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Authors

Bullain, Szofia S

Corrada, Maria M

Shah, Barbara Agee

et al.

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Poor Physical Performance and Dementia in the Oldest Old:

The 90+ Study

Szofia S. Bullain, MD, **Maria M. Corrada, ScD**, **Barbara Agee Shah, NP, MSN**, **Farah H. Mozaffar, MBBS**, **Martina Panzenboeck, MD**, and **Claudia H. Kawas, MD**
Departments of Neurology (Drs Bullain, Corrada, and Kawas) and Neurobiology and Behavior (Dr Kawas) and Institute for Memory Impairments and Neurological Disorders (Drs Bullain, Corrada, Mozaffar, Panzenboeck, and Kawas and Ms Shah), University of California, Irvine.

Abstract

Objective—To examine the cross-sectional relationship between physical performance and dementia in the oldest old (those 90 years of age).

Design—Cross-sectional study.

Setting—The 90+ Study is a population-based, longitudinal, epidemiologic study of aging and dementia performed at the University of California, Irvine, from January 1, 2003, through November 30, 2009.

Participants—A total of 629 participants from The 90+ Study were included in the study. The mean age was 94 years, and most (72.5%) were women.

Main Outcome Measures—All-cause dementia, based on *Diagnostic and Statistical Manual of Mental Disorders (Fourth Edition)* criteria, was the main outcome measure. The independent variables were physical performance measures, including 4-m walk, 5 chair stands, standing balance, and grip strength, each scored from 0 to 4 (0, unable to perform; 4, best performance). Odds of dementia in relation to the physical performance measures were estimated by logistic regression after adjustment for age and sex.

Correspondence: Szofia S. Bullain, MD, University of California, Irvine, 1515 Hewitt Hall, 843 Health Sciences Rd, Irvine, CA 92697 (sbullain@uci.edu).

Results—Poor physical performance in all measures was significantly associated with increased odds of dementia ($P < .001$). Odds ratios for every unit decrease in physical performance score were 2.1 for 4-m walk, 2.1 for chair stands, 1.9 for standing balance, and 1.7 for grip strength.

Conclusions—We found a strong cross-sectional relationship between poor physical performance and dementia in people 90 years and older. Our findings suggest that dementia is a complex neurodegenerative process that may affect physical performance and cognition. Additional research is necessary to determine the temporal relationship between poor physical performance and cognitive dysfunction.

People 90 years and older, the oldest old, represent a unique segment of society that has not been well studied. Although these people have accomplished unparalleled longevity, they also have the highest incidence rates of dementia[1] and disability.[2] As the oldest old segment of the population increases,[3] the number of people with dementia is projected to increase significantly.[4] Caring for our oldest old will require increasing amounts of resources as the population ages.

Previous cross-sectional and prospective studies[5–10] have found a relationship between poor physical performance and cognitive impairment in younger elderly populations. Furthermore, longitudinal analyses[9–11] suggest that the decline in physical performance precedes the onset of cognitive decline. This observation promotes the possibility that poor physical performance might be a modifiable risk factor for dementia.

The association between poor physical performance and dementia in the oldest old has not been studied despite the fact that they have the highest rates of dementia and disability. The goal of this study is to examine the cross-sectional relationship between physical performance and all-cause dementia in the oldest old. The characterization of this association in our cohort could aid the understanding of the role of poor physical performance in late-age dementia.

METHODS

STUDY POPULATION

Participants were from The 90+ Study, a population-based, longitudinal study of aging and dementia in persons 90 years and older.[12] The cohort consists of primarily white, well-educated, female survivors from the Leisure World Cohort Study,[13] an epidemiologic investigation of a retirement community in Orange County, California, established in the early 1980s. The 90+ Study conducts prospective clinical investigations, including neurologic examinations, physical performance measures, neuropsychological testing, and medical history assessments every 6 months. The 90+ Study included 847 participants with at least 1 in-person visit from January 1, 2003, through November 30, 2009.

