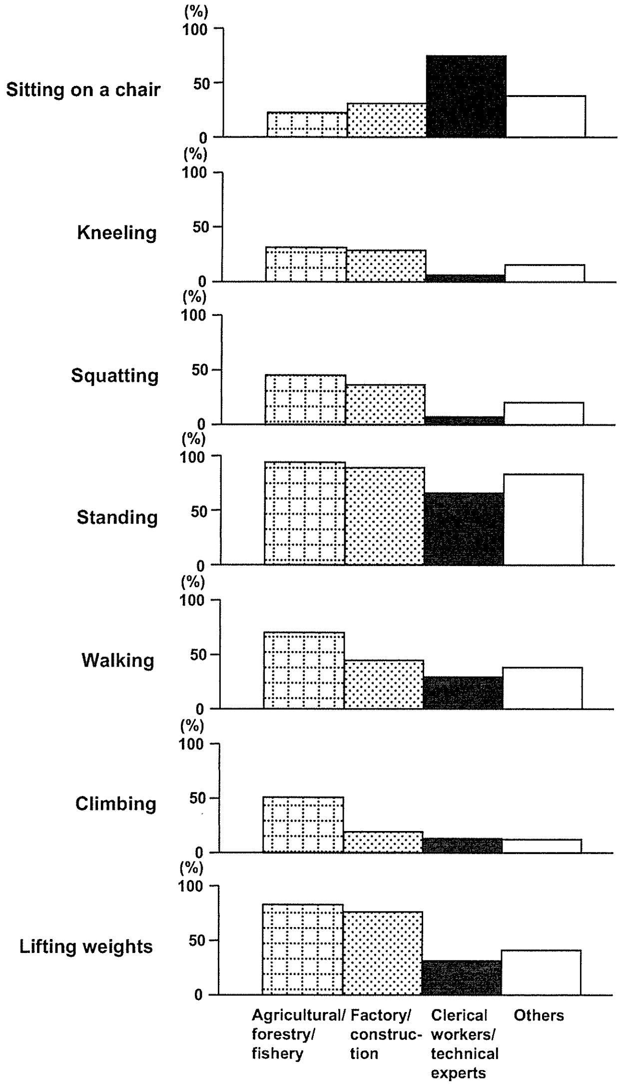

Fig. 2. Percentage of participants engaged in each occupational activity: sitting on a chair ≥2 h/day, kneeling ≥1 h/day, squatting ≥1 h/day, standing ≥2 h/day, walking ≥3 km/day, climbing ≥1 h/day, or lifting weights ≥10 kg ≥1 time/week among agricultural, forestry, and fishery workers; factory and construction workers; clerical workers and technical experts; and others.

Mean ± standard deviation (SD) values of mJSW (mm) in agricultural, forestry, or fishery workers; factory or construction workers; clerical workers or technical experts; and other workers were 2.4 ± 1.2, 2.5 ± 1.1, 2.8 ± 1.0, and 2.4 ± 1.1, respectively. Tukey HSD test after adjustment for age, gender, and BMI showed that there were no significant associations between job titles and mJSW. Further, because characteristics such as height, weight, mJSW and OPA differ significantly between men and women, we conducted separate analyses of the association of job title with mJSW and OPA in men and women. mJSW (mm) in agricultural, forestry, or fishery workers; factory or construction workers; clerical workers or technical experts; and other workers were 2.7 ± 1.1, 2.9 ± 0.9, 3.0 ± 0.9, and 2.9 ± 1.0 in men and 2.0 ± 1.1, 2.2 ± 1.1, 2.6 ± 0.9, and 2.3 ± 1.1 in women respectively. There were no associations in men, but for women, agricultural, forestry, or fishery workers had significantly lower mJSW than clerical workers or technical experts using Tukey HSD test without adjustment. To adjust for body size, we used Tukey HSD test after adjustment for height, and the results were similar ($P < 0.05$). Further, after adjustment for age and BMI, the results were also similar ($P < 0.05$). Mean ± SD values of OPA (mm^2) in agricultural, forestry, or fishery workers; factory or construction workers; clerical workers or technical experts; and other workers were 2.9 ± 6.5, 2.9 ± 6.8, 1.6 ± 4.0 and 3.9 ± 10.2, respectively. Tukey HSD test after adjustment for age and BMI showed no significant association between job titles and OPA in either men or women.

Tables III and IV show the mean values of mJSW and OPA according to occupational activity. SD for OPA was quite a large in the present study, because the range was 0–121.5 mm^2 and 1,055 (75.2%) had no osteophytes. Sitting was associated with higher mJSW and lower OPA by linear regression analysis without adjustment; after adjustment for age, gender, and BMI, the significance disappeared. Kneeling and squatting were significantly associated with lower mJSW as well as higher OPA. Walking and lifting weights were significantly associated with lower mJSW, but not with OPA. When we analyzed the association of occupational activities with mJSW and OPA in men and women separately, the results in women were similar to results in the overall population, but there were few factors associated with mJSW or OPA in men (Supplementary Tables I and II).

