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Physical Fitness and Cognitive Function in an 85-Year-Old Community-Dwelling Population

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Key Words
Cognitive function · Physical fitness · Community-dwelling population · Mini-Mental State Examination

Abstract
Background: Little is known about the association between physical fitness and cognitive function in very elderly people (over 80 years of age). ***Objectives:*** To evaluate that relationship in 85-year-old community-dwelling individuals. ***Methods:*** Out of 207 participants (90 males, 117 females) who were 85 years old and community-dwelling, 205 completed the Mini-Mental State Examination (MMSE) for evaluating cognitive function. The numbers of subjects who completed physical fitness measurements such as hand-grip strength, isometric leg extensor strength, one-leg standing time, stepping rate, and walking speed were 198, 159, 169, 168, and 151, respectively. ***Results:*** There were significant associations in MMSE with hand-grip strength (right or left hand), isometric leg extensor strength, stepping rate, and walking speed by simple regression analysis. MMSE was still significantly associated with hand-grip strength (β = 0.305, p = 0.005 for right side; β = 0.309, p = 0.004 for left side), stepping rate (β = 0.183, p = 0.046), and walking speed (β = –0.222, p = 0.014) by multiple regression analysis after adjustments for the amount of education, gender, smoking, drinking, complication of stroke, body weight, body height, regular medical care, serum albumin, blood HbA1c, and marital status. By logistic regression analysis, the prevalence of a normal MMSE score (MMSE $\geq$24) was increased by 9% with each 1-kg increase in hand-grip strength of the left hand (OR 1.087, 95% CI 1.003–1.179, p = 0.042), and was increased by 6% with each step per 10 s in stepping rate (OR 1.060, 95% CI 1.000–1.122, p = 0.048). ***Conclusion:*** In a very elderly population of 85-year-olds, cognitive function was associated with some physical fitness measurements, independent of confounding factors.

Introduction

Physical fitness training has been reported to improve physical fitness levels [1–3], physical function [1, 2, 4–6], mental status [3, 7], and cognitive function [1, 2, 8–14] in elderly people. Biomarkers including hand-grip strength

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were associated with cognition in 180 women between 60 and 90 years of age [15], and sensorimotor variables including balance-gait measurements were linked to intellectual functioning in 516 elderly aged between 70 and 103 years [16]. A review by the latter group of authors concluded that sensorimotor and cognitive aging are causally related and functionally interdependent in old age [17]. On the other hand, some investigators found that cross-sectional or post-test comparisons show no significant relationship between aerobic fitness and cognition [18]. Randomized clinical designs also showed a negative relationship between aerobic fitness and cognitive performance [19]. The other researchers also failed to correlate changes in aerobic power (VO_{2max}) to changes in cognitive measures [20].

In a meta-analytic study focusing on older adults from 55 to 80 years of age, fitness-induced benefits for cognition occurred in the executive-control process, and the effects were moderated by a number of programmatic and methodological factors [21]. With neuroimaging research, aerobic fitness has been found to reduce aging-related brain tissue loss in older adults [22], and significant increases in brain volume in both gray and white matter regions have been found as a function of fitness training for older adults aged between 60 and 79 years [23]. In addition, greater aerobic fitness has been found to be related to greater cerebral white matter integrity in select brain regions [24]. Reaction times are faster, and the P3 component of event-related brain potentials on electroencephalogram is greater in elderly aged 69 years who regularly engage in moderate physical activity than in those who do not [25]. Baseline measures of cardiorespiratory fitness are positively associated with preservation of cognitive function over a 6-year period and with performance levels on cognitive tests conducted 6 years later in healthy adults aged 55 and older [11]. Decreases in the duration or intensity of physical activity over a 10-year period in elderly with a mean age of 74.9 years resulted in a stronger cognitive decline was found than in subjects who maintained the duration or intensity of their physical activity [26].

Although an association between physical fitness and cognition in the elderly seems established, that association has, as mentioned above, been examined primarily in individuals under the age of 80 years. Because of increases in longevity in Japan, however, the number of people older than 80 is growing, thus necessitating investigation of these very elderly. Few studies have dealt with elderly subjects above the age of 80 [1], and in that study, the subjects included only 20 institutionalized elderly individuals aged between 75 and 99 years. We hypothesized that, in the very elderly (over 80 years), higher scores on physical fitness tests would be related to higher Mini-Mental State Examination (MMSE) scores in a similar fashion to that of people younger than 80. Therefore, in the present study we evaluated the association between cognition and physical fitness in 205 noninstitutionalized, 85-year-old community-dwelling elderly subjects. Each subject completed five different physical fitness tests (hand-grip, isometric leg extensor, one-leg standing time, leg-stepping rate, and walking speed) and the MMSE. Although this study did not measure aerobic or cardiovascular fitness, but measured only fitness tests suitable for the very elderly, the evaluation of the association by cross-sectional design may still be valuable in an 85-year-old population.