PHYSICAL PERFORMANCE MEASURES

Physical performance measures were evaluated based on measures from the Adult Changes of Thought Study,[14] which used items from the Short Physical Performance Battery.[15] Physical performance measures included 4-m timed walk, 5 timed chair stands, 10-second

standing balance, and grip strength. All 4 physical performance measures were scored from 0 to 4 (0, unable to perform; 1,first quartile of performance; 2,second quartile of performance; 3, third quartile of performance; and 4, quartile of best performance) based on sex-specific quartiles of this cohort. For the 4-m timed walk, participants were asked to walk along a marked path at their usual pace. Walk was timed and measured in seconds. Five chair stands were evaluated by instructing participants to fold their arms across their chests and to stand from a sitting position once; if they successfully rose from the chair, they were asked to stand and sit 5 times as quickly as possible. Stands were timed and measured in seconds. For tests of standing balance, participants were asked to attempt to maintain their feet in a side-by-side position (score 1), then in a semitandem position (heel of one foot beside the big toe of the other foot; score 2), and finally in a full tandem position (heel of one foot directly in front of the other foot) for 10 seconds each. Participants were given a score of 3 if they were able to stand in full tandem position for 1 to 9 seconds or a score of 4 if they could hold the full tandem position for 10 seconds or longer. Grip strength of the dominant hand was measured in kilograms by using a dynamometer (Lafayette Hand Dynamometer, model 78010). The score was based on the mean of 3 trials. Table 1 summarizes the sex-specific cutoffs for each score in each of the 4 physical performance measures.

DEMENTIA DIAGNOSIS

The dependent variable in these analyses was all-cause dementia. Cognitive and functional statuses were determined by trained examiners with a detailed neurologic evaluation and assessment that included the Mini-Mental State Examination,[16] the Washington University Clinical Dementia Rating Scale,[17] and the Functional Activities Questionnaire.[18] Dementia was diagnosed based on *Diagnostic and Statistical Manual of Mental Disorders (Fourth Edition)* criteria.[19]

ADDITIONAL COVARIATES

Potential confounding variables, such as history of cardiovascular or cerebrovascular disease and level of education, were assessed and included in the analyses. Detailed medical history, including these variables, was obtained from the participants or their informants. Cardiovascular disease was defined as present if the participant had a history of coronary artery disease, myocardial infarction, atrial fibrillation and other arrhythmias, heart valve disease, or congestive heart failure. Cerebrovascular disease was defined as present if the participant had a history of hemorrhagic or ischemic stroke or transient ischemic attacks. Education was defined as a categorical variable (high school education or less, vocational school or some college education, or college degree or higher).

STATISTICAL ANALYSIS

A flowchart of the participant inclusion process is shown in Figure 1. We restricted the main analyses to the 629 participants who had neurologic examination and complete physical performance data to enable direct comparison of the 4 physical performance measures. Complete physical performance data required evaluation of all 4 physical performance tasks

during the same visit. Physical performance evaluation was conducted regardless of physical status. Data were analyzed from the first visit in which these criteria were met.

Characteristics of participants with and without dementia were compared using Pearson χ^2 tests for categorical variables and t tests for continuous variables. Odds of dementia in relation to physical performance were estimated by logistic regression after adjustment for age and sex. Subanalyses were conducted to adjust for additional potential confounders, such as history of cardiovascular disease, cerebrovascular disease, and level of education. We also conducted a test for linear trend for the odds of dementia in relation to each physical performance measure.

To include as many participants as possible with available data, we conducted secondary analyses with all participants who had incomplete physical performance data. These participants completed the neurologic examination and evaluations for at least 1 but not all physical performance tasks.

Seventy-nine participants were excluded from the main and secondary analyses; 67 participants did not complete the in-person neurologic examination and 12 did not complete any of the 4 physical performance measures.

All analyses were performed using SPSS statistical software, version 19 (SPSS, Inc).

RESULTS

Characteristics of the 629 participants included in the main analyses are listed in Table 2. The mean age of the participants was 94 years (range, 90–104 years), and 31 (4.9%) were centenarians. Most participants were women (72.5%), and most (73.8%) had more than a high school education. Individuals were included regardless of their physical status. A total of 14.7% of participants had a history of hip replacement and 65.7% of participants used a walking aid at least occasionally. Of the participants with walking aids, 29.4% used a cane, 44.7% used a walker, and 24.0% used a wheelchair. A total of 2.4% of the participants were unable to bear weight or were bedridden. Of the 629 participants, 162 (25.8%) were classified as having dementia. Participants with dementia were older, more likely to be women, and more likely to have a history of stroke (19.4% vs 9.2%, $P < .001$) or transient ischemic attack (31.8% vs 16.1%, $P < .001$).

