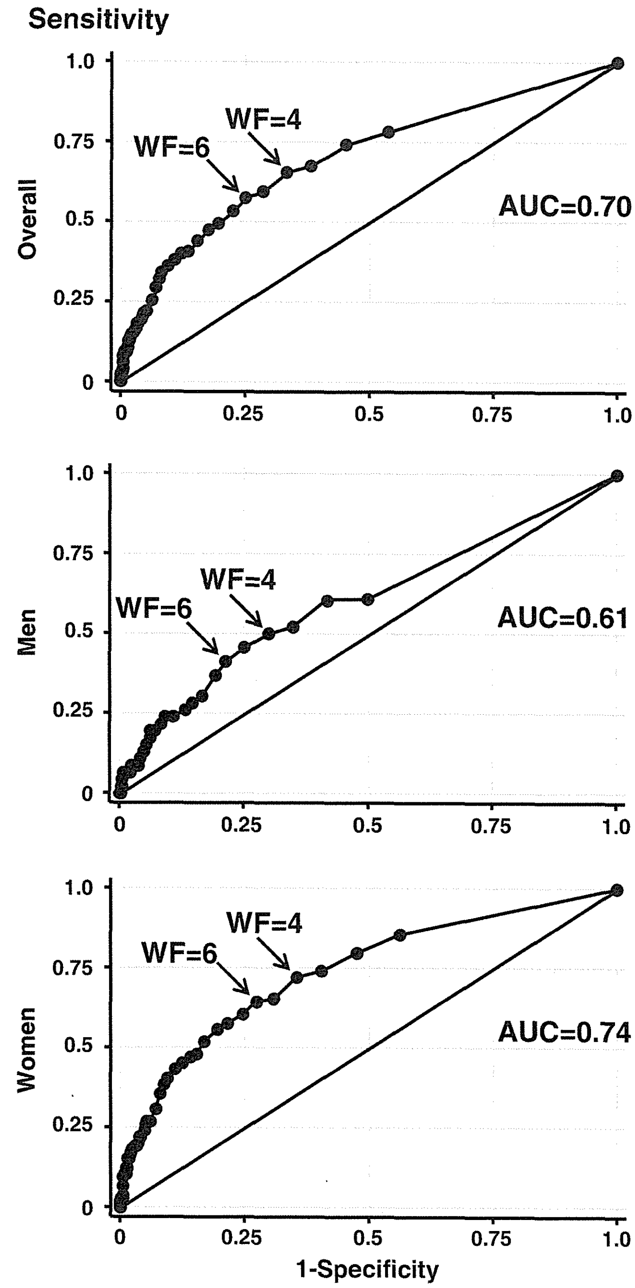

Fig. 1 Receiver operating characteristic (ROC) curve analysis for discriminating the occurrence group of certified need of care in the overall population, in men, and in women. *AUC* area under ROC curve, *WF* WOMAC (Western Ontario and McMaster Universities Osteoarthritis Index) function score

occurrence group of certified need of care after adjusting for age, sex, BMI, and region (Table 4). The group with WOMAC function score ≥4 was significantly associated with the occurrence of certified need of care compared with the group with the score <4 with the highest HR in the overall population [HR 2.54, 95 % CI (1.76–3.67)] and in women [HR 3.13, 95 % CI (1.95–5.02)]. In men, the group with WOMAC function score ≥5 was significantly

Table 3 Sensitivity and specificity of the occurrence of certified need of care determined by the cut-off point of the WOMAC function score

Cut-off point	Overall population			Men			Women		
	Sensitivity (%)	Specificity (%)	Sensitivity + specificity (%)	Sensitivity (%)	Specificity (%)	Sensitivity + specificity (%)	Sensitivity (%)	Specificity (%)	Sensitivity + specificity (%)
WF = 4pts	65.3	66.7	132.0	50.0	70.0	120.0	72.1	64.5	136.6
WF = 5pts	59.3	71.4	130.7	45.7	75.0	120.7	65.4	69.2	134.6
WF = 6pts	57.3	75.0	132.3	41.3	78.6	119.9	64.4	72.6	137.0

WOMAC the Western Ontario and McMaster Universities Arthritis Index, *WF* WOMAC function score

Table 4 Association of groups divided by the WOMAC function score with the occurrence of certified need of care in the LTCI system

	Overall population		Men		Women	
	HR (95 % CI)	*P* value	HR (95 % CI)	*P* value	HR (95 % CI)	*P* value
WF ≥ 4 pts vs WF < 4 pts	2.54 (1.76, 3.67)	<0.001	1.85 (1.01, 3.39)	0.045	3.13 (1.95, 5.02)	<0.001
WF ≥ 5 pts vs WF < 5 pts	2.35 (1.64, 3.36)	<0.001	1.88 (1.03, 3.43)	0.040	2.71 (1.73, 4.27)	<0.001
WF ≥ 6 pts vs WF < 6 pts	2.50 (1.75, 3.58)	<0.001	1.84 (1.00, 3.39)	0.051	3.03 (1.93, 4.76)	<0.001

Hazard ratios (HRs) and 95 % confidence intervals (CIs) were determined by Cox proportional hazards regression analysis after adjusting for age, sex, body mass index, and region in the overall population, and after adjusting for age, body mass index, and region in men and in women, respectively

WOMAC the Western Ontario and McMaster Universities Arthritis Index, *LTCI* long-term care insurance system, *WF* WOMAC function score

Table 5 Association of the WOMAC function score with the occurrence of different certified need of care levels in the LTCI system

Outcome variable	Overall population		Men		Women	
	HR (95 % CI)	*P* value	HR (95 % CI)	*P* value	HR (95 % CI)	*P* value
RSL1–2 and RCL 1–5	1.05 (1.03, 1.06)	<0.001	1.03 (1.01, 1.06)	0.008	1.05 (1.04, 1.07)	<0.001
RCL 1–5	1.05 (1.03, 1.07)	<0.001	1.04 (1.00, 1.07)	0.046	1.06 (1.03, 1.08)	<0.001
RCL 2–5	1.06 (1.04, 1.08)	<0.001	1.04 (1.01, 1.08)	0.015	1.06 (1.04, 1.09)	<0.001
RCL 3–5	1.05 (1.03, 1.08)	<0.001	1.05 (0.99, 1.10)	0.099	1.06 (1.02, 1.09)	0.001
RCL 4–5	1.04 (1.00, 1.08)	0.048	1.02 (0.95, 1.10)	0.501	1.05 (1.00, 1.10)	0.057
RCL 5	1.01 (0.93, 1.09)	0.830	0.99 (0.82, 1.20)	0.945	1.01 (0.93, 1.11)	0.780

Hazard ratios (HRs) and 95 % confidence intervals (CIs) were determined by Cox proportional hazards regression analysis after adjusting for age, sex, body mass index, and region in the overall population, and after adjusting for age, body mass index, and region in men and in women, respectively

WOMAC the Western Ontario and McMaster Universities Arthritis Index, *LTCI* long-term care insurance system, *RSL* requiring support level, *RCL* requiring long-term care level

associated with the occurrence of certified need of care compared with the group with a score of <5 with the highest HR [HR 1.88, 95 % CI (1.03–3.43)].

Furthermore, we examined association of the WOMAC function domain with the occurrence of different certified need of care levels in the LTCI system (Table 5). When the outcome variable of the occurrence was defined as requiring support level (RSL) 1–2 and requiring long-term care level (RCL) 1–5, RCL 1–5, and RCL 2–5, there were significant associations in the overall population, in men, and in women, respectively. When the outcome variable of the occurrence was defined as RCL 3–5, there were significant associations in the overall population and in women. When the outcome variable of the occurrence was defined as RCL 4–5, there was significant association in the overall population.

Discussion

The present study determined association of physical ADLs with the incidence of certified need of care in the national LTCI system in elderly participants of Japanese population-based cohorts. All 17 items in the WOMAC function domain were significantly associated with the occurrence of certified need of care in the overall population. ROC curve analysis showed that cut-off values of the WOMAC function score of around 4–6 maximized the sum of sensitivity and specificity of the occurrence of certified need of care. Furthermore, multivariate Cox hazards regression analysis revealed that the group with WOMAC function score ≥4 was significantly associated with the occurrence of certified need of care with the highest HR after adjusting for confounders in the overall population and in women, while the group with WOMAC function score ≥5 was significantly associated with the highest HR in men.

In the present study, we could not obtain information on causes of certified need of care in the LTCI system. Therefore, we could not analyze the direct association of each causing condition with the WOMAC function domain. The Government of Japan reported that the top five leading causes of certified need of care were cerebral stroke (21.5 %), dementia (15.3 %), asthenia as a result of older age (13.7 %), joint disease (10.9 %) and fall-related fracture (10.2 %), comprising 71.6 % of all causes in 2010 [10]. Based on these data, most of the causes of incident certification in the present study are inferred to be among the top five leading conditions. Although we could not know the exact percentage of each causing condition, joint disease and fall-related fracture are inferred to represent approximately 20 % in total causes of incident certification in the present study, and cerebral stroke, dementia, and asthenia as a result of older age are inferred to represent approximately 50 % in total causes of incident certification.

The Government of Japan also reported that the percentage of joint disease and fall-related fracture was 16.7 % for the cause of RCL 1–5 [10]. Furthermore, it was 17.6, 19.8, 14.8, 17.4, and 9.8 % for the cause of RCL 1, 2, 3, 4, and 5, respectively [10]. Although we could not know the exact percentage of joint disease and fall-related fracture for the cause of each RCL in the present study, the percentage for the cause of RCL 1–4 is inferred to be approximately 15 % or more based on the data of the Government of Japan, which may be the reason why the WOMAC domain was significantly associated with the occurrence of certified need of care including RCLs 1–4 in the overall population.

The WOMAC physical function domain assesses difficulties in ADLs, including going up/down stairs, getting in/out of a car and bath, shopping, and household duties. Therefore, results of the present study indicate that the severity of physical dysfunction in ADLs predicts subsequent deterioration in ADLs, leading to the occurrence of certified need of care. Previous studies reported that low physical function was a predictor of subsequent ADL disability in the elderly [11, 12]. Although no previous studies have investigated the association of physical ADLs with the incidence of certified need of care in the national LTCI system in large-scale population-based cohorts, those previous findings are consistent with the present results in that low physical activity predicted subsequent deterioration in ADLs.

All 17 items in the WOMAC domain were significantly associated with the occurrence of certified need of care in women. On the other hand, 9 of 17 items were significantly associated with the occurrence of certified need of care in men. In addition, the HR for each item in the association was higher in women than in men for 15 of 17 items. The sex difference identified in this association may be due to the difference in the prevalence of knee osteoarthritis between the sexes. Muraki et al. [13] reported that prevalence of radiographic knee osteoarthritis determined by the Kellgren–Lawrence grade ≥ 2 was 47.0 % in men and 70.2 % in women, respectively, in subjects aged 60 years and older in Japanese population-based cohorts. Therefore, women are more likely than men to be affected by knee osteoarthritis and have difficulties in physical function of the lower extremities, leading to higher scores on the WOMAC function scale. Another reason for the sex differences may be the weaker muscle strength in women; muscle strength in men is higher than that in women in all decades of life [14], which may obscure the association in men, as muscle strength has been reported to be inversely associated with the WOMAC domains [15].

