Clinical Interventions in Aging

Dovepress
open access to scientific and medical research

Open Access Full Text Article

ORIGINAL RESEARCH

Separate physical tests of lower extremities and postural control are associated with cognitive impairment. Results from the general population study Good Aging in Skåne (GÅS-SNAC)

This article was published in the following Dove Press journal:
Clinical Interventions in Aging
25 June 2012

Eva Bramell-Risberg[1]
Gun-Britt Jarnlo[2]
Sölve Elmståhl[1]

[1]Division of Geriatric Medicine, [2]Division of Physiotherapy, Department of Health Sciences, Lund University, Lund, Sweden

Purpose: To investigate whether separate physical tests of the lower extremities, that assess movement speed and postural control, were associated with cognitive impairment in older community-dwelling subjects.

Subjects and methods: In this population-based, cross-sectional, cohort study, the following items were assessed: walking speed, walking 2 × 15 m, Timed Up and Go (TUG) at self-selected and fast speeds, one-leg standing, and performance in step- and five chair-stand tests. The study comprised 2115 subjects, aged 60–93 years, with values adjusted for demographics, health-related factors, and comorbidity. Global cognitive function was assessed using the Mini-Mental State Examination (MMSE), and cognitive impairment was defined by the three-word delayed recall task of the MMSE. Subjects who scored 0/3 on the three-word delayed recall task were defined as cases (n = 328), those who scored 1/3 were defined as intermediates (n = 457), and the others as controls (n = 1330).

Results: Physical tests performed rapidly were significantly associated with cognitive impairment; this was the case in increased time of five chair stands ($P = 0.009$, odds ratio [OR] = 1.03), TUG ($P < 0.001$, OR = 1.11) and walking 2 × 15 m ($P < 0.001$, OR = 1.05). Inability to stand on one leg for 10 seconds was associated with increased risk of being a case ($P < 0.001$, OR = 1.78), compared to those able to stand for 30 seconds or longer. More steps during the step test ($P < 0.001$, OR = 0.95) and higher fast walking speed ($P < 0.001$, OR = 0.51) were associated with lower risk of being a case.

Conclusion: Slower movements and reduced postural control were related to an increased risk of being cognitively impaired. All tests that were performed rapidly were able to separate cases from controls. These findings suggest that physical tests that are related to lower extremity and postural control, emphasizing velocity, might be useful in investigating relationships between physical and cognitive function; furthermore, they can be used to complement cognitive impairment diagnoses.

Keywords: cognition, movement speed, TUG, walking

Introduction

Impaired motor function and motor slowing have been found in individuals with mild cognitive impairment, and the degree of impairment in lower extremity function is related to risk of Alzheimer's disease (AD).[1] Gait and cognitive function are closely related, both in normal aging and in age-associated dementias.[2] Slower walking speed is associated with, and predictive of, cognitive decline in cross-sectional[3] and longitudinal studies.[4–6] However, some studies have shown contradicting results

Correspondence: Eva Bramell-Risberg
Department of Health Sciences, Division of Geriatric Medicine, Skåne University Hospital, Malmö SE-205 02 Malmö, Sweden
Tel +46 40331000
Fax +46 40391313
Email eva.bramell-risberg@med.lu.se

http://dx.doi.org/10.2147/CIA.S31777

and limited generalization due to several factors, such as small study sample, few individuals above 80 years of age,[7–9] study sampling from outpatient clinics[7] or clinical trials,[3] and selection bias involving selection of best performers.[4] In addition, exclusion of potential confounders such as disease condition and life habits[7–9] have been found, as well as lack of controlling for confounders.[6–9]

Physical performance tests performed at high speed may require additional physiological reserves and impose higher demands on overall balance and attention control.[3] Some studies[1,6,10] have only used tests at self-selected speeds, whereas walking at a fast speed, for example, has been found to be a more sensitive measure in differentiating levels of cognition.[3] Different test methodologies and results, based on continuous, categorical, or composite measures, as well as the use of different rating systems, limit comparability.

Impaired memory is an early indicator of cognitive impairment.[11–13] Poor performance on delayed recall, as a marker of memory impairment,[14] and tests of executive function, are associated with a high risk of progression to dementia.[13,15,16] The Mini-Mental State Examination (MMSE), which addresses multiple cognitive domains, is widely used to detect cognitive impairment.[17] To our knowledge, no previous study has described the association of cognitive impairment, assessed by the three-word delayed recall task of the MMSE, with separate physical tests. To increase generalization, this was analyzed in a large study sample from an elderly general population, controlling for known confounders. The aim was to investigate whether separate physical tests of the lower extremities, which assess movement speed and postural control, were associated with cognitive impairment in elderly community-dwelling subjects.

Materials and methods

Study population

This investigation is part of an ongoing Swedish population study, "Good Aging in Skåne" (GÅS), which, in turn, is one of four components of the Swedish National Study on Aging and Care (SNAC).[18] The GÅS study includes men and women from nine age cohorts – 60, 66, 72, 78, 81, 84, 87, 90, and 93 years of age – randomized from five municipalities and covering both urban and rural areas using the National Municipality Registry. The GÅS study population was recruited between February 2001 and July 2004. Of the 4893 eligible subjects invited by letter to participate in the study, 2931 accepted the invitation (participation rate 60%). Subjects were investigated at the medical research center or, if that was inconvenient, in their own homes.

The exclusion criteria were dementia and stroke,[19,20] based on clinical examination, medical history, or information found in the National Diagnosis Register (which includes diagnoses for all inpatient cases in Swedish hospitals since 1987), and impaired global cognitive function, defined as a score below 24 on the MMSE.[17,20,21] Further exclusion criteria were depressive mood,[19,20] defined as a mean score above 20 on the Montgomery–Asberg Depression Rating Scale (MADRS),[22] and medication with neuroleptics.[23] Based on these criteria, 761 subjects were excluded, and an additional 55 subjects were excluded due to not having performed the walking test at a self-selected walking speed or the step test.

The total study population, thus, consisted of 2115 subjects – 974 men (46.1%) and 1141 women (53.9%), who were divided into three groups: 328 cases, 457 subjects in an intermediate group, and 1330 controls, according to the neuropsychological assessment by the MMSE. The 328 cases consisted of subjects who scored 0 out of 3 (0/3) on the three-word delayed-recall item of the MMSE. The intermediate group was made up of those who could recall one out of three words (1/3), and the 1330 controls scored 2/3 and 3/3.