Poor performance in each task was associated with increased odds of dementia (Figure 2 and Table 3). In addition, each physical performance task had a strong dose-response relationship with the outcome measure. Even minimal impairment in the physical performance measures resulted in increasing odds of dementia, and the odds of dementia continued to increase steadily with poorer performance in each task.

The most notable effect was seen in poor performance on the 4-m walk test. Participants who were unable to walk (score, 0) were almost 30 times more likely to have dementia than people with the fastest walking time (score, 4). However, even minimal slowing in the walking speed (1.5 seconds, from score 4 to score 3) resulted in 4 times greater odds of

dementia. The next highest odds of dementia were associated with poor performance in 5 chair stands, followed by grip strength and standing balance.

When analyses were conducted separately for men and women, the results showed a similar dose-dependent association and magnitude of the effect for most physical performance tasks and levels of performance (score, 1–4). The only notable difference was in the magnitude of the association between the "unable to do" category (score, 0) and dementia on the 4-m walk test, in which the odds ratio was 138.4 (95% CI, 12.5–1529.4) for men and 27.1 (95% CI, 9.7–75.9) for women. However, the increased odds ratio for men is likely due to the small sample size (7 [4%]). In addition, the wide CI reveals the imprecision of the estimate, precluding us from making any inferences. Adjustment for confounders (level of education and history of cerebrovascular and cardiovascular diseases) did not change the odds of dementia significantly in any performance measure.

The odds of dementia revealed a significant linear trend for all 4 physical performance measures. The odds ratios for every unit decrease in physical performance were 2.1 for the 4-m walk, 2.1 for 5 chair stands, 1.9 for standing balance, and 1.7 for grip strength ($P < .001$ for all measures).

Two hundred eighteen participants were not included in the main analyses because they failed to complete the neurologic examination or had incomplete physical performance measure evaluation (missed evaluation of   1 physical performance measurements). These excluded participants were older (mean age, 94.8 vs 94.0 years; $P = .006$), more likely to be women (79.8% vs 72.5%, $P = .03$), and more likely to have dementia (61.6% vs 25.8%, $P < .001$). The excluded participants were also more likely to use walking aids (75.9% vs 65.7%, $P = .007$) or be bedridden (11.2% vs 2.4%, $P < .001$) compared with participants in the main analyses. No significant differences were found in history of cardiovascular diseases ($P = .09$), cerebrovascular diseases ($P = .40$), hip replacement surgery ($P = .78$), and level of education ($P = .90$) between included and not included participants.

The secondary analyses included participants with incomplete physical performance evaluations in addition to participants in the main analyses. The overall trend and magnitude of the association were similar in the main and secondary analyses, particularly on the 4-m walk, 5 chair stands, and grip strength measures (Table 3). The odds ratio for dementia became slightly higher in the secondary analysis in the 2 lowest categories of performance for standing balance.

COMMENT

Our cross-sectional study found a strong dose-dependent association between poor physical performance and dementia in the oldest old, with higher odds of dementia associated with poorer physical performance. The results reveal that even modest declines in physical performance are associated with increased odds of dementia. The strongest association is seen with gait slowing, followed by 5 chair stands, grip strength, and standing balance. These associations remain essentially unchanged after adjustment for several confounders.

Our results are consistent with other cross-sectional analyses[5,6,8,20,21] that found a significant association between poor physical performance and poor cognitive function in younger elderly individuals, although methodologic differences between our study and other cross-sectional analyses make direct comparison challenging. Most studies found an association between slower gait and cognitive impairment measured on tests of global cognition[8,21] and the Clinical Dementia Rating Scale.[20] One study[6] found that cognitive impairment was also associated with weaker grip strength in addition to gait slowing. Furthermore, a similarly linear, dose-response relationship between gait speed and performance on tests of global cognition, memory, and attention was also found by some studies.[5,8,21]

In addition to the cross-sectional analyses, prospective studies have also reported an association between poor physical performance (including walking, balance, chair stand, and grip strength)[9] or neurologic gait abnormalities[10] and the development of all-cause[9] or vascular dementia.[10] Another study[11] has shown that gait slowing was associated with the development of persistent cognitive impairment (Clinical Dementia Rating Scale score 0.5). Furthermore, gait slowing was a predictor of decline in several geriatric outcome measures, such as global health, falls, and new difficulties with activities of daily living.[22]

Although all measures of physical performance (4-m walk, standing balance, repeat chair stand, and grip strength) were associated with dementia in our study, slow walking had the highest odds of dementia among all physical performance measures.