Functional declines in locomotive organs including physical ADLs usually progress slowly and gradually. As such, it may be difficult for people to recognize this decline in their daily life. Therefore, it is of particular importance to raise awareness of the growing risk caused by such disorders, and to take action to improve and maintain the health of the locomotive organs. The Japanese Orthopaedic Association proposed the concept of "locomotive syndrome" in 2007 for the promotion of preventive healthcare of the locomotive organs [16–18]. Locomotive syndrome refers to conditions under which the elderly have been receiving support or long-term care, or high-risk conditions under which they may soon require support or long-term care, that are caused by musculoskeletal disorders [16–18]. Population approaches, including promotion of the concept of locomotive syndrome to both younger and older generations, are important, in addition to high-risk approaches, including identifying those at risk for certified need of care and practicing intervention programs to reduce the risk of certified need of care.

Because the WOMAC function scale is a self-assessment questionnaire that is easy to conduct and evaluate, it can be used to screen elderly persons at high risk of certified need of care in the LTCI system. Multivariate Cox hazards regression analysis showed that a WOMAC function score of 5 in men and 4 in women best discriminated between the occurrence and the non-occurrence group of certified need of care in this study population. Elderly men with a WOMAC function score ≥ 5 had a 1.88-fold higher risk of occurrence of certified need of care compared with elderly men with a score <5. Elderly women with a WOMAC function score ≥ 4 had a 3.13-fold higher risk of occurrence of certified need of care compared with elderly women with a score <4. Elderly persons screened by these cut-off values should receive early intervention for the prevention of subsequent deterioration in ADLs that could lead to certified need of care. Further studies, along with the accumulation of epidemiologic evidence, are necessary to develop intervention programs that are safe and effective for elderly subjects who are at high risk of certified need of care.

There are some limitations in the present study. First, we could not obtain information on causes of certified need of care in the LTCI system. Therefore, we could not analyze the direct association of each causing condition with measured factors, and could not determine the risk factors for occurrence of certified need of care with respect to each causing condition. The Japanese government reported that the top five leading causes of certified need of care were cerebral stroke, dementia, asthenia, osteoarthritis, and fall-related fracture, comprising 71.6 % of all causes in 2010 [10]. Based on these data, most of the causes of incident certification in the present study are inferred to be among the top five leading conditions. Additional studies are necessary to identify those direct associations. Second, participants at baseline in the present study were those who could walk to the survey site and could understand and sign an informed consent form. Since those who could not were not included in the analyses, the study participants do not truly represent the general population due to health bias, which should be taken into consideration when generalizing the results of the present study.

In conclusion, the present study determined association of physical ADLs with the occurrence of certified need of care in the LTCI system in elderly participants of Japanese population-based cohorts. The severity of physical dysfunction is a predictor of the occurrence of certified need of care. Further studies are necessary to develop intervention programs that are safe and effective for elderly individuals who are at high risk of certified need of care.

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Conflict of interest There are no conflicts of interest.

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ORIGINAL ARTICLE

Exercise habits during middle age are associated with lower prevalence of sarcopenia: the ROAD study

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Abstract
Summary The present cross-sectional study investigated the prevalence of sarcopenia and clarified its associated factors in 1,000 elderly participants of Japanese population-based cohorts. Exercise habit in middle age was associated with low prevalence of sarcopenia in older age, suggesting that it is a protective factor against sarcopenia in older age.
Introduction The present study investigated the prevalence of sarcopenia using the European Working Group on Sarcopenia in Older People (EWGSOP) definition, and clarified the association of sarcopenia with physical performance in the elderly participants of Japanese population-based cohorts of the Research on Osteoarthritis/osteoporosis Against Disability (ROAD) study.
Methods We enrolled 1,000 participants (aged ≥65 years) from the second visit of the ROAD study who had completed assessment of handgrip strength, gait speed, and skeletal muscle mass measured by bioimpedance analysis. Presence of sarcopenia was determined according to the EWGSOP algorithm. Information collected included exercise habits in middle age.
Results Prevalence of sarcopenia was 13.8 % in men and 12.4 % in women, and tended to be significantly higher according to increasing age in both sexes. Factors associated with sarcopenia, as determined by logistic regression analysis, were chair stand time (odds ratio [OR], 1.09; 95 % confidence interval [CI], 1.04–1.14), one-leg standing time (OR, 0.97; 95 % CI, 0.96–0.99), and exercise habit in middle age (OR, 0.53; 95 % CI, 0.31–0.90). Exercise habit in middle age was associated with low prevalence of sarcopenia in older age. Furthermore, linear regression analysis revealed that exercise habits in middle age were significantly associated with grip strength ($P<.001$), gait speed ($P<.001$), and one-leg standing time ($P=.005$) in older age.
Conclusions This cross-sectional study suggests that exercise habit in middle age is a protective factor against sarcopenia in older age and effective in maintaining muscle strength and physical performance in older age.

Keywords Elderly · Epidemiology · Exercise · Physical performance · Sarcopenia

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Introduction

Sarcopenia is characterized by generalized loss of skeletal muscle mass and muscle strength and/or function in the elderly, causing multiple adverse health outcomes, including physical disability, poor quality of life, and death [1–6]. Although cross-sectional studies have investigated prevalence of sarcopenia [7–13], epidemiologic evidence using population-based samples is insufficient despite the urgent need for strategies to prevent and treat this condition.

Japan is a super-aged society, and the proportion of the aged population is increasing. The percentage of individuals aged ≥65 years was 23 % in 2010 and is expected to reach 30.1 % in 2024 and 39 % in 2051 [14]. The government of Japan reported that musculoskeletal disorders were present in 22.9 % of the entire population of those who were certified as requiring assistance or long-term care elderly in 2010 and were ranked first among its causes, together with joint diseases, falls, fractures, and spinal cord disorders [15]. For preventing and treating musculoskeletal disorders, there is an urgent need to develop and establish a prevention strategy and treatment programs that are effective in reducing the risk of disability among the elderly, which leads to requirement of assistance or long-term care. Although sarcopenia is a common musculoskeletal disease in the elderly, it is not clearly categorized [15]. There appears to be insufficient recognition of sarcopenia in daily clinical practice and society, leading to the disease being undiagnosed and untreated. One of the reasons may be the lack of a broadly accepted definition of sarcopenia until the European Working Group on Sarcopenia in Older People (EWGSOP) developed a practical clinical definition and consensus diagnostic criteria for this disease in 2010 [4]. There is a growing consensus that sarcopenia should not be defined merely on the basis of muscle mass but also with regard to muscle strength and function [4]. However, few epidemiologic studies have been based on the EWGSOP definition of sarcopenia using population-based samples, and no epidemiologic study has investigated the relationship between exercise habits in middle age and sarcopenia in older age.

The Research on Osteoarthritis/osteoporosis Against Disability (ROAD) study is a prospective cohort study aimed at elucidating the environmental and genetic background of musculoskeletal diseases [16, 17]. The present study investigated the prevalence of sarcopenia using the EWGSOP definition, and clarified the association of sarcopenia with exercise habits in middle age and physical performance in the elderly participants of Japanese population-based cohorts of the ROAD study.

Methods

Participants

From 2005–2007, we began a large-scale population-based cohort study entitled Research on Osteoarthritis/osteoporosis Against Disability consisting of 3,040 participants in three regions (baseline study) [16, 17]. The ROAD study is a prospective cohort study with the aim of elucidating the environmental and genetic backgrounds of musculoskeletal diseases. It is designed to examine the extent to which risk factors for these diseases are related to clinical features of the diseases, laboratory and radiographic findings, bone mass, bone geometry, lifestyle, nutritional factors, anthropometric and neuromuscular measures, and fall propensity. It also aims to determine how these diseases affect activities of daily living and quality of life of Japanese men and women. The subjects were residents of any one of three communities: an urban region in Itabashi, Tokyo; a mountainous region in Hidakagawa, Wakayama; and a coastal region in Taiji, Wakayama. The inclusion criteria were as follows: ability to (1) walk to the clinic where the survey was performed, (2) provide self-reported data, and (3) understand and sign an informed consent form. Participants from the urban region were aged ≥60 years and were recruited from those enrolled in a randomly selected cohort study from the previously established Itabashi Ward residential registration database [18]. Invitation letters were distributed only to inhabitants whose names were listed on this database. Participants from Hidakagawa and Taiji were aged ≥40 years and were recruited from residential registration listings. Residents aged <60 years from Itabashi and <40 years from Hidakagawa and Taiji who were interested in participating in the study were also invited. A total of 99.8, 84.3, and 54.7 % of the participants were aged ≥60 years in Itabashi, Hidakagawa, and Taiji, respectively. The response rates in the groups aged ≥60 years were 75.6 % in Itabashi, 68.4 % in Hidakagawa, and 29.3 % in Taiji. Two-thirds of the 3, 040 participants in the baseline survey were women, and their mean age was 1 year less than that of the male participants. No significant difference was observed in body mass index (BMI) between the sexes.

After the baseline study, a second survey was performed in the same communities from 2008 to 2010, in which 2,674 inhabitants (892 men, 1,782 women) aged 21–97 years participated (second visit) [19]. Invitation letters were distributed to the inhabitants whose names were listed on the baseline database of the ROAD study. In addition to the former participants, inhabitants aged ≥60 years from Itabashi and those aged ≥40 years from Hidakagawa and Taiji who were willing to participate in the ROAD survey performed in 2008–2010 were also included in the second visit. In addition, residents aged <60 years from Itabashi and <40 years from Hidakagawa and Taiji who were interested in participating in the study were invited to be examined as well at the baseline. The inclusion criteria were as follows: ability to (1) walk to the clinic where the survey was performed, (2) provide self-reported data, and (3) understand and sign an informed consent form. No other exclusion criteria were used. Thus, 2,674 residents (892 men and 1,782 women) aged 21–97 years participated in the second visit. Of the 2,674 participants, 1, 846 individuals aged ≥65 years visited the clinic and underwent an examination at the survey site located in Hidakagawa (504 individuals), Taiji (391 individuals), the University of Tokyo Hospital (132 individuals), or Tokyo Metropolitan Geriatric Hospital (819 individuals). For participants from Itabashi, the survey site was randomly assigned to either the University of Tokyo Hospital or Tokyo

Metropolitan Geriatric Hospital. Since gait speed was not measured at Tokyo Metropolitan Geriatric Hospital, 819 individuals who visited this hospital were removed from the present study. Of 1,846 participants, the remaining 1,019 individuals aged ≥65 years who visited the survey site located in Hidakagawa, Taiji, or at the University of Tokyo Hospital and underwent an examination including gait speed assessment were recruited for the present study. Of the 1,019 individuals, 19 were removed because 1 did not undergo handgrip strength measurement and 18 did not undergo skeletal muscle mass measurement. For the present study, we enrolled 1,000 participants (349 men and 651 women aged ≥65 years) from the second visit who completed assessment of handgrip strength, gait speed, and skeletal muscle mass. The mean age of the participants was 75.7 (SD, 5.9) years in men and 74.4 (SD, 6.1) years in women. All participants provided written informed consent, and the study was conducted with approval from the Ethics Committee of the University of Tokyo.

