Physical Fitness and 4-Year Mortality in an 80-Year-Old Population

Yutaka Takata,1 Toshihiro Ansai,2 Sumio Akifusa,2 Inho Soh,2 Yutaka Yoshitake,3 Yasuo Kimura,4 Kazuo Sonoki,1 Kiyoshi Fujisawa,1 Shuji Awano,2 Shuntaro Kagiyama,1 Tomoko Hamasaki,2 Ikuo Nakamichi,1 Akihiro Yoshida,2 and Tadamichi Takehara2

Divisions of 1General Internal Medicine and 2Community Oral Health Science, Kyushu Dental College, Kitakyushu, Japan.
3Department for Interdisciplinary Studies of Lifelong Sport and Physical Activity, National Institute of Fitness and Sports in Kanoya, Japan.
4Faculty of Culture and Education, Saga University, Japan.

Background. Because little is known about the relationship between physical fitness and mortality among very elderly people, we evaluated this association in a Japanese population of 80-year-old community residents.

Methods. Among 1282 80-year-old residents of Fukuoka Prefecture, Japan, 697 individuals (277 men and 420 women) underwent physical fitness tests of handgrip strength, isometric leg extensor strength, isokinetic leg extensor power, stepping rate, and one-leg standing time. Four years later, the dates and causes of death among the participants during those years were analyzed based on data from resident registration cards and from official death certificates.

Results. During the 4-year follow-up period, 107 individuals (58 men and 49 women) died. Of these deaths, 27 were due to cardiovascular disease (CVD), 27 to cancer, 22 to pneumonia, and the rest to other causes. The relative hazard ratios (HR) for all-cause mortality, adjusted for various confounding factors, fell with increases in stepping rate, and the HR for pneumonia mortality fell with increases in leg extensor strength. In contrast, there was no association between cardiovascular or cancer mortality and physical fitness.

Conclusions. A partial association was found between impaired physical fitness at the age of 80 years and increased mortality in the 4 years thereafter. Mortality due to all causes was related only to stepping rate, and mortality due to pneumonia was related to leg extensor strength. Mortality due to CVDs or cancers was not associated with physical fitness.

Physical activity and physical fitness are widely known to be inversely related to mortality due to diseases generally (1–22), CVDs (2,4,5,8,9,11,16,18,19,23–25), and cancers (5,9,15,26). Similarly, Franco and colleagues (27) recently reported physical activity’s effects on life expectancy in individuals aged 50 years or older (mean, 60 years) residing in Framingham, England, and found that total and CVD-free life expectancies may be increased by avoiding a sedentary lifestyle. That study showed an inverse relationship between physical activity level and death from cardiovascular disease or non-CVD (27). Elsewhere, aged women (65 years or older) who increased physical activity levels between baseline and follow-up also had lower mortality from all causes, CVDs, and cancer (5). Similarly, men who improved or maintained adequate physical fitness were less likely to die from all causes and from CVD during the follow-up (16). In another study, 245 elderly persons with an average age of 76 years undertook exercises once every 2 months for 5 years, resulting in both decreased mortality and an improved state of independence among the female participants (20). However, the relationship between physical fitness and mortality might differ between very elderly (80 years or older) people and those who are younger. We hypothesized that the protective effects of physical performance might be attenuated in late life. Therefore, we evaluated this relationship in a Japanese population of 80-year-old community residents.