Gait requires a seamless coordination of several neurologic systems, including motor, sensory, and cerebellar activities, which may explain in part why it showed the strongest association with dementia. In one prospective study, slow walking preceded measurable cognitive dysfunction by a mean of 3.7 years,[11] suggesting that gait impairment is a risk factor for dementia. Although gait impairment is highly associated with large vessel strokes, adjustment for history of strokes and transient ischemic attacks did not change the results significantly. This result is somewhat counterintuitive; however, it could be explained by the low prevalence of large vessel strokes in our cohort. In The 90+ Study, large vessel strokes only accounted for 8.6% of all cerebrovascular events.[23] It is therefore likely that in our cohort, the relationship between poor physical performance and dementia is not mediated by large vessel strokes but other factors, such as frailty and physical inactivity, that are not accounted for in this study.

We were concerned about the potential bias of only including participants with complete physical performance data in the main analyses. However, the inclusion of the participants with incomplete data in the secondary analyses only had minimal effect on the results of the main analyses. The negligible change in odds ratio in the secondary analyses suggests that results of the main analyses are stable estimates of the odds of dementia in relationship to poor physical performance in the oldest old.

There are multiple potential explanations for the observed association between poor physical performance and dementia. One explanation could be that a neurodegenerative process or combination of processes leads to motor and cognitive decline but the impairment of these

functions is detected at different times. Cognition may not deteriorate as rapidly as physical performance, or individuals, especially those with high educational attainment, might be better at developing strategies to compensate for cognitive loss than for physical impairment. In addition, our methods of detecting subtle cognitive changes might be less sensitive compared with detecting changes in physical performance. If one process leads to impairment in both physical performance and cognition, subtle changes in gait and physical performance might serve as early markers for cognitive decline but may not be targeted as modifiable risk factors.

Another explanation of this association could be that decline in physical performance contributes to physical inactivity, which then leads to decline in cognition. Physical activity increases the levels of several classes of growth factors, including brain-derived neurotrophic factor[24] and insulin like growth factor 1.[25] At present, these factors are thought to play a key role in regulating the effects of exercise on learning.[26] This hypothesis could imply that poor physical performance is a potentially modifiable risk factor for late-age dementia. This model is also supported by the modest success of exercise programs in improving cognitive function,[27–29] although other studies[30,31] did not find an effect.

To our knowledge, this is the first report examining the association between poor physical performance and dementia in the oldest old. The strengths of the study include a large sample of well-studied oldest old. In addition, the inclusion of several potential confounders bolsters the quality of the analysis. A limitation of our study, however, is the cross-sectional design, which precludes our ability to analyze the temporal relationship between poor physical performance and dementia. A longitudinal analysis of the relationship between physical performance and dementia in The 90+ Study is under way to evaluate whether poor physical performance precedes the development of cognitive loss in the oldest old. Another potential limitation is the difficulty of establishing the diagnosis of dementia in the oldest old, which can be challenging due to high rates of sensory limitations, fatigue, medical comorbidities, and limited participation in cognitively demanding activities. To address these limitations, we have modified our testing methods (eg, used larger print and provided sound amplifiers) and provided frequent breaks during evaluations. Furthermore, we modified our questionnaires to distinguish between functional loss due to cognition and functional loss due to physical reasons and whenever possible obtained additional information regarding functional loss from informants. Despite these challenges, we have extensive experience in diagnosing dementia in the oldest old. Our dementia diagnosis from the neurologic examination has a sensitivity of 94.6% and a specificity of 86.3% compared with the diagnosis obtained from a multidisciplinary consensus conference that used all available information (neuropsychological evaluations, informant questionnaires, medical records, and laboratory results) (M.M.C., unpublished data, 2012). Additional details of the diagnostic challenges and strategies of dementia in the oldest old are described in a recent publication.[32] A further limitation of this study is the homogeneous demographics of our sample. However, a recent report by the US Census Bureau[33] suggests that the participants of The 90+ Study are fairly representative of the oldest old in the United States, especially regarding sex (76% female) and ethnicity (88% white). A significant difference of our study participants, however, is the higher educational attainment of The 90+ Study participants. More than twice as many of our participants completed education beyond high school

compared with the national average.[33] Thus, more research is needed to determine the generalizability of our findings to other populations.