Methods

The data were from 5 years of follow-up in a population-based study of age-related general and oral health in Fukuoka Prefecture, Japan. The subjects in this study were 827 persons who were 85 years of age, who were born in 1917 and lived in 1 of 9 districts (Bunzen City, Munakata City, Yukuhashi City, Tobata Ward of Kitakyushu City, Kanda Town, Katsuyama Town, Toyotsu Town, Tsuiki Town, or Shinyoshitomi Village) in Fukuoka Prefecture, Japan. Of the 827 persons, 410 refused, 210 had died in the previous 5 years, and 207 participated in the present study. The study was approved by the Human Investigations Committee of Kyushu Dental College, and was conducted in full accordance with ethical principles, including the World Medical Association Declaration of Helsinki, as revised in 2002. Informed written consent was obtained from all participants in accordance with these principles.

Out of 207 participants (90 males, 117 females), 205 (88 males, 117 females) completed the MMSE for assessing cognitive function, which consists of a list of questions, and which was administered by experienced speech-language-hearing therapists or occupational therapists. The MMSE is a standardized evaluation of cognitive function and is widely used in epidemiological studies [27, 28]. A full score on the MMSE is 30, and cognitive impairment was defined as a score of less than 24. All subjects were asked to fill out a medical questionnaire, which included current smoking, alcohol drinking, years of education, and history of stroke. Blood pressure was measured and blood samples were collected. Blood was collected with the subject seated for the determination of serum concentration of albumin and blood concentration of HbA1c.

Subjects completed five types of neuromuscular tests: two tests of muscle strength (hand-grip, isometric leg extensor), one test of balance (one-leg standing time), one test of neuromuscular endurance (stepping rate), and one test of walking (walking speed). The numbers of subjects participating in the tests were 198, 159, 169, 168, and 151, respectively. Nonparticipation in each physical fitness test was due to either an inability to perform the task or refusal to perform it. The grip strength of each hand was measured by a Smedley hand dynamometer (DM-100S; Yagami, Nagoya, Japan). The average value of two trials for each hand was taken as the score for the test. Leg extensor strength was measured by a portable chair incorporating a strain gauge connected to a load cell [29]. The subject sat upright with the legs hanging vertically and the knee initially bent at 90°. The trial was performed once for each leg. The averaged value from both trials was used as the subject's score for leg extensor strength ((right leg + left leg)/2). The stepping rate was measured once for each side using an industrial stepping rate counter (Stepping Counter GF-300; Yagami); while seated, the subject was instructed to step with each leg as rapidly as possible for 10 s [30, 31]. The averaged value of the two stepping rates was used as the subject's score. One-leg standing time was the number of seconds the subject was able to stand on one leg (with eyes open) without hopping or putting the raised foot down, or until 2 min had elapsed. Each subject took instructions from a study investigator, who observed the test from beginning to end. One trial was performed on the right and one on the left leg, and the average value of the two measurements was used as the score. Walking speed was the number of seconds it took to walk 10 m. The trial was done twice, with the average value used as the score for the subject. Although a 6-min walking test would generate more information on cardiovascular fitness than the 10-meter walking test, we selected the latter because it was easier and safer for the very elderly to do. To examine the validity and reproducibility of each fitness variable, the correlation coefficient (r) and p value were calculated by simple regression analysis. r and p values in the fitness tests were, respectively, 0.956 and 0.000 for right hand-grip strength, 0.959 and 0.000 for left hand-grip strength, 0.882 and 0.000 for isometric leg extensor strength, 0.589 and 0.000 for one-leg standing time, 0.995 and 0.000 for stepping rate, and 0.932 and 0.000 for walking speed.