The majority of subjects, 2060 (97.4%), were examined at the research center, and 55 (2.6%) were examined in their own homes. Subjects examined at home were older ($P < 0.001$), and the proportion of women was higher than that of men – 67% versus 33% ($P = 0.010$).

Data collection

Data were collected from medical history, clinical examination, neuropsychological evaluation, assessments of physical performance, and self-administered questionnaires regarding sociodemographic and health-related factors, ambulation, activities of daily living (ADL), and comorbidity.

Measurements of global cognitive function and memory

The MMSE[21] was part of the neuropsychological evaluation. MMSE scores range from 0 to 30 points, with a score below 24 indicating impaired global cognitive function.[17] The three-word delayed recall subtest of the MMSE, a brief measure of memory function,[24] was used to define the degree of cognitive impairment. The subscores of this test have shown better validity to assess episodic memory than the total MMSE score.[14] This subtest assesses the domain of episodic memory;[14,25] its scores range from 0 to 3, reflecting the number of words correctly recalled. In the present study, the words "key," "toothbrush," and "lamp" were used, and the subjects were informed that they would be asked to recall the words later. A score of 0 was used to define the case group with cognitive impairment.

Measurement of depressive illness

Depressive illness was assessed using the Montgomery–Asberg Depression Rating Scale,[22] a subscale of the Comprehensive Psychiatric Rating Scale.[26] Nine questions and one observational item cover the symptoms of the *DSM-IV* criteria[27] for depressive disorder. Symptoms and signs were rated on a scale ranging from 0 to 6 points, with a maximum score of 60. A mean score of 20 or less was defined as no severe depressive illness.[28]

Measurement of physical function

Timed Up and Go

The Timed Up and Go (TUG) test measures the time (in seconds) it takes to rise from a chair, walk 3 m, turn, walk back, and sit down again.[29] A chair with armrests and a seat height of 45 cm were used, and the time from leaving the seat until seated again was measured. The subjects were allowed to rise using their preferred method. High test–retest[30] and intra- and inter-rater reliability[29] have been demonstrated for this test in older people, and the results show correlation with the Berg Balance Scale ($r = -0.81$) and self-selected walking speed ($r = -0.61$).[29]

Walking 15 m and 2 × 15 m, including a 180° turn

From a 2 m flying start, the subjects were instructed to walk 15 m, turn at a marker, and return to and pass the starting point before stopping. The time was recorded for the first 15 m and 2 × 15 m for both self-selected and fast speeds. The walking speed (WS) was calculated (m/s), using the time for the first 15 m. Measures of WS at both self-selected and high speeds have been found to be highly reliable (intraclass correlation [ICC] $\geq$ 0.903) and significantly correlated with muscle strength in the lower extremities.[31] The 2 × 15 m walking test is a more complex test, which includes both a longer walking distance and a provocation of balance. The reliability of the 2 × 15 m walking test at both speeds has been shown to be very high in elderly women (ICC 0.95–0.98). The results also correlated with balance tests, such as one-leg standing (OLS) and tandem stance ($r = 0.39$–0.64).[32]

Step test

Subjects were placed in front of a block 7.5 cm high, positioned stably against a wall. The subjects stood, with feet parallel, at a marked distance of 5 cm from the block. They were asked to place one foot entirely on the block and then return it to the floor, repeatedly, as quickly as possible. Subjects were unsupported, but the examiner stood close by for safety. The total number of steps completed during 15 seconds was recorded, first for the right and then for the left leg.[33] The best value from two tests of each leg was used in the analysis. The test has been shown to be reliable (ICC $>$ 0.90) and to correlate with self-selected walking speed.[33]

Chair stands

Subjects were asked to rise from a chair, five times, as quickly as possible, with their arms folded and their hands on their shoulders. The chair had no armrests, and the height of the seat was 45 cm. Subjects were instructed to stand up completely between repetitions. Before the test, the subjects were asked to rise without using their hands, to ensure that the procedure was safe. The test was performed once, and the time required to complete five stands was recorded. High reliability coefficients have been reported ($r = 0.80$; ICC = 0.89, 95% confidence interval [CI] = 0.79, 0.95).[34,35] Performance is associated with muscle strength and balance, as well as sensorimotor and psychological factors.[36]

One-leg standing – eyes open

With their eyes open and their arms loosely hanging, the subjects were asked to stand first on the right leg and then on the left leg, for as long as possible. The raised leg was flexed at the knee joint, with the foot well off the floor. Timing began when the subject lifted the foot. For safety, the examiner stood close to the subject throughout the tests. The clock was stopped when the subject touched the floor with the raised foot, changed the position of the supporting foot, or after 60 seconds had elapsed. Subjects were barefoot during the test, and a trial was carried out before testing. The best result of two tests was used in the analysis. Performance was categorized into four categories: $<$10 seconds, $<$20 seconds, $<$30 seconds, and $\geq$30 seconds. The reliability has been shown to be moderate ($r = 0.69$),[34] to high (ICC = 0.93–0.99)[37] in middle-aged and older people.

Procedures of measurements of physical function

Each subject was given verbal instructions and a demonstration of each test. Each subject was tested on a single occasion, and the tests were carried out in the following order: OLS, step test, chair stands, TUG, and walking 2 × 15 m. Subjects wore their ordinary shoes, except in the OLS test. A standard digital stopwatch was used. For the TUG and walking test at self-selected speed, the instructions were to walk at a normal, comfortable speed; for fast speed, the instructions were to walk as fast as possible without running. The walking test was performed in a hospital corridor; this test was not carried out in the participants' homes. The subjects were allowed to rest for approximately 2 minutes between each test. The TUG test and walking 2 × 15 m, including a 180° turn, were performed first at the self-selected speed and then at maximal (fast) walking speed. Subjects who performed the TUG and walking tests with walking aids were not included in the analysis.

Covariates

Sociodemographic data included age, sex, marital status, place of residence, and education. Functional status included data on walking ability, personal activities of daily living (P-ADL), and instrumental activities of daily living (I-ADL).[38] P-ADL included bathing, dressing, toileting, rising from bed/chair, continence, and feeding, while I-ADL included cleaning, shopping, transportation, and cooking. Detailed descriptive data are provided in Tables 1 and 2.