In summary, similar to younger elderly populations, our study found that poor physical performance is associated with increased odds of dementia in the oldest old. The establishment of this association may serve as a major stepping stone to further investigate whether poor physical performance is in the causal pathway and a potentially modifiable risk factor for late-age dementia.

Acknowledgments

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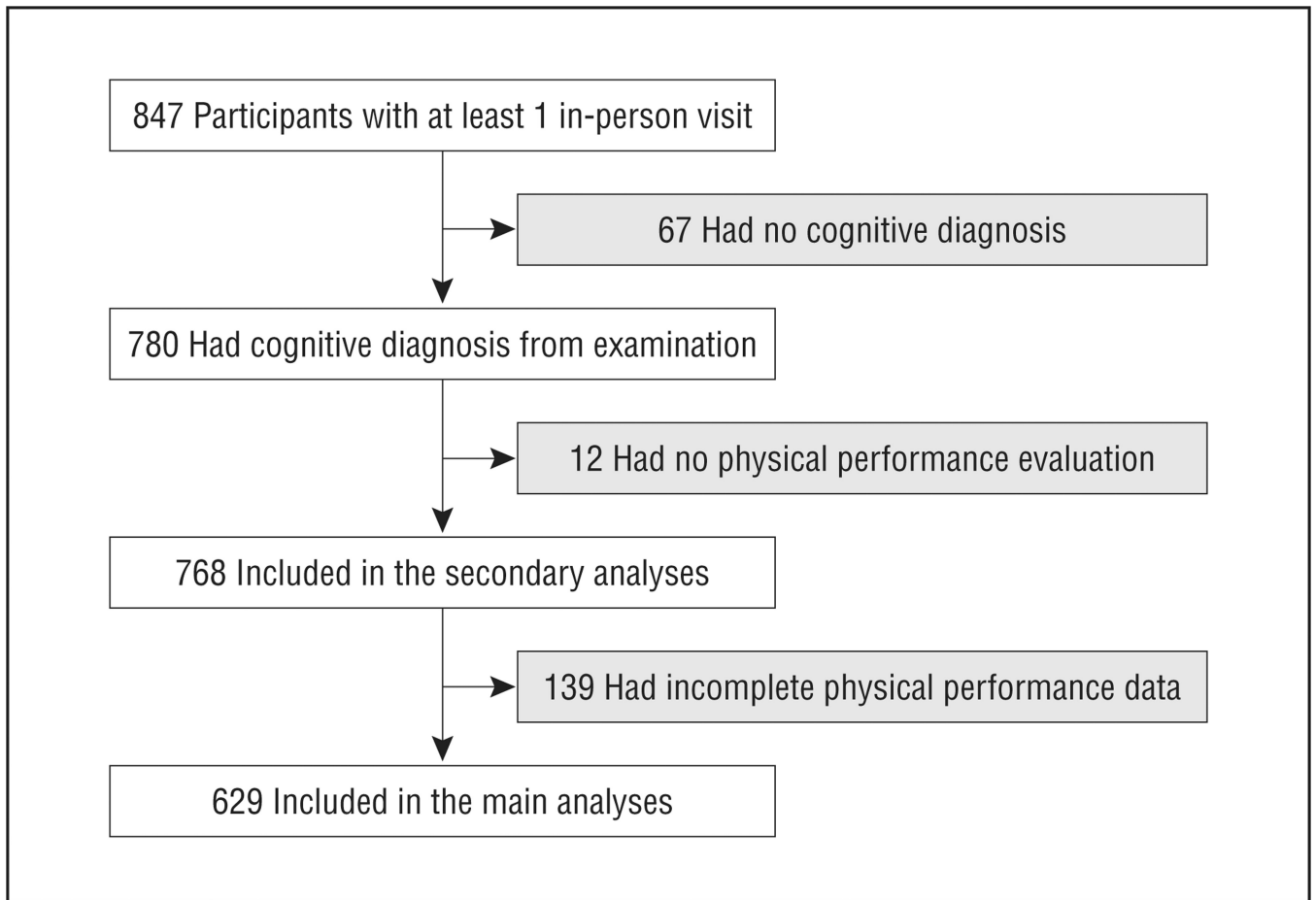
Figure 1.
Flowchart of participant selection process. Main analyses include participants with complete physical performance evaluations (all 4 tasks evaluated). Secondary analyses include additional participants with incomplete physical performance evaluations (at least 1 but not all 4 tasks evaluated).