Participants completed an interviewer-administered questionnaire comprising 400 items regarding lifestyle information such as smoking habits, alcohol consumption, and physical activity. An interviewer asked the following question regarding past physical activity: "During the time you were aged 25–50 years, did you ever practice sports or physical exercise sufficient to produce sweating or shortness of breath?" Possible responses were as follows: never, occasionally, <2 hours per week, and ≥2 hours per week. Those who answered "occasionally, <2 hours per week, or ≥2 hours per week" were defined as having exercise habits in middle age. The following question was asked regarding current physical activity: "Do you practice walking more than 30 minutes every day?" Those who answered "yes" were defined as having a current walking habit.

Anthropometric and physical performance measurements

Anthropometric measurements, including height and weight, were obtained, and body mass index (weight [kg]/height [m^2]) was estimated based on the measured height and weight. Grip strength was measured on the right and left sides using a TOEI LIGHT handgrip dynamometer (TOEI LIGHT CO. LTD, Saitama, Japan), and the highest measurement was used to characterize maximum muscle strength. Subjects were defined as having low grip strength if grip strength was <30 kg in men and <20 kg in women, as reported by Lauretani and colleagues [20].

Skeletal muscle mass was measured by bioimpedance analysis [21–25] using the Body Composition Analyzer MC-190 (Tanita Corp., Tokyo, Japan). The protocol was described by Tanimoto and colleagues [10, 12], and the method has been validated [26]. Appendicular skeletal muscle mass (ASM) was derived as the sum of the muscle mass of the arms and the legs. Absolute ASM was converted to an appendicular muscle mass index (SMI) by dividing by height in meters squared (kg/m^2). Subjects were defined as having low skeletal muscle mass if the SMI was <2 SDs of the young adult mean. We used an SMI of <7.0 kg/m^2 in men and <5.8 kg/m^2 in women as cut-off points for low skeletal muscle mass based on the reference data of SMI measured by the MC-190 in 1,719 healthy young Japanese volunteers aged 18–39 years [10].

To measure physical performance, the time taken to walk 6 m at normal walking speed in a hallway was recorded, and usual gait speed was calculated. Subjects were defined as having low gait speed if usual gait speed was ≤0.8 m/s. The time taken for five consecutive chair rises without the use of hands was also recorded. Timing began with the command "Go" and ended when the buttocks contacted the chair on the fifth landing. One-leg standing time with eyes open was measured on both sides, and the best measurement was used. Participants were asked to stand on one leg while continuing to elevate their contralateral limb. Timing commenced when the participant assumed the correct posture and ended when any body part touched a supporting surface.

Statistical analysis

All statistical analyses were performed using STATA statistical software (STATA, College Station, TX). Differences in the values of the parameters between two groups were tested for significance using the nonpaired Student's *t* test and chi-square test. Trends in values were tested using the Jonckheere-Terpstra trend test. Factors associated with sarcopenia were determined using multivariate logistic regression analysis with sarcopenia as the dependent variable; the odds ratio (OR) and 95 % confidence interval were determined after adjusting for age, sex, and BMI. Factors associated with exercise habits in middle age were determined using multivariate linear regression analysis with exercise habits in middle age as the independent variable; the regression coefficient and 95 % CI were determined after adjusting for age, sex, and BMI.

Results

Table 1 shows the characteristics of the participants according to EWGSOP sarcopenia status. Age was significantly greater, while BMI, ASM, and SMI were significantly lesser in those with sarcopenia than in those without sarcopenia in both men and women. In physical performance, chair stand time was significantly greater and one-leg standing time was significantly lesser in those with sarcopenia than in those without sarcopenia in both men and women. The percentage of individuals with exercise habits in middle age was significantly lower in those with sarcopenia than in those without sarcopenia in both men and women.

Table 1 Characteristics of participants according to EWGSOP sarcopenia status

	Men		Women	
	No sarcopenia	Sarcopenia	No sarcopenia	Sarcopenia
No. of subjects	301	48	570	81
Age, years	75.1 (5.8)	79.9 (5.2)*	73.5 (5.6)	80.8 (5.8)*
Height, cm	161.9 (6.0)	158.5 (5.8)*	148.9 (6.4)	145.6 (6.6)*
Weight, kg	61.2 (9.5)	52.9 (6.5)*	52.4 (8.4)	42.6 (6.3)*
BMI, kg/m^2	23.3 (3.0)	21.0 (2.0)*	23.6 (3.3)	20.0 (2.3)*
ASM, kg	19.8 (3.0)	16.0 (1.7)*	13.8 (1.8)	11.4 (1.2)*
SMI, kg/m^2	7.54 (0.90)	6.36 (0.47)*	6.22 (0.66)	5.35 (0.30)*
Grip strength, kg	36.9 (6.8)	28.0 (4.0)*	23.9 (4.6)	16.8 (3.4)*
Usual gait speed, m/s	1.11 (0.25)	0.85 (0.27)*	1.06 (0.28)	0.82 (0.22)*
Chair stand time, s	9.6 (3.7)	11.9 (4.2)*	9.9 (4.2)	13.4 (5.9)*
One-leg standing time, median (IQR), s	31.0 (10.0–60.0)	8.0 (4.0–16.0)*	26.0 (8.0–60.0)	11.0 (5.0–23.0)*
Smoking, %	15.6	16.7	2.3	6.2
Alcohol consumption, %	58.8	45.8	14.7	18.8
Current walking habits, %	56.5	45.0	55.1	56.5
Exercise habits in middle age, %	69.9	46.2†	43.3	26.1†

Except where indicated otherwise, values are mean (SD)

ASM appendicular skeletal muscle mass, *BMI* body mass index, *EWGSOP* European Working Group on Sarcopenia in Older People, *IQR* interquartile range, *SMI* skeletal muscle mass index

*$P<.001$ vs. no sarcopenia in the same sex group by unpaired Student's *t* test; †$P<.01$ vs. no sarcopenia in the same sex group by chi-square test

Figure 1 shows sex- and age-wise distributions of prevalence of sarcopenia (Fig. 1a), low SMI (Fig. 1b), low grip strength (Fig. 1c), and low gait speed (Fig. 1d). The total prevalence of sarcopenia was 13.8 % in men and 12.4 % in women. Prevalence of sarcopenia (number of cases/subjects) in the age strata of 65–69, 70–74, 75–79, 80–84, and ≥85 years was 1.6 % (1/63), 5.7 % (5/88), 17.8 % (19/107), 23.2 % (16/69), and 31.8 % (7/22) in men and 0.6 % (1/163), 5.5 % (10/182), 13.8 % (22/160), 22.9 % (25/109), and 62.2 % (23/37) in women. Prevalence of sarcopenia tended to be significantly higher according to increasing age ($P<.001$ for trend) in both men and women. Prevalence of low grip strength and low gait speed also tended to be significantly higher according to increasing age ($P<.001$ for trend) in both men and women. However, the increasing tendency of prevalence of low SMI ($P<.001$ for trend) was milder compared with that of sarcopenia, low grip strength, and low gait speed.

Then, we determined the factors associated with sarcopenia by logistic regression analysis; the upper part of Table 2 shows the results using sarcopenia as the dependent variable. In the overall population, age (OR, 1.20; 95 % CI, 1.15–1.24) and BMI (OR, 0.68; 95 % CI, 0.63–0.75) were significantly associated with sarcopenia, whereas sex was not. In physical performance, chair stand time (OR, 1.09; 95 % CI, 1.04–1.14) and one-leg standing time (OR, 0.94; 95 % CI, 0.96–0.99) were significantly associated with sarcopenia in the overall population after adjusting for age, sex, and BMI. Current walking habit (OR, 0.69; 95 % CI, 0.42–1.12) was not significantly associated with sarcopenia. However, exercise habit in middle age (OR, 0.53; 95 % CI, 0.31–0.90) was associated with sarcopenia in the overall population after adjusting for age, sex, and BMI, indicating that exercise habit in middle age was significantly associated with low prevalence of sarcopenia in older age. The significance of the association did not change when current walking habit was added as an explanatory variable in this logistic regression model (OR, 0.53; 95 % CI, 0.32–0.90). In addition, we investigated the association of each category—occasionally, <2 h per week, and ≥2 h per week—with sarcopenia using "never" as a reference, in addition to the association of the presence of exercise habits in middle age with sarcopenia. The associated ORs for the three categories were comparable, but they did not reach significance level (occasionally: OR, 0.63; 95 % CI, 0.34–1.17; <2 h per week: OR, 0.30; 95 % CI, 0.09–1.01; ≥2 h per week: OR, 0.49; 95 % CI, 0.22–1.09).

The lower part of Table 2 shows the results of linear regression analysis using SMI, grip strength, gait speed, chair stand time, or one-leg standing time as the dependent variable and exercise habit in middle age as the independent variable. Exercise habit in middle age was significantly associated with grip strength in older age ($P<.001$), gait speed in older age ($P<.001$), and one-leg standing time in older age ($P=.005$) after adjusting for age, sex, and BMI in the overall population. We conducted the same analyses in men and women separately (Tables 3 and 4) and found results similar to those in the overall population. Some sex differences were observed in the present results. Exercise habit in middle age was significantly associated with grip strength and gait speed in older age in both men and women, whereas it was significantly associated with chair stand time and one-leg standing time only in men; however, the sample size of men was smaller than that of women. In the overall population, exercise habit in middle age was not associated with chair stand time.