Health status included smoking and drinking habits and physical activity during the past year (Table 2). Comorbidity was based on questions regarding specific diseases, medical history, medication, clinical examination, and questionnaires. Comorbidity was classified according to the International Classifications of Diseases and Related Health problems, and congestive heart failure was classified according to the New York Heart Association criteria[39] (Table 2). Physiological measures included anemia, defined by the Department of Clinical Chemistry, Malmö University Hospital as <117 g/dL hemoglobin (Hb) for women and <134 g/dL Hb for men, and body mass index, computed as weight in kilograms divided by the square of height in meters (Table 2). Data on sociodemographics, health-related factors, and functional status were self-reported. Medical assessment was performed by a physician, and cognitive function was assessed by a specially trained behaviorist in psychology. Assessment of pain and physical performance tests were conducted by trained, registered nurses. All subjects were asked if they experienced pain in their back or in any joints of the lower extremities during rising, standing, walking, and climbing stairs. Pain was dichotomized into yes/no. Joint pain in the legs was not differentiated according to joint.

Statistical analysis

Differences between the three groups were assessed with a Chi-square test and regression analysis. Comparisons were made between groups for the variables listed in Table 2. Confounders with a P-value below 0.05, listed in Table 2, were adjusted for in the model. The association between cognitive impairment, categorized into three groups, as the dependent variable, and the results of physical performance tests, as independent variables, was tested using an ordinal regression model. A separate regression model was computed for each test, including adjustment for confounders. To reduce the effect of skewed distribution of the results of the OLS test, the data were categorized into time categories used by others to assess balance.[40–42]

Table 3 presents descriptive data from the performance of physical tests for cases, intermediates, and controls, stratified according to age. No further stratification was made, due to the limited numbers in each group. For the physical performance tests significantly related to the grouping variable in the ordinal regression models, additional analysis was performed to study the extent of the association between them and cognitive impairment. A general linear model was employed, using each test as the dependent variable and

Table 1 Characteristics of the participants (n = 2115)

	Cases n = 328	Intermediates n = 457	Controls n = 1330
Age, mean ± SD	75.8 ± 10.2	71.8 ± 9.5	69.0 ± 9.1
Male/female (%)	(50.9/49.1)	(50.1/49.9)	(43.5/56.5)
Age groups, n (%)			
Males			
60–69 years	64 (38.3)	129 (56.3)	398 (68.9)
70–79 years	46 (27.5)	51 (22.3)	92 (15.9)
≥80 years	57 (34.1)	49 (21.4)	88 (15.2)
Females			
60–69 years	45 (28.0)	86 (37.7)	456 (60.6)
70–79 years	33 (20.5)	75 (32.9)	130 (17.3)
≥80 years	83 (51.6)	67 (29.4)	166 (22.1)
Marital status, n (%)			
Married/cohabiting	155 (47.8)	269 (59.5)	810 (61.2)
Widow/widower	107 (33.0)	92 (20.4)	225 (17.0)
Divorced/not cohabiting	41 (12.7)	66 (14.6)	197 (14.9)
Unmarried	21 (6.5)	25 (5.5)	91 (6.9)
Place of residence, n (%)			
Rural	30 (9.3)	44 (9.8)	132 (10.0)
Urban	294 (90.7)	407 (90.2)	1190 (90.0)
Walking ability, n (%)			
Independent walking	271 (82.6)	414 (90.6)	1229 (92.4)
Dependent on walking aids/wheelchair	57 (17.4)	43 (9.4)	101 (7.6)
P-ADL, n (%)			
Dependent in ≤1 activity	310 (98.7)	438 (99.1)	1304 (99.7)
I-ADL, n (%)			
Dependent in ≤1 activity	293 (92.7)	410 (94.0)	1239 (95.6)

Abbreviations: SD, standard deviation; P-ADL, personal activities of daily living; I-ADL, instrumental activities of daily living.

Table 2 Comparisons of the covariates education, health indicators, and comorbidity between cases, intermediates, and controls (n = 2115)

	Cases n = 328	Intermediates n = 457	Controls n = 1330	*P*
Education				<0.001
Elementary school not completed	6 (1.9)	20 (4.4)	27 (2.0)	–
Elementary school completed	190 (58.6)	246 (54.5)	586 (44.4)	–
Secondary school completed	80 (24.7)	119 (26.4)	401 (30.4)	–
≥1 year extra study or university with/without degree	48 (14.8)	66 (14.6)	307 (23.2)	–
Smoking habits				ns
Current smoker	44 (13.6)	82 (18.2)	245 (18.5)	–
Stopped smoking	121 (37.3)	165 (36.7)	532 (40.2)	–
Never smoked	159 (49.1)	203 (45.1)	546 (41.3)	–
Drinking habits				<0.001
No alcohol/drank alcohol a few times during the past year but not during the past month	126 (39.1)	165 (36.9)	358 (27.2)	–
Drank alcohol during the past month	196 (60.9)	282 (63.1)	960 (72.8)	–
Physical activity during the past year				0.001
Hardly any, mostly sedentary	67 (20.7)	89 (19.8)	184 (13.9)	–
Light activity (2–4 hours/week)	168 (52.0)	217 (48.2)	652 (49.4)	–
Strenuous activity (1–2 hours several times per week)	88 (27.2)	144 (32.0)	483 (36.6)	–
Comorbidity				
Pulmonary disease (asthma, chronic bronchitis, emphysema)	44 (13.5)	57 (12.5)	142 (10.7)	ns
Coronary heart disease (myocardial infarction, angina)	58 (17.7)	89 (19.5)	171 (12.9)	0.001
Diabetes	25 (7.6)	28 (6.1)	82 (6.2)	ns
Rheumatoid arthritis	22 (6.8)	19 (4.2)	62 (4.7)	ns
Neurological disease	1 (0.3)	9 (2.0)	22 (1.7)	ns
Osteoarthritis of knee/hip	76 (23.2)	88 (19.3)	215 (16.2)	0.009
Fractures of lower extremities	32 (9.8)	46 (10.1)	100 (7.5)	ns
Congestive heart failure with symptoms	34 (10.7)	39 (8.8)	51 (3.9)	<0.001
Anemia	32 (9.8)	35 (7.7)	63 (4.7)	0.001
BMI				ns
Normal weight, BMI ≤ 24.99	112 (34.5)	158 (34.8)	473 (35.6)	–
Overweight, BMI 25.0–29.99	144 (44.3)	197 (43.4)	598 (45.1)	–
Obese, BMI ≥ 30.0	69 (21.2)	99 (21.8)	256 (19.3)	–
Pain				
Back	101 (30.8)	121 (26.5)	374 (28.1)	ns
Right leg	103 (31.4)	150 (32.8)	429 (32.3)	ns
Left leg	107 (32.6)	135 (29.5)	394 (29.6)	ns
Medication				
Use of sedatives	47 (14.3)	59 (12.9)	184 (13.8)	ns

Note: The values given are numbers of subjects, with percentages in parentheses.
Abbreviations: *P*, probability; BMI, body mass index; ns, not significant.

cognitive impairment, categorized into the three groups, as the independent variable. A contrast test was performed to assess the difference between intermediates and controls. Each model was adjusted for the same confounders mentioned above.