To determine independent associations of the significant occupational factors shown in Table III with mJSW, multiple regression analysis was performed with age, gender, BMI, and the significant occupational factors as independent variables. Because chi-square test showed that squatting was strongly associated with kneeling (odds ratio 139.5, $P < 0.0001$), we used kneeling when both squatting and kneeling were significantly associated KOACAD parameters. Squatting, kneeling, walking, and lifting weights were significantly associated with mJSW by the abovementioned analysis (Table III); thus, when we used age, gender, BMI, kneeling, walking, and lifting weights as independent variables, multiple regression analysis showed that kneeling was independently associated with mJSW (regression coefficient −0.17, 95% confidence interval [CI] −0.30 to −0.04, $P = 0.01$), and lifting weights tended to be independently associated with mJSW (regression coefficient −0.11, 95% CI −0.22 to 0.002, $P = 0.055$), but walking was not

Table III
mJSW according to occupational activity

	Occupational activity		Crude regression coefficient (95% CI)	P value	Adjusted regression coefficient* (95% CI)	P value
	No	Yes				
Sitting on a chair ≥2 h/day	2.4 ± 1.2	2.6 ± 1.0	0.22 (0.11–0.33)	0.0002	0.08 (−0.02 to 0.19)	0.117
Standing ≥2 h/day	2.6 ± 1.1	2.3 ± 1.2	−0.33 (−0.47 to −0.19)	<0.0001	−0.21 (−0.34 to −0.09)	0.0009
Kneeling ≥1 h/day	2.6 ± 1.0	2.3 ± 1.1	−0.36 (−0.49 to −0.23)	<0.0001	−0.24 (−0.35 to −0.12)	<0.0001
Squatting ≥1 h/day	2.7 ± 0.9	2.5 ± 1.1	−0.19 (−0.34 to −0.03)	0.016	−0.06 (−0.21 to 0.08)	0.364
Walking ≥3 km/day	2.6 ± 1.0	2.4 ± 1.2	−0.20 (−0.32 to −0.09)	0.0005	−0.11 (−0.21 to −0.002)	0.046
Climbing ≥1 h/day	2.5 ± 1.0	2.5 ± 1.2	−0.06 (−0.20 to 0.07)	0.038	−0.02 (−0.15 to 0.11)	0.733
Lifting weights ≥10 kg ≥ once/week	2.6 ± 1.0	2.5 ± 1.1	−0.10 (−0.21 to 0.01)	0.08	−0.16 (−0.26 to −0.06)	0.003

Values are mean ± SD.
* Adjusted regression coefficient was calculated using multiple regression analysis after adjustment for age, gender, and BMI.

Table IV
OPA according to occupational activity

	Occupational activity		Crude regression coefficient (95% CI)	*P* value	Adjusted regression coefficient* (95% CI)	*P* value
	No	Yes				
Sitting on a chair ≥2 h/day	3.5 ± 8.8	2.4 ± 6.7	−1.06 (−1.89 to −0.22)	0.013	−0.39 (−1.19 to 0.41)	0.339
Kneeling ≥1 h/day	2.5 ± 6.9	4.8 ± 10.9	2.25 (1.22 to 3.29)	<0.0001	1.62 (0.65–2.60)	0.0011
Squatting ≥1 h/day	2.5 ± 6.8	4.3 ± 10.5	1.72 (0.78 to 2.66)	0.0004	1.03 (0.13–1.92)	0.025
Standing ≥2 h/day	2.1 ± 5.6	3.2 ± 8.3	1.02 (−0.12 to 2.16)	0.079	0.25 (−0.84 to 1.33)	0.657
Walking ≥3 km/day	3.0 ± 8.7	3.0 ± 7.0	0.05(−0.79 to 0.88)	0.912	−0.56 (−1.37 to −0.24)	0.170
Climbing ≥1 h/day	3.1 ± 8.4	2.7 ± 6.2	−0.39 (−1.38 to 0.59)	0.434	−0.78 (−1.76 to 0.20)	0.119
Lifting weights ≥10 kg ≥ once/week	3.0 ± 8.1	3.0 ± 7.8	0.04 (−0.79 to 0.88)	0.920	0.20 (−0.60 to 1.00)	0.624

Values are mean ± SD.
* Adjusted regression coefficient was calculated using multiple regression analysis after adjustment for age, gender, and BMI.

(regression coefficient −0.055, 95% CI −0.164 to 0.054, $P=0.32$). Further, when we analyzed the independent associations of occupational activities with mJSW in women in the same way, kneeling was independently associated with mJSW (regression coefficient −0.20, 95% CI −0.36 to −0.03, $P=0.02$), and walking tended to be independently associated with mJSW (regression coefficient −0.13, 95% CI −0.27 to 0.005, $P=0.058$), but lifting weights were not (regression coefficient −0.09, 95% CI −0.23 to 0.05, $P=0.22$).

Discussion

The present study is the first epidemiologic study using a large-scale, population-based cohort to determine the association of job title and occupational activity with joint space narrowing and osteophytosis separately. These variables were estimated not by categorical grade but by continuous values such as mJSW and OPA at the knee. In the present study, kneeling, squatting, walking, and heavy lifting were significantly associated with mJSW. For OPA, kneeling and squatting were significantly associated with higher OPA, whereas other activities were not.