All data are reported as means ± SD. Differences in mean values between groups were assessed by analysis of variance. Categorical variables were compared using the χ^2 test. Multiple regression analysis was carried out to evaluate the relationship between MMSE scores and physical fitness measurements after adjustment for confounding variables including smoking and drinking. Because of differences in physical fitness measurements between groups according to gender, smoking, drinking, and marital status, these factors were entered as confounders in the multiple regression. In addition, since cerebrovascular disease, other complicated diseases, and nutritional status could influence fitness tests, these were also included as confounding factors. Because of the high correlation between right and left hand-grip strength (r = 0.883, p = 0.000), these fitness variables should be entered separately in the multiple regression analyses. Logistic regression was also used to determine which fitness measurements were associated with a better MMSE score. All statistical analyses were performed using SPSS 15.0 (SPSS Japan, Tokyo, Japan). Results were considered statistically significant when $p < 0.05$.

Table 1. Simple regression analysis for relationships between MMSE score and various physical fitness measurements and confounding factors in 85-year-old subjects

Independent variables	r value	p value	n
Hand-grip strength (right hand)	0.262	0.000	196
Hand-grip strength (left hand)	0.272	0.000	193
Isometric leg extensor strength	0.167	0.037	157
One-leg standing time	0.116	0.137	167
Stepping rate	0.215	0.005	166
Walking speed	–0.227	0.005	150
Serum albumin concentration	0.070	0.324	203
HbA1c	0.152	0.031	203
Smoking	–0.075	0.291	201
Drinking	–0.133	0.062	199
Complication of cerebrovascular diseases	0.072	0.303	205
Regular medical care	–0.003	0.963	203
Body height	0.197	0.005	204
Body weight	0.155	0.027	204
Gender	–0.038	0.586	205
Education level	0.264	0.000	195
Marital status	–0.038	0.595	201

Results

The average MMSE score was 23.8 ± 4.5 points (24.0 ± 4.4 for males, 23.6 ± 4.7 for females, p = 0.583), serum concentrations of albumin were 4.3 ± 0.3 g/dl (4.3 ± 0.3 for males, 4.4 ± 0.3 for females, p = 0.004), HbA1c was 5.5 ± 0.7% (5.6 ± 0.7 for males, 5.5 ± 0.6 for females, p = 0.355), the education level was 9.4 ± 2.6 years (9.9 ± 3.0 for males, 9.0 ± 2.1 for females, p = 0.022), height was 148.8 ± 9.7 cm (157.1 ± 6.5 for males, 142.5 ± 6.6 for females, p = 0.000), and body weight was 50.4 ± 9.9 kg (55.4 ± 9.7 for males, 46.6 ± 8.2 for females, p = 0.000). No gender difference was found in MMSE scores or HbA1c, whereas males had lower serum albumin concentrations and higher education levels, and were taller and heavier than females. The right hand-grip strength was 21.0 ± 6.8 kg (26.4 ± 6.4 for males, 17.1 ± 3.8 for females, p = 0.000), left hand-grip strength was 19.8 ± 6.5 kg (24.9 ± 6.0 for males, 16.2 ± 4.0 for females, p = 0.000), isometric leg extensor strength 22.0 ± 8.8 kg (27.9 ± 8.3 for males, 17.3 ± 6.0 for females, p = 0.000), one-leg standing time 7.9 ± 10.9 s (11.6 ± 14.2 for males, 4.7 ± 5.3 for females, p = 0.000), stepping rate 31.4 ± 7.9/10 s (34.7 ± 8.2 for males, 28.6 ± 6.5 for females, p = 0.000), and walking speed 6.5 ± 1.7 s/10 m (6.0 ± 1.6 for males, 7.0 ± 0.2 for females, p = 0.000). These fitness values were all better in males than in females. Cigarette smoking (11.5 vs. 0%, p = 0.000), alcohol drinking (60.9 vs. 44.2%, p = 0.023) and complication of cerebrovascular diseases (12.2 vs. 4.3%, p = 0.039) were more prevalent in males than in females.