METHODS

In 1998, a total of 1282 individuals who were 80 years old resided in three cities (Buzen, Yukuhashi, and Munakata), four towns (Katsuyama, Tikuji, Toyotsu, and Kanda), one village (Shinyoshitomi), and one ward (Tobata of Kitakyushu City) in Japan’s Fukuoka Prefecture. These nine locations were selected randomly from urban, suburban, and rural communities to achieve a balance of living environments in terms of sociodemographic backgrounds, dietary habits, health behaviors, and available medical care. Of these 1282 individuals, 697 (54.4%) (277 men and 420 women) agreed to participate in the study and then underwent both a physical examination (including several performance tests) and a laboratory blood examination. An additional 130 individuals agreed to participate but were unable to take the tests. Serum concentrations of glucose and cholesterol were measured by an enzymatic method using an autoanalyzer. The coefficients of variation calculated by (standard deviation [SD]/mean) × 100% were 1.58% for glucose and 0.76% for cholesterol. The 697 participants were followed-up for 4 years after the baseline
examination. For all participants, this follow-up was started after the baseline examination in April 1998 and stopped in March 2002, so that everyone was followed up equally for 4 years. We recorded the dates and causes of all deaths among participants, based on resident registration cards and official death certificates. The causes of death were classified according to the 10th revision of the International Classification of Diseases (ICD-10). There was no loss of 4-year follow-up. The study was conducted according to the principles expressed in the Declaration of Helsinki, and was approved by the Human Investigations Committee of Kyushu Dental College. Written informed consent was obtained from all participants.

During the baseline examination, participants completed six types of neuromuscular tests: four tests of muscle strength (handgrip, single-leg and double-leg isometric leg extensor, isokinetic leg extensor), one test of balance (one-leg standing time), and one test of neuromuscular endurance (stepping rate). The numbers of individuals participating in the tests were 644, 557, 558, 549, 567, and 572, respectively. The grip strength of each hand was measured by a Smedley hand dynamometer (DM-100s; Yagami, Nagoya, Japan). The higher 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. The participant sat upright with the legs hanging vertically and the knee initially bent at 90°. The trial was performed twice—once for each leg individually, and again for both legs simultaneously. The value for each side was summed as the participant’s score for leg extensor strength (right leg + left leg). Isokinetic leg extensor power was determined by a dynamometer (Aneropress 3500; Combi, Tokyo, Japan). The participant sat on the seat of the instrument and was instructed to press his or her feet forward on the plate as rapidly as possible until the legs were fully extended. The body mass of the participant was applied as resistance. The best score from five trials was used for statistical analysis. The stepping rate was measured using an industrial stepping rate counter (Stepping Counter; Yagami); while sitting, the participant was instructed to step with each leg as rapidly as possible for 10 seconds. The stepping rates for both legs were summed as the participant’s score. One-leg standing time was the number of seconds the participant was able to stand on one leg (with eyes open) without hopping or putting the raised foot down, or until 2 minutes had elapsed. Each participant 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.

The test–retest reliability of each measure of physical fitness was evaluated by using simple regression analysis. The coefficient of correlation between the first and second trials of handgrip strength of the right hand was 0.960, that between the first and second handgrip strength measurement of the left hand was 0.950, that between one-leg standing time on the right and left feet was 0.718, that between leg extensor strength in the right and left legs was 0.804, that between stepping rate on the right and left sides was 0.831, and that between the first and second isokinetic leg extensor power measurements was 0.830.

Performance scores were assigned on a scale of 1–4 for each test, with 1 representing the lowest level of performance and 4 the highest, according to Guralnik and colleagues (28,29) and Ferrucci and colleagues (30). The cutoff value for each test score was obtained to divide the participants into quartiles. The scores were defined as shown in Table 1. The sum of the scores for the six performance tests was called the combined performance score. Thus, each participant had a combined score in the range of 6–24.

Activities of daily living (ADL) status was determined by public health nurses who classified the participants into six groups. Individuals in ADL-1 (n = 554) were almost independent in everyday life; they left home on their own and used transportation to go where they wanted. Those in ADL-2 (n = 84) were almost independent in everyday life; they left home on their own but stayed mainly in the neighborhood. Those in ADL-3 (n = 26) were almost independent in indoor living and did not stay in bed during the day but needed assistance to leave home. Those in ADL-4 (n = 10) were almost independent in indoor living, but they sometimes stayed in bed during the day, left home infrequently, and required assistance when they did go out. Those in ADL-5 (n = 8) needed some assistance indoors and stayed mainly in bed in the daytime but could sit up. Those in ADL-6 (n = 2) spent all day in bed and needed assistance to eat, change clothes, and use the toilet.