Although agricultural, forestry, and fishery workers have been historically among the first to be identified in relation to knee OA in Caucasians[34,35], no studies have focused on mJSW or OPA separately. The present study is the first to examine the association of characteristic features of knee OA such as mJSW and OPA separately with job title, and clarified that, among women, agricultural, forestry, and fishery workers had significantly lower mJSW compared with clerical workers and technical experts. As other authors have hypothesized, the combination of intense exposure to heavy labor of varied nature and repeated local stresses, especially at a young age, could contribute to some systemic mechanism in the development of OA[36]. This argument would support the implementation of preventive measures as a priority to reduce the intensity of physical labor in this sector—particularly for young female farm workers. In contrast, there were no associations between job titles and mJSW in men. Because men are known to have greater muscle strength than women at all ages[37], and muscle strength has a protective effect on knee OA[38,39], it might be that the greater muscle strength obscures the harmful effects of agricultural, forestry, and fishery work, leading to lower risk for knee OA in men.

For kneeling and squatting, studies in Caucasians have suggested that these occupational activities, and job titles that require them, are associated with knee OA[19–24], whereas our previous study showed that these activities were significantly associated with severe knee OA. However, in all previous studies, knee OA was diagnosed by KL grade or whether subjects had undergone total knee arthroplasty. The present study was the first to clarify the association of kneeling and squatting with joint space narrowing and osteophytosis separately. In addition, these variables were not estimated using a categorical method but rather with continuous values such as mJSW and OPA. This study clarified that kneeling and squatting were significantly associated with decreased mJSW as well as increased OPA. There were no occupational activities associated with both joint space narrowing and osteophytosis except for kneeling and squatting; in addition, kneeling had a larger impact on mJSW than lifting weights. Thus, these occupational activities must be strongly associated with knee OA.

Walking and lifting weights were associated with joint space narrowing but not with osteophytosis in the present study. This discrepancy may be partly explained by the high prevalence of osteophytosis in Japan. In fact, our previous study[4] showed that KL = 2 OA, which consists of definite osteophytosis but no definite joint space narrowing, was high in subjects in Japan compared with studies in Caucasians[40,41], whereas KL = 3 OA, which consists of definite joint space narrowing, did not differ significantly between these two ethnic groups. The higher prevalence of osteophytosis in Japan could be due to lifestyle factors, because the Japanese traditional lifestyle includes sitting on the heels on a mat and using Japanese-style lavatories; these positions may cause mechanical stress to the knee joint and possibly lead to acceleration of osteophytosis. The burden on the knee associated with walking and lifting weights may be weaker compared with the burden associated with kneeling and squatting; thus, the association between osteophytosis and occupational activities of walking and lifting weights may be obscured by the traditional Japanese lifestyle. In addition, the separate associations of walking and lifting weights with joint space narrowing and osteophytosis suggest that these two features of knee OA may have distinct etiological mechanisms. In fact, a recent cross-sectional study has shown that osteophytosis was unrelated not only to joint space narrowing on plain radiographs, but also to cartilage loss measured by quantitative magnetic resonance imaging[27]. The present study also showed that mJSW and OPA were significantly correlated, but each predicted only 21% of the variation in the other. Furthermore, our study on an experimental mouse model for OA has identified a cartilage-specific molecule, carminerin, that regulates osteophytosis without affecting joint cartilage destruction during OA progression[28,29].

In the present study, we found gender differences regarding the association of occupational activities with mJSW. In women, kneeling, squatting, walking, and lifting weights were significantly associated with mJSW, whereas in men, only squatting was significantly associated with mJSW. This difference may be partly explained by muscle strength in men. Because men are known to have greater muscle strength than women at all ages, and muscle strength has a protective effect on knee OA[37–39], it might be that the greater muscle strength obscures the harmful effects of occupational activities on knees in men.

Our technique to measure mJSW is a little different from many other methods (Ref) in that the tibia margin is defined using both the tibial plateau (bright band) and the rim, whereas other methods use the tibial plateau alone[42,43]. However, our preparatory examination showed higher reproducibility in "the middle line between the anterior and posterior margins of the tibial plateau"[32]. In fact, in our previous study[32], to decide the ideal algorithms for the measurements, we initially evaluated the reproducibility of "the tibial plateau alone" and "'the middle line between the anterior and posterior margins of the tibial plateau" by an intraclass coefficient of correlation (ICC) on radiographs of 20 individuals taken at a 2-week intervals with various knee flexion angles (0, 10, 20, and 30°) and X-ray beam angulations (0, 5, 10, and 15°). Results showed higher reproducibility in "the middle line between the anterior and posterior margins of the tibial plateau" at each condition.

There were several limitations to the present study. First, this is a cross-sectional study on factors associated with knee OA, so a causal association with occupational activity could not be determined. However, information collected included a lifetime occupational history and details of specific workplace physical activities; therefore, ample evidence on the background of joint space narrowing and osteophytosis at the knee could be obtained. Second, a rotation of the knee could cause a large error, especially in OPA, which could hide associations of independent variables with this metric. However, the patella was centralized over the lower end of the femur with the aid of fluoroscopy when we took X-rays; thus the rotational error is likely to be small and have minimal effects on the results of the present study.

In conclusion, the present cross-sectional study using a large-scale population from the ROAD study revealed distinct risk factors of occupational activities for joint space narrowing and osteophytosis in Japanese subjects. Other occupational activities of kneeling and squatting were associated with joint space narrowing as well as osteophytosis. Walking and heavy lifting were associated with joint space narrowing, but not with osteophytosis. Further studies, along with longitudinal data from the ROAD study, will elucidate the environmental background of OA and help clarify clinical evidence for the development of disease-modifying treatments.