Table 2. Comparison of various physical fitness measurements and confounding factors between subjects with normal cognitive function (MMSE ≥24) and those with impaired cognitive function (MMSE <24)

	Normal MMSE Group (n)	Impaired MMSE Group (n)	p value
MMSE	26.5 ± 1.8 (128)	19.3 ± 4.2 (77)	0.000
Hand-grip strength, kg (right hand)	21.8 ± 7.1(126)	19.3 ± 5.8 (70)	0.009
Hand-grip strength, kg (left hand)	20.6 ± 6.7 (125)	17.9 ± 5.5 (68)	0.003
Isometric leg extensor strength, kg	22.7 ± 8.7 (103)	20.7 ± 9.1 (54)	0.176
One-leg standing time, s	8.0 ± 10.3 (109)	7.7 ± 12.2 (58)	0.878
Stepping rate (/10 s)	32.3 ± 7.1 (109)	29.1 ± 8.6 (57)	0.016
Walking speed, s	6.4 ± 1.6 (100)	6.7 ± 1.8 (50)	0.312
Serum albumin concentration, g/dl	4.3 ± 0.3 (127)	4.3 ± 0.3 (76)	0.518
HbA1c, %	5.5 ± 0.6 (127)	5.4 ± 0.7 (76)	0.268
Smoking, yes/no	8/119 (127)	2/72 (74)	0.330
Drinking, yes/no	70/56 (126)	33/40 (73)	0.186
Complication of cerebrovascular diseases, yes/no	10/118 (128)	5/72 (77)	0.790
Regular medical care, yes/no	120/7 (127)	69/7 (76)	0.393
Body weight, kg	51.3 ± 10.4 (128)	48.5 ± 8.6 (76)	0.038
Body height, cm	150.0 ± 9.3 (128)	146.6 ± 10.1 (76)	0.017
Male/female	55/73 (128)	33/44 (77)	1.000
Education level, years	9.8 ± 2.5 (124)	8.7 ± 2.5 (71)	0.005
Marital status, spouse yes/no	55/72 (127)	34/40 (74)	0.769

The relationships between MMSE score and physical fitness measurements were examined by simple regression analysis. Significant associations in MMSE were found with hand-grip strength (right or left hand), isometric leg extensor strength, stepping rate, walking speed, HbA1c, body height, body weight, and education level, but not with one-leg standing time or other variables (table 1). Hand-grip strength (right or left hand), stepping rate, body height, body weight, and education level were greater in individuals with normal cognitive function than in those with impaired cognition (table 2), whereas other factors did not differ between the groups. MMSE scores were not different between smokers (n = 9) and nonsmokers (n = 191) (25.0 ± 1.9 vs. 23.8 ± 4.5, p = 0.119), nor were there any differences among those who smoked more than 10 cigarettes a day (n = 3), those who smoked 1–10 cigarettes a day (n = 7), and those who did not smoke (n = 191). Body height was correlated well with fitness measurements (r = 0.686, p = 0.000 for right hand-grip strength; r = 0.700, p = 0.000 for left hand-grip strength; r = 0.526, p = 0.000 for isometric leg extensor strength; r = 0.216, p = 0.005 for one-leg standing time; r = 0.393, p = 0.000 for stepping rate; r = –0.297, p = 0.000 for walking speed).

MMSE in individuals (n = 196) who took the right hand-grip strength test was better than in those (n = 9) who did not (24.1 ± 4.2 vs. 17.2 ± 6.6, p = 0.014), and MMSE was also better in those (n = 193) who took the left hand-grip strength test than in those (n = 12) who did not (24.1 ± 4.2 vs. 18.4 ± 6.3, p = 0.010). Individuals who took the isometric leg extensor strength test (n = 157) also had better MMSE scores than those who did not (n = 48) (24.3 ± 3.9 vs. 22.0 ± 5.9, p = 0.016). Similarly, individuals who did the one-leg standing test (n = 167) had better MMSE than those who did not (24.2 ± 3.9 vs. 21.9 ± 6.5, p = 0.041) (n = 38). Individuals who did the stepping rate test (n = 166) had higher MMSE scores than those who did not (24.3 ± 3.9 vs. 21.6 ± 6.4, p = 0.017) (n = 39). Individuals who did the walking speed test (n = 150) also had better MMSE than those who did not (24.3 ± 3.9 vs. 22.2 ± 5.6, p = 0.013) (n = 55).