Figure 2.
Odds of dementia for 4 physical performance measures in the oldest old. Odds of dementia and 95% CIs (error bars) were estimated from logistic regression models adjusted for age and sex. A total of 629 individuals participated in all 4 physical performance tasks.

Table 1
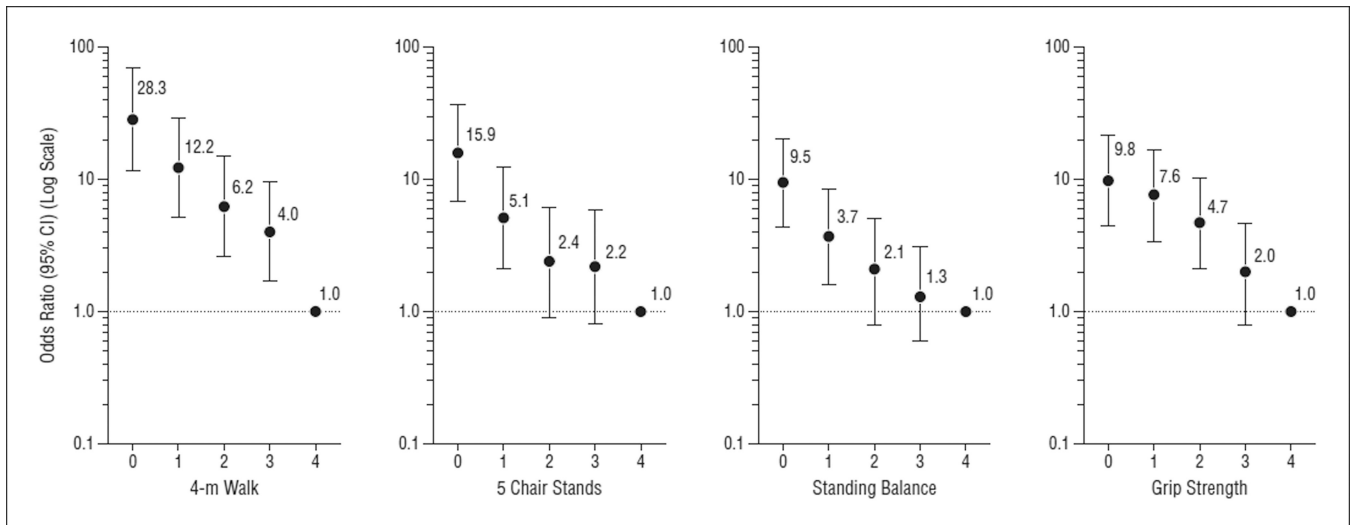
Sex-Specific Quartiles of Physical Performance Measures in the Oldest Old

Score[a]	4-m Walk, s		5 Chair Stands, s		Standing Balance		Grip Strength, kg	
	Men	Women	Men	Women	Men	Women	Men	Women
0	Unable to perform	Unable to perform	Unable to perform	Unable to perform	Unable to stand side by side for 10 s	Unable to stand side by side for 10 s	Unable to perform	Unable to perform
1	8.5	11.0	20.4	22.3	Side by side 10 s	Side by side 10 s	16.0	8.0
2	6.1–8.4	7.8–10.9	16.2–20.3	16.8–22.2	Semi-tandem 10 s	Semi-tandem 10 s	16.1–20.3	8.1–11.0
3	4.6–6.0	5.6–7.7	12.8–16.1	13.4–16.7	Full tandem 1–9 s	Full tandem 1–9 s	20.4–25.3	11.1–14.3
4	4.5	5.5	12.7	13.3	Full tandem 10 s	Full tandem 10 s	25.4	14.4

[a]Scores from 1 to 4 are based on sex-specific quartiles of performance.