Author contributions

All authors have made substantial contributions to all three of sections (1), (2) and (3) below;

(1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data

(2) drafting the article or revising it critically for important intellectual content

(3) final approval of the version to be submitted.

Competing interest

There are no competing interest.

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Supplementary material

Supplementary data related to this article can be found online at doi:10.1016/j.joca.2011.03.008.

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ORIGINAL ARTICLE

Association of knee osteoarthritis with onset and resolution of pain and physical functional disability: The ROAD study

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Abstract

Objectives. To examine the onset and resolution of pain and physical functional disability using Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and their association with knee osteoarthritis (OA) in the longitudinal large-scale population of the nationwide cohort study, Research on Osteoarthritis/osteoporosis Against Disability (ROAD).

Methods. Subjects from the ROAD study who had been recruited during 2005–2007 were followed up 3 years later. A total of 1,578 subjects completed the WOMAC questionnaire at baseline and follow up, and the onset and resolution rate of pain and physical functional disability were examined. We also examined the association of onset of pain and physical functional disability and their resolution with severity of knee OA as well as age, body-mass index and grip strength.

Results. After a 3.3-year follow-up, the onset rate of pain was 35.0% and 35.3% in men and women, respectively, and the onset rate of physical functional disability was 38% and 40%, respectively. Resolution rate of pain was 20.3% and 26.2% in men and women, respectively, and resolution rate of physical functional disability was 16% and 14% in men and women, respectively. Knee OA was significantly associated with onset and resolution of pain and physical functional disability in women, but there was no significant association of knee OA with onset of pain and resolution of physical functional disability in men.

Conclusions. The present longitudinal study revealed the onset rate of pain and physical functional disability as well as their resolution, and their association with knee OA.

Keywords

Knee joint, Osteoarthritis, Epidemiology, Longitudinal studies

History

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Introduction

Knee osteoarthritis (OA), characterized by pathological features including joint space narrowing and osteophytosis, is a major public health issue causing chronic pain and disability among the elderly in most developed countries [1]. The prevalence of radiographic knee OA in Japan is high [2], with 25,300,000 subjects aged 40 years and older estimated to experience radiographic knee OA [3]. According to the recent National Livelihood Survey of the Ministry of Health, Labour and Welfare in Japan, OA is ranked fourth among diseases that cause disabilities that subsequently require support with activities of daily living [4].

The principal clinical symptoms of knee OA are pain and physical functional disability [5], but the correlation of these symptoms with radiographic severity of knee OA is controversial [2,6–8]. Thus it would be interesting to determine whether the impact of radiographic knee OA on pain and physical functional disability differs according to the severity of OA. In terms of disease-specific scales for estimating pain and physical functional disability due to knee OA, the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) has been used for Caucasians [9] and Asians [10,11], although these reports were not population-based studies. Furthermore, there is little information on the impact of knee OA on onset of pain and physical functional disability using WOMAC in Japan, although a population survey suggests that the disease pattern differs among races [12–14]. In addition, to the best of our knowledge, although pain and physical functional disability can disappear or improve, there is no information on the impact of knee OA on the resolution of pain and physical functional disability.

Grip strength is a useful marker of muscle function and sarcopenia [15]. There is growing evidence that reduced grip strength is associated with adverse outcomes including morbidity, disability, falls, higher fracture rates, increased length of hospital stay and mortality [16–18]. A previous study also showed that grip strength is related to total muscle strength [19]. Thus, the association of knee OA with pain and physical functional disability may be influenced by grip strength, but again, no studies have examined the association of knee OA and grip strength with onset of pain and disability as well as their resolution simultaneously in the same population using a longitudinal cohort study.

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The objective of the present study was to clarify the onset and resolution rate of pain and physical functional disability using WOMAC in Japanese men and women who were part of the large-scale, longitudinal, population-based cohort study known as the Research on Osteoarthritis/osteoporosis Against Disability (ROAD) study. In addition, we examined the association of body--mass index (BMI), grip strength and severity of knee OA with onset of pain and physical functional disability as well as their resolution in men and women.

Materials and methods

Subjects

The ROAD study was a nationwide prospective study for bone and joint diseases (with OA and osteoporosis as the representative bone and joint diseases) constituting population-based cohorts established in several communities in Japan. As a detailed profile of the ROAD study has already been described elsewhere [2,3,20], only a brief summary is provided here. During 2005–2007, we created a baseline database that included clinical and genetic information for 3,040 inhabitants (1,061 men; 1,979 women) aged 23–95 years (mean, 70.6 years), recruited from listings of resident registrations in three communities: an urban region in Itabashi, Tokyo; a mountainous region in Hidakagawa, Wakayama; and a coastal region in Taiji, Wakayama. 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. Participants completed an interviewer-administered questionnaire of 400 items that included lifestyle information such as smoking habit, alcohol consumption, family history, medical history and previous knee injury history. Furthermore, subjects were interviewed by well-experienced orthopedists regarding the treatment for knee OA, such as medication, injections, physical therapy, bracing, etc. between the baseline and follow-up study. Anthropometric measurements included height and weight, from which BMI (weight [kg]/height^2 [m^2]) was calculated. Grip strength was measured on bilateral sides using a TOEI LIGHT handgrip dynamometer (Toei Light Co., Ltd., Saitama, Japan), and the better measurement was used to represent maximum muscle strength. During 2008–2010, we attempted to trace and review all 3,040 subjects; they were invited to attend a follow-up interview. The interviews were conducted by the same trained orthopedists who undertook the baseline study during 2005–2007.