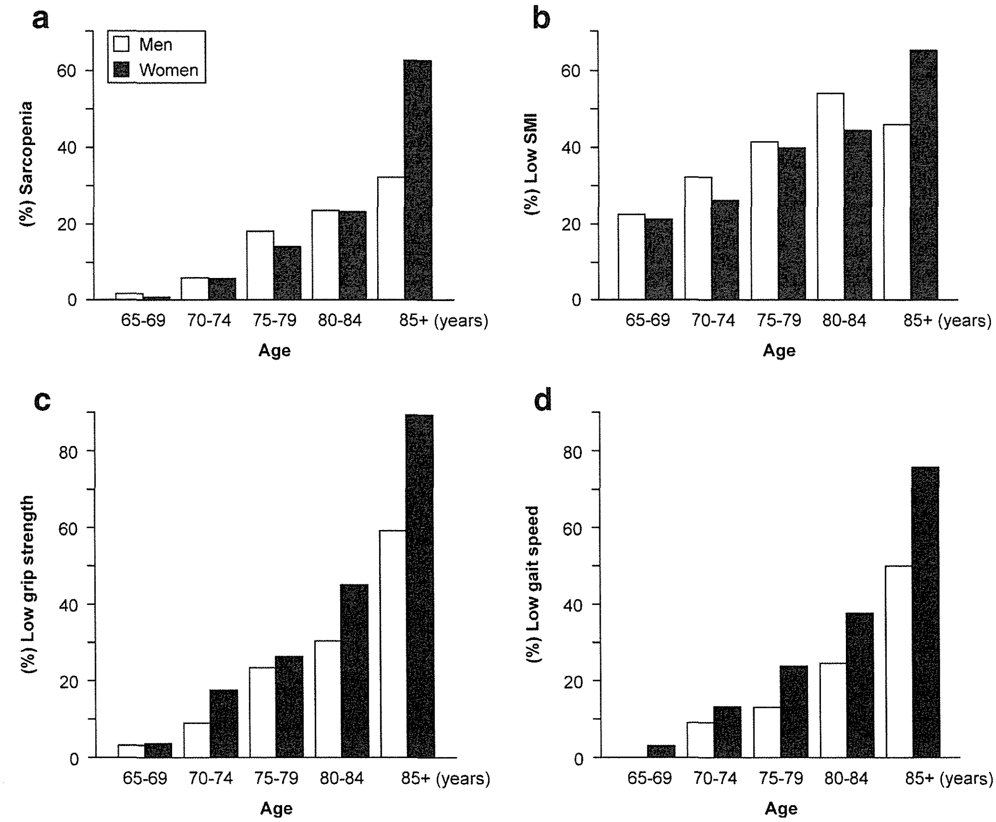

Fig. 1 Percentage of sarcopenia (**a**), low skeletal muscle mass index (*SMI*) (**b**), low grip strength (**c**), and low gait speed (**d**) in men and women in each age stratum (65–69, 70–74, 75–79, 80–85, and ≥85 years). Low SMI was defined as a value of <7.0 kg/m^2 in men and <5.8 kg/m^2 in women. Low grip strength was defined as a value of <30 kg in men and <20 kg in women. Low gait speed was defined as a value of ≤ 0.8 m/s

Discussion

The present study investigated the prevalence of sarcopenia using the EWGSOP definition in the elderly participants of Japanese population-based cohorts. We determined that age was positively associated with sarcopenia and that BMI was inversely associated, but sex was not. Exercise habit in middle age was associated with increased muscle strength and physical performance and low prevalence of sarcopenia in older age. To the best of our knowledge, this is the first study to show the relationship between exercise habits in middle age and sarcopenia in older age in the elderly participants of population-based cohorts.

Previous studies have reported the prevalence of sarcopenia and its associated factors. For example, Tanimoto and colleagues reported the prevalence of sarcopenia in

Table 2 Factors associated with sarcopenia and exercise habits in middle age in the overall population

Factors associated with sarcopenia	Odds ratio	95 % CI	*P* value
Age (+1 year)	1.20	1.15–1.24	<.001
Sex (women vs. men)	0.98	0.63–1.53	.9
BMI (+1 kg/m^2)	0.68	0.63–0.75	<.001
Chair stand time (+1 s)	1.09[a]	1.04–1.14	.001
One-leg standing time (+1 s)	0.97[a]	0.96–0.99	<.001
Smoking (yes vs. no)	1.86[a]	0.86–4.02	.1
Alcohol consumption (yes vs. no)	1.00[a]	0.60–1.67	.9
Current walking habits (yes vs. no)	0.69[a]	0.42–1.12	.1
Exercise habits in middle age (yes vs. no)	0.53[a]	0.31–0.90	.01
Factors associated with exercise habits in middle age	Regression coefficient	95 % CI	*P* value
SMI	0.09[b]	−0.02–0.19	.1
Grip strength	1.73[c]	1.02–2.44	<.001
Gait speed	0.07[c]	0.04–0.10	<.001
Chair stand time	−0.47[c]	−1.02–0.09	.09
One-leg standing time	4.14[c]	1.26–7.02	.005

BMI body mass index, *CI* confidence interval, *SMI* skeletal muscle mass index

[a] Odds ratio and 95 % CI were calculated by logistic regression analysis after adjusting for age, sex, and BMI

[b] Regression coefficient and 95 % CI were calculated by linear regression analysis after adjusting for age and sex

[c] Regression coefficient and 95 % CI were calculated by linear regression analysis after adjusting for age, sex, and BMI

Table 3 Factors associated with sarcopenia and exercise habits in middle age in men

Factors associated with sarcopenia	Odds ratio	95 % CI	*P* value
Chair stand time (+1 s)	1.09[a]	1.01–1.18	.03
One-leg standing time (+1 s)	0.97[a]	0.95–0.99	.001
Smoking (yes vs. no)	1.49[a]	0.59–3.75	.4
Alcohol consumption (yes vs. no)	0.78[a]	0.40–1.53	.4
Current walking habits (yes vs. no)	0.60[a]	0.28–1.27	.1
Exercise habits in middle age (yes vs. no)	0.48[a]	0.22–1.03	.06
Factors associated with exercise habits in middle age	Regression coefficient	95 % CI	*P* value
SMI	0.16[b]	−0.06 to 0.38	.1
Grip strength	3.17[c]	1.70 to 4.65	<.001
Gait speed	0.10[c]	0.04 to 0.15	.001
Chair stand time	−1.12[c]	−1.95 to −0.28	.009
One-leg standing time	7.81[c]	2.57 to 13.05	.004

CI confidence interval, *SMI* skeletal muscle mass index

[a] Odds ratio and 95 % CI were calculated by logistic regression analysis after adjusting for age and BMI

[b] Regression coefficient and 95 % CI were calculated by linear regression analysis after adjusting for age

[c] Regression coefficient and 95 % CI were calculated by linear regression analysis after adjusting for age and BMI

Japanese community-dwelling elderly individuals based on the EWGSOP definition using bioimpedance analysis (MC-190) [12]. They reported a prevalence of 11.3 % in men and 10.7 % in women [12], which is similar to our results. Although the cut-off value for low SMI was the same in these two studies, the cut-off value used for handgrip strength was different; we used cutoff values of <30 kg in men and <20 kg in women, in accordance with Lauretani and colleagues [20], while they used values of <30.3 kg in men and <19.3 kg in women, based on the lowest quartile of handgrip strength in their study population [12]. In the population of the present study, the lowest quartile of grip strength was 30.5 kg in men and 20.0 kg in women. Considering that these two studies showed similar results, cut-off values of 30 kg in men and 20 kg in women for handgrip strength [20] also may be appropriate for the practical case definition of the EWGSOP algorithm in the Japanese population.

Patel and colleagues reported the prevalence of sarcopenia in Caucasians using the EWGSOP definition, in which low muscle mass is defined as the lowest tertile of lean or fat-free

Table 4 Factors associated with sarcopenia and exercise habits in middle age in women

Factors associated with sarcopenia	Odds ratio	95 % CI	*P* value
Chair stand time (+1 s)	1.08[a]	1.02–1.15	.01
One-leg standing time (+1 s)	0.98[a]	0.96–1.00	.01
Smoking (yes vs. no)	2.44[a]	0.61–9.72	.2
Alcohol consumption (yes vs. no)	1.26[a]	0.58–2.71	.5
Current walking habits (yes vs. no)	0.75[a]	0.39–1.44	.3
Exercise habits in middle age (yes vs. no)	0.55[a]	0.27–1.13	.1
Factors associated with exercise habits in middle age	Regression coefficient	95 % CI	*P* value
SMI	0.06[b]	−0.05 to 0.17	.2
Grip strength	1.03[c]	0.29 to 1.78	.007
Gait speed	0.06[c]	0.01 to 0.10	.01
Chair stand time	−0.12[c]	−0.83 to 0.60	.7
One-leg standing time	2.19[c]	−1.24 to 5.62	.2

CI confidence interval, *SMI* skeletal muscle mass index

[a] Odds ratio and 95 % CI were calculated by logistic regression analysis after adjusting for age and BMI

[b] Regression coefficient and 95 % CI were calculated by linear regression analysis after adjusting for age

[c] Regression coefficient and 95 % CI were calculated by linear regression analysis after adjusting for age and BMI

mass [11]. They recommended use of the lowest tertile of muscle mass as a cut-off value if the reference value of muscle mass in a young healthy population is unavailable. In the population of the present study, the lowest tertile of SMI was 6.92 kg/m^2 in men and 5.80 kg/m^2 in women, which is similar to the cut-off value of <2 SDs of the young adult mean (7.0 kg/m^2 in men and 5.8 kg/m^2 in women) [10]. For evaluating low muscle mass, use of the lowest tertile may be an appropriate alternative method if the reference value of a young healthy population is unavailable.

The present study showed an association between sarcopenia and physical performance, including chair stand time and one-leg standing time, which is consistent with results of previous reports using the EWGSOP definition [11, 13]. However, these were comparisons between sarcopenia and current status of physical performance or exercise habit. Therefore, causal association was unclear whether sarcopenia was caused by decreased physical performance or activity or whether low physical performance or activity was due to sarcopenia. We also revealed that exercise habit in middle age was associated with increased muscle strength and physical performance and low prevalence of sarcopenia in older age. These results suggest that exercise habit in middle age is a protective factor against sarcopenia in older age and effective in maintaining muscle strength and physical performance in older age.

Some sex differences were observed in the present results. Exercise habit in middle age was significantly associated with grip strength and gait speed in older age in both men and women, whereas it was significantly associated with chair stand time and one-leg standing time only in men; however, the sample size of men was smaller than that of women. In the overall population, exercise habit in middle age was not associated with chair stand time; this finding may have been influenced by the fact that the sample size of women was almost twice that of men. The present results suggest that the impact of exercise habit in middle age on physical ability in older age is greater in men than in women.

Since exercise is a modifiable factor, it is a promising finding that exercise habit may be effective in preventing sarcopenia. In the present study, exercise habit was defined as physical activity in the period when the individual was aged 25–50 years, in which subjects practiced sports or physical exercise sufficient to produce sweating or shortness of breath, occasionally or more frequently. Although exercise habit was associated with low prevalence of sarcopenia at the age of ≥65 years, some details remain unclear, including exercise type, intensity, time, and other factors appropriate for prevention of sarcopenia. In addition to the association of the presence of exercise habit in middle age with sarcopenia, we further investigated the association of each category—occasionally, <2 h per week, and ≥2 h per week—with sarcopenia using "never" as a reference. Among the three categories, the analysis could not determine the best frequency and amount of exercise for protection from sarcopenia. The associated ORs for the three categories were comparable, and no dose–response tendency was seen in the relationship between frequency and amount of exercise and prevalence of sarcopenia; the associations also did not reach significance level. The present results suggest that abstaining from exercise during middle age is a risk factor for sarcopenia in older age. Furthermore, the presence of exercise habit in middle age might be much more important than the frequency and amount of exercise. Further studies are necessary to develop intervention programs and to test their effectiveness, along with accumulation of epidemiologic evidence including longitudinal studies.