Table 2

Characteristics of the Study Participants

Characteristic	All Participants (N = 629)	Study Participants[a]		P Value[b]
		Participants Without Dementia (n = 467)	Participants With Dementia (n = 162)	
Age, mean (SD), y	94.0 (2.8)	93.7 (2.6)	94.9 (3.1)	<.001
MMSE score, mean (SD)[c]	24.36 (4.9)	26.44 (2.7)	18.33 (5.0)	<.001
Female sex	456 (72.5)	318 (68.1)	138 (85.2)	<.001
Educational level[d]				
High school	164 (26.2)	108 (23.1)	56 (35.2)	
Vocational school or some college	204 (32.6)	156 (33.4)	48 (30.2)	.01
College degree	258 (41.2)	203 (43.5)	55 (34.6)	
Living situation				
Alone	300 (47.7)	280 (60.0)	20 (12.3)	
At home with family or caregiver	193 (30.7)	136 (29.1)	57 (35.2)	<.001
Assisted living or nursing home	136 (21.6)	51 (10.9)	85 (52.5)	
Cardiovascular disease[e]	256 (41.1)	195 (41.8)	61 (38.9)	.51
Cerebrovascular disease[f]	163 (26.8)	103 (22.5)	60 (39.7)	<.001

Abbreviation: MMSE, Mini-Mental State Examination.

[a] Data are presented as number (percentage) of participants unless otherwise indicated.

[b] P value comparing participants with and without dementia using Pearson χ^2 test for categorical variables and t test for continuous variables.

[c] 624 Participants with available data.

[d] 626 Participants with available data.

[e] 623 Participants with available data.

[f] 609 Participants with available data.

Table 3

Odds of Dementia for 4 Physical Performance Tasks in Main and Secondary Analyses[a]

Physical Performance Task	Main Analyses			Secondary Analyses		
	No.	Odds Ratio (95% CI)	P Value	No.	Odds Ratio (95% CI)	P Value
4-m Walk	629			751		
0	81	28.3 (11.5–70.1)	<.001	126	29.7 (14.3–61.8)	<.001
1	120	12.2 (5.2–28.9)	<.001	147	9.3 (4.7–18.4)	<.001
2	129	6.2 (2.6–14.9)	<.001	149	4.1 (2.0–8.3)	<.001
3	151	4 (1.7–9.7)	.002	165	2.8 (1.4–5.7)	.004
4	148	1 [Reference]		164	1 [Reference]	
5 Chair stands	629			730		
0	202	15.9 (6.9–36.5)	<.001	268	15.6 (7.7–31.7)	<.001
1	96	5.1 (2.1–12.7)	<.001	107	4.2 (1.9–9.2)	<.001
2	111	2.4 (0.9–6.2)	.07	116	1.9 (0.8–4.5)	.12
3	100	2.2 (0.8–5.9)	.11	111	1.6 (0.7–3.8)	.29
4	120	1 [Reference]		128	1 [Reference]	
Standing balance	629			739		
0	182	9.5 (4.4–20.4)	<.001	247	14.2 (6.7–30.0)	<.001
1	93	3.7 (1.6–8.4)	.002	107	5.2 (2.4–11.7)	<.001
2	81	2.1 (0.8–5.1)	.11	89	2.4 (1.0–5.8)	.04
3	162	1.3 (0.6–3.1)	.53	182	1.6 (0.7–3.5)	.28
4	111	1 [Reference]		114	1 [Reference]	
Grip strength	629			661		
0	124	9.8 (4.5–21.5)	<.001	134	8.1 (3.9–16.7)	<.001
1	114	7.6 (3.4–16.7)	<.001	119	6.5 (3.1–13.5)	<.001
2	133	4.7 (2.1–10.3)	<.001	138	4.1 (2.0–8.5)	<.001
3	124	2 (0.8–4.7)	.13	131	1.8 (0.8–3.9)	.17
4	134	1 [Reference]		139	1 [Reference]	

[a]Odds of dementia and 95% CIs were estimated from logistic regression models adjusted for age and sex. Main analyses include participants with complete physical performance evaluations. Secondary analyses include additional participants with incomplete physical performance evaluations.