Radiographic assessment

All participants underwent radiographic examination of both knees using an anterior–posterior view with weight-bearing and foot map positioning. Fluoroscopic guidance with a horizontal anterior–posterior X-ray beam was used to properly visualize the joint space. Knee radiographs at baseline and follow-up were read in pairs without knowledge of the participant's clinical status by a single well-experienced orthopedist (S.M.), and the Kellgren Lawrence (KL) grade was defined using the KL radiographic atlas for overall knee radiographic grades [21]. In the KL grading system, radiographs are scored from grade 0 to grade 4, with the higher grades being associated with more severe OA. To evaluate the intraobserver variability of the KL grading, 100 randomly selected radiographs of the knee 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. & H.O.) using the same atlas for interobserver variability. The intra- and inter variabilities evaluated for KL grades (0–4) were confirmed by kappa analysis to be sufficient for assessment (0.86 and 0.80, respectively).

Instruments

The WOMAC, a 24-item OA-specific index, consists of three domains: pain, stiffness and physical function. Each of these 24 items is graded on either a 5-point Likert scale or a 100-mm visual analog scale [22,9]. In the present study, we used the Likert scale (version LK 3.0). The domain score ranges from 0 to 20 for pain, 0 to 8 for stiffness and 0 to 68 for physical function. Japanese versions of the WOMAC have also been validated [23]. In the present study, onset of pain and physical functional disability were defined as WOMAC pain score = 0 at baseline and > 0 at follow up and WOMAC physical function score = 0 at baseline and > 0 at follow up, respectively. Resolution of pain and physical functional disability were defined as WOMAC pain score > 0 at baseline and = 0 at follow up and WOMAC physical function score > 0 at baseline and = 0 at follow up, respectively. Worsening pain and physical functional disability were defined as WOMAC pain and physical function at follow up was worse than at baseline, respectively.

Statistical analysis

The differences in age, height, weight, BMI, grip strength, and WOMAC pain and physical function scores at baseline and follow up between men and women were examined using a non-paired Student's t-test. The prevalence of knee OA was compared between men and women using chi-square test. Tukey's honestly significant difference test after adjustment for age and BMI was used to compare WOMAC pain and physical functional score and differences between baseline and follow up among subjects with KL = 0/1, 2 and 3/4. The non-paired Student's t test was used to compare age, BMI and grip strength between subjects with and without onset of pain and physical functional disability as well as those with and without resolution of pain and physical functional disability. Chi-square test was used to compare prevalence of knee OA between subjects with and without onset of pain and physical functional disability as well as those with and without resolution of pain and physical functional disability. Multiple logistic regression analysis after adjustment for age was also used to determine the association of severity of knee OA with onset of pain and physical functional disability as well as their resolution. In addition, to determine independent association of age, BMI, grip strength and knee OA with onset of pain and physical function as well as their resolution, multiple logistic regression analysis was used with significant variables ($p < 0.01$) in univariate analyses as explanatory variables. Data analyses were performed using SAS version 9.0 (SAS Institute Inc., Cary, NC).

Results

Of the 3,040 subjects in the baseline study during 2005–2007, 125 had died by the time of the review held 3 years later, 123 did not participate in the follow-up study due to bad health, 69 had moved away, 83 declined the invitation to attend the follow-up study, and 155 did not participate in the follow-up study for other reasons. Among the 2,485 subjects who did participate in the follow-up study, we excluded 39 subjects who were younger than 40 years at baseline. Those participating in the follow-up study were younger than those who did not survive or who did not participate for other reasons (responders 68.6 years, non-responders 75.1 years; $p < 0.0001$). The follow-up study participants also were more likely to be women (responders 66.3% women, nonresponders 61.8% women; $P = 0.03$) and were more likely to have knee OA at the baseline examination than either those who did not survive to follow-up or those who did not participate for other reasons (responders 51.5%, nonresponders 60.9%; $P < 0.0001$). Among them, 1,578 subjects provided completed WOMAC questionnaires both at baseline and follow up. We also excluded three subjects

Table 1. Characteristics of subjects.

	Overall	Men	Women	p value
N	1558	553	1005	
Age	67.0 ± 11.0	68.1 ± 10.7	66.5 ± 11.0	0.004
Height	155.2 ± 8.9	163.4 ± 6.5	150.8 ± 6.5	< 0.0001
Weight	55.5 ± 10.4	62.2 ± 10.2	51.8 ± 8.5	< 0.0001
BMI	22.9 ± 3.3	23.2 ± 3.1	22.8 ± 3.3	0.0043
Grip strength	27.2 ± 9.5	35.4 ± 8.7	22.7 ± 6.4	< 0.0001
Knee OA (%)	49.3	38.7	55.2	< 0.0001
WOMAC at baseline				
Pain	1.12 ± 2.18	1.02 ± 2.05	1.18 ± 2.25	0.157
Physical function	3.03 ± 6.63	2.56 ± 5.71	3.29 ± 7.07	0.0268
WOMAC at follow up				
Pain	1.82 ± 2.83	1.72 ± 2.67	1.88 ± 2.91	0.291
Physical function	5.59 ± 9.7	4.73 ± 8.30	6.06 ± 10.36	0.0061

Knee OA was defined as Kellgren Lawrence grade 2 or worse at baseline.
BMI, body–mass index; OA, osteoarthritis; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

who did not undergo plain radiography at knee and 17 subjects who underwent total knee arthroplasty before the follow-up study, leaving a total of 1,558 subjects (553 men and 1,005 women). The mean duration between baseline and follow up was 3.3 ± 0.6 years.