All calculations were performed using SPSS software Windows (v 18.0 IBM Corporation, Armonk, NY). The level of significance was set to less than 0.05.

Ethics

The study was approved by the Regional Ethical Review Board, Lund University (LU 744-00). All participants gave written consent.

Results

The age ($P < 0.001$) and sex ($P = 0 .008$) distributions differed significantly among the three groups. Cases were older than both of the other groups, and the proportion of women was higher in the control group (Table 1). A higher proportion of individuals in the control and intermediate groups were married/cohabiting than in the case group. There were more widows/widowers in the case group than in the two other groups. Regarding walking ability, more dependence on walking aids was found among the cases than in the other two groups. No differences were found among the groups regarding place of residence and ADL (Table 1). Total independence in P-ADL was noted in 73.9% of the cases,

Table 3 Results of the physical performance tests for cases, intermediates, and controls stratified according to age

	Cases		Intermediates		Controls	
	n	mean ± SD	n	mean ± SD	n	mean ± SD
Step test, right leg (n)						
60–69	109	17.3 ± 5.21	214	17.3 ± 4.08	845	18.2 ± 4.37
70–79	74	13.8 ± 3.63	123	14.8 ± 4.28	219	15.8 ± 4.12
≥80	121	12.4 ± 3.94	107	12.4 ± 3.74	236	13.0 ± 4.07
Step test, left leg (n)						
60–69	109	17.6 ± 5.20	212	17.3 ± 3.93	841	18.2 ± 4.20
70–79	75	13.8 ± 3.54	123	14.8 ± 4.16	218	15.8 ± 3.91
≥80	122	12.0 ± 3.65	106	12.5 ± 3.76	235	12.7 ± 3.96
Chair stands (s)						
60–69	108	10.8 ± 5.04	214	10.4 ± 3.49	837	10.1 ± 2.81
70–79	72	12.7 ± 3.69	116	12.4 ± 3.74	218	11.2 ± 3.04
≥80	115	14.6 ± 5.70	100	14.0 ± 4.99	222	14.2 ± 5.47
TUG self-selected speed[a] (s)						
60–69	109	8.9 ± 1.65	215	9.0 ± 1.92	849	8.8 ± 1.67
70–79	75	11.1 ± 2.35	123	10.7 ± 2.60	221	10.0 ± 2.14
≥80	120	13.1 ± 4.01	104	12.2 ± 3.42	223	12.7 ± 3.75
TUG fast speed[a] (s)						
60–69	109	6.9 ± 1.44	215	6.8 ± 1.32	849	6.6 ± 1.27
70–79	75	8.3 ± 1.61	122	8.2 ± 1.76	220	7.7 ± 1.66
≥80	120	10.5 ± 3.78	104	9.4 ± 2.47	224	9.6 ± 2.51
Self-selected WS[a] (m/s)						
60–69	109	1.5 ± 0.26	214	1.5 ± 0.21	846	1.5 ± 0.21
70–79	73	1.3 ± 0.20	120	1.3 ± 0.19	220	1.3 ± 0.21
≥80	105	1.1 ± 0.19	92	1.2 ± 0.18	186	1.1 ± 0.20
Fast WS[a] (m/s)						
60–69	109	1.8 ± 0.34	214	1.8 ± 0.30	844	1.9 ± 0.30
70–79	73	1.5 ± 0.25	119	1.6 ± 0.26	219	1.6 ± 0.31
≥80	105	1.4 ± 0.26	92	1.4 ± 0.27	186	1.4 ± 0.26
Time 2 × 15 m, self-selected speed[a] (s)						
60–69	109	22.2 ± 4.19	214	22.2 ± 3.42	847	22.1 ± 3.48
70–79	73	25.9 ± 4.07	120	25.7 ± 3.98	219	24.8 ± 4.65
≥80	104	28.8 ± 4.82	90	27.9 ± 4.46	186	28.7 ± 6.00
Time 2 × 15 m, fast speed[a] (s)						
60–69	109	18.2 ± 3.80	214	18.2 ± 4.86	845	17.6 ± 3.23
70–79	73	21.6 ± 4.20	119	21.1 ± 3.69	219	20.1 ± 3.68
≥80	104	24.5 ± 5.59	92	23.3 ± 4.59	186	23.4 ± 4.40

Note: [a]Only the results from subjects not needing walking aids to perform the test were included in the analysis.
Abbreviations: SD, standard deviation; TUG, Timed Up and Go; WS, walking speed.

78.7% in the intermediate group, and 80.4% of the controls. The corresponding values for I-ADL were 82.3%, 81.4%, and 86.8%, respectively.

Cases were not able to increase their walking speed from self-selected to fast speed as much as the controls and intermediates were. Subjects 60–69 years old were faster and performed better than those in the older age groups. However, differences in mean values for the three groups, stratified according to age, were small (Table 3). In the adjusted model, the association between cognitive impairment and the results of the physical performance tests was significant for the five tests performed at fast speed. The corresponding analysis for tests performed at self-selected speed showed no significant associations (Table 4). An increase in the time required to perform five repeated chair stands, the TUG test, and walking 2 × 15 m at fast speed was associated with being a case and, thus, with increased risk of being cognitively impaired. A greater number of steps during the step test and a higher WS at the higher speed were associated with decreased risk of being a case (Table 4).

All physical tests analyzed with a general linear model adjusted for confounders showed significant differences between cases and controls (Table 5). The performance of the TUG test at fast speed also differed between cases and intermediates (Table 5). The results of the step test (both left

Table 4 Multiple ordinal regression of cognitive impairment, with controls, intermediates, and cases as the dependent variable, and separate physical performance tests[a], adjusted for confounders