Table 3 shows the data on multiple regression analyses for MMSE score with various physical fitness measurements and confounding factors, such as education level, gender, smoking, drinking, complication of stroke, body weight, height, regular medical care, level of serum albumin, level of blood HbA1c, and marital status. Standardized regression coefficients (β) and nonstandardized regression coefficients (B) with 95% confidence intervals (95% CI) are shown in parentheses. Hand-grip strength, whether on the right side (β = 0.305, B = 0.171, 95% CI 0.051–0.291, p = 0.005) or left side (β = 0.309, B = 0.183,

Table 3. Multiple regression analysis for MMSE score with various physical fitness measurements and confounding factors in 85-year-old subjects

Independent variables	β value	Independent variables	β value	Independent variables	β value
Hand-grip strength (right hand)	0.305[2]	Hand-grip strength (left hand)	0.309[3]	Isometric leg extensor strength	0.186
Albumin	–0.013	Albumin	–0.016	Albumin	0.066
HbA1c	0.165[1]	HbA1c	0.163[1]	HbA1c	0.083
Marital status	0.070	Spouse	0.075	Spouse	–0.004
Smoking	–0.024	Smoking	–0.020	Smoking	–0.043
Drinking	–0.120	Drinking	–0.135	Drinking	–0.105
Complication of CVDs	0.041	Complication of CVDs	0.037	Complication of CVDs	0.135
Regular medical care	–0.006	Regular medical care	–0.010	Regular medical care	–0.010
Body height	0.045	Body height	0.023	Body height	0.130
Body weight	–0.023	Body weight	–0.006	Body weight	0.001
Gender	0.213	Gender	0.188	Gender	0.232
Education level	0.206[2]	Education level	0.213[2]	Education level	0.247[2]
CoD (R^2)	0.170	CoD (R^2)	0.170	CoD (R^2)	0.156
One-leg standing time	0.058	Stepping rate	0.183[1]	Walking speed	–0.222[1]
Albumin	0.064	Albumin	0.000	Albumin	0.043
HbA1c	0.110	HbA1c	0.114	HbA1c	0.095
Spouse	0.012	Spouse	0.007	Spouse	–0.011
Smoking	–0.062	Smoking	–0.052	Smoking	–0.042
Drinking	–0.102	Drinking	–0.144	Drinking	–0.048
Complication of CVDs	0.137	Complication of CVDs	0.132	Complication of CVDs	0.124
Regular medical care	0.018	Regular medical care	0.022	Regular medical care	–0.066
Body height	0.158	Body height	0.070	Body height	0.133
Body weight	0.050	Body weight	0.071	Body weight	0.036
Gender	0.176	Gender	0.182	Gender	0.212
Education level	0.250[3]	Education level	0.220[1]	Education level	0.257[3]
CoD (R^2)	0.153	CoD (R^2)	0.165	CoD (R^2)	0.187

β = Standardized regression coefficients; CVDs = cerebrovascular diseases; CoD = coefficients of determination.
[1] $p < 0.05$, [2] $p < 0.01$, [3] $p < 0.005$.

95% CI 0.059–0.306, p = 0.004), was densely associated with MMSE score by multiple regression analysis adjusted for various confounding factors. The stepping rate (β = 0.183, B = 0.088, 95% CI 0.001–0.174, p = 0.046) and walking speed (β = –0.222, B = –0.504, 95% CI –0.903 to –0.105, p = 0.014) were also associated with MMSE scores after adjustment for the same influencing factors. Education level also consistently correlated with MMSE scores. There was no significant association between MMSE and isometric leg extensor strength (β = 0.186, B = 0.079, 95% CI –0.007 to 0.165, p = 0.072) or one-leg standing time (β = 0.058, B = 0.020, 95% CI –0.037 to 0.076, p = 0.495). Multiple regression analysis was also carried out according to gender. Right hand-grip strength was similarly associated with MMSE score in men and women (β = 0.311, B = 0.184, 95% CI 0.023–0.345, p = 0.025 for men; β = 0.253, B = 0.262, 95% CI 0.056–0.468, p = 0.013 for women), whereas the association of left hand-grip strength with MMSE was significant for men (β = 0.352, B = 0.229, 95% CI 0.056–0.402, p = 0.010), but not for women (β = 0.164, B = 0.155, 95% CI –0.035 to 0.345, p = 0.109). Other fitness measurements were not associated with MMSE in the analysis by gender.

We also calculated the odds ratios (OR) and 95% CI for achievement of normal cognitive function (MMSE of 24 or higher) by logistic regression analysis adjusted for the same confounding factors as in the multiple regression analysis. The prevalence of normal MMSE scores was increased by 9% with each 1-kg increase in left hand-grip strength (OR 1.087, 95% CI 1.003–1.179, p = 0.042), and was increased by 6% with each step per 10 s in the stepping rate (OR 1.060, 95% CI 1.000–1.122, p = 0.048). No significant association was found by logistic regression analysis (p = 0.454) between MMSE score and walking speed.