All data were reported as means ± SD. Differences in mean values between groups were assessed by analysis of variance. Categorical variables were compared using the chi-square test. Associations between neuromuscular performance and time to 4-year mortality were assessed using the multivariate Cox proportional hazards regression model. Gender, smoking, body mass index (BMI), systolic blood pressure (SBP), marital status, and levels of total serum

### Table 1. Performance Scores Assigned on a Scale of 1–4 for Each Physical Fitness Test at the Age of 80 Years

<table>
<thead>
<tr>
<th>Physical Fitness Measurements</th>
<th>Score 1</th>
<th>Score 2</th>
<th>Score 3</th>
<th>Score 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handgrip strength (n)</td>
<td>&lt; 20 kg (156)</td>
<td>20–23.9 kg (167)</td>
<td>24–29.5 kg (149)</td>
<td>≥ 29.5 kg (&lt; 172)</td>
</tr>
<tr>
<td>One-leg standing time (n)</td>
<td>&lt; 4.6 s (140)</td>
<td>4.6–8.2 s (144)</td>
<td>8.3–16.95 s (141)</td>
<td>≥ 16.95 s (142)</td>
</tr>
<tr>
<td>Leg extensor strength, right leg + left leg (n)</td>
<td>&lt; 30 kg (136)</td>
<td>30–40 kg (139)</td>
<td>41–52 kg (138)</td>
<td>≥ 52 kg (&lt; 144)</td>
</tr>
<tr>
<td>Leg extensor strength, both legs (n)</td>
<td>&lt; 27 kg (135)</td>
<td>27–36 kg (145)</td>
<td>37–46 kg (132)</td>
<td>≥ 46 kg (&lt; 146)</td>
</tr>
<tr>
<td>Stepping rate (n)</td>
<td>&lt; 51 steps/10 s (141)</td>
<td>51–60 steps/10 s (137)</td>
<td>61–71 steps/10 s (145)</td>
<td>≥ 71 steps/10 s (&lt; 149)</td>
</tr>
<tr>
<td>Isokinetic leg extensor power (n)</td>
<td>&lt; 220 W (138)</td>
<td>220–318 W (136)</td>
<td>319–461 W (136)</td>
<td>≥ 461 W (139)</td>
</tr>
</tbody>
</table>
cholesterol and glucose were fitted as continuous variables. All statistical analyses were performed using StatView 5.0 (SAS Institute, Cary, NC). Statistical significance was accepted at \( p \leq .05 \).

**RESULTS**

During the 4-year follow-up period from April 1998 to March 2002, 107 individuals (58 men and 49 women) died. Of these deaths, 27 were due to CVD (8 heart failures, 5 myocardial infarctions, 5 strokes, 4 aortic aneurysms, 3 ischemic heart diseases, 1 sick sinus syndrome, 1 hypertensive heart disease), 27 to cancer (6 lung, 3 pancreatic, 3 hepatic, 2 colon, 2 gastric, 2 uterine, 2 urinary system cancers, 7 cancers of other organs), 22 to pneumonia, 6 to disorders of the respiratory system other than pneumonia, 5 to gastrointestinal disease, 5 to accidents, 4 to hepatic failure, 2 to suicide, 2 to senility, 2 to renal failure, 1 to collagen disease, 1 to cholangiopathy, and 3 to unclassified other diseases. Of the 22 participants who died of pneumonia, 13 were complicated with the following diseases: 5 cerebrovascular diseases, 2 diabetes mellitus, 1 brain tumor, 1 femur fracture, 1 chronic pulmonary insufficiency, 1 pulmonary fibrosis, 1 metastatic lung cancer, and 1 pulmonary emphysema. In summary, 2 participants who died due to pneumonia had cancer as a complication (1 brain tumor, 1 metastatic lung cancer), and no patient had heart disease, according to the official death certificates.

