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Association of Disease-Specific Mortality with Fitness Measurements and Nonparticipation in an 80-Year-Old Population

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1. Introduction

A lower level of physical fitness and activity is known to be associated with a shorter survival rate in community-dwelling populations of adults and elderly (Blair et al., 2001; Erlichman et al., 2002; Rantanen, 2003; Mitnitski et al., 2005). Subjects' cardiorespiratory fitness level based on a cycle ergometer or treadmill was predictive of total mortality (Kampert et al., 1996; Bodegard et al., 2005; Park et al., 2009), fatal cardiac event (Laukkanen et al., 2004; Bodegard et al., 2005), or cancer mortality (Evenson et al., 2003) in adult persons. Leisure time activity and walking pace were also inversely associated with all-cause mortality and mortalities due to coronary heart disease, cardiovascular disease, respiratory disease, and cancers in middle-aged men (Kampert et al., 1996; Simith et al., 2000; Lam et al., 2004; Batty et al., 2010).

In an elderly population of 75-year-olds, poor physical activity was a predictor of mortality in women but not in men (Era and Rantanen, 1997). Increasing and maintaining physical activity could lengthen life for older women aged between 65 and 75 years (Gregg et al., 2003). Physical fitness as measured by the stepping rate of legs was also inversely related to all-cause 4-year mortality in an 80-year-old population (Takata et al., 2007). In an elderly population, poor muscle strength is related to increased mortality. Lowest tertiles of 75- and 80-year-old individuals for strength of handgrip, elbow flexion, knee extension, trunk extension, and trunk flexion had a higher total mortality than that of individuals in the highest tertiles (Portegijs et al., 2007). Handgrip strength was a predictor of all-cause mortality in the oldest elderly population (Ling et al., 2010), persons aged 65 and over (Gale et al., 2007), and persons aged 70-79 years (Newman et al., 2006).

As mentioned above, although a lower level of physical activity, physical fitness, or muscle strength is likely to be associated with a higher total mortality in an elderly population, the

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association between these findings and disease-specific mortality has not been investigated. Therefore, the purpose of the present study was to determine an association in physical fitness measurements including muscle strength with disease-specific mortality during a 12-year follow-up in an 80-year-old population.

2. Materials and methods

In 1998, a total of 1282 individuals who were 80 years old resided in three cities (Buzen, Yukuhashi, and Munakata), four towns (Katsuyama, Tikujo, Toyotsu, and Kanda), one village (Shinyoshitomi), and one ward (Tobata of Kikakyushu City) in Japan's Fukuoka Prefecture. These nine locations were selected randomly from urban, suburban, and rural communities with the goal of achieving a balance of living environments, including socio-demographic backgrounds, dietary habits, health behaviors, and medical treatment. Of these 1282 individuals, 694 (54.1%) (274 males and 420 females) agreed to participate in the present study, and each participant underwent both a physical examination and a laboratory blood examination. The 694 participants were followed up for 12 years after the baseline examination. Confirmation of whether the patient was living or had died was obtained by asking the family via a telephone call or home visit. The cause of death was classified according to the 10th version of the International Classification of Diseases (ICD-10). Thirty-eight subjects were lost to follow-up over the 12 years. 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. Informed consent for study participation was obtained from all participants.

Measurements of physical fitness included hand-grip strength, one-leg standing time, leg extensor strength of a single leg, leg extensor strength of both legs, stepping rate of legs, and isokinetic leg extensor power. The numbers of subjects participating in these physical fitness tests were 642, 551, 555, 556, 567, and 547, respectively. Hand-grip strength was measured in each hand using a Smedley hand dynamometer (DM-100s; Yagami, Nagoya, Japan). The best value of two trials for each hand was taken as the score for the test. One-leg standing time was measured with the eyes open. This time represented the number of seconds until the subject had to hop, since the subject was instructed to hop as a way to avoid putting the raised foot down, until the raised foot was lowered to the floor, or until 2 min had elapsed. One trial was performed on the right and one on the left leg; the better score was used for statistical analysis. The leg extensor strength test was measured using a portable chair incorporating a strain gauge connected to a load cell. The subject sat in the chair in a vertical position with the legs hanging vertically and the knee initially bent at 90°. The trial was performed three times—once for each leg individually, and again for both legs simultaneously. The value for each side in this test was summed as the subject's score for leg extension strength of single leg. On the other hand, the value for both legs simultaneously was used as leg extension strength of both legs. The stepping rate was measured using an industrial stepping rate counter (Stepping Counter; Yagami, Nagoya, Japan); while sitting, the subject was instructed to step with each leg as rapidly as possible during 10 seconds. The stepping rate for both legs was summed as the subject's score. Isokinetic leg extensor power was determined by a dynamometer (Aneropress 3500; Combi, Tokyo, Japan). The subject 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 subject was applied as resistance. The best score from five trials was used for statistical analysis.

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. Associations between physical fitness and time to 12-year mortality were assessed using the multivariate Cox proportional hazards regression model. Gender, smoking, body mass index (BMI), and levels of total serum cholesterol and glucose were fitted as continuous variables. Comparisons of the survival rates among groups according to physical fitness measurements and participation in tests were assessed by the method of Kaplan and Meier, followed by a log-rank test to assess the significance between survival curves. All statistical analyses were performed using SPSS 16.0 (SPSS Japan, Inc., Tokyo, Japan). Results were considered statistically significant when P had a value below 0.05.

3. Results

During the follow-up period of 12 years from April 1998 to March 2010, out of 694 subjects who participated in the present study, 414 died, 242 were alive, and 38 were lost to follow-up. The follow-up rate was 94.5%. Of the 414 who died, 106 deaths were due to cardiovascular and cerebrovascular diseases, 73 to respiratory disease, 71 to cancer, 39 to senility, 18 to digestive system disease, 14 to exogenous death, 7 to neurological disease, 6 to urinary tract diseases, 12 to other diseases, and 68 to unknown reasons. The percentages of death due to all causes for men and women were 75.5% and 54.7% (χ^2=29.184, P=0.000), those of death due to cardiovascular and cerebrovascular diseases for men and women were 18.1% and 14.8% (χ^2=1.254, P=0.281), those of death due to cancers for men and women were 14.0% and 8.7% (χ^2=4.539, P=0.040), those of death due to respiratory diseases for men and women were 16.2% and 7.7% (χ^2=11.686, P=0.001), and those of death due to senility for men and women were 4.2% and 7.2% (χ^2=2.560, P=0.130), respectively. The cardiovascular cerebrovascular diseases suffered by study participants were heart failure (37), brain infarction (23), myocardial infarction (16), aortic aneurysm (9), brain bleeding (3), ischemic heart diseast (3), hypertension (2), stroke (1), pulmonary infarction (1), sick sinus syndrome (1), subdural bleeding (1), subarachnoidal bleeding (1), carotid artery aneurysm (1), angina (1), and cardiac rupture. Details were unknown in 5 cases. The respiratory diseases suffered by study participants were pneumonia (59), respiratory failure (8), bronchial asthma (1), emphysema (1), chronic bronchitis (1), and chronic obstructive lung disease (1). Details were unknown in 2 cases. The cancers suffered by study participants were lung cancer (16), gastric cancer (12), hepatic cancer (10), colon cancer (6), urinary tract cancer (5), pancreatic cancer (4), uterine cancer (4), bile duct cancer (2), ovarian cancer (1), leukemia (1), gallbladder cancer (1), multiple myeloma (1), laryngeal cancer (1), peritoneal cancer (1), chondrosarcoma (1), malignant lymphoma (1), and malignant mesothelioma (1). Details were unknown in 2 cases.