The characteristics of the 1,578 participants at baseline in the present study are shown in Table 1. Men were significantly older than women, and BMI was significantly higher in men than in women. The prevalence of knee OA was significantly higher in women than in men at baseline. WOMAC pain score was not significantly different between gender, while, physical function score was significantly worse in women than in men at baseline and follow up. The scores of WOMAC pain and physical function scores worsened at follow up compared with those at baseline in men and women ($p < 0.05$).

The scores of WOMAC pain and physical function scores and their differences between baseline and follow up according to the KL grade are shown in Supplementary Table 1 available online at http://informahealthcare.com/doi/abs/10.3109/14397595.2014.883055. In men, differences in WOMAC physical function scores were significantly larger in subjects with KL 3/4 than those with KL 0/1 after adjustment for age and BMI, while differences in WOMAC pain scores were not. In women, after adjustment for age and BMI, differences in WOMAC pain and physical function scores between baseline and follow up were significantly larger in subjects with KL 3/4 than those with KL 0/1.

Among 366 men and 634 women in subjects without pain at baseline, 128 (35.0%) men and 224 (35.3%) women had onset of pain at follow up (Table 2). In men, subjects with onset of pain tended to be older than those without pain, while BMI and grip strength were not significantly different between them. In women, age and BMI were significantly different between subjects with and without onset of pain, and grip strength tended to be higher in subjects with onset of pain than those without pain. Among 346 men and 601 subjects without physical functional disability at baseline, 132 (38.2%) men and 243 (40.4%) women had onset of physical functional disability at follow up (Table 2). Age and BMI were significantly different between subjects with and without onset of physical functional disability in both men and women, and BMI tended to be higher in subjects with onset of physical functional disability than those without it in women only.

We next examined onset of pain and physical functional disability according to KL grade (Figure 1). There were no significant differences in onset of pain among men with KL 0/1 knee, KL 2 knee OA and KL 3/4 knee OA (33.3%, 36.0% and 46.2%, respectively, $p = 0.4149$ by chi-square test), while there were significant differences in onset of pain among women with KL 0/1 knee, KL 2 knee OA and KL 3/4 knee OA (30.4%, 38.6% and 48.5%, respectively, $p = 0.0082$ by chi-square test). Multiple logistic regression analysis after adjustment for age showed that women with KL 3/4 knee OA had significant higher onset of pain compared with those with KL 0/1. There were significant differences in onset of physical functional disability among subjects with KL 0/1 knee OA, KL 2 knee OA and KL 3/4 knee OA in men and women (men 33.2%, 41.7% and 66.7%, respectively, $p = 0.0023$ by chi-square test, women 35.8%, 43.8% and 53.1%, respectively, $p = 0.0165$ by chi-square test). Multiple logistic regression analysis after adjustment for age showed that men with KL 3/4 knee OA had a significant higher onset of physical functional disability compared with those with KL 0/1.

In addition, we examined the association of age, BMI, grip strength and WOMAC pain and physical function scores at baseline with resolution of pain and physical functional disability (Table 3). Among 187 men and 371 women with WOMAC pain at baseline, pain disappeared in 38 (20.3%) men and 97 (26.2%) women at follow up. In men, WOMAC pain score at baseline was significantly different between subjects with resolution of pain and those with continuous pain. BMI tended to be higher in subjects with continuous pain than in those with resolution of pain. In women, age, BMI, grip strength and WOMAC pain score at baseline were significantly different between subjects with resolution of pain and those with continuous pain. Among 207 men and 404 women with physical functional disability at baseline,

Table 2. Age, BMI, grip strength, and WOMAC pain and physical function score according to onset of pain and physical functional disability in subjects without pain and physical functional disability at baseline.

	Pain $N = 1,000$			Physical function $N = 947$		
	Continuous no pain	Onset of pain	p value	Continuous no physical functional disability	Onset of physical functional disability	p value
Men						
N	238	128		214	132	
Age	65.3 ± 11.3	67.6 ± 10.8	0.056	63.3 ± 11.0	68.9 ± 10.2	< 0.0001
BMI	23.1 ± 3.1	23.1 ± 2.8	0.7981	23.1 ± 3.0	23.0 ± 3.2	0.8946
Grip strength	37.1 ± 8.8	36.6 ± 9.3	0.6531	37.4 ± 8.6	35.9 ± 9.1	0.0149
Women						
N	410	224		358	243	
Age	62.7 ± 11.0	65.4 ± 9.9	0.0017	60.2 ± 10.4	65.7 ± 10.0	< 0.0001
BMI	22.0 ± 3.1	22.7 ± 3.1	0.0023	22.2 ± 3.1	22.6 ± 3.1	0.0823
Grip strength	24.2 ± 6.4	23.3 ± 6.5	0.0948	25.3 ± 6.5	22.8 ± 5.3	< 0.0001

Values are the means ± standard deviation.
BMI, body mass index; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