The deceased individuals had lower serum total cholesterol concentrations and higher glucose concentrations than those who remained alive, as shown in Table 2. Individuals with low cholesterol levels (<186 mg/dL, \( n = 217 \)) had significantly higher total mortality rates (23.0% for the lowest group, 10.9% for the intermediate group, and 12.0% for the highest group: \( \chi^2 = 15.5, p = .0004 \)) than those with intermediate (between 186 and 220 mg/dL, \( n = 230 \)) or high cholesterol levels (\( \geq 221 \) mg/dL, \( n = 225 \)). BMI was higher in the survivors. Men and smokers were more likely to die during the follow-up period, whereas alcohol drinkers survived at rates similar to participants who never drank. SBP did not differ between individuals who survived and those who did not. Respiratory diseases (pneumonia, bronchial asthma, bronchiectasis, emphysema, pneumothorax, pulmonary tuberculosis, pneumoconiosis, and others), CVDs (cerebrovascular diseases, ischemic heart disease, arrhythmias, congenital heart diseases, and other heart diseases), and cancers (gastrointestinal system, liver/bile duct/pancreatic system, brain, uterus, ovary, nephrourinary system, and other organs) were considered prevalent complication diseases. The prevalence of these complications did not differ between individuals who survived and those who died during the follow-up period.

The mean values for handgrip strength, leg extensor strength (right leg + left leg), leg extensor strength (both legs), isokinetic leg extensor power, stepping rate, and one-leg standing time (balance performance test) were 25.3 ± 7.4 kg, 42.1 ± 16.2 kg, 38.0 ± 15.1 kg, 355.3 ± 184.6 W, 61.0 ± 15.1/10 seconds, and 13.7 ± 15.8 seconds, respectively. One-leg standing time for the worse (shorter duration) score was 9.2 ± 16.2 seconds, and that for the summed score was 25.4 ± 36.7 seconds. A gender difference was apparent in neuromuscular performance (handgrip strength, \( p < .0001 \); leg extensor strength [right leg + left leg], \( p < .0001 \); leg extensor strength [both legs], \( p < .0001 \); isokinetic leg extensor power, \( p < .0001 \); stepping rate, \( p < .0001 \); and one-leg standing time, \( p < .0001 \)).

Neuromuscular performance was compared between individuals who survived and those who did not survive the follow-up period (Tables 3 and 4). Men (Table 3) and women (Table 4) were evaluated separately. In men, handgrip strength, extensor strength of either or both legs, and isokinetic leg extensor power were significantly higher in the surviving group than in the nonsurviving group, whereas in women handgrip strength and stepping rate were higher in the former than in the latter. In contrast, neuromuscular performance was similar between men who died of CVD and men who did not. Stepping ability was slightly impaired in women who died due to CVD compared to those who did not. Men who did not die due to pneumonia had higher handgrip and leg extensor strength than men who died of pneumonia, whereas there was no difference in neuromuscular performance between women who did not die due to pneumonia and those who did. Men who did not die of cancer had greater handgrip and isokinetic leg extension power than men who did. In contrast, no difference was observed in neuromuscular performance between women who died of cancer and women who did not.

The combined performance scores were 19.3 ± 3.5 for men and 12.6 ± 3.4 for women. For each sex, these scores were compared between those who survived and those who died during the following 4 years. This score was lower in men who died due to all-cause diseases, due to pneumonia, or due to cancers than in those who survived (Table 3). In women, there was no significant difference in combined performance score between individuals who survived and those who did not (Table 4).

One-leg standing time using the worse (shorter duration) score also did not differ between individuals who died and those who survived (7.7 ± 12.7 vs 9.5 ± 16.7, \( p = .3901 \)), between those who died due to CVDs and those who survived (5.4 ± 3.6 vs 9.4 ± 6.5, \( p = .2884 \)), between those who died due to pneumonia and those who survived (9.7 ± 8.4 vs 9.2 ± 16.3, \( p = .9303 \)), and between those who died and those who survived (7.7 ± 12.7 vs 9.5 ± 16.7, \( p = .3901 \)).