Discussion

We found a significant association between cognitive function evaluated by MMSE and physical fitness measurements of hand-grip strength, walking speed, and stepping rate after adjustment for various confounding factors in very elderly, 85-year-old community-dwelling individuals. In contrast, there was no association in cognitive function with isometric leg extensor strength or one-leg standing time. The prevalence of normal MMSE scores was increased by 9% with each 1-kg increase in left hand-grip strength, and was increased by 6% with each step per 10 s in the stepping rate. These associations were found independently of influencing factors such as gender, education, smoking, drinking, complication of stroke, body weight, height, regular medical care, level of serum albumin, level of blood HbA1c, and marital status. The participants who were not able to do some physical tasks had lower MMSE scores as well. This finding supports the assumption of a close relationship between cognitive and physical functioning in the very elderly. Since the MMSE mainly indicates whether a person is demented or not and does not allow for more detailed analyses of cognitive functioning, some additional tasks in the cognitive domain should be included in our future work. Additionally, we should increase the number of trials or include a practice phase for physical tasks in future experiments, since the one-leg standing is difficult even for younger adults, that is the present results could reflect the subjects' unfamiliarity with a task rather than their actual ability.

In 20 frail long-term-care facility residents aged 75–99 years (mean age 88 years), seated range-of-motion exercises and strength training using simple equipment such as elastic resistance bands (resistance ranging from 2.5 to 9 lb) and soft weights (2–4 lb) for 1 year increased not only physical activity levels but also MMSE scores by 3.1 [1]. Correlation coefficients in Teng-modified MMSE with walking speed were 0.20–0.23, and those with standing balance were 0.16 in nondisabled people aged 70–79 [14]. These values were similar to our findings, in which the correlation coefficients were –0.227 and 0.116, respectively. Cardiopulmonary fitness has been found to be a strong predictor of cognition in a cross-sectional study comprising 25 young (18–30 years), 25 young-old (65–74 years), 25 middle-old (75–84 years), and 25 old-old adults (85–92 years) [32]. In addition, a meta-analytic study compared the effects of fitness on cognition among participants in young-old (55–65 years), middle-old (66–70 years), and old-old (71–80 years) individuals, and found the most benefit in middle-old and more benefit in old-old compared to young-old [21]. In light of these findings together with ours, it seems likely that an association between physical fitness and cognition may exist in very elderly people older than 80 as it does in elderly aged 80 years or younger. However, some studies did not find a relationship between fitness and cognition [18–20], suggesting that this association is not conclusively recognized. The mechanisms underlying the found association between hand-grip strength, walking speed, stepping rate, and MMSE scores remained obscure from our findings. However, fitness could reduce the risk of various medical diseases, such as cardiovascular disease, stroke, hypertension, and diabetes, which are known to be related to poor cognitive function in the elderly [33]. Fitness also was reported to be associated with cerebral blood flow, which is linked to cognitive function [34]. Additionally, animal studies provide evidence of an association between fitness and brain structure and function [35].

However, there are limitations to the present study: a fairly small group of participants, an average MMSE <24, a cross-sectional design, the use of MMSE rather than a neuropsychological test battery, and the small fit of the multiple regression model ($0.153 < R^2 < 0.187$). Additionally, since the average MMSE score was below 24, indicating that this population is cognitively impaired, our subjects may have had some problems understanding how to do the fitness tests.

Only specific physical fitness measurements, such as hand-grip strength, stepping time, and walking speed, were found to be independently related to cognitive function in our oldest-old population, while the other measurements, those of leg extensor strength and one-leg standing time, were not associated with cognition. The mechanisms involved in this discrepancy are not resolved from the present findings. However, the age of the subjects, 85 years, could be responsible for this phenomenon, since fitness tests such as hand-grip strength, stepping rate, and walking speed are relatively easy to perform even for the very elderly, whereas leg-extensor strength and one-leg standing are hard for this population, resulting in a weak association with cognition. Further study, including a larger group of very elderly subjects, and a longitudinal rather than cross-sectional design may be needed to answer this question.

In conclusion, although the present study was cross-sectional and no longitudinal survey was made to clarify the association between physical fitness and cognitive function, we evaluated this association for the first time in a relatively large population of very elderly, 85-year-old noninstitutionalized individuals, and found a significant association between cognitive function and some physical fitness measurements, independent of confounding factors.

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