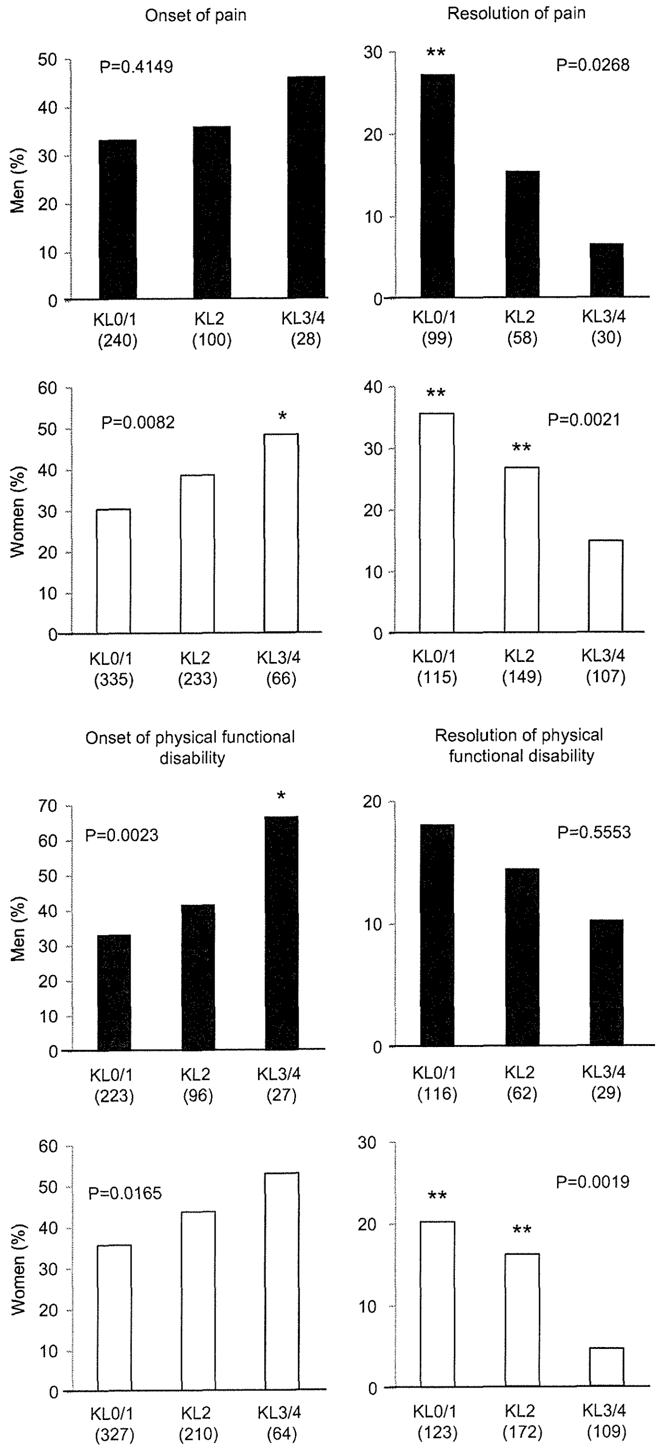

Figure 1. Onset and resolution rate of pain and physical functional disability according to Kellgren Lawrence (KL) grade in men and women. The number of subjects in each subgroup is shown in brackets. Chi-square test was used to determine the association of KL grade with onset of pain and physical functional disability as well as their resolution. $^*p<0.05$ versus KL grade 0/1 by multiple logistic regression analysis after adjustment for age. $^{**}p<0.05$ versus KL grade 3/4 by multiple logistic regression analysis after adjustment for age.

disability disappeared in 33 (15.9%) men and 58 (14.4%) women at follow up. In men, age and grip strength were significantly different between subjects with resolution of physical functional disability and those with continuous physical functional disability. Age, BMI, grip strength and WOMAC physical function score at baseline were significantly different between subjects with resolution of physical functional disability and those with continuous physical functional disability. In women, age, BMI, grip strength and WOMAC physical function score at baseline were significantly different between subjects with resolution of physical functional disability and those with continuous physical functional disability.

We next examined resolution of pain and physical functional disability according to KL grade (Figure 1). There were significant differences in resolution of pain among subjects with KL 0/1 knee, KL 2 knee OA and KL 3/4 knee OA in men and women (men 27.3%, 15.5% and 6.7%, respectively, $p=0.0268$ by chi-square test; women 35.7%, 26.8% and 15.0%, respectively, $p=0.0021$ by chi-square test). Multiple logistic regression analysis after adjustment for age showed that men with KL 3/4 knee OA had a significantly higher onset of pain compared with those with KL 0/1. Regarding resolution of physical functional disability, there were no significant differences among subjects with KL 0/1 knee, KL 2 knee OA and KL 3/4 knee OA in men (18.1%, 14.5% and 10.3%, respectively, $p=0.5553$ by chi-square test), while there were significant differences subjects with KL 0/1 knee, KL 2 knee OA and KL 3/4 knee OA in women (20.3%, 16.3% and 4.6%, respectively, $p=0.0019$ by chi-square test). Multiple logistic regression analysis after adjustment for age showed that women with KL 2 and 3/4 knee OA had a significantly higher onset of physical functional disability compared with those with KL 0/1.