| Basal Characteristics at the Age of 80 Years in Individuals Who Survived or Did Not Survive the 4-Year Follow-Up Period |
|-------------|-----------------|-------------|-----------------|
| Basal Characteristics Alive | Dead | \( p \) |
| % Men | 37.1% | 54.2% | .001 |
| % Smokers | 10.2% | 28.0% | <.001 |
| BMI, kg/m² | 22.9 ± 3.3 | 21.7 ± 3.0 | .001 |
| % Alcohol drinkers | 56.3% | 53.3% | .565 |
| SBP (mmHg) | 147.8 ± 22.3 | 151.0 ± 23.2 | .226 |
| Marital status | 49.50% | 54.30% | .365 |
| Cholesterol, mg/dL | 207.7 ± 37.4 | 194.6 ± 40.7 | .001 |
| Glucose, mg/dL | 120.2 ± 49.5 | 131.7 ± 60.4 | .039 |
| % Complication | 19.6% | 22.3% | .527 |

Note: BMI = body mass index; SBP = systolic blood pressure.
due to cancers and those who survived (7.4 ± 15.8 vs 9.3 ± 16.2, \( p = .5977 \)). Likewise, one-leg standing time using the summed score did not differ between individuals who died and those who survived (23.4 ± 33.9 vs 25.7 ± 37.1, \( p = .6140 \)), between those who died due to CVDs and those who survived (15.2 ± 8.0 vs 25.8 ± 37.2, \( p = .2162 \)), between those who died due to pneumonia and those who survived (35.1 ± 40.6 vs 25.3 ± 36.6, \( p = .4007 \)), and between those who died due to cancers and those who survived (23.6 ± 43.2 vs 25.5 ± 36.4, \( p = .8142 \)).

Individuals with CVD (\( n = 33 \)) were more likely than those without it to die due to pneumonia (\( n = 661 \) (4/33, 12.1% vs 18/661, 2.7%, \( p = .0026 \)), and had relatively lower leg extension strength (37.8 ± 19.4 vs 42.3 ± 16.4 for right leg + left leg, 35.8 ± 19.8 vs 38.1 ± 14.9 for both legs).

A combined performance score was obtained for 471 of 554 (85.0%) participants with ADL-1, 51 of 84 (60.7%) with ADL-2, 4 of 26 (15.4%) with ADL-3, 0 of 10 (0%) with ADL-4, 0 of 8 (0%) with ADL-5, and 0 of 2 (0%) with ADL-6. Because the participation rate markedly decreased with increased ADL impairment for each measurement, it was difficult to evaluate the relationships between ADL levels and levels measured in physical fitness tests. In contrast, data on exercise levels were self-reported in a questionnaire asking whether the participants exercised regularly. The combined performance score was 15.8 ± 4.9 (\( n = 317 \)) for individuals who exercised regularly, 14.8 ± 4.6 (\( n = 199 \)) for those who did not exercise regularly, and 14.9 ± 4.2 (\( n = 16 \)) for those who did not understand whether or not they exercised regularly; there were no significant differences among the three groups (\( F = 2.55 \), \( p = .0791 \)).