Physical performance test[b]	n	Estimate	*P*	OR	95% CI
Step test, right leg (n)	1970	–0.049	<0.001	0.95	0.93–0.98
Step test, left leg (n)	1964	–0.046	<0.001	0.96	0.93–0.98
Chair stands (s)	1931	0.033	0.009	1.03	1.01–1.06
TUG self-selected speed[c] (s)	1960	0.024	0.216	1.02	0.99–1.06
TUG fast speed[c] (s)	1958	0.102	<0.001	1.11	1.05–1.17
Self-selected WS[c] (m/s)	1891	–0.204	0.416	0.82	0.50–1.33
Fast WS[c] (m/s)	1887	–0.678	<0.001	0.51	0.35–0.73
Time, 2 × 15 m, self-selected speed[c] (s)	1888	0.006	0.621	1.01	0.98–1.03
Time, 2 × 15 m, fast speed[c] (s)	1887	0.051	<0.001	1.05	1.03–1.08
OLS <10s, right leg	1877	0.376	0.006	1.46	1.11–1.91
OLS <20s, right leg	–	0.487	0.002	1.63	1.20–2.21
OLS <30s, right leg	–	0.192	0.321	1.21	0.83–1.77
OLS <10s, left leg	1874	0.578	<0.001	1.78	1.34–2.37
OLS <20s, left leg	–	0.295	0.060	1.34	0.99–1.82
OLS <30s, left leg	–	0.409	0.031	1.51	1.04–2.19

Notes: [a]Multiple ordinal regression with controls, intermediates, and cases (highest category) as dependent variable; [b]adjusted for age, sex, education, drinking habits, physical activity during the past year, anemia, coronary heart disease, congestive heart failure with symptoms, and osteoarthritis of the hip/knee; [c]only the results from subjects not needing walking aids to perform the test were included in the analysis.
Abbreviations: *P*, probability; OR, odds ratio; CI, 95% confidence interval; TUG, Timed Up and Go; WS, walking speed; OLS, one-leg standing, eyes open.

and right legs), WS, and walking 2 × 15 m at the higher speed were also significantly different between the controls and intermediates. The test that showed a tendency to differentiate among all three groups was walking 2 × 15 m at higher speed (Table 5). OLS was more impaired in cases and intermediates, who showed poorer performance in the OLS test than did the controls (Table 4). An inability to stand on one leg for 10 seconds was associated with increased risk of being a case, compared to those able to stand for 30 seconds or longer.

Table 5 An adjusted general linear model[b] between separate performance tests and cognitive impairment for cases, controls, and intermediates

Physical performance test[a]	Controls/intermediates vs cases			Intermediates vs controls
	B	*P*	95% CI	*P*[d] 95% CI
Step test, right leg (n)				
Controls	0.794	0.002	0.28–1.31	0.006
Intermediates	0.183	0.541	–0.40–0.77	–1.05 to –0.18
Step test, left leg (n)				
Controls	0.721	0.005	0.22–1.22	0.023
Intermediates	0.228	0.433	–0.34–0.80	–0.92 to –0.07
Chair stands (s)				
Controls	–0.614	0.013	–1.10 to –0.13	0.195
Intermediates	–0.344	0.222	–0.90–0.21	–0.14–0.68
TUG fast speed[c] (s)				
Controls	–0.454	<0.001	–0.67 to –0.24	0.360
Intermediates	–0.367	0.004	–0.62 to –0.12	–0.10–0.27
Fast WS[c] (m/s)				
Controls	0.055	0.002	0.02–0.09	0.036
Intermediates	0.023	0.266	–0.02–0.06	–0.06 to –0.00
Time, 2 × 15 m, fast speed[c] (s)				
Controls	–0.931	<0.001	–1.41 to –0.45	0.047
Intermediates	–0.519	0.063	–1.07–0.03	0.01–0.82

Notes: [a]Adjusted for age, sex, education, drinking habits, physical activity during the past year, anemia, coronary heart disease, congestive heart failure with symptoms, and osteoarthritis of the hip/knee; [b]the case group was the reference; [c]only the results from subjects not needing walking aids to perform the test were included in the analysis.
Abbreviations: B, estimate; *P*, probability; *P*[d], *P*-value for comparison between intermediates and controls; OR, odds ratio; CI, 95% confidence interval; TUG, timed up and go; WS, walking speed; OLS, one-leg standing, eyes open.

The proportion of low achievers (<10 seconds) among cases was, for right/left leg, 50%/51%, compared with 28%/26% among the controls ($P < 0.001$). The corresponding proportions for high achievers (≥30 seconds), for right/left leg, were 28%/27% and 53%/53%, respectively ($P < 0.001$).

Discussion

In this cross-sectional, population-based study, we found a significant association between cognitive impairment and measures of physical performance targeting the lower extremities, speed of movement, coordination, and postural control. In the adjusted model, the results of physical performance tests performed at high speed and the OLS test were significantly associated with cognitive impairment. The results of this study showed that separate, objective, performance-based measures related to lower extremity function and postural control, which emphasize speed and challenge physical capacity, are useful in investigating the relationships between physical and cognitive function. This is in agreement with studies made by such authors as Tabbarah et al,[4] Wang et al,[43] Aggarwal et al,[1] Fitzpatrick et al,[3] Eggermont et al,[10] and Bottiggi and Harrison.[44] However, comparisons with the results of previous research may be difficult, due to differences in study design and test methodology.

We found that slower speed in the fast-walking condition was associated with cognitive impairment, in agreement with previous studies.[3–5,45] Poor performance in fast WS was found to be more predictive of significant cognitive decline over a 3-year follow-up than performance in self-selected WS.[5] Tabbarah et al[4] reported that fast WS was related to baseline cognition, and that subjects with poorer baseline cognition were more likely to experience a decline in fast WS. Fitzpatrick et al[3] found that the risk of low cognition was almost twice as great in slow walkers than in fast walkers when measuring fast WS. Others have found self-selected WS to be associated with cognitive impairment.[6,46–48] In our study we found no such association, which may be due to our study design. The subjects were provided with several meters to accelerate and decelerate before and after the test, as well as a long walking distance, which are methods that have been recommended to achieve a steady state of walking in the frail elderly.[49] In our study, a longer time to perform the walking 2 × 15 m test was related to increased risk of being cognitively impaired, but only at the higher walking speed. The ability to turn is related to cognitive impairment,[4] and it was included in this test. The requirements of high speed during walking, the long distance, and the 180° turn may have challenged level of fitness, endurance, and postural control. Correlations have been found between the results of this test and several balance measures.[32]

Walking has generally been viewed as a largely automated motor task that requires minimal higher-level cognitive input. This view may be too simplistic and, in fact, walking may be a complex motor task that demands attention and is related to higher cognitive functions, such as executive function.[50–53] Gait parameters have been found to be associated with a decline in specific cognitive domains.[45,47,50] Hausdorff el al[50] found higher self-selected walking speed to be associated with good performance in executive function, but not with memory or cognitive function in general in community-dwelling subjects. In their prospective study, Verghese et al[47] found that declines in memory and executive function were associated with gait velocity. Soumaré et al[45] found a slower fast WS at baseline, as well as the degree of decline in fast WS, to be associated with poorer performance in cognitive tests of verbal fluency and psychomotor speed.