The present study has several limitations. First, since this was a cross-sectional design, a causal relationship could not be determined. Second, information regarding exercise habits in middle age was obtained by self-report, and there is a possibility of recall bias. Third, the present study included participants who could walk to the survey site and could understand and sign an informed consent form. Since those who did not meet these inclusion criteria were not included in the analyses, the study participants do not truly represent the general population because of health bias. This should be considered when generalizing the results of the present study. Fourth, the results may have been affected by the characteristics of the population, including age and BMI. In the present study, age was positively associated with sarcopenia, whereas BMI was inversely associated with sarcopenia. Therefore, care should be taken when extrapolating the data to other populations with different characteristics, including age and BMI, which may confound the results.

In conclusion, the present study revealed prevalence of sarcopenia in the elderly participants of Japanese population-based cohorts. Exercise habit in middle age was associated with increased muscle strength and physical performance and low prevalence of sarcopenia in older age. These results suggest that exercise habit in middle age is a protective factor against sarcopenia in older age and is effective in maintaining muscle strength and physical performance in older age. Further long-term longitudinal epidemiological studies are necessary to develop effective intervention programs for the prevention and treatment of sarcopenia.

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Conflicts of interest None.

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Original Full Length Article

Risk factors for falls in a longitudinal population-based cohort study of Japanese men and women: The ROAD Study

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ABSTRACT

The objective of this study was to clarify the associations of physical performance and bone and joint diseases with single and multiple falls in Japanese men and women using a population-based longitudinal cohort study known as Research on Osteoarthritis/osteoporosis Against Disability (ROAD). A total of 452 men and 896 women were analyzed in the present study (mean age, 63.9 years). A questionnaire was used to assess the number of falls during the 3-year follow-up. Grip strength, 6-m walking time, and chair stand time were measured at baseline. Knee osteoarthritis (OA) and lumbar spondylosis were defined as Kellgren Lawrence = 2, 3 or 4. Vertebral fracture (VFx) was assessed with the Japanese Society of Bone and Mineral Research criteria. Osteoporosis was defined by bone mineral density using dual energy X-ray absorptiometry based on World Health Organization criteria. Knee and lower back pain were estimated by an interview. During a 3-year follow-up, 79 (17.4%) men and 216 (24.1%) women reported at least one fall, and 54 (11.9%) men and 111 (12.4%) women reported multiple falls. Knee pain was a risk factor for multiple falls in women, but not in men. VFx tended to be associated with multiple falls in women, but not in men. A longer 6-m walking time was a risk factor for multiple falls in women, whereas a longer chair stand time was a risk factor for multiple falls in men. We found gender differences in risk factors for falls.

Introduction

Falls are one of the main causes of injury, disability, and death among the elderly [1,2]. In Japan, according to the recent National Livelihood Survey of the Ministry of Health, Labour and Welfare, falls and fractures are ranked fifth among diseases that cause disabilities and subsequently require support with activities of daily living [3]. However, few population-based studies have been performed on the incidence of falls based on sex and age. Furthermore, in terms of factors associated with falls, muscle strength, balance, vision, functional capacities, and cognitive impairment are traits that diminish with aging, and these factors have been suggested as predictive risk factors for falls and fractures [4,5]. However, the association of bone and joint diseases, especially osteoarthritis (OA), with falls remains unclear.

The representative sites of OA are the knee and lumbar spine. Knee OA and lumbar spondylosis (LS) are major public health issues because they cause chronic pain and disability [6,7]. The prevalence rates of radiographic knee OA and LS are 54.6% and 70.2%, respectively, in persons aged 40 years and older in Japan, which indicates that 25,300,000 and 37,900,000 persons aged 40 years and older are estimated to experience radiographic knee OA and LS, respectively [10]. The National Livelihood Survey ranked OA fourth among diseases that cause disabilities and subsequently require support with activities of daily living [3], but there have been few studies of the association between falls and OA [11,12]. In previous studies, knee OA was assessed only by interview and not by radiography. The principal clinical symptom of knee OA is pain [13], but its correlation with the radiographic severity of knee OA is not as strong as expected [8]. In fact, in a study in Japan, approximately 20% of persons without knee OA had knee pain, and 30% of persons with severe knee OA had no knee pain [8]. Thus, knee OA diagnosed by interview could be limited by variable accuracy. In addition, men and women were not examined separately in these previous studies, although sex differences have been found in the prevalence of knee OA [8]. Our previous study showed that knee pain is significantly associated with falls in women [14], but that study used a cross-sectional design; thus, a causal relationship remains unclear. Regarding LS, to the best of our knowledge, no population-based studies have been performed

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regarding its association with falls except for our previous cross-sectional study [14], which showed that LS is not significantly associated with falls. In addition, among fractures due to osteoporosis (OP), vertebral fracture (VFx) is the most likely to lead to marked public health problems. VFx is reportedly associated with functional impairment [15], back pain, kyphosis [16,17], esophageal reflux [18], depressive mood [19], respiratory dysfunctions [20], and mortality [21]. However, whether VFx is an independent risk factor for the incidence of falls remains unclear.

Measuring walking speed is a simple way to assess health and function in older adults [22,23]. Walking speed has been found to be associated with falls in a few studies [4,24–26], although most studies were limited by a small sample size, a cross-sectional design [24,25], or evaluation of a single sex [4,26]. In addition, although walking abnormalities indicative by a slower walking speed are significantly associated with bone and joint diseases such as knee OA, LS, and their associated pain [14], no longitudinal studies have been performed to determine the associations of falls with bone and joint diseases and walking abnormalities at the same time. Furthermore, measuring the chair stand time is also reported to be a simple and established method to assess health and function in the elderly [27,28], but to the best of our knowledge, no longitudinal studies have been performed to determine the associations of falls with chair stand time.

Previous studies have shown that associations between individual risk factors and a single fall are few in number and weak compared to risk factors for multiple falls [12], indicating that single and multiple falls may have different backgrounds. Thus, to determine factors associated with falls, single and multiple falls should be analyzed separately.

The objective of this study was to clarify the associations of physical performance and bone and joint diseases with the incidence of single and multiple falls in Japanese men and women using a population-based longitudinal cohort study known as Research on Osteoarthritis/osteoporosis Against Disability (ROAD).

Methods

Participants

The ROAD study is a nationwide, prospective study designed to establish epidemiologic indices for evaluation of clinical evidence for the development of a disease-modifying treatment for bone and joint diseases (OP and OA are the representative bone and joint diseases, respectively). ROAD consists of population-based cohorts in three communities in Japan. A detailed profile of the ROAD study has been described elsewhere [8–10,29]; a brief summary is provided here. To date, we have completed the creation of a baseline database that includes clinical and genetic information for 3,040 participants (1,061 men and 1,979 women) ranging in age from 23 to 95 years (mean, 70.6 years) who were recruited from resident registration listings in three communities: an urban region in Itabashi, Tokyo; a mountainous region in Hidakagawa, Wakayama; and a coastal region in Taiji, Wakayama.

Residents of these regions were recruited from the resident registration list of the relevant region. Participants in the urban region were recruited from a randomly selected cohort from the Itabashi-ward residents' registration database [30]. The participation rate was 75.6%. Participants in mountainous and coastal regions were also recruited from the resident registration lists, and the participation rates in these two areas were 56.7% and 31.7%, respectively. The inclusion criteria, apart from residence in the communities mentioned above, were the ability to (1) walk to the survey site, (2) report data, and (3) understand and sign an informed consent form. The baseline survey of the ROAD study was completed in 2006. All participants provided written informed consent, and the study was conducted with the approval of the ethics committees of the University of Tokyo and the Tokyo Metropolitan Institute of Gerontology.

Assessment of falls

Three years after the baseline data were obtained, we attempted to trace and review all 3,040 participants between 2008 and 2010; they were invited to attend a follow-up interview. All participants were interviewed with regard to falls by experienced interviewers and were asked the following questions: "Have you experienced falls during the 3-year follow-up, and if yes, how many falls did you experience"? At baseline, all participants were also interviewed regarding falls by experienced interviewers and were asked the following questions: "Have you experienced falls during the 12 months preceding baseline, and if yes, how many falls did you experience"? According to a previous study on falls [31], a fall is defined as a sudden, unintentional change in position causing an individual to land at a lower level on an object, the floor, or the ground, other than as a consequence of a sudden onset of paralysis, epileptic seizure, or overwhelming external force.

Pain assessment

All participants were interviewed by experienced orthopedists regarding knee pain and lower back pain at baseline and were asked the following questions based on previous studies [8,9]: "Have you experienced knee pain on most days in the past month, in addition to now"? and "Have you experienced lower back pain on most days in the past month, in addition to now"? Those who answered "yes" were defined as having pain. Buttock pain and sciatica were not included as lower back pain in the present study.

Radiographic assessment

At baseline, all participants underwent radiographic examination of both knees using anteroposterior and lateral views with weight-bearing and foot-map positioning; radiographic examination of the anteroposterior and lateral views of the lumbar spine, including intervertebral levels L1/2 to L5/S, was also performed. VFx was assessed by lateral radiographs of the lumbar spine (L1-L5) in terms of a wedge, biconcave, or crush appearance according to the Japanese Society of Bone and Mineral Research criteria [32]. The films were marked up, and morphometric measurements of anterior, middle, and posterior heights on lateral radiography of the thoracic and lumbar spine were made. Wedge appearance was defined as a site at which the anterior height of the vertebra was $\leq$75% of the posterior height. Biconcave appearance occurred if the height of the central part of the vertebra was $\leq$80% of that of the anterior or posterior parts of the vertebra. Crush appearance occurred if the height of the anterior, central, and posterior parts of an axial vertebra were all reduced to $\leq$80% of the normal value (Supplementary Fig. 1). Knee and lumbar spine radiographs were also read without knowledge of the participant's clinical status by a single, experienced orthopedist (S.M.) using the Kellgren Lawrence (KL) radiographic atlas [33] to determine the severity of KL grading. Radiographs were scored as grade 0–4, with higher grades associated with more severe OA. We defined knee OA and LS as KL $\geq$2 in at least one knee and one intervertebral level, respectively. To evaluate the intraobserver variability of KL grading, 100 randomly selected radiographs of the knee and lumbar spine were scored by the same observer more than 1 month after the first reading. One hundred other radiographs were also scored by two experienced orthopedic surgeons (S.M. and H.O.) using the same atlas for interobserver variability. The intra- and interobserver variabilities evaluated were confirmed by kappa analysis to be sufficient for assessment (0.86 and 0.80 for knee OA, and 0.84 and 0.76 for LS, respectively).