In multivariate Cox analyses, simultaneous adjustments were applied for gender, smoking, BMI, SBP, marital status, the levels of both total serum cholesterol and glucose, and complications of prevalent diseases at the age of 80 years. Because all of the participants were born in 1917, and were 80 years old at the time the study was begun, there was no difference in age. Therefore, age was not included in the multivariate analyses. The relative hazard ratios (HR)
for all-cause mortality, adjusted for various confounding factors, fell by 2% with each step per 10-second increase in the stepping rate, and the HR for pneumonia mortality fell (9% for right leg + left leg or 7% for both legs) with each 1-kg increase in leg extensor strength by right leg + left leg or both legs (Table 5). Similarly, HR for pneumonia mortality decreased by 24% with each 1-point increase in the combined score. The coefficient of variation calculated by (SD/mean) × 100% was used to compare the effects between one physical fitness measurement and another measurement. These coefficients were 24.6% for stepping rate, 38.5% for leg extensor strength (right leg + left leg), 39.8% for leg extensor strength (both legs), and 31.2% for combined score. Thus, a 1-point increase in the combined score contributes most strongly to the decrease in mortality. In contrast, there was no association between cardiovascular or cancer mortality and neuromuscular performance measurements including the combined performance score. Neuromuscular abilities, such as handgrip strength, one-leg standing time, leg extensor strength, and isokinetic leg extensor power, also were not related to total mortality, and handgrip strength, one-leg standing time, stepping rate, and isokinetic leg extensor power were not related to mortality due to pneumonia. Findings using Cox proportional hazards models without multivariate adjustment are also shown in Table 5, although no significant association was found between mortality and physical measurements. Gender interaction, using Cox proportional hazards modeling without adjustment, was highly significant in the comparisons between total mortality and handgrip strength (p < .0001), one-leg standing time (p = .0081), leg extensor strength (right + left) (p < .0001), leg extensor strength (both legs) (p = .0002), stepping rate (p = .0037), and isokinetic extensor power (p = .0011). We also found a slight gender interaction when we examined the association between pneumonia death and handgrip strength (p = .0354), leg extensor strength (right leg + left leg (p = .0050), or both legs (p = .0106) using Cox proportional hazards modeling with multivariate adjustment.
Table 5. Multivariate Cox Analyses of Physical Fitness Measurements for Total Mortality and for Mortalities Due to Cardiovascular Diseases, Cancer, or Pneumonia

<table>
<thead>
<tr>
<th>Physical Fitness Measurements</th>
<th>HR (95% CI) Without Multivariate Adjustment</th>
<th>HR (95% CI) With Multivariate Adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total mortality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handgrip strength</td>
<td>0.99 (0.96–1.02)</td>
<td>0.97 (0.93–1.02)</td>
</tr>
<tr>
<td>One-leg standing time</td>
<td>1.00 (0.98–1.01)</td>
<td>0.99 (0.97–1.01)</td>
</tr>
<tr>
<td>Leg extensor strength, right</td>
<td>0.99 (0.98–1.01)</td>
<td>0.98 (0.96–1.01)</td>
</tr>
<tr>
<td>Leg extensor strength, left</td>
<td>0.99 (0.98–1.01)</td>
<td>0.98 (0.96–1.01)</td>
</tr>
<tr>
<td>Stepping rate</td>
<td>0.99 (0.98–1.00)</td>
<td>0.98 (0.96–1.00)*</td>
</tr>
<tr>
<td>Isokinetic leg extensor power</td>
<td>1.00 (1.00–1.00)</td>
<td>1.00 (1.00–1.00)</td>
</tr>
<tr>
<td>Combined performance score</td>
<td>0.98 (0.94–1.03)</td>
<td>0.93 (0.86–1.00)</td>
</tr>
<tr>
<td>Cardiovascular mortality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handgrip strength</td>
<td>0.95 (0.90–1.02)</td>
<td>0.98 (0.89–1.07)</td>
</tr>
<tr>
<td>One-leg standing time</td>
<td>0.98 (0.93–1.02)</td>
<td>0.97 (0.91–1.02)</td>
</tr>
<tr>
<td>Leg extensor strength, right</td>
<td>0.98 (0.95–1.01)</td>
<td>0.99 (0.96–1.03)</td>
</tr>
<tr>
<td>Leg extensor strength, left</td>
<td>0.98 (0.95–1.01)</td>
<td>0.99 (0.95–1.04)</td>
</tr>
<tr>
<td>Stepping rate</td>
<td>0.97 (0.94–1.00)</td>
<td>0.98 (0.94–1.01)</td>
</tr>
<tr>
<td>Isokinetic leg extensor power</td>
<td>1.00 (1.00–1.00)</td>
<td>1.00 (1.00–1.00)</td>
</tr>
<tr>
<td>Combined performance score</td>
<td>0.91 (0.82–1.01)</td>
<td>0.89 (0.77–1.04)</td>
</tr>
<tr>
<td>Pneumonia mortality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handgrip strength</td>
<td>1.02 (0.96–1.08)</td>
<td>0.93 (0.84–1.03)</td>
</tr>
<tr>
<td>One-leg standing time</td>
<td>1.00 (0.97–1.04)</td>
<td>0.97 (0.92–1.03)</td>
</tr>
<tr>
<td>Leg extensor strength, right</td>
<td>0.97 (0.93–1.01)</td>
<td>0.91 (0.85–0.97)*</td>
</tr>
<tr>
<td>Leg extensor strength, left</td>
<td>0.98 (0.94–1.03)</td>
<td>0.93 (0.87–0.99)*</td>
</tr>
<tr>
<td>Stepping rate</td>
<td>0.99 (0.96–1.03)</td>
<td>0.96 (0.91–1.01)</td>
</tr>
<tr>
<td>Isokinetic leg extensor power</td>
<td>1.00 (1.00–1.00)</td>
<td>1.00 (0.99–1.00)</td>
</tr>
<tr>
<td>Combined performance score</td>
<td>0.96 (0.83–1.10)</td>
<td>0.76 (0.61–0.95)*</td>
</tr>
<tr>
<td>Cancer mortality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handgrip strength</td>
<td>1.00 (0.95–1.06)</td>
<td>0.98 (0.90–1.07)</td>
</tr>
<tr>
<td>One-leg standing time</td>
<td>0.99 (0.95–1.02)</td>
<td>0.99 (0.95–1.03)</td>
</tr>
<tr>
<td>Leg extensor strength, right</td>
<td>1.01 (0.98–1.03)</td>
<td>1.01 (0.97–1.05)</td>
</tr>
<tr>
<td>Leg extensor strength, left</td>
<td>1.00 (0.98–1.03)</td>
<td>1.00 (0.96–1.05)</td>
</tr>
<tr>
<td>Stepping rate</td>
<td>1.00 (0.97–1.03)</td>
<td>1.00 (0.97–1.04)</td>
</tr>
<tr>
<td>Isokinetic leg extensor power</td>
<td>1.00 (1.00–1.00)</td>
<td>1.00 (1.00–1.00)</td>
</tr>
<tr>
<td>Combined performance score</td>
<td>1.02 (0.93–1.11)</td>
<td>1.02 (0.87–1.19)</td>
</tr>
</tbody>
</table>