The TUG test is a test of basic functional mobility, and its performance has been found to be correlated with balance, gait speed, and functionality.[29,54] The standard procedure adopted in the test is to walk at a self-selected speed; however, in our study, the subjects were also asked to walk as fast as possible without running. TUG test performance at self-selected speed was found to be significantly different between controls and subjects with AD, but not between controls and subjects with mild cognitive impairment.[10] We found TUG time to be associated with cognitive impairment at the higher speed, but not at the self-selected walking speed, which is in agreement with the findings of others who urged their subjects to perform the test at a higher speed.[55] A longer time on the TUG test, performed at fast speed, has also been associated with lower executive function.[53]

The chair stand test has been regarded as an indicator of lower limb strength in older people; however, performance is also influenced by other physiological and psychological factors related to balance and mobility.[36] The test procedure used may vary in the following factors: starting the timing; whether the timing ceases after completing the fifth stand or upon returning to a seated position after the last stand; whether support of the arms is allowed; and whether speed of performing the task is stipulated or not.[56] We used the procedure proposed by Bohannon,[56] timing five completed stands, with the emphasis on fast performance and performing the test without support of the upper limbs. We found this test to be associated with cognitive impairment, in agreement with earlier studies,[4,48] while others have not.[43,57]

Performance-based measures of balance have been described as attention-demanding physical tasks.[4] The step test measures the speed of stepping movements during a dynamic standing task.[33] It is a complex test that challenges both stability and dynamic postural control. The test is performed at high speed, and it includes alternating movement patterns. To perform the task quickly, the subject must actively stop and reverse the direction of the moving leg, which places high demands on stability, limb coordination, and coordinated muscle activity in different muscle groups. Apart from demands on coordination of motor and postural control, the task also requires attention, planning, timing of movement sequences, and self-monitoring of motor behavior, which reflect executive function.[52,58] We found an increase in the number of steps, ie, high movement speed, indicating good postural stability, to be associated with a lower risk of being cognitively impaired. Previous research has shown that slowing of rapid, alternating movements is associated with cognitive impairment;[59] however, to the best of our knowledge, no one has studied how the step test is associated with cognition.

Using a composite measure score of balance, Wang et al[43] found better balance to be associated with a lower risk of dementia, and the presence of poor balance to predict future cognitive decline in healthy older adults. We found poor performance of the OLS test to be related to an increased risk of being cognitively impaired, as have others.[4,42] About half of our cases were not capable of balancing on one leg for 10 seconds and, compared to the controls, a considerably lower proportion was able to stand on one leg for $\geq$30 seconds. When using the ability to stand on one leg for up to 10 seconds as a time limit, Tabbarah et al[4] found low OLS time to be related to a decline in cognitive performance.

The three-word recall task of the MMSE has been found to be a good and valid measure of memory impairment to assess the domain of episodic memory, one of the earliest domains to decline in the course of cognitive impairment and incident dementia.[14] The use of the subtest scores of the three-word recall item together with the total scores of the MMSE may increase the sensitivity of the MMSE in screening for mild cognitive impairment.[60] The methodology of the three-word recall has been discussed previously.[59] The three-word recall item has been shown to be sensitive to memory decline in older adults.[24] However, variability in this test has been found among healthy elderly subjects as well,[61] which may have led to misclassification of some of our subjects and, thus, affected the results. To reduce the effect of variability, adjustments were made for age, and prompting was used, as suggested by Chandler et al.[24] We categorized the scores of delayed recall into three groups, to study whether physical performance tests were able to differentiate cases from controls and intermediates. It was found that all the physical tests performed at high speed were able to separate cases from controls. WS, walking 2×15 m, and the step test also differentiated controls from intermediates. However, the lack of differentiation between cases and intermediates may indicate some degree of misclassification, or that moderate cognitive impairment also is related to physical performance. Our data indicate, from a clinical point of view, that tests of physical function that are performed at high speed, especially the step test and TUG, seem to be the most sensitive indicators of early memory decline.

Physical tests performed at higher speeds may challenge the overall balance control system, necessitating attention and conscious control. The motor tests chosen may seem simple, but they require complex motor skills and psychomotor coordination, as well as the ability to sustain attention during a sequence of goal-directed movements. The anatomical network of motor control is interlinked with the network of higher-level cognitive processes, in particular executive functions, which are necessary for the implementation of goal-directed behavior.[51] As mentioned previously, associations have been found between the results of physical performance tests and executive function.

The strengths of the present study are that it is a population-based cohort study, involving a large number of old to very old community-dwelling people without clinical dementia. Examinations were conducted both at the research center and at the subjects' homes, in order to reduce the effect of selection bias of the frailest individuals. Established, separate standardized tests of physical performance were applied and assessed by trained, licensed nurses. Several possible confounders that could influence the test results were also taken into account, such as comorbidity, education, lifestyle factors, medication, and pain. Using measures that are educationally unbiased may be of value when assessing elderly people with varying or lower levels of education, or backgrounds that differ linguistically or culturally.[62] Physical performance tests that assess postural control and movements of the lower extremities that are sensitive to cognitive decline may facilitate early diagnosis and the identification of elderly people in need of monitoring, with regard to both cognitive and physical function.

A limitation of this study is that only subjects attending the research center performed the 2×15 m walking test, possibly excluding more frail individuals and introducing a floor effect on parameters related to this test. One consequence of this may be that the actual differences in functioning may have been greater than those observed. Another limitation is that neuropsychological measurements were not included in this study to evaluate components of executive function. Therefore, no conclusions can be drawn regarding the relationship between the tests used and executive function.

Conclusion

Slower movement speed and poor postural stability were related to an increased risk of being cognitively impaired, while higher movement speed and good postural stability were related to decreased risk. All tests performed at a rapid rate of speed were able to differentiate cases from controls. The TUG test, a test of complex motor functions that challenges postural control and adaptive motor behavior, when performed at high speed, was found to be best at differentiating cases from intermediates. The test that was best at differentiating between controls and intermediates was the attention-demanding alternating step test performed at high speed, challenging postural control. Forthcoming longitudinal follow-up studies will indicate the possible benefit of using separate measures of motor function and postural control as additional predictive measures of early cognitive decline, especially memory impairment, as a potential marker of early neurodegenerative disease.

Acknowledgments

The project "Good Aging in Skåne", part of the Swedish National study on Aging and Care (http://www.snac.org; http://www.skane.se/sus/geriatrik), is supported by the Swedish Ministry of Health and Social Affairs, the county of Region Skåne, and the Medical Faculty of Lund University.