Bone mineral density (BMD) measurement

BMD was measured at the lumbar spine (L2–4) and the proximal femur using dual energy X-ray absorptiometry (DXA) (Hologic

Discovery; Hologic, Waltham, MA, USA) at baseline. For quality control, the same DXA equipment was used, and the same spine phantom was scanned daily to monitor the machine's performance in study populations at different regions. The BMD of the phantom was adjusted to 1.032 ± 0.016 g/cm^2 ($\pm 1.5\%$) during all examinations. In addition, the same physician (N.Y.) examined all participants to prevent observer variability. Coefficient of variance (CV) for L2–L4 in the phantom was 0.35%, and CVs for L2–L4, the proximal femur, Ward's triangle, and the trochanter examined in five volunteers were 0.61–0.90, 1.02–2.57, 1.97–5.45, and 1.77–4.17%, respectively [34].

OP was defined based on World Health Organization (WHO) criteria in which OP was diagnosed as T-scores of BMD ≤ 2.5 standard deviations (SDs) lower than peak bone mass [35]. Mean L2–4 BMD (SD) for young adult men and women measured using the Hologic QDR devices in Japan is reportedly 1.011 g/cm^2 (0.119 g/cm^2) [36]. Mean femoral neck BMD (SD) in Japan is reported to be 0.863 g/cm^2 (0.127 g/cm^2) for young men and 0.787 (0.109) for young women [36]. The present study therefore defined OP using these indices as lumbar spine BMD <0.714 g/cm^2 for both men and women, and as femoral neck BMD <0.546 g/cm^2 for men and <0.515 g/cm^2 for women.

Physical performance

At baseline, anthropometric measurements were taken, including height and weight, and body mass index (BMI) (weight [kg]/height^2 [m^2]) was estimated based on the measured height and weight. Grip strength was measured on bilateral sides using a TOEI LIGHT handgrip dynamometer (TOEI LIGHT CO., LTD, Saitama, Japan), and the best measurement was used to characterize maximum muscle strength. To measure physical performance, the time taken to walk 6 m at normal walking speed in a hallway was recorded. Participants were told to walk from a marked starting line to a 6-m mark as if they were walking down their hallway at home. Time was measured in seconds with a stopwatch and rounded to the nearest hundredth of a second. The average of two trials was recorded. These gait-speed trial measurements are considered highly reliable in community-dwelling elderly persons [37]. The time taken for five consecutive chair rises without the use of hands was also recorded. Hands were folded in front of the chest with feet flat on the floor, following the protocol described by Guralnik et al. [27] and used by other researchers [28]. Time was measured in seconds with a stopwatch and rounded to the nearest hundredth of a second. Timing began with the command "Go" and ended when the buttocks contacted the chair on the fifth landing. The reliability of this protocol is adequate [27].

Cognition assessment

At baseline, cognition was also evaluated for all participants using a Mini-Mental State Examination, and a cut-off score of <24 was used to select participants with cognitive impairment [38].

Statistical analyses

The differences in age and anthropometric measurements between the responders (those who completed the study) and non-responders (those lost to follow-up or who did not complete the study as described below) and between men and women were examined with a non-paired Student's *t*-test. Differences in physical performance measurements between the responders and non-responders and between men and women were examined with Wilcoxon signed-rank test. Differences in age and anthropometric measurements, among non-fallers, single fallers, and multiple fallers, were examined with one-way analysis of variance. Differences in physical performance measurements among non-fallers, single fallers, and multiple fallers were examined with the Kruskal–Wallis test. The prevalence of bone and joint diseases and cognitive impairment was compared between men and women and among non-fallers, single fallers, and multiple fallers with the chi square test. Multinomial logistic regression analysis after adjusting for age and BMI was used to determine the association of anthropometric measurements, physical performance, bone and joint diseases, and cognitive impairment with single and multiple falls compared with the absence of falls in men and women. Further, to determine an independent association of physical performance with single and multiple falls compared with the absence of falls, we used multinomial logistic regression analysis with age, BMI, 6-m walking time, and chair stand time as explanatory variables. To determine independent risk factors for single and multiple falls, we used multinomial logistic regression analysis with age, BMI, physical performance, bone and joint diseases, and cognitive impairment as explanatory variables. Data analyses were performed using SAS version 9.0 (SAS Institute Inc., Cary, NC, USA).

Results

Of the 1,690 participants in the mountainous and seaside cohorts at baseline in 2006 and 2007, 40 (2.4%) had died by the time of the review 3 years later, 97 (5.7%) did not participate in the follow-up study due to poor health, 16 (0.9%) had moved away, 51 (3.0%) declined the invitation to attend the follow-up study, and 47 (2.8%) did not participate in the follow-up study for other reasons. Among the 1,439 volunteers who did participate in the follow-up study, 68 (4.0%) provided incomplete fall questionnaires. In addition, six (0.4%) provided incomplete pain questionnaires; these were excluded. We also excluded eight (0.5%) participants who had undergone total knee arthroplasty before baseline. An additional nine (1.9%) participants did not perform the 6-m walking time or chair stand time, leaving a total of 1,348 (79.8%) participants (452 men and 896 women) from whom radiographs at baseline and complete fall and pain histories were obtained. The mean followup time was 2.93 ± 0.12 years, ranging from 2.65 to 3.22 years. Table 1 shows characterisctics of responders and non-responders. The responders were significantly younger than the non-responders (63.9 and 70.7 years, respectively). Physical performance measurements were better in responders than non-responders. Prevalence of knee OA, LS and knee pain was lower in responders (47.0, 61.6 and 9.7%,

Table 1
Baseline characteristics of responders and non-responders.

	Overall	Responders	Non-responders
Number of participants	1,690	1,348	342
Female (%)	64.7	66.5	57.9***
Age (years)	65.2 ± 12.0	63.9 ± 11.8	70.7 ± 11.4*
Height (cm)	155.2 ± 9.3	155.6 ± 9.0	153.6 ± 10.1*
Weight (kg)	55.6 ± 10.8	56.1 ± 10.7	53.7 ± 10.8*
BMI (kg/m^2)	23.0 ± 3.4	23.1 ± 3.4	22.7 ± 3.4
Grip strength (kg) (median [IQR])	26.0 [21.0–33.0]	26.0 [21.0–34.0]	24.0 [18.0–30.0]**
6-m walking time (s) (median [IQR])	5.0 [4.0–7.0]	5.0 [4.0–6.0]	7.0 [5.0–9.0]**
Chair stand time (s) (median [IQR])	9.0 [7.0–12.0]	9.0 [7.0–11.0]	12.0 [8.25–15.0]**
Cognitive impairment (%)	4.5	2.8	11.4***
Radiographic knee OA (%)	50.4	47.0	63.8***
Radiographic LS (%)	63.2	61.6	69.1***
Radiographic VFx	10.1	9.7	12.0
Knee pain (%)	24.3	22.2	32.6***
Lower back pain (%)	21.1	20.6	22.9
Previous falls (%)	17.3	16.3	21.0***

Values are mean ± SD, except where indicated.
BMI: body mass index, OA: osteoarthritis, LS: lumbar spondylosis, VFx: vertebral fracture, IQR: interquartile range.
* $p<0.05$ vs. responders by non-paired Student's *t*-test.
** $p<0.05$ vs. men by Wilcoxon signed-rank test.
*** $p<0.05$ vs. men by chi square test.

Table 2
Baseline characteristics of participants.

	Men	Women
Number of participants	452	896
Age (years)	64.9 ± 11.7	63.3 ± 11.8*
Height (cm)	164.0 ± 7.0	151.3 ± 6.6*
Weight (kg)	63.3 ± 10.7	52.5 ± 8.7*
BMI (kg/m^2)	23.5 ± 3.2	22.9 ± 3.4*
Grip strength (kg) (median [IQR])	37.0 [32.0–42.5]	23.5 [20.0–23.5]**
6-m walking time (s) (median [IQR])	5.0 [4.0–6.0]	5.0 [4.0–6.0]
Chair stand time (s) (median [IQR])	8.5 [7.0–11.0]	9.0 [7.0–11.0]
Cognitive impairment (%)	3.6	2.4
Radiographic knee OA (%)	37.4	51.9***
Radiographic LS (%)	76.1	54.2
Radiographic VFx	8.9	10.1
Knee pain (%)	15.3	25.7***
Lower back pain (%)	18.8	21.5
Previous falls (%)	13.1	18.0***

Values are mean ± SD, except where indicated.
BMI: body mass index, OA: osteoarthritis, LS: lumbar spondylosis, VFx: vertebral fracture, IQR: interquartile range.
* $p<0.05$ vs. men by non-paired Student's t-test.
** $p<0.05$ vs. men by Wilcoxon signed-rank test.
*** $p<0.05$ vs. men by chi square test.

respectively) than non-responders (63.8, 69.1 and 12.0, respectively). Prevalence of previous falls was significantly lower in responders than non-responders (16.3 and 21.0%, respectively).

Table 2 shows the age, anthropometric measurements, physical performance, and prevalence of cognitive impairment, bone and joint diseases, and previous falls of participants at baseline in men and women. Regarding physical performance, grip strength and chair stand time were significantly better in men (37.0 kg and 8.5 s, respectively) than in women (23.5 kg and 9.0 s, respectively), but the 6-m walking time was not (5.0 s and 5.0 s, respectively). The prevalence of radiographic knee OA and knee pain was significantly higher in women (51.9% and 25.7%, respectively) than in men (37.4% and 15.3%, respectively), whereas that of LS and lower back pain was not different between men and women. The prevalence of previous falls was significantly higher in women than in men (18.0% and 13.1%, respectively).

During the 3-year follow-up, 79 (17.4% [95% confidence interval [CI] 14.3–21.2]) men and 216 (24.1% [95% CI 21.4–27.0]) women reported at least one fall, and 54 (11.9% [95% CI 9.3–15.3]) men and 111 (12.4% [95% CI 10.4–14.7]) women reported multiple falls. The chi square test showed that the incidence of falls was significantly different between men and women ($p=0.0011$). The incidence of single and multiple falls was significantly higher in the mountainous regions (11.5% and 17.4%, respectively) than coastal regions (8.1% and 7.8%, respectively). With increasing age, the incidence of falls increased in women, but the incidence of falls was similar in men in their 60s and 70s (Fig. 1).

Table 3 shows the age, anthropometric measurements, physical performance, and BMD at baseline between non-fallers, single fallers, and multiple fallers. Age and BMI were significantly higher in female fallers than non-fallers, but this was not the case in men. Grip strength was worse in female fallers than non-fallers, but this was not the case in men. The 6-m walking time and chair stand time were longer in both male and female fallers than in non-fallers. LS and neck BMD were significantly lower in female fallers than non-fallers, but this was not the case in men.