Notes: “Without Multivariable Adjustment” model was not adjusted for gender, smoking, body mass index (BMI), systolic blood pressure (SBP), marital status, levels of total serum cholesterol or glucose, or complications from prevalent diseases. “With Multivariable Adjustment” model was adjusted for these things.

*p < .01; †p < .05.

HR = hazard ratio; CI = confidence interval.

Discussion

A large body of epidemiological evidence indicates that physical activity or physical fitness helps prevent death due to all causes, CVD, and cancer. However, much of the evidence has come from studies conducted in people younger than 80 years. We evaluated this relationship in a very elderly (80-year-old) population using the Cox proportional hazards regression model with adjustment for various confounding factors, and found significant associations between leg extensor strength and mortality due to pneumonia, as well as between stepping rate and mortality due to all-cause diseases. In contrast, no association was found between neuromuscular performance and mortality due to CVDs or cancers.

Davis and colleagues (31) found, among women, less consistency of association between nonrecreational physical activity and early death in an elderly group (65–74 years old) than in a middle-aged group. Similarly, Gregg and colleagues (5) reported that the association between increased physical activity and reduced mortality tended to be weaker among elderly women (at least 75 years old) than among younger women. Era and Rantanen (14) also found that poor physical capacity at baseline in 75- or 80-year-olds was a significant predictor of all-cause mortality among women only. Studying an elderly Japanese population whose average age was 77 years, Oida and colleagues (20) found that regular exercise significantly affected mortality among women but not among men. Considering both the past and present findings, it seems likely that the effects of physical activity on life expectancy may fade with aging; especially, the associations between impaired neuromuscular performance and mortality due to CVD or cancer may disappear by the age of ≥ 80 years.

However, further investigation will be needed to determine the age at which physical fitness ceases to contribute to longevity. It also seems essential to perform young–old and old–older studies before drawing conclusions about the direct role of age.

