>75</td>
<td>-</td>
<td>- .06</td>
<td>.04</td>
</tr>
<tr>
<td>Living alone (%)</td>
<td>60</td>
<td>-</td>
<td>.11</td>
<td>.03</td>
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<tr>
<td>OARS IADL score</td>
<td>13.4 ± 0.9</td>
<td>9-14</td>
<td>.45***</td>
<td>.33***</td>
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<tr>
<td>OARS BADL score</td>
<td>13.0 ± 1.2</td>
<td>10-14</td>
<td>.27***</td>
<td>.26***</td>
</tr>
<tr>
<td>FSQ score</td>
<td>29.5 ± 4.1</td>
<td>16-36</td>
<td>.53***</td>
<td>.43***</td>
</tr>
<tr>
<td>&gt; 2 IADL impairments (%)</td>
<td>17</td>
<td>-</td>
<td>- .37***</td>
<td>- .22*</td>
</tr>
<tr>
<td>GDS score</td>
<td>1.8 ± 1.8</td>
<td>0-8</td>
<td>- .19*</td>
<td>- .15</td>
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<td>Routine medications</td>
<td>3.7 ± 2.2</td>
<td>0-9</td>
<td>- .16</td>
<td>- .24*</td>
</tr>
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<td>Hospitalization in previous year (%)</td>
<td>20</td>
<td>-</td>
<td>- .17*</td>
<td>- .14</td>
</tr>
<tr>
<td>Blessed score</td>
<td>2.1 ± 2.1</td>
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<td>.02</td>
<td>.03</td>
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<td>Verbal fluency</td>
<td>15.5 ± 4.5</td>
<td>6-31</td>
<td>.05</td>
<td>.01</td>
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<tr>
<td>Associated learning</td>
<td>13.3 ± 3.1</td>
<td>7-21</td>
<td>.02</td>
<td>.09</td>
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<td>20-min delayed recall</td>
<td>5.5 ± 1.2</td>
<td>2.5-7.0</td>
<td>- .05</td>
<td>- .17</td>
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<td>Trailmaking A time (s)</td>
<td>53.5 ± 25.3</td>
<td>18.0-180.0</td>
<td>- .34***</td>
<td>- .29***</td>
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<td>Trailmaking A no. lines</td>
<td>24.0 ± 0.3</td>
<td>21-24</td>
<td>.15</td>
<td>.28***</td>
</tr>
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<td>Trailmaking B time (s)</td>
<td>124.1 ± 39.9</td>
<td>18.0-180.0</td>
<td>- .23*</td>
<td>- .20*</td>
</tr>
<tr>
<td>Trailmaking B no. lines</td>
<td>22.6 ± 3.6</td>
<td>3-24</td>
<td>.25***</td>
<td>.15</td>
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<tr>
<td>Cancellation Letters time (s)</td>
<td>145.0 ± 56.0</td>
<td>68.9-364.2</td>
<td>- .17</td>
<td>- .15</td>
</tr>
<tr>
<td>Cancellation Letters no. correct</td>
<td>56.0 ± 4.2</td>
<td>35-60</td>
<td>.16</td>
<td>.06</td>
</tr>
<tr>
<td>Cancellation Figures time (s)</td>
<td>128.8 ± 47.7</td>
<td>61.8-300.2</td>
<td>- .37***</td>
<td>- .22*</td>
</tr>
<tr>
<td>Cancellation Figures no. correct</td>
<td>57.0 ± 4.0</td>
<td>38-60</td>
<td>.04</td>
<td>- .04</td>
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</tbody>
</table>

† Controlling for age.

*p < .05; **p < .01.
contribute to declines in physical performance. Slowing of cognitive processing speed is likely to impair the speed and accuracy of motor responses to postural perturbations (25). Postural instability in elderly adults is associated with fear of falling (26), which is associated with mobility restriction (27–29) and gait impairments (30). Thus, it is likely that older adults with impaired cognitive processing speed will have impaired postural control and motor slowing with consequent declines in their mobility. Inactivity could, in tum, lead to muscle atrophy and further declines in gait and balance that could contribute to the impairments in physical performance observed in this study.

The association between cognitive processing speed and physical performance demonstrated in this study does not answer the question as to whether poor cognitive processing speed causes declines in physical performance, or if declines in physical function contribute to cognitive/psychomotor slowing. Because the effects of Factor 1 on PPT score were independent of our measures of chronic illness (number of medications) and acute disease (hospitalization in previous year), it is possible that effect of cognitive slowing was mediated through the independent effects of aging on the brain. Our sample did not include individuals with more severe cardiovascular, cerebrovascular, or neurological disease. We cannot rule out, however, the possibility that such diseases could affect cognitive function, with subsequent decrements in physical function.

There is some evidence to suggest that physically fit older adults experience fewer profound declines in cognitive performance than do sedentary older adults (31,32). Most of the evidence for an association between fitness and cognition has been demonstrated by studies that included measures of cognitive processing and psychomotor speed such as simple and choice reaction time. Exercise intervention studies in older adults have not consistently demonstrated improvements in cognitive measures, despite clinically and statistically significant improvements in aerobic capacity (33,34). Other interventions to prevent the age-related decline in cognitive processing speed may prove beneficial in the prevention of frailty.

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