We next examined the incidence rate of falls during the 3-year follow-up according to previous falls at baseline in men and women (Supplementary Fig. 2). The incidence rates of multiple falls were 7.9%, 22.7%, and 48.7% in men and 8.8%, 20.4%, and 43.1% in women among non-fallers, single fallers, and multiple fallers, respectively. The incidence rates of single falls were 5.9%, 9.1%, and 0.0% in men and 12.5%, 7.8%, and 8.6% in women among non-fallers, single fallers, and multiple fallers, respectively. The chi square test showed that the incidence of falls during the 3-year follow-up was significantly associated with previous falls at baseline in men and women ($p<0.0001$).

Fig. 2 shows the incidence rate of falls during the 3-year follow-up according to the presence of bone and joint diseases and cognitive impairment. The incidence rates of multiple falls were 16.6% and 9.2% in men and 14.8% and 9.7% in women in those with and without knee OA, respectively. The incidence rates of a single fall were 8.3% and 3.9% in men and 14.2% and 9.1% in women in those with and without knee OA, respectively. The chi square test showed that knee OA at baseline was significantly associated with the incidence rate of falls during the 3-year follow-up in men and women ($p<0.0001$). Regarding knee pain, the incidence rates of multiple falls were 18.8% and 10.7% in men and 18.7% and 10.2% in women in those with and without knee pain, respectively. The incidence rates of a single fall were 8.7% and 5.0% in men and 10.4% and 10.4% in women in those with and without knee OA, respectively. The chi square test showed that knee pain at baseline was significantly associated with the incidence of falls during the 3-year follow-up in men and women ($p<0.0001$). LS and lower back pain were not significantly associated with the incidence of falls in men ($p=0.52$ and 0.77, respectively) or in women ($p=0.45$ and 0.58, respectively). VFx at baseline was significantly associated with the incidence of falls in women (multiple falls 22.2% and 11.3%, single falls 14.4% and 11.4%, in those with and without VFx, respectively, $p=0.005$), but not in men ($p=0.06$). OP defined by L2–4 and femoral neck BMD was not associated with the incidence of falls in men and women. Cognitive impairment

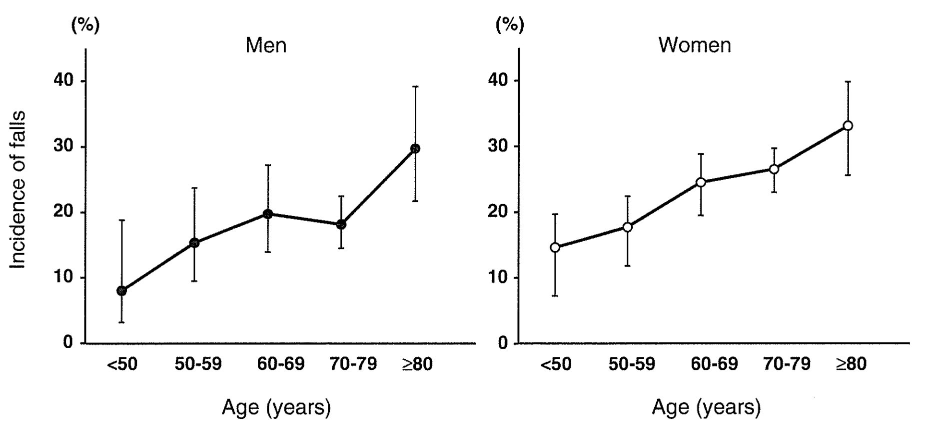

Fig. 1. Incidence rate of falls (error bars represent 95% confidence intervals) by gender and age strata.

Table 3
Comparison of characteristics among non-fallers, single fallers, and multiple fallers in men and women.

	Men				Women			
	Non-fallers	Single fallers	Multiple fallers	p value	Non-fallers	Single fallers	Multiple fallers	p value
Number of participants	373	25	54		680	105	111	
Age (years)	64.4 (11.7)	67.2 (13.2)	67.6 (10.1)	0.10	62.4 (11.6)	66.0 (12.6)	66.7 (11.4)	<0.001
BMI (kg/m²)	23.4 (3.1)	24.6 (3.9)	23.7 (3.3)	0.16	22.8 (3.5)	22.7 (3.1)	23.8 (3.5)	0.01
Grip strength (kg) (median [IQR])	37.0 [32.0–43.0]	37.0 [30.0–41.5]	35.0 [28.8–40.0]	0.08	24.0 [20.0–27.0]	23.0 [19.5–27.0]	22.0 [18.0–26.0]	0.01
6-m walking time (s) (median [IQR])	4.5 [4.0–6.0]	5.5 [4.6–7.3]	6.2 [5.0–6.6]	<0.0001	5.0 [4.0–6.0]	5.0 [4.0–6.5]	5.5 [4.0–7.5]	<0.0001
Chair stand time (s) (median [IQR])	8.0 [7.0-10.0])	11.0 [9.0-12.0]	10.0 [8.0-13.0]	<0.0001	9.0 [7.0-11.0]	9.0 [8.0-12.0]	10.0 [8.0-12.25]	0.0001
LS BMD	1.05 (0.20)	1.05 (0.20)	1.05 (0.15)	0.99	0.89 (0.18)	0.85 (0.16)	0.86 (0.17)	0.04
Neck BMD	0.75 (0.13)	0.77 (0.12)	0.75 (0.10)	0.79	0.65 (0.13)	0.61 (0.11)	0.63 (0.11)	0.003

Values are the means (standard deviation), except where indicated.
One-way analysis of variance was used to determine the differences in age, height, weight and BMI among non-fallers, single fallers, and multiple fallers.
Kruskal–Wallis test was used to determine the differences in grip strength, 6-m walking time and chair stand time among non-fallers, single fallers, and multiple fallers.
The chi square test was used to determine the differences in the prevalence of cognitive impairment among non-fallers, single fallers, and multiple fallers.
BMI: body mass index, LS: lumbar spondylosis, BMD: bone mineral density.

was associated with the incidence of falls in men (multiple falls 31.3% and 10.9%, single falls 18.8% and 5.1%, in those with and without cognitive impairment, respectively, $p = 0.002$), but not in women ($p = 0.19$).

In men, multinomial logistic regression analysis after adjusting for age and BMI showed that a longer 6-m walking time, longer chair stand time, and previous falls were risk factors for falls, but grip strength, bone and joint diseases, and cognitive impairment were not

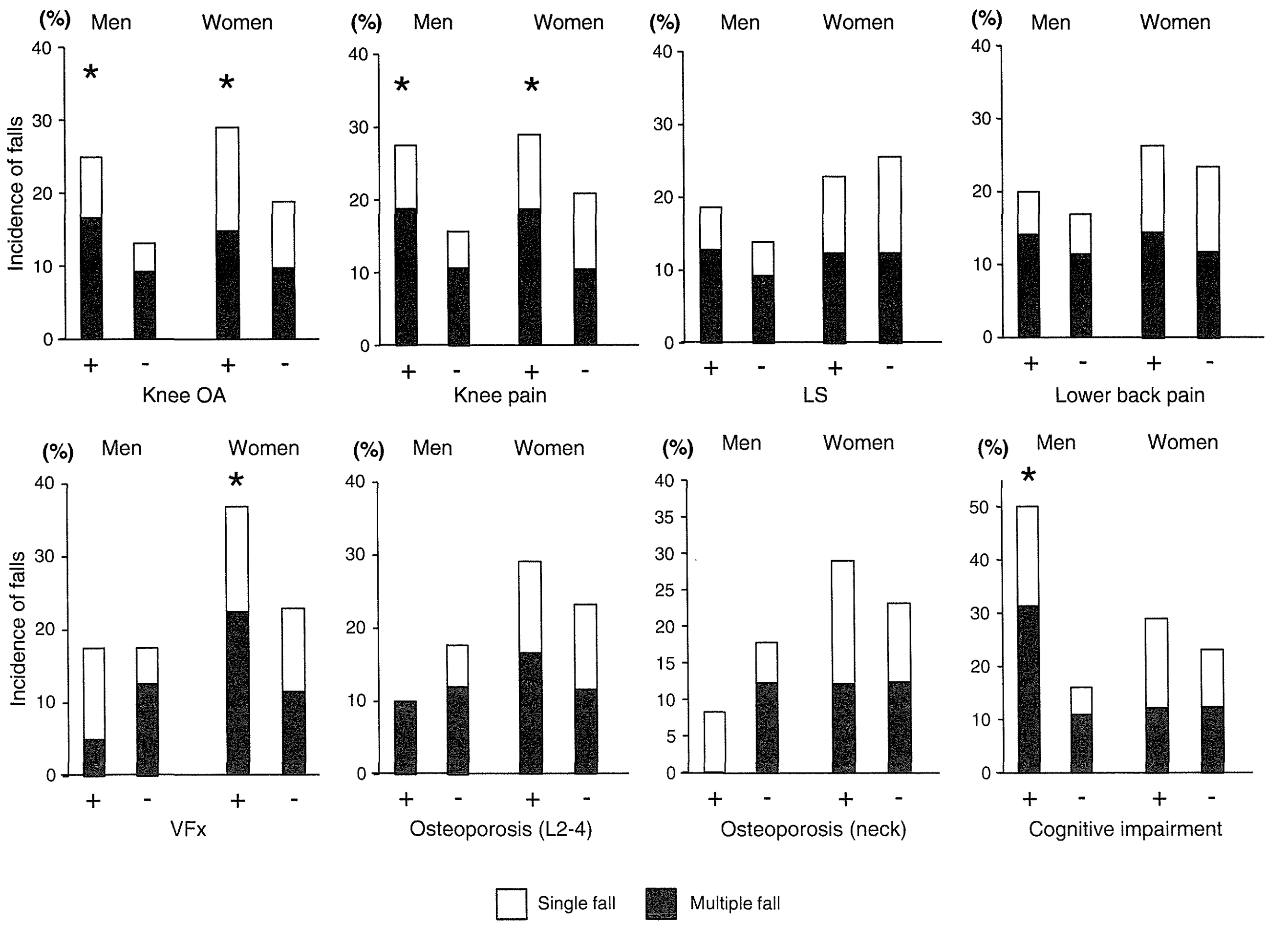

Fig. 2. Incidence of single and multiple falls by bone and joint diseases and cognitive impairment. *$p < 0.05$ vs. participants without each disease or pain, respectively, according to the chi square test. OA, osteoarthritis; LS, lumbar spondylosis; VFx, vertebral fracture.

Table 4
Risk factors for single and multiple falls in men.