Disclosure

The authors report no conflicts of interest in this work.

References

1. Aggarwal NT, Wilson RS, Beck TL, Bienias JL, Bennett DA. Motor dysfunction in mild cognitive impairment and the risk of incident Alzheimer disease. *Arch Neurol*. 2006;63(12):1763–1769.
2. Scherder E, Eggermont L, Swaab D, et al. Gait in ageing and associated dementias; its relationship with cognition. *Neurosci Biobehav Rev*. 2007;31(4):485–497.
3. Fitzpatrick AL, Buchanan CK, Nahin RL, et al. Associations of gait speed and other measures of physical function with cognition in a healthy cohort of elderly persons. *J Gerontol A Biol Sci Med Sci*. 2007;62(11):1244–1251.
4. Tabbarah M, Crimmins EM, Seeman TE. The relationship between cognitive and physical performance: MacArthur Studies of Successful Aging. *J Gerontol A Biol Sci Med Sci*. 2002;57(4):M228–M235.
5. Deshpande N, Metter EJ, Bandinelli S, Guralnik J, Ferrucci L. Gait speed under varied challenges and cognitive decline in older persons: a prospective study. *Age Ageing*. 2009;38(5):509–514.
6. Buracchio T, Dodge HH, Howieson D, Wasserman D, Kaye J. The trajectory of gait speed preceding mild cognitive impairment. *Arch Neurol*. 2010;67(8):980–986.
7. Kluger A, Gianutsos JG, Golomb J, et al. Patterns of motor impairment in normal aging, mild cognitive decline, and early Alzheimer's disease. *J Gerontol B Psychol Sci Soc Sci*. 1997;52(1):P28–P39.
8. Franssen EH, Souren LE, Torossian CL, Reisberg B. Equilibrium and limb coordination in mild cognitive impairment and mild Alzheimer's disease. *J Am Geriatr Soc*. 1999;47(4):463–469.
9. Camicioli R, Howieson D, Oken B, Sexton G, Kaye J. Motor slowing precedes cognitive impairment in the oldest old. *Neurology*. 1998;50(5): 1496–1498.
10. Eggermont LH, Gavett BE, Volkers KM, et al. Lower-extremity function in cognitively healthy aging, mild cognitive impairment, and Alzheimer's disease. *Arch Phys Med Rehabil*. 2010;91(4):584–588.
11. Winblad B, Palmer K, Kivipelto M, et al. Mild cognitive impairment – beyond controversies, towards a consensus: report of the International Working Group on Mild Cognitive Impairment. *J Intern Med*. 2004; 256(3):240–246.
12. Chen P, Ratcliff G, Belle SH, Cauley JA, DeKosky ST, Ganguli M. Cognitive tests that best discriminate between presymptomatic AD and those who remain nondemented. *Neurology*. 2000;55(12): 1847–1853.
13. Blacker D, Lee H, Muzikansky A, et al. Neuropsychological measures in normal individuals that predict subsequent cognitive decline. *Arch Neurol*. 2007;64(6):862–871.
14. Carcaillon L, Amieva H, Auriacombe S, Helmer C, Dartigues JF. A subtest of the MMSE as a valid test of episodic memory? Comparison with the Free and Cued Reminding Test. *Dement Geriatr Cogn Disord*. 2009;27(5):429–438.
15. Small BJ, Fratiglioni L, Viitanen M, Winblad B, Backman L. The course of cognitive impairment in preclinical Alzheimer disease: three- and 6-year follow-up of a population-based sample. *Arch Neurol*. 2000;57(6):839–844.
16. Gauthier S, Reisberg B, Zaudig M, et al. Mild cognitive impairment. *Lancet*. 2006;367(9518):1262–1270.
17. Tombaugh TN, McIntyre NJ. The mini-mental state examination: a comprehensive review. *J Am Geriatr Soc*. 1992;40(9):922–935.
18. Lagergren M, Fratiglioni L, Hallberg IR, et al. A longitudinal study integrating population, care and social services data. The Swedish National study on Aging and Care (SNAC). *Aging Clin Exp Res*. 2004;16(2):158–168.
19. Cesari M, Onder G, Russo A, et al. Comorbidity and physical function: results from the aging and longevity study in the Sirente geographic area (ilSIRENTE study). *Gerontology*. 2006;52(1):24–32.
20. Inzitari M, Carlo A, Baldereschi M, et al. Risk and predictors of motor-performance decline in a normally functioning population-based sample of elderly subjects: the Italian Longitudinal Study on Aging. *J Am Geriatr Soc*. 2006;54(2):318–324.
21. 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(3):189–198.
22. Montgomery SA, Asberg M. A new depression scale designed to be sensitive to change. *Br J Psychiatry*. 1979;134:382–389.
23. Iyer S, Naganathan V, McLachlan AJ, Le Couteur DG. Medication withdrawal trials in people aged 65 years and older: a systematic review. *Drugs Aging*. 2008;25(12):1021–1031.
24. Chandler MJ, Lacritz LH, Cicerello AR, et al. Three-word recall in normal aging. *J Clin Exp Neuropsychol*. 2004;26(8):1128–1133.
25. Iwasa H, Gondo Y, Yoshida Y, et al. Cognitive performance as a predictor of functional decline among the non-disabled elderly dwelling in a Japanese community: a 4-year population-based prospective cohort study. *Arch Gerontol Geriatr*. 2008;47(1):139–149.
26. Asberg M, Montgomery SA, Perris C, Schalling D, Sedvall G. A comprehensive psychopathological rating scale. *Acta Psychiatr Scand Suppl*. 1978;271:5–27.

27. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders: DSM-IV*, 4th ed. Washington DC: American Psychiatric Press Inc; 1994.
28. Snaith RP, Harrop FM, Newby DA, Teale C. Grade scores of the Montgomery-Asberg Depression and the Clinical Anxiety Scales. *Br J Psychiatry*. 1986;148:599–601.
29. Podsiadlo D, Richardson S. The timed "Up and Go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc*. 1991;39(2):142–148.
30. Steffen TM, Hacker TA, Mollinger L. Age- and gender-related test performance in community-dwelling elderly people: Six-Minute Walk Test, Berg Balance Scale, Timed Up and Go Test, and gait speeds. *Phys Ther*. 2002;82(2):128–137.
31. Bohannon RW. Comfortable and maximum walking speed of adults aged 20–79 years: reference values and determinants. *Age Ageing*. 1997;26(1):15–19.
32. Jarnlo GB, Nordell E. Reliability of the modified figure of eight – a performance test for elderly women. *Physiotherapy Theory and Practice*. 2003;19(1):35–43.
33. Isles RC, Choy NL, Steer M, Nitz JC. Normal values of balance tests in women aged 20–80. *J Am Geriatr Soc*. 2004;52(8):1367–1372.
34. Curb JD, Ceria-Ulep CD, Rodriguez BL, et al. Performance-based measures of physical function for high-function populations. *J Am Geriatr Soc*. 2006;54(5):737–742.
35. Tiedemann A, Shimada H, Sherrington C, Murray S, Lord S. The comparative ability of eight functional mobility tests for predicting falls in community-dwelling older people. *Age Ageing*. 2008;37(4):430–435.
36. Lord SR, Murray SM, Chapman K, Munro B, Tiedemann A. Sit-to-stand performance depends on sensation, speed, balance, and psychological status in addition to strength in older people. *J Gerontol A Biol Sci Med Sci*. 2002;57(8):M539–M543.
37. Lin MR, Hwang HF, Hu MH, Wu HD, Wang YW, Huang FC. Psychometric comparisons of the timed up and go, one-leg stand, functional reach, and Tinetti balance measures in community-dwelling older people. *J Am Geriatr Soc*. 2004;52(8):1343–1348.
38. Sonn U, Asberg KH. Assessment of activities of daily living in the elderly. A study of a population of 76-year-olds in Gothenburg, Sweden. *Scand J Rehabil Med*. 1991;23(4):193–202.
39. Criteria Committee N. *Diseases of the Heart and Blood Vessels: Nomenclature and Criteria for Diagnosis*. Boston, Mass: Little Brown and Co, Inc; 1964:114.
40. Vereeck L, Wuyts F, Truijen S, Van de Heyning P. Clinical assessment of balance: normative data, and gender and age effects. *Int J Audiol*. 2008;47(2):67–75.
41. Horak FB, Wrisley DM, Frank J. The Balance Evaluation Systems Test (BESTest) to differentiate balance deficits. *Phys Ther*. 2009;89(5):484–498.
42. Kido T, Tabara Y, Igase M, et al. Postural instability is associated with brain atrophy and cognitive impairment in the elderly: the J-SHIPP study. *Dement Geriatr Cogn Disord*. 2010;29(5):379–387.
43. Wang L, Larson EB, Bowen JD, van Belle G. Performance-based physical function and future dementia in older people. *Arch Intern Med*. 2006;166(10):1115–1120.
44. Bottiggi K, Harrison A. The association between change in motor function and cognition in older adults: a descriptive review. *Phys Ther Rev*. 2008;13(2):91–101.
45. Soumaré A, Tavernier B, Alperovitch A, Tzourio C, Elbaz A. A cross-sectional and longitudinal study of the relationship between walking speed and cognitive function in community-dwelling elderly people. *J Gerontol A Biol Sci Med Sci*. 2009;64(10):1058–1065.
46. Marquis S, Moore MM, Howieson DB, et al. Independent predictors of cognitive decline in healthy elderly persons. *Arch Neurol*. 2002;59(4):601–606.
47. Verghese J, Wang C, Lipton RB, Holtzer R, Xue X. Quantitative gait dysfunction and risk of cognitive decline and dementia. *J Neurol Neurosurg Psychiatry*. 2007;78(9):929–935.
48. Auyeung TW, Kwok T, Lee J, Leung PC, Leung J, Woo J. Functional decline in cognitive impairment – the relationship between physical and cognitive function. *Neuroepidemiology*. 2008;31(3):167–173.
49. Lindemann U, Najafi B, Zijlstra W, et al. Distance to achieve steady state walking speed in frail elderly persons. *Gait Posture*. 2008;27(1):91–96.
50. Hausdorff JM, Yogev G, Springer S, Simon ES, Giladi N. Walking is more like catching than tapping: gait in the elderly as a complex cognitive task. *Exp Brain Res*. 2005;164(4):541–548.
51. Sheridan PL, Hausdorff JM. The role of higher-level cognitive function in gait: executive dysfunction contributes to fall risk in Alzheimer's disease. *Dement Geriatr Cogn Disord*. 2007;24(2):125–137.
52. Yogev-Seligmann G, Hausdorff JM, Giladi N. The role of executive function and attention in gait. *Mov Disord*. 2008;23(3):329–342; quiz 472.
53. McGough EL, Kelly VE, Logsdon RG, et al. Associations between physical performance and executive function in older adults with mild cognitive impairment: gait speed and the timed "up and go" test. *Phys Ther*. 2011;91(8):1198–1207.
54. Bohannon RW. Reference values for the timed up and go test: a descriptive meta-analysis. *J Geriatr Phys Ther*. 2006;29(2):64–68.
55. Pondal M, del Ser T. Normative data and determinants for the timed "up and go" test in a population-based sample of elderly individuals without gait disturbances. *J Geriatr Phys Ther*. 2008;31(2):57–63.
56. Bohannon RW. Reference values for the five-repetition sit-to-stand test: a descriptive meta-analysis of data from elders. *Percept Mot Skills*. 2006;103(1):215–222.
57. Rosano C, Simonsick EM, Harris TB, et al. Association between physical and cognitive function in healthy elderly: the health, aging and body composition study. *Neuroepidemiology*. 2005;24(1–2):8–14.
58. Royall DR, Lauterbach EC, Cummings JL, et al. Executive control function: a review of its promise and challenges for clinical research. A report from the Committee on Research of the American Neuropsychiatric Association. *J Neuropsychiatry Clin Neurosci*. 2002;14(4):377–405.
59. Bramell-Risberg E, Jarnlo GB, Elmstahl S. Slowing of alternating forearm movements is associated with cognitive impairment in community-dwelling older people. *Dement Geriatr Cogn Disord*. 2010;29(5):457–466.
60. Diniz BS, Yassuda MS, Nunes PV, Radanovic M, Forlenza OV. Mini-mental State Examination performance in mild cognitive impairment subtypes. *Int Psychogeriatr*. 2007;19(4):647–656.
61. Cullum CM, Thompson LL, Smernoff EN. Three-word recall as a measure of memory. *J Clin Exp Neuropsychol*. 1993;15(2):321–329.
62. Kluger A, Gianutsos JG, Golomb J, Ferris SH, Reisberg B. Motor/psychomotor dysfunction in normal aging, mild cognitive decline, and early Alzheimer's disease: diagnostic and differential diagnostic features. *Int Psychogeriatr*. 1997;9(Suppl 1):307–316; discussion 317–321.