Basal characteristics at the start of study in individuals at age of 80-year who died or did not die during the following 12-year are shown in Table 1. BMI and serum level of total cholesterol were lower in non-survivors than in survivors, while serum level of glucose was higher in the former than in the latter. Systolic blood pressure (SBP) did not differ between individuals who were alive and those who died during the follow-up period. Men and smokers were more prevalent in the non-survivor than in the survivor group, whereas no difference was found in the percent of alcohol drinkers or the percent who suffered complications between the non-survivors and the survivors.

	Alive (n)	Dead (n)	P-value
SBP, mmHg	151.0±22.5 (230)	149.7±23.9 (384)	0.517
Cholesterol, mg/dL	214.4±35.3 (235)	199.6±38.2 (399)***	0.000
Glucose, mg/dL	115.0±40.7 (233)	126.1±57.5 (395)**	0.005
BMI, kg/m^2	23.2±3.1 (241)	22.4±3.4 (397)**	0.006
% Men	26.9% (242)	48.3% (414)***	0.000
% Smokers	4.6% (240)	17.7% (407)***	0.000
% Alcohol drinkers	56.7% (231)	54.8% (403)	0.648
% Complications	84.1% (232)	83.5% (401)	0.867

Table 1. Basal characteristics at the start of study in individuals at age of 80-year-old who die or did not die during the following 12-year period. *P<0.05, **P<0.01, ***P<0.001

At the start of the study, when all participants were 80 years old, 642, 551, 555, 556, 567, and 547 individuals completed the handgrip strength test, one-leg standing test, leg extension strength test of a single leg, leg extension strength test of both legs, stepping rate test of legs, and leg extension power test, respectively. Scores for each physical fitness test were compared between men (Table 2A) or women (Table 2B) who were alive and those who died from all causes, cardiovascular disease, respiratory disease, cancer, or senility during the 12-year follow-up period. Scores of handgrip strength, one-leg standing, leg extension strength of a single leg, leg extension strength of both legs, and leg extension power were higher in men who survived than in those in the all-cause mortality group, while scores of stepping rate of legs were not different. Scores for handgrip strength, leg extension strength of a single leg, leg extension strength of both legs, and leg extension power were higher in men who did not die due to respiratory disease than in those who died due to respiratory disease. Men who did not die due to senility also had a higher score of one-leg standing time than that of men who died due to senility. Similarly, in women, scores for handgrip strength, leg extension strength of a single leg, leg extension strength of both legs, stepping rate of legs, and leg extension power were higher in survivors than in non-survivors. Scores for stepping rate were slightly higher in women who did not die due to cardiovascular disease than in women who died due to cardiovascular disease. Women who did not die from respiratory disease had a higher score for leg extension power than that of women who died from respiratory disease. Women who died from cancer had a slightly higher score of leg extension strength of a single leg than that of women who did not die from cancer. Scores for handgrip strength, leg extension strength of a single leg, leg extension strength of both legs, and leg extension power were higher in women who did not die due to senility than in women who died due to senility.

A. Men

	Alive			Died			P value
	n	Mean	SD	n	Mean	SD	
Handgrip strength							
All-cause death	61	33.8	6.2	186	31.1**	6.4	0.005
Cardiovascular death	204	31.9	6.4	43	31.2	6.5	0.554
Respiratory death	207	32.3	6.4	40	29.2**	5.9	0.006
Cancer death	212	32.0	6.2	35	30.5	7.4	0.227
Senile death	237	31.7	6.5	10	32.5	5.0	0.711
One-leg standing time							
All-cause death	54	22.0	22.0	155	15.4*	18.7	0.033
Cardiovascular death	174	17.4	19.9	35	15.8	19.4	0.659
Respiratory death	180	17.3	19.8	29	15.8	20.0	0.693
Cancer death	178	17.6	20.5	31	14.5	15.1	0.428
Senile death	201	17.5	20.1	8	7.8***	2.8	0.000
Leg extension strength (right leg + left leg)							
All-cause death	59	57.3	13.2	163	51.5**	15.1	0.009
Cardiovascular death	185	52.4	14.7	37	56.2	15.2	0.147
Respiratory death	189	50.0	13.3	32	45.4**	13.7	0.001
Cancer death	190	53.3	15.1	32	51.2	13.0	0.443
Senile death	214	52.9	14.9	8	56.3	10.3	0.530
Leg extension strength (both legs)							
All-cause death	59	52.9	12.5	162	47.5**	13.7	0.009
Cardiovascular death	184	48.8	13.6	37	49.6	13.5	0.750
Respiratory death	189	50.0	13.3	32	42.8**	13.5	0.006
Cancer death	189	49.1	13.6	32	47.8	13.2	0.620
Senile death	213	48.8	13.6	8	53.9	12.8	0.295
Stepping rate of legs							
All-cause death	59	68.6	14.8	166	64.9	15.6	0.116
Cardiovascular death	187	66.4	15.8	38	63.7	13.8	0.345
Respiratory death	193	65.9	15.3	32	66.1	17.0	0.951
Cancer death	193	65.7	15.6	32	67.5	14.7	0.539
Senile death	217	65.5	15.5	8	76.4	11.7	0.051
Leg extension power							
All-cause death	59	568.2	160.2	163	461.7***	180.4	0.000
Cardiovascular death	182	493.1	177.9	40	476.1	197.1	0.593
Respiratory death	191	501.4	178.0	31	419.7*	187.5	0.019
Cancer death	191	495.3	183.8	31	457.3	163.2	0.279
Senile death	214	489.4	182.1	8	505.3	166.0	0.799