	Crude OR (95% CI)		Adjusted OR (95% CI)	
	Single falls	Multiple falls	Single falls	Multiple falls
Grip strength (5 kg increase)	0.90 (0.71–1.14)	0.84 (0.71–0.99)	1.14 (1.01–1.29)	0.88 (0.72–1.08)
6-m walking time (1 s increase)	1.12 (0.98–1.27)	1.13 (1.03–1.26)	1.11 (0.95–1.25)	1.11 (1.01–1.23)
Chair stand time (1 s increase)	1.17 (1.03–1.32)	1.21 (1.11–1.33)	1.15 (1.00–1.32)	1.21 (1.09–1.33)
LS BMD (0.1 mg/cm^2 increase)	1.00 (0.80–1.22)	1.00 (0.86–1.16)	0.92 (0.73–1.15)	0.97 (0.83–1.13)
Neck BMD (0.1 mg/cm^2 increase)	1.10 (0.81–1.47)	0.98 (0.78–1.21)	1.07 (0.73–1.51)	1.01 (0.77–1.30)
Knee OA	2.44 (1.09–5.56)	2.08 (1.18–3.70)	2.07 (0.84–5.21)	1.77 (0.95–3.33)
Knee pain	2.04 (0.72–5.09)	2.05 (0.99–4.00)	1.65 (0.57–4.21)	1.78 (0.85–3.55)
VFx	2.58 (0.82–6.85)	0.40 (0.06–1.36)	2.48 (0.75–7.04)	0.32 (0.05–1.13)
Cognitive impairment	6.19 (1.29–23.1)	4.83 (1.41–15.1)	13.48 (0.98–178.64)	3.17 (0.44–21.99)
Previous falls				
Single fall	–	–	–	3.52 (1.07–9.97)
Multiple falls	1.18 (0.25–4.61)	9.54 (3.15–30.08)	–	12.6 (5.80–27.97)

Multinomial logistic regression analysis was used to calculate the crude odds ratio (OR) and 95% confidence interval (CI) compared with non-fallers.
Adjusted OR was calculated using multinomial logistic regression analysis after adjusting for age and body mass index (BMI).
OA: osteoarthritis, VFx: vertebral fracture, BMD: bone mineral density, LS: lumbar spondylosis.
Radiographic knee OA was defined as Kellgren Lawrence grade 3 or 4.

(Table 4). Previous falls were significantly associated with the incidence of multiple falls. In women, multinomial logistic regression analysis after adjusting for age and BMI showed that a longer 6-m walking time was a risk factor for multiple, but not single falls (Table 5). Chair stand time also tended to be associated with the incidence of single and multiple falls. Regarding bone and joint diseases, knee pain was a risk factor for single and multiple falls. VFx also tended to be associated with multiple falls, but radiographic knee OA was not associated with falls. Cognitive impairment was a risk factor for multiple falls, but not for single falls. A history of previous falls was a risk factor for multiple, but not single falls.

To determine the independent association of each physical performance parameter with the incidence of falls, multinomial logistic regression analysis was performed with age, BMI, 6-m walking time, and chair stand time as explanatory variables. We found that a longer chair stand time was an independent risk factor for multiple falls (OR 1.18, 95% CI 1.06–1.32), but a longer 6-m walking time was not (OR 1.05, 0.93–1.16). In women, a longer 6-m walking time tended to be associated with the incidence of multiple falls (OR 1.09, 95% CI 0.98–1.22), but a longer chair stand time was not (OR 1.01, 95% CI 0.94–1.07). After adjusting for previous falls, the independent association of a longer chair stand time with the incidence of falls remained in men (OR 1.15, 95% CI 1.02–1.30), and the independent association of a longer 6-m walking time with the incidence of falls remained in women (OR 1.12, 95% CI 1.00–1.25). In addition, knee pain and cognitive impairment in women were also significantly associated with falls, and VFx tended to be associated with falls with multinomial logistic regression analysis after adjusting for age and BMI. Thus, to determine the independent association of physical performance, bone and joint diseases, and cognitive impairment, multinomial logistic regression analysis was used with age, BMI, 6-m walking time, knee pain, VFx, and cognitive impairment as explanatory variables. We found that a longer 6-m walking time was an independent risk factor for multiple falls (OR 1.08, 95% CI 1.00–1.18), but the significant association of knee pain, VFx, and cognitive impairment with the incidence of falls disappeared (OR 1.47, 95% CI 0.91–2.35, OR 1.52, 95% CI 0.80–2.81, and OR 1.16, 95% CI 0.35–3.24, respectively).

Discussion

The present study is the first longitudinal population-based cohort study to examine whether physical performance, bone and joint diseases, and cognitive impairment are risk factors for single and multiple falls in men and women. We found gender differences in risk factors for

Table 5
Risk factors for single and multiple falls in women.

	Crude OR (95% CI)		Adjusted OR (95% CI)	
	Single falls	Multiple falls	Single falls	Multiple falls
Grip strength (5 kg increase)	0.84 (0.70–0.99)	0.81 (0.68–0.95)	0.94 (0.77–1.11)	0.91 (0.75–1.08)
6-m walking time (1 s increase)	1.10 (1.01–1.19)	1.16 (1.08–1.25)	1.04 (0.94–1.14)	1.11 (1.02–1.20)
Chair stand time (1 s increase)	1.07 (1.02–1.12)	1.07 (1.03–1.12)	1.04 (0.99–1.10)	1.04 (0.99–1.09)
LS BMD (0.1 mg/cm^2 increase)	0.88 (0.78–1.00)	0.90 (0.80–1.01)	0.96 (0.83–1.11)	0.92 (0.80–1.06)
Neck BMD (0.1 mg/cm^2 increase)	0.75 (0.63–0.90)	0.85 (0.72–1.01)	0.79 (0.62–1.01)	0.87 (0.69–1.10)
Knee OA	1.79 (1.18–2.78)	1.75 (1.16–2.63)	1.52 (0.94–2.50)	1.12 (0.79–1.82)
Knee pain	1.83 (1.17–2.83)	2.22 (1.44–3.37)	1.62 (1.00–2.60)	1.60 (1.00–2.54)
VFx	1.54 (0.78–2.85)	2.40 (1.35–4.12)	1.15 (0.57–2.20)	1.81 (0.98–3.24)
Cognitive impairment	0.42 (0.02–2.12)	2.12 (0.68–5.60)	0.73 (0.19–2.61)	4.95 (1.50–16.08)
Previous falls				
Single fall	0.55 (0.16–1.74)	1.51 (0.33–5.41)	0.70 (0.30–1.43)	2.48 (1.40–4.28)
Multiple falls	0.86 (0.39–1.81)	8.55 (3.80–19.20)	1.06 (0.35–2.62)	6.93 (3.76–12.72)

Multinomial logistic regression analysis was used to calculate the crude odds ratio (OR) and 95% confidence interval (CI) compared with non-fallers.
Adjusted OR was calculated using multinomial logistic regression analysis after adjusting for age and body mass index (BMI).
OA: osteoarthritis, VFx: vertebral fracture, BMD: bone mineral density, LS: lumbar spondylosis.
Radiographic knee OA was defined as Kellgren Lawrence grade 3 or 4.

falls. Regarding physical performance, a longer chair stand time was an independent risk factor for falls in men, whereas a longer 6-m walking time was an independent risk factor for falls in women. Knee pain, VFx, and cognitive impairment were associated with falls in women, but not in men.

The present study is a population-based longitudinal study to determine whether bone and joint diseases are risk factors for falls in Japanese men and women. After adjusting for age and BMI, knee pain was a risk factor for falls in women, but not in men. The sex differences regarding the association of knee pain with falls may be partly explained by the weaker quadriceps muscles in women, which is known to be an independent risk factor for falls [16]. Muscle strength is higher in men than in women in all decades [39], which may obscure the association of knee pain with falls. In addition, given the insignificant association of radiographic knee OA with falls, falls may occur due to symptoms such as pain rather than radiographic changes in the knee itself. Our study and other previous cross-sectional studies also suggested that knee pain is significantly associated with falls [11]. In other words, falls may be preventable when pain is relieved by medical care, even if patients have radiographic knee OA.

In the present study, LS and lower back pain were not associated with falls, whereas VFx was associated with falls. Lower BMD was not associated with falls in the present study, and thus, radiographic changes but not OP may be associated with falls. Studies of patients with VFx have reported increased kyphosis angles [16,17], which is an independent risk factor for injurious falls [40]. Previous studies [41,42] have demonstrated that people with kyphosis have greater balance abnormalities as assessed by computerized dynamic posturography. Specifically, they reported that women with OP-related kyphosis had greater mediolateral displacement and increased mediolateral velocity compared to controls [42]. In addition, lateral spontaneous sway amplitude has been reported to be the single best predictor of future risk of falls [43]. These observations may partly explain the association between VFx and falls.

In the present study, after adjusting for age and BMI, both a longer 6-m walking time and a longer chair stand time were associated with falls in men and women. A previous study also showed that slower walking speed is a risk factor for falls [44], although men and women were not separately analyzed in the study. To determine the independent association of the 6-m walking time and chair stand time, we further used multinomial logistic regression analysis with age, BMI, 6-m walking time, and chair stand time as explanatory factors, and found that in men, a longer chair stand time was an independent risk factor for multiple falls, but a longer 6-m walking time was not. In women, a longer 6-m walking time was associated with the incidence of multiple falls, whereas a longer chair stand time was not. This indicates that slower walking speed may more strongly affect the risk of falling in women than in men, whereas a longer chair stand time may more strongly affect the risk of falling in men than in women. The walking time and chair stand time can be easily and quickly measured in clinical and research settings without requiring monitoring devices or extensive training. The present study may indicate that walking time is a simple and quick option for measuring the risk of falling, particularly in women, and measuring the chair stand time is a simple and quick option for estimating the risk of falling, particularly in men.

The present study has several limitations. First, our participants lived in the community, and thus, our findings may not apply to elderly persons residing in institutions. Second, we did not include other anatomical locations of weight-bearing OA such as hip OA in the analysis, although this disorder also affects falls [45]. However, the prevalence of KL = 3 or 4 hip OA is 1.4% and 3.5% in Japanese men and women [46], respectively, which is lower than that of KL = 3 or 4 knee OA (12.2% and 21.0% in men and women, respectively) in the present study. Thus, it is possible that hip OA would not strongly affect the results of the present study. Third, non-responders were older, had lower physical performance and higher prevalence of knee pain, which were risk factors for falls. This means that the incidence of falls in the present study may have been underestimated. Fourth, the accuracy and reliability of recall of falls over the past 3 years was not assessed in the present study. Previous studies have shown that 13–32% of elderly subjects with confirmed falls did not recall falling over a 12-month period [47], even when excluding subjects with cognitive impairment. Therefore, the incidence of falls may be underestimated, particularly in older subjects and those with cognitive impairment. In addition, individuals are more likely to recall a fall that resulted in injury, which may have influenced the results of this study.

Conclusion

The present longitudinal analysis using a large-scale population from the ROAD study revealed gender differences in risk factors for falls. A longer walking time was a risk factor for falls in women, whereas a longer chair stand time was a risk factor for falls in men. Knee pain and VFx were risk factors for falls in women, but not in men. Further studies, along with continued longitudinal surveys in the ROAD study, will help elucidate the background of bone and joint diseases and their relationship with falls.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.bone.2012.10.020.

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