To determine the independent association of age, BMI, grip strength and KL grade with onset of pain and physical functional disability, we next used multiple logistic regression analysis with significant variables ($p<0.01$) by non-paired Student's t test or chi-square test shown in Table 2 and Figure 1 as explanatory variables (Table 4). Regarding onset of pain, there were no significant variables in men; thus, we did not examine the independent association with onset of pain. In women, older age and higher BMI were independently associated with onset of pain. Older age and KL 3/4 knee OA were independent risk factors for onset of physical functional disability in men, whereas older age, higher BMI and weaker grip strength were independent risk factors for onset of physical functional disability in women. The significant association of knee OA with onset of physical functional disability disappeared after adjustment age, BMI and grip strength in women.

We also examined independent associations of age, BMI, grip strength and KL grade with resolution of pain and physical functional disability (Table 5). KL 0/1 knee and lower WOMAC pain score at baseline were significantly associated with resolution of pain in men, whereas lower BMI, higher grip strength and lower WOMAC pain score were significantly associated with resolution of pain in women. Regarding physical function, only age was significantly associated with resolution of physical functional disability in men, whereas higher grip strength, KL 2 knee OA and lower WOMAC physical function score were significantly associated with resolution of physical functional disability in women. KL 01 knee also tended to be associated with resolution of physical functional disability in women. Because treatment for knee OA might affect the resolution of pain and physical functional disability, we further examined the association of treatment for knee OA with the resolution of pain and physical functional disability. Among subjects with pain at baseline, the resolution rate of pain was 36.2% in subjects who underwent treatment for knee OA, and 14.2% in subjects who did not undergo treatment for knee OA. Among subjects with physical functional disability at baseline, the resolution rate of physical functional disability was 19.3% in subjects who underwent treatment for knee OA, while, 7.2% in subjects who did not undergo treatment for knee OA. The resolution rate of pain and physical functional disability was significantly different between subjects who had and had not undergone treatment for knee OA (chi-square test, $p<0.0001$). Thus, we examined independent associations of age, BMI, grip strength and KL grade with resolution of pain and physical functional disability after adjustment for the treatment for

Table 3. Age, BMI, grip strength, and WOMAC pain and physical function score according to resolution of pain and physical functional disability in subjects with pain and physical functional disability at baseline, respectively.

	Pain $N = 558$			Physical function $N = 611$		
	Resolution of pain	Continuous pain	p value	Resolution of physical functional disability	Continuous physical functional disability	p value
Men						
N	38	149		33	174	
Age	72.3 ± 8.9	71.9 ± 8.5	0.8	67.9 ± 11.6	73.4 ± 7.6	0.0118
BMI	22.8 ± 3.0	23.7 ± 3.3	0.08	23.4 ± 3.2	23.6 ± 3.2	0.8041
Grip strength	32.6 ± 6.4	32.4 ± 7.5	0.8694	34.9 ± 6.7	31.4 ± 7.3	0.0091
WOMAC at baseline						
Pain	1.82 ± 1.20	3.32 ± 2.69	< 0.0001	–	–	–
Physical function	–	–	–	4.85 ± 7.69	7.20 ± 7.58	0.1132
Women						
N	97	274		58	346	
Age	68.1 ± 12.6	72.4 ± 8.6	0.0022	68.1 ± 11.1	73.2 ± 8.2	0.0015
BMI	22.4 ± 3.2	24.0 ± 3.6	< 0.0001	22.3 ± 3.2	23.6 ± 3.6	0.0066
Grip strength	22.9 ± 7.2	19.8 ± 4.9	0.0002	23.7 ± 7.4	19.7 ± 5.4	0.0002
WOMAC at baseline						
Pain	1.84 ± 1.18	3.68 ± 2.90	< 0.0001	–	–	–
Physical function	–	–	–	3.33 ± 4.32	8.99 ± 9.54	< 0.0001

Values are the means ± standard deviation.
BMI, body mass index; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

knee OA. Results were similar to findings without adjustment for treatment of knee OA (Supplementary Table 2 available online at http://informahealthcare.com/doi/abs/10.3109/14397595.2014.883055). In addition, we examined associations of age, BMI, grip strength and severity of knee OA with worsening pain and physical functional disability in subjects with pain and physical functional disability at baseline (Supplementary Table 3 available online at http://informahealthcare.com/doi/abs/10.3109/14397595.2014.883055). Multiple logistic regression analysis showed that weaker grip strength was a risk factor for worsening pain, whereas KL 3/4 knee OA was a risk factor for worsening physical functional disability (Supplementary Table 4 available online at http://informahealthcare.com/doi/abs/10.3109/14397595.2014.883055).

Discussion

This is the first longitudinal population-based study to examine the onset, resolution and worsening of pain and physical functional disability using WOMAC. We also clarified the associations of age, BMI, grip strength and knee OA with the onset, resolution and worsening of pain and physical functional disability.

Our previous study showed that onset of knee pain during 3 years was approximately 20% and 30% in men and women, respectively [24]. The Chingford study also showed that more than 10% women had onset of pain during 2 years [25]. However, in these previous studies, knee pain was defined as present or absent, rather than as an established measure of pain such as WOMAC. In addition, in our previous study, we did not examine resolution of pain. In the present study, we found that 35% of men and women had onset of pain. These values were higher than onset values obtained from questionnaires in our previous study [24], indicating that WOMAC may be more powerful for detecting pain than questionnaires regarding only the presence or absence of pain. We also found that pain disappeared in approximately 20% men and 25% women using WOMAC. The Chingford study previously showed that knee pain disappeared in approximately 40% of Caucasian women during 2