B. Women

	Alive			Died			P value
	n	Mean	SD	n	Mean	SD	
Handgrip strength							
All-cause death	166	21.8	3.3	193	20.2***	4.7	0.000
Cardiovascular death	304	20.9	4.1	55	21.1	4.7	0.743
Respiratory death	332	21.0	4.2	27	19.9	4.0	0.161
Cancer death	328	20.9	4.2	31	21.4	4.4	0.504
Senile death	336	21.1	4.1	23	18.7**	4.2	0.009
One-leg standing time							
All-cause death	150	12.2	13.4	160	10.6	11.9	0.280
Cardiovascular death	262	11.6	13.0	48	9.9	10.4	0.388
Respiratory death	288	11.2	12.8	22	13.2	10.5	0.474
Cancer death	282	11.2	12.1	28	13.2	17.6	0.427
Senile death	290	11.6	13.0	20	8.6	6.6	0.307
Leg extension strength (right leg + left leg)							
All-cause death	144	37.0	11.9	156	31.8***	12.4	0.000
Cardiovascular death	254	34.5	12.2	46	33.3	13.3	0.547
Respiratory death	278	34.5	12.4	22	31.7	11.5	0.308
Cancer death	270	33.8	12.4	30	38.6*	11.4	0.042
Senile death	282	35.0	12.2	18	23.4***	10.4	0.000
Leg extension strength (both legs)							
All-cause death	146	32.1	10.5	156	28.2**	10.7	0.001
Cardiovascular death	254	29.9	10.3	48	30.9	12.9	0.548
Respiratory death	280	30.3	10.7	22	27.2	10.9	0.202
Cancer death	273	29.8	11.0	29	32.0	8.0	0.293
Senile death	284	30.7	10.6	18	20.4***	8.9	0.000
Stepping rate of legs							
All-cause death	148	59.3	13.3	161	55.5*	13.5	0.014
Cardiovascular death	261	58.0	13.5	48	53.7*	13.2	0.042
Respiratory death	287	57.4	13.5	22	56.2	14.6	0.687
Cancer death	279	57.1	13.8	30	59.4	11.3	0.391
Senile death	290	57.3	13.6	19	58.0	13.4	0.829
Leg extension power							
All-cause death	142	273.1	103.5	150	236.1**	99.7	0.002
Cardiovascular death	247	254.4	101.8	45	252.4	110.7	0.907
Respiratory death	271	257.5	103.9	21	210.2*	81.9	0.019
Cancer death	263	250.3	102.4	29	288.3	104.8	0.059
Senile death	277	257.3	102.8	15	195.1*	92.1	0.023

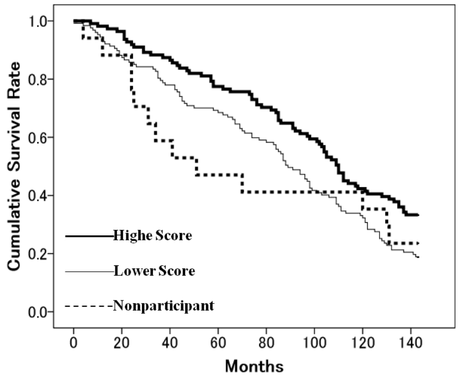
Table 2. Physical fitness measurements at the start of the study in 80-year-old men (A) and women (B) who died or did not die due to all causes, cardiovascular disease, respiratory disease, cancer, or senility, during the 12-year follow-up period.. *$P<0.05$, **$P<0.01$, ***$P<0.001$

Overall survival curves obtained by the Kaplan-Meier method during the 12-year follow-up period in men and women who had a higher score, lower score, or did not participate in physical fitness tests such as handgrip strength (Fig. 1A), one-leg standing (Fig. 1B), leg extension strength of a single leg (Fig. 1C), leg extension strength of both legs (Fig. 1D), stepping rate of legs (Fig. 1E), and leg extension power (Fig. 1F) are shown in Figure 1. Table 3A shows the χ^2 and P with the log rank test by the Kaplan-Meier method for comparisons of the overall survival curves among groups. Men and women who had a high score on the handgrip strength test survived longer than those with a low score. Women with a high score on the handgrip test also survived longer than women who did not participate in this test (Fig 1A, Table 3A). The survival rate in the group with a high score on the one-leg standing test was better than that in men or women nonparticipants. Women with a low score on the one-leg standing time test also had a better survival rate than that of those who did not participate in this fitness test (Fig. 1B, Table 3A). Men and women with high scores for leg extension strength of a single leg, leg extension strength of both legs, or leg extension power had a better survival rate than that of those with low scores on these tests or that of those who did not participate in these tests. Men with low scores for leg extension strength of both legs also survived slightly longer than nonparticipants (Figs. 1C, 1D, 1F, Table 3A). Men or women with high scores for stepping rate had a better survival rate than those who did not participate in this test. Women with a high score for stepping rate also had a better survival rate than that of those with a low score (Fig. 1E, Table 3A).

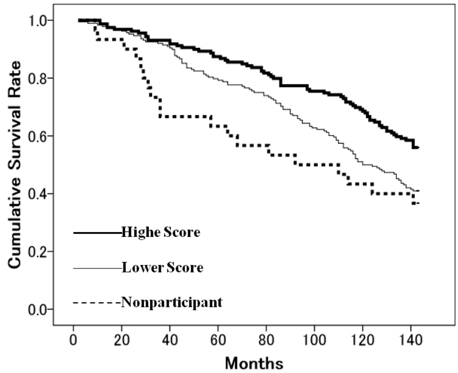
Survival rates for men who did not die from cardiovascular diseases were better in those with a high score on the leg extension strength test of both legs and on the stepping rate test of legs than for those who did not participate in these fitness tests. Men with cardiovascular disease and with a low score on the leg extension strength test of a single leg or both legs also had a better survival rate than that of nonparticipants. Women with high score on stepping rate test also did not die from cardiovascular diseases as compared to women with low score on this test (Table 3B).

Survival curves in men and women who did not die due to respiratory disease also were compared among individuals with a high score, a low score, or nonparticipation for various fitness tests. Men and women with high score on leg extension power test had better survival rate from respiratory disease than those with low score or nonparticipation on this test. Men with low score on the leg extension power test also had a better survival rate than that of nonparticipants. Men with high score on leg extension strength test of single leg and leg extension strength test of both legs had longer survival curves from respiratory disease than men with low score or without participation on these fitness tests. Longer survival curves from respiratory disease were found in men with a high score on the handgrip test than in those with a low score. Similarly, men with a high score on the one-leg standing time test or the stepping rate test survived longer than nonparticipants. Men with a low score on the stepping rate test also survived longer than men who were nonparticipants (Table 3C).

Survival curves in men and women, who did not die from cancer, were not different among individuals with high score, low score, and nonparticipation for each fitness test (Table 3D). Men with low score for leg extension strength test of double legs or stepping rate test of leg died from senility fewer than nonparticipants. Survival rate in men who did not die from senility were longer in those with high score for leg extension power test than in those without participation. A better survival rate was found in women with high score for

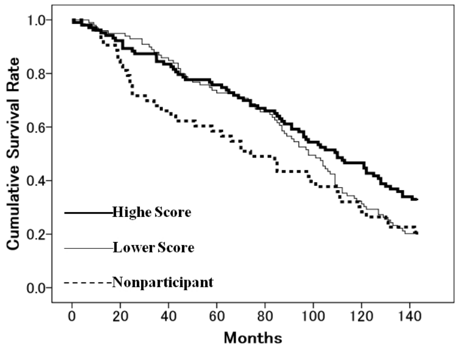


Men

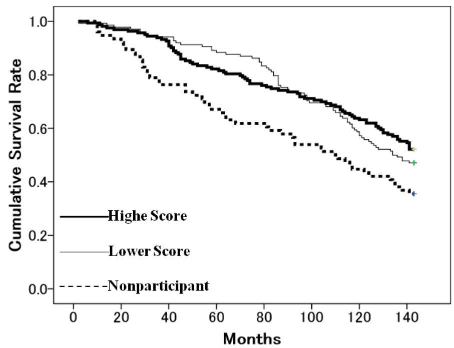


Women

A. Handgrip strength

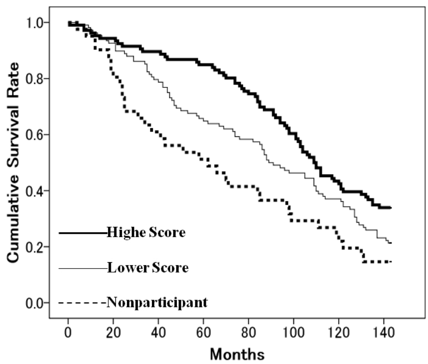


Men

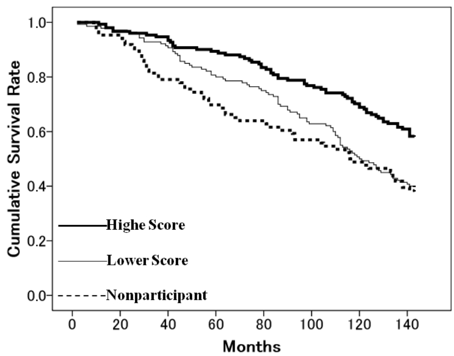


Women

B. One-leg standing

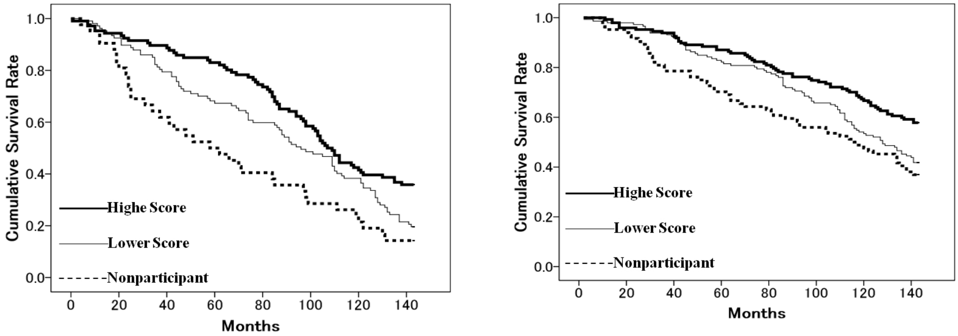


Men



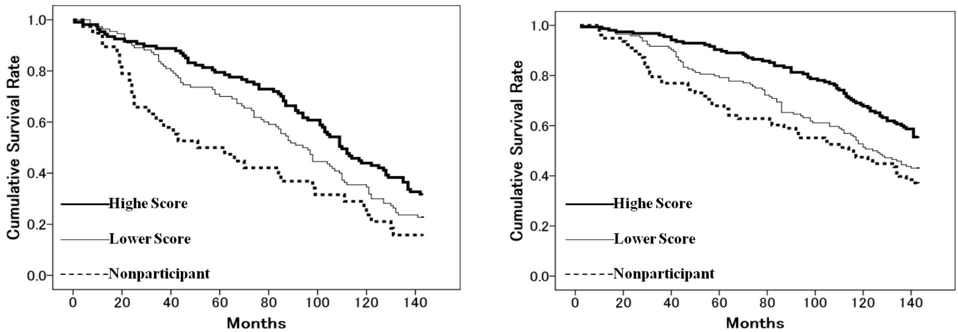
Women

C. Leg extension strength of a single leg (right leg + left leg)



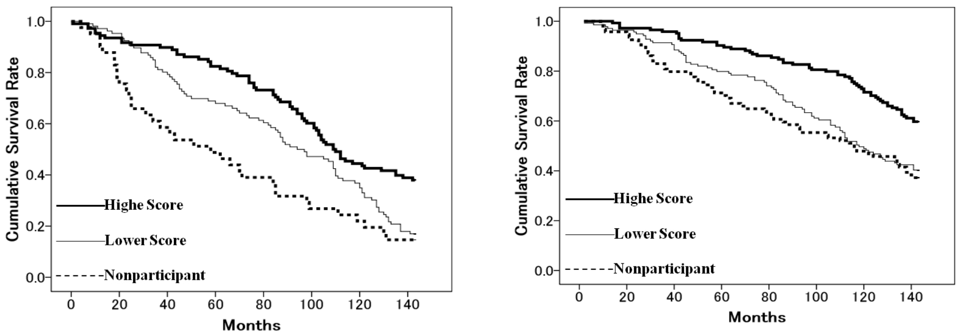
Men Women

D. Leg extension strength of both legs



Men Women

E. Stepping rate of legs



Men Women

F. Leg extension power

Fig. 1. Overall survival curve during the 12-year follow-up period in men and women who had a higher score (▬▬▬), lower score (———), or did not participate (···········) in physical fitness tests such as handgrip strength (Fig. 1A), one-leg standing (Fig. 1B), leg extension strength of a single leg (Fig. 1C), leg extension strength of both legs (Fig. 1D), stepping rate of legs (Fig. 1E), and leg extension power (Fig. 1F) .

handgrip strength test, leg extension strength test of single leg, leg extension strength test of double legs, or leg extension power test than in those with low score or nonparticipation for test. Women with a high score on the one-leg standing test also had a better survival rate than that of nonparticipants (Table 3E).

	Men		Women	
	χ^2 value	P values	χ^2 value	P values
Handgrip strength test				
among 3 groups	7.849*	0.020	11.904**	0.003
between high score *vs.* low score	7.467**	0.006	8.743**	0.003
between high score *vs.* nonparticipant	2.249	0.134	7.452**	0.006
between low score *vs.* nonparticipant	0.011	0.917	1.147	0.284
One-leg standing test				
among 3 groups	5.817	0.055	9.333**	0.009
between high score *vs.* low score	3.058	0.080	0.428	0.513
between high score *vs.* nonparticipant	4.801*	0.028	8.437**	0.004
between low score *vs.* nonparticipant	0.747	0.387	5.513*	0.019
Leg extension strength test of a single leg				
among 3 groups	13.729**	0.001	15.064**	0.001
between high score *vs.* low score	5.200*	0.023	10.651**	0.001
between high score *vs.* nonparticipant	12.912***	0.000	12.088**	0.001
between low score *vs.* nonparticipant	3.500	0.061	0.430	0.512
Leg extension strength test of both legs				
among 3 groups	14.970**	0.001	12.904**	0.002
between high score *vs.* low score	5.577*	0.018	6.663*	0.010
between high score *vs.* nonparticipant	13.671***	0.000	11.709**	0.001
between low score *vs.* nonparticipant	3.941*	0.047	1.551	0.213
Stepping rate test of legs				
among 3 groups	10.760**	0.005	12.787**	0.002
between high score *vs.* low score	3.800	0.051	6.858**	0.009
between high score *vs.* nonparticipant	9.935**	0.002	11.662**	0.001
between low score *vs.* nonparticipant	3.320	0.068	1.383	0.240
Leg extension power test				
among 3 groups	19.701***	0.000	19.175***	0.000
between high score *vs.* low score	9.682**	0.002	13.530***	0.000
between high score *vs.* nonparticipant	16.706***	0.000	16.197***	0.000
between low score *vs.* nonparticipant	3.520	0.061	0.597	0.440

A. Comparisons among survival curves during the 12-year follow-up period in men or women who did not die from any cause, and had a high score, low score, or nonparticipation in the physical fitness tests listed.

	Men		Women	
	χ^2 value	P values	χ^2 value	P values
Handgrip strength test				
among 3 groups	2.724	0.256	0.801	0.670
between high score *vs.* low score	0.582	0.446	0.726	0.394
between high score *vs.* nonparticipant	2.752	0.097	0.025	0.875
between low score *vs.* nonparticipant	1.345	0.246	0.194	0.660
One-leg standing test				
among 3 groups	4.030	0.133	0.015	0.993
between high score *vs.* low score	0.917	0.338	0.000	0.996
between high score *vs.* nonparticipant	3.822	0.051	0.003	0.953
between low score *vs.* nonparticipant	1.400	0.237	0.014	0.905
Leg extension strength test of a single leg				
among 3 groups	6.730*	0.035	2.766	0.251
between high score *vs.* low score	0.317	0.573	2.800	0.094
between high score *vs.* nonparticipant	3.677	0.055	0.698	0.403
between low score *vs.* nonparticipant	6.280*	0.012	0.275	0.600
Leg extension strength test of both legs				
among 3 groups	6.223*	0.045	0.196	0.907
between high score *vs.* low score	0.000	0.992	0.051	0.821
between high score *vs.* nonparticipant	4.216*	0.040	0.195	0.659
between low score *vs.* nonparticipant	5.045*	0.025	0.065	0.798
Stepping rate test of legs				
among 3 groups	8.064*	0.018	6.648*	0.036
between high score *vs.* low score	3.448	0.063	6.678*	0.010
between high score *vs.* nonparticipant	7.440**	0.006	0.972	0.324
between low score *vs.* nonparticipant	1.809	0.179	1.014	0.314
Leg extension power test				
among 3 groups	3.411	0.182	2.391	0.302
between high score *vs.* low score	1.914	0.166	2.388	0.122
between high score *vs.* nonparticipant	2.509	0.113	0.652	0.419
between low score *vs.* nonparticipant	0.481	0.488	0.250	0.617

B. Comparisons among survival curves during the 12-year follow-up period in men or women who did not die from cardiovascular disease, and had a high score, low score, or nonparticipation in the physical fitness tests listed.

	Men		Women	
	χ^2 value	P values	χ^2 value	P values
Handgrip strength test				
among 3 groups	9.739**	0.008	3.426	0.180
between high score *vs.* low score	9.992**	0.002	2.941	0.086
between high score *vs.* nonparticipant	1.979	0.160	2.089	0.148
between low score *vs.* nonparticipant	0.110	0.740	0.131	0.718
One-leg standing test				
among 3 groups	8.307*	0.016	3.646	0.162
between high score *vs.* low score	2.035	0.154	1.681	0.195
between high score *vs.* nonparticipant	7.718**	0.005	0.747	0.388
between low score *vs.* nonparticipant	2.665	0.103	3.531	0.060
Leg extension strength test of a single leg				
among 3 groups	17.233***	0.000	4.006	0.135
between high score *vs.* low score	11.127**	0.001	3.581	0.058
between high score *vs.* nonparticipant	17.127***	0.000	2.719	0.099
between low score *vs.* nonparticipant	1.656	0.198	0.000	0.999
Leg extension strength test of both legs				
among 3 groups	16.817***	0.000	4.564	0.102
between high score *vs.* low score	11.044**	0.001	3.948*	0.047
between high score *vs.* nonparticipant	16.284***	0.000	3.383	0.066
between low score *vs.* nonparticipant	1.534	0.215	0.012	0.914
Stepping rate test of legs				
among 3 groups	9.651**	0.008	1.992	0.369
between high score *vs.* low score	0.010	0.920	0.375	0.541
between high score *vs.* nonparticipant	7.836**	0.005	2.059	0.151
between low score *vs.* nonparticipant	7.124**	0.008	0.740	0.390
Leg extension power test				
among 3 groups	17.995***	0.000	11.839**	0.003
between high score *vs.* low score	7.648**	0.006	12.360***	0.000
between high score *vs.* nonparticipant	17.326***	0.000	7.351**	0.007
between low score *vs.* nonparticipant	3.989*	0.046	0.176	0.675

C. Comparisons among survival curves during the 12-year follow-up period in men or women who did not die from respiratory disease, and had a high score, low score, or nonparticipation in the physical fitness tests listed.

	Men		Women	
	χ^2 value	P values	χ^2 value	P values
Handgrip strength test				
among 3 groups	0.374	0.830	0.385	0.825
between high score *vs.* low score	0.383	0.536	0.061	0.806
between high score *vs.* nonparticipant	0.013	0.908	0.173	0.678
between low score *vs.* nonparticipant	0.014	0.907	0.377	0.539
One-leg standing test				
among 3 groups	0.726	0.696	0.480	0.787
between high score *vs.* low score	0.713	0.398	0.473	0.492
between high score *vs.* nonparticipant	0.018	0.894	0.032	0.858
between low score *vs.* nonparticipant	0.252	0.616	0.141	0.707
Leg extension strength test of a single leg				
among 3 groups	1.181	0.554	3.132	0.209
between high score *vs.* low score	1.099	0.295	1.385	0.239
between high score *vs.* nonparticipant	0.544	0.461	2.475	0.116
between low score *vs.* nonparticipant	0.011	0.915	0.363	0.547
Leg extension strength test of both legs				
among 3 groups	0.473	0.789	1.630	0.443
between high score *vs.* low score	0.415	0.519	0.999	0.318
between high score *vs.* nonparticipant	0.286	0.592	1.120	0.290
between low score *vs.* nonparticipant	0.000	0.984	0.042	0.838
Stepping rate test of legs				
among 3 groups	0.653	0.721	0.881	0.644
between high score *vs.* low score	0.444	0.505	0.012	0.914
between high score *vs.* nonparticipant	0.474	0.491	0.890	0.346
between low score *vs.* nonparticipant	0.069	0.793	0.685	0.408
Leg extension power test				
among 3 groups	2.552	0.279	1.158	0.561
between high score *vs.* low score	1.864	0.172	0.081	0.776
between high score *vs.* nonparticipant	2.011	0.156	1.149	0.284
between low score *vs.* nonparticipant	0.111	0.739	0.574	0.449

D. Comparisons among survival curves during the 12-year follow-up period in men or women who did not die from cancer, and had a high score, low score, or nonparticipation in the physical fitness tests listed.

	Men		Women	
	χ^2 value	P values	χ^2 value	P values
Handgrip strength test				
among 3 groups	0.692	0.708	13.709**	0.001
between high score *vs.* low score	0.287	0.592	7.993**	0.005
between high score *vs.* nonparticipant	0.500	0.479	14.736***	0.000
between low score *vs.* nonparticipant	0.155	0.694	2.190	0.139
One-leg standing test				
among 3 groups	3.034	0.219	3.999	0.135
between high score *vs.* low score	2.160	0.142	0.868	0.352
between high score *vs.* nonparticipant	2.960	0.085	4.126*	0.042
between low score *vs.* nonparticipant	0.151	0.697	1.369	0.242
Leg extension strength test of a single leg				
among 3 groups	4.290	0.117	14.829**	0.001
between high score *vs.* low score	0.012	0.914	12.770***	0.000
between high score *vs.* nonparticipant	3.190	0.074	14.281***	0.000
between low score *vs.* nonparticipant	3.387	0.066	0.145	0.704
Leg extension strength test of both legs				
among 3 groups	4.901	0.086	16.023***	0.000
between high score *vs.* low score	0.830	0.362	13.538***	0.000
between high score *vs.* nonparticipant	2.192	0.139	16.511***	0.000
between low score *vs.* nonparticipant	5.041*	0.025	0.315	0.575
Stepping rate test of legs				
among 3 groups	5.060	0.080	4.525	0.104
between high score *vs.* low score	0.638	0.424	0.000	0.988
between high score *vs.* nonparticipant	2.671	0.102	3.554	0.059
between low score *vs.* nonparticipant	5.046*	0.025	3.196	0.074
Leg extension power test				
among 3 groups	4.874	0.087	15.178**	0.001
between high score *vs.* low score	0.000	0.994	6.547*	0.011
between high score *vs.* nonparticipant	3.907*	0.048	15.939***	0.000
between low score *vs.* nonparticipant	3.234	0.072	2.446	0.118

E. Comparisons among survival curves during the 12-year follow-up period in men or women who did not die from senility, and had a high score, low score, or nonparticipation in the physical fitness tests listed.

Table 3. χ^2 value and P value with the log rank test by the Kaplan-Meier method for comparisons of the survival curves among groups in men or women who had a high score, a low score, or nonparticipation in physical fitness tests during the 12-year follow-up period in subjects who did not die due to any cause (A), cardiovascular diseases (B), respiratory disease (C), cancer (D), or senility (E).

Survival curves were also compared between participants and nonparticipants. Men who participated survived longer than nonparticipants in the case of the fitness tests of single or double leg extension strength, stepping rate of legs, or leg extension power, while women who participated survived longer than nonparticipants in the case of the fitness tests for one-leg standing time, single or double leg extension strength, stepping rate of legs, or leg extension power (Table 4A). Cardiovascular deaths were more prevalent in men who did not participate than in men who participated in fitness tests of single or double leg extension strength or stepping rate of legs, while no difference in cardiovascular deaths was found between women who participated and those who did not participate in any fitness test (Table 4B). Similarly, mortality due respiratory disease was more prevalent for nonparticipating men than for participating men in the case of the fitness tests of one-leg standing time, single or double leg extension strength, stepping rate of legs, or leg extension power, while there was no difference in respiratory mortality between women who participated and those who did not participate in any fitness test (Table 4C). No difference was found in cancer mortality between nonparticipants and participants in men or women (Table 4D). Mortality due to senility was higher in women who did not participate in the handgrip strength test, single or double leg extension strength test, stepping rate test of legs, and leg extension power test, whereas senility mortality was more prevalent in nonparticipating men for tests of single or double leg extension strength, stepping rate of legs, or leg extension power (Table 4E).

	Men		Women	
	χ^2 value	P values	χ^2 value	P values
Handgrip strength test				
between participants and nonparticipants	0.629	0.428	3.664	0.056
One-leg standing test				
between participants and nonparticipants	3.087	0.079	8.955	0.003**
Leg extension strength test of a single leg				
between participants and nonparticipants	9.102	0.003**	5.609	0.018*
Leg extension strength test of both legs				
between participants and nonparticipants	9.994	0.002**	6.969	0.008**
Stepping rate test of legs				
between participants and nonparticipants	7.449	0.006**	6.759	0.009**
Leg extension power test				
between participants and nonparticipants	11.226	0.001**	7.530	0.006**

A. Comparisons among survival curves during the 12-year follow-up period in men or women who did not die from any cause, between participants and nonparticipants in the physical fitness tests listed.

	Men		Women	
	χ^2 value	P values	χ^2 value	P values
Handgrip strength test				
between participants and nonparticipants	2.228	0.136	0.096	0.757
One-leg standing test				
between participants and nonparticipants	3.287	0.070	0.014	0.904
Leg extension strength test of a single leg				
between participants and nonparticipants	6.391	0.011*	0.028	0.868
Leg extension strength test of both legs				
between participants and nonparticipants	6.220	0.013*	0.141	0.708
Stepping rate test of legs				
between participants and nonparticipants	5.256	0.022*	0.003	0.957
Leg extension power test				
between participants and nonparticipants	1.793	0.181	0.028	0.867

B. Comparisons among survival curves during the 12-year follow-up period in men or women who did not die from cardiovascular disease, between participants and nonparticipants in the physical fitness tests listed.

	Men		Women	
	χ^2 value	P values	χ^2 value	P values
Handgrip strength test				
between participants and nonparticipants	0.132	0.716	0.698	0.403
One-leg standing test				
between participants and nonparticipants	6.816	0.009**	2.163	0.141
Leg extension strength test of a single leg				
between participants and nonparticipants	8.190	0.004**	0.852	0.356
Leg extension strength test of both legs				
between participants and nonparticipants	7.829	0.005**	1.063	0.302
Stepping rate test of leg				
between participants and nonparticipants	9.650	0.002**	1.702	0.192
Leg extension power test				
between participants and nonparticipants	12.316	0.000***	1.234	0.267

C. Comparisons among survival curves during the 12-year follow-up period in men or women who did not die from respiratory disease, between participants and nonparticipants in the physical fitness tests listed.

	Men		Women	
	χ^2 value	P values	χ^2 value	P values
Handgrip strength test				
between participants and nonparticipants	0.000	0.984	0.311	0.577
One-leg standing test				
between participants and nonparticipants	0.041	0.840	0.010	0.919
Leg extension strength test of a single leg				
between participants and nonparticipants	0.083	0.773	1.480	0.224
Leg extension strength test of both legs				
between participants and nonparticipants	0.059	0.808	0.492	0.483
Stepping rate test of legs				
between participants and nonparticipants	0.220	0.639	0.857	0.355
Leg extension power test				
between participants and nonparticipants	0.819	0.365	1.031	0.310

D. Comparisons among survival curves during the 12-year follow-up period in men or women who did not die from cancer, between participants who had a high score and nonparticipants in the physical fitness tests listed.

	Men		Women	
	χ^2 value	P values	χ^2 value	P values
Handgrip strength test				
between participants and nonparticipants	0.375	0.540	6.758	0.009**
One-leg standing test				
between participants and nonparticipants	1.283	0.257	3.290	0.070
Leg extension strength test of a single leg				
between participants and nonparticipants	4.284	0.038*	4.792	0.029*
Leg extension strength test of both legs				
between participants and nonparticipants	4.284	0.038*	5.421	0.020*
Stepping rate test of leg				
between participants and nonparticipants	4.537	0.033*	4.524	0.033*
Leg extension power tests				
between participants and nonparticipants	4.874	0.027*	11.045	0.001**

E. Comparisons among survival curves during the 12-year follow-up period in men or women who did not die from senility, between participants and nonparticipants in the physical fitness tests listed.
*P<0.05, **P<0.01, ***P<0.001

Table 4. χ^2 value and P value with the log rank test by the Kaplan-Meier method for comparisons of the survival curves among groups in men or women who participated or did not participate in physical fitness tests during the 12-year follow-up period in subjects who did not die due to any cause (A), cardiovascular diseases (B), respiratory disease (C), cancer (D), or senility (E).

Associations between physical fitness measurements and mortalities due to all causes, cardiovascular diseases, respiratory diseases, cancers, or senility were assessed by multivariate Cox regression analyses adjusted for gender, serum level of total cholesterol and glucose, BMI, and smoking, being performed to calculate the risk for mortality associated with a 1 kg, 1 s, 1 step/10 s, 1 W increase (continuous analysis) in each fitness measurement (Table 5). Since all subjects were 80 years old at the start of the study, age was not included as a confounding factor in these analyses. All-cause mortality adjusted for various confounding factors fell 0.2% with 1 W increase in leg extension power. Similarly, total mortality decreased by 1-2% with 1 kg increase in single or double leg extension strength. A decrease in all-cause mortality by 3% was also found with 1 kg increase in handgrip strength. A 1% fall in all-cause mortality was found with an increase of 1 s in one-leg standing time or an increase of 1 step/10 s in stepping rate (Table 5A). Mortality due to cardiovascular diseases was decreased by 2% with a 1 step/10 s increase in stepping rate, while the mortality rate was not associated with the other fitness measurements (Table 5B). There were associations between muscle strength of leg extension or handgrip and mortality due to respiratory diseases. A 3-4% decrease in mortality due to respiratory diseases was found with a 1 kg increase in single or double leg extension strength. Similarly, mortality due to respiratory diseases was decreased by 0.3% with a 1 W increase in leg extension power. A 1 kg increase in handgrip strength was also associated with a 6% fall in mortality from respiratory diseases (Table 5C). No associations were found between mortality from cancers and physical fitness measurements (Table 5D). Mortality due to senility was associated with muscle strength. A 5-6% fall in mortality from senility was found with a 1 kg increase in single or double leg extension strength. Similarly, a 0.3% fall in mortality from senility was found with a 1 W increase in leg extension power. A 1 kg increase in handgrip strength was associated with a 9% decrease in mortality due to senility (Table 5E).

Physical fitness measurement	Hazard ratio	95% CI	P value
Hand grip strength (kg)	0.970**	0.949-0.990	0.004
One-leg standing time (s)	0.991*	0.983-0.999	0.030
Leg extension strength, single leg (kg)	0.983***	0.974-0.992	0.000
Leg extension strength, two legs (kg)	0.986**	0.976-0.997	0.009
Stepping rate (steps/10 s)	0.987**	0.980-0.995	0.001
Leg extension power (W)	0.998***	0.998-0.999	0.000

A. Mortality due to all causes

Physical fitness measurement	Hazard ratio	95% CI	P value
Hand grip strength (kg)	0.987	0.946-1.029	0.525
One-leg standing time (s)	0.989	0.973-1.006	0.194
Leg extension strength, single leg (kg)	0.996	0.979-1.013	0.649
Leg extension strength, two legs (kg)	0.999	0.980-1.018	0.916
Stepping rate (steps/10 s)	0.981**	0.966-0.995	0.008
Leg extension power (W)	0.999	0.997-1.000	0.087

B. Mortality due to cardiovascular diseases

Physical fitness measurement	Hazard ratio	95% CI	P value
Hand grip strength (kg)	0.943*	0.897-0.992	0.022
One-leg standing time (s)	0.992	0.974-1.011	0.422
Leg extension strength, single leg (kg)	0.963**	0.941-0.985	0.001
Leg extension strength, two legs (kg)	0.968*	0.944-0.993	0.012
Stepping rate (steps/10 s)	0.991	0.972-1.009	0.324
Leg extension power (W)	0.997**	0.995-0.999	0.006

C. Mortality due to respiratory diseases

Physical fitness measurement	Hazard ratio	95% CI	P value
Hand grip strength (kg)	1.001	0.953-1.051	0.965
One-leg standing time (s)	0.995	0.978-1.013	0.608
Leg extension strength, single leg (kg)	1.004	0.983-1.024	0.725
Leg extension strength, two legs (kg)	1.002	0.979-1.025	0.859
Stepping rate (steps/10 s)	1.007	0.989-1.025	0.452
Leg extension power (W)	1.000	0.998-1.002	0.765

D. Mortality due to cancers

Physical fitness measurement	Hazard ratio	95% CI	P value
Hand grip strength (kg)	0.911*	0.847-0.980	0.012
One-leg standing time (s)	0.957	0.910-1.007	0.089
Leg extension strength, single leg (kg)	0.945**	0.914-0.976	0.001
Leg extension strength, two legs (kg)	0.941**	0.906-0.978	0.002
Stepping rate (steps/10 s)	1.009	0.982-1.037	0.520
Leg extension power (W)	0.997*	0.993-1.000	0.036

E. Mortality due to senility

Note: In A through E, the analyses calculate the risk of mortality associated with a 1 kg, 1 s, 1 step/ 10 s, and 1 W increase in each fitness measurement (continuous analysis), and were adjusted for gender, serum level of total cholesterol and glucose, BMI, and smoking.

*P<0.05, **P<0.01, ***P<0.001

Table 5. Multivariate Cox analyses for mortality in total subjects (men and women) due to all causes (A), cardiovascular diseases (B), respiratory diseases (C), cancers (D), or senility (E) with physical fitness measurements at the start of study.

4. Discussion

We found an inverse association between muscle strength of leg extension or handgrip and mortalities due to all causes, respiratory disease, or senility in an 80-year-old community-dwelling Japanese population. One-leg standing time and stepping rate of legs were also inversely associated with total mortality. Mortality due to cardiovascular disease was associated only with stepping rate, and mortality due to cancers was not associated with any fitness measurement. Not only low scores but also nonparticipation for all fitness tests was related to shorter survival. Nonparticipation in tests for leg extension strength or stepping rate was partly related to cardiovascular death, while nonparticipation in tests of leg extension strength, steeping rate, leg extension power, or one-leg standing was partly related to respiratory disease death. No association was found in cancer death with nonparticipation for any fitness test. Senility death was partly related to nonparticipation for all fitness tests.

Poor muscle strength has been reported to be independently associated with mortality risk in healthy middle-aged men (Rantanen et al., 2000; Rantanen, 2003; Metter et al., 2004), people aged 20-69 years (Katzmarzyk et al., 2002), and elderly people (Era and Rantanen, 1997; Gale et al., 2006; Newman et al., 2006a; Portegijs et al., 2007; Takata et al., 2007; Ling et al., 2010). After adjusting for confounders, a significant elevation in all-cause mortality was found in the lowest tertile of handgrip strength at age 85 years, and in the lowest two tertiles of handgrip strength at age 89 years (65.0% women; Ling et al., 2010). Both handgrip strength and knee extension strength (51.6% women) were strongly related to all-cause mortality in participants aged 70-79 years (Newman et al., 2006). Similarly, the lowest tertile of handgrip, elbow flexion, knee extension, trunk extension, and trunk flexion was related to approximately twofold higher mortality from all causes in community-dwelling 75- and 80-year-old people (67.2% women; Portegijs et al., 2007). Poorer grip strength was associated with increased mortality from not only all causes but also from cardiovascular disease and from cancer in men aged 65 and over (Gale et al., 2006), while this association was not found in women. We also previously found an association between pneumonia mortality and leg extension strength of a single leg in an 80-year-old population with a 4-year follow-up period (Takata et al., 2007). The present findings that mortality due to respiratory disease or senility was higher in elderly with poor muscle strength of leg extension or handgrip indicate a new association between disease-specific mortality and muscle strength. Since there have been only a few investigations of the elderly with regard to the association between disease-specific mortality and muscle strength, further investigations are needed.

In studies of middle-aged populations, there have been several reports indicating an association in disease-specific mortality with physical activity or physical fitness. Blair and his coworkers (2001) summarized results from 67 articles and found greater longevity and reduced risk of coronary heart disease, cardiovascular disease, stroke, and colon cancer in more active individuals. They also found that men aged 20 to 82 years who maintained adequate fitness or improved their physical fitness were less likely to die from all causes and from cardiovascular disease than persistently unfit men (1995). An inverse association between exercise frequency and mortality in adults aged 35 years and over was stronger for cardiovascular than cancer deaths and was strongest in the case of respiratory mortality (Lam et al., 2004). Leisure time activity was inversely related to all-cause, cardiovascular, coronary heart disease, and noncardiovascular mortality among men aged 40 to 64 years (Batty et al., 2003). Walking pace was inversely related to mortality due to all causes, coronary heart disease, and total cancer in males aged 40 to 69 years (Batty et al., 2010). Similarly, a strong inverse association was found in individuals with an average age of 43 years between all-cause mortality and level of physical fitness in both men and women. The risk of mortality from cancer declined with increasing levels of fitness or physical activity among men, but not among women with an average age of 43 years (Kampert et al., 1996). Walking pace in men aged 40 to 64 years demonstrated inverse relations with mortality from all causes, coronary heart disease, other cardiovascular disease, all cancers, respiratory disease, colorectal cancer, and hematopoietic cancer with adjustment for confounding factors (Smith et al., 2000). Adjusted cancer mortality was lower in the most fit quintile relative to the other four quintiles for men but not for women with an average age of 46 years (Evenson et al., 2003). Peak exercise oxygen consumption with a cycle ergometer exercise test in men aged 42 to 60 years was predictive of non-fatal and fatal cardiac events among men with and without risk factors (Laukkanen et al., 2004). Both regular physical activity and a high level of fitness in middle-aged men were inversely related to all-cause, cancer, and cardiovascular mortalities (Park et al, 2009).

In a similar fashion to the middle-aged population, there are studies indicating an association between poor physical activity and disease-specific mortality in the elderly population, though there are fewer studies investigating an association between disease-specific mortality and physical fitness level of the elderly population. Women aged 65 years or over with increased walking and physical activity had lower mortality from all causes, cardiovascular disease, and cancer (Gregg et al., 2003). Inability to complete walking 400 m in participants aged 70 to 79 years was associated with a higher risk of total mortality and incident cardiovascular disease (Newman et al., 2006b).

Nonparticipation in regular exercise was associated with high mortality due to all causes and cardiovascular disease, but not cancers among women aged 40 to 70 years (Nechuta et al., 2010). In a population-based survey for 54,372 Finnish people aged 25 to 64 years, nonparticipant men had twice and nonparticipant women had 2.5-fold higher all-cause mortality than the participating men and women. Nonparticipants had also significantly higher cause-specific mortalities due to cardiovascular disease and violence, whereas no difference was found in mortality due to cancer between participants and nonparticipants (Jousilahti et al., 2005). Annual mortality among nonparticipants was twice that of the participants during a follow-up period of 11.8 years in that study. Coronary death was significantly more common among nonparticipants (Rosengren et al., 1987). In very elderly persons older than 90 years, nonparticipants for follow-up study had lower levels of physical activity and leisure activity (Fernandez-Ballesteros et al., 2010), suggesting that nonparticipants are likely to have a worse survival rate than participants. These investigations all suggest that all-cause and cardiovascular disease mortality seems higher in nonparticipants than in participants during long-term surveys or in regular exercise program. However, little is known about an association in mortality with nonparticipation in fitness tests in an elderly population. We found in the present study that 80-year-old subjects who were nonparticipants in physical fitness tests were partly associated with higher mortality from all causes, cardiovascular disease, respiratory disease, and senility as compared to participants, while no association was found between nonparticipation and cancer mortality.

A limitation of the present study is that the sample size was relatively small. Since the subject age was limited to 80 years, the association between physical fitness and mortality in very elderly individuals older than 80 years should be evaluated in a future study. It is also possible that residual confounding factors other than gender, serum level of total cholesterol and glucose, BMI, and smoking could influence the findings. However, the present findings clearly suggest that physical fitness measurements and nonparticipation in tests predict all-cause and disease-specific mortality at the age of 80 in community-dwelling adults.

5. Conclusion

In the present study, lower fitness levels for various muscle strength tests were found to be associated with increases in not only all-cause mortality but also disease-specific mortality in an 80-year-old community-dwelling population. Nonparticipation in fitness tests was also associated with increased mortalities. These findings suggest that very elderly persons could survive longer by elevating their level of physical fitness and muscle strength. Intervention study in a very elderly population is needed to clarify the effect of fitness on longevity.

6. References

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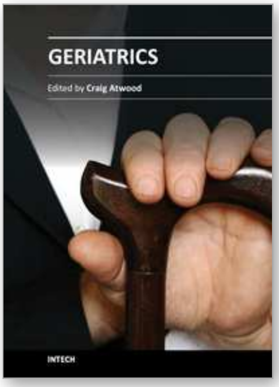

Geriatrics

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With the baby boomer generation reaching 65 years of age, attention in the medical field is turning to how best to meet the needs of this rapidly approaching, large population of geriatric individuals. Geriatric healthcare by nature is multi-dimensional, involving medical, educational, social, cultural, religious and economic factors. The chapters in this book illustrate the complex interplay of these factors in the development, management and treatment of geriatric patients, and begin by examining sarcopenia, cognitive decline and dysphagia as important factors involved in frailty syndrome. This is followed by strategies to increase healthspan and lifespan, such as exercise, nutrition and immunization, as well as how physical, psychological and socio-cultural changes impact learning in the elderly. The final chapters of the book examine end of life issues for geriatric patients, including effective advocacy by patients and families for responsive care, attitudes toward autonomy and legal instruments, and the cost effectiveness of new health care technologies and services.

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