In a Canadian middle-aged population (6), a significantly higher risk for total mortality was observed in both men and women belonging to the lowest quartile of sit-up ability, whereas grip strength was not predictive of mortality. This finding suggested that abdominal muscular endurance, which is necessary for the ability to do sit-ups, may be predictive of mortality. Similarly, in the present study, only stepping rate was associated with total mortality, and only leg extensor strength (right leg + left leg, and both legs) was associated with pneumonia mortality. In contrast, grip strength was not associated with mortality due to all causes, CVDs, pneumonia, or cancers. Because there was a positive association between complication with CVD and pneumonia death in the present study, it may be conjectured that individuals with CVD had both impaired leg extensor strength due to CVD-induced hemiparesis and a tendency toward dysphagia, which is related to aspiration pneumonia. These associations may be responsible for our finding that leg extensor strength was the only independent predictor of pneumonia death. Although pneumonia is a main cause of death in very elderly persons, very few investigators have focused on this relationship. Therefore, it seems valuable to further elucidate the association between neuromuscular performance and mortality due to pneumonia.

An association was also observed between stepping rate and total mortality. Because disease-specific mortality was not related to stepping rate significantly, this association seems difficult to explain. However, neuromuscular performance, probably neural firing rate, also may be related to cerebrovascular disease and CVD, which are responsible for...
pneumonia. Strokes are the most common cause of neurologic disease affecting deglutition, and impaired swallowing is known to be associated with aspiration pneumonia (32). The slight associations between stepping rate and pneumonia death ($p = .0847$) or cardiovascular death ($p = .1254$), although statistically not significant, could support this speculation. The findings shown in Tables 3 and 4 indicate that higher levels of muscle strength were related to a lower risk of death. Although the reason for this association was not clearly elucidated in our study, it could be related to physical reserves and the ability to counteract diseases when they occur.

However, as the sample size in the present study is very small in a number of subgroups and even overall, there is a large chance of type II error. This limitation should be considered before conclusions are drawn from the study. The events of this study, which used the Cox proportional hazards regression model with multivariate adjustment, also may be competing against each other. This competition could be the cause of the borderline significance with several of the diseases. In addition, besides the 697 individuals who participated in the study, 130 others agreed to participate but were unable to take the physical fitness tests and thus were excluded. During the 4-year follow-up period, 32 of those 130 individuals died (total mortality 24.6%; 14 pneumonias, 5 CVDs, 9 cancers, and 4 others), whereas 107 of the 697 participants died (total mortality 15.4%). This finding suggests that the 697 individuals were generally healthier than those who were unable to participate. Therefore, it is possible that this condition, that is, the ability to take these tests, may have skewed the results. It was also not apparent whether our findings might be specific to Japanese elderly populations. Further studies that are free of these limitations are necessary.

Conclusion

A partial association was observed between impaired neuromuscular performance at the age of 80 years and increased mortality during a 4-year follow-up period. Mortality due to all causes was related only to stepping rate, and mortality due to pneumonia was related only to leg extensor strength. Mortality due to CVDs or cancers was not associated with any measure of neuromuscular performance.

Acknowledgments

This work was supported in part by Grants-in-Aid for Scientific Research (B) 15390655, (B) 18390570, (B) 15390655, (B) 15592194, and (C) 16592092 from the Ministry of Education, Culture, Sports, Science, and Technology, Japan. The work regarding physical fitness in this study was supported by a Grant-in-Aid for Scientific Research from the National Institute of Fitness and Sports in Kanoya (President’s Discretionary Budget, to Y. Yoshitake).

Correspondence

Address correspondence to Yutaka Takata, MD, PhD, Division of General Internal Medicine, Kyushu Dental College, Manazuru 2-6-1, Kokurakita-ku, Kitakyushu City 803-8580, Japan. E-mail: yutaka@kyu-dent.ac.jp

References


Received June 13, 2006
Accepted October 19, 2006
Decision Editor: Luigi Ferrucci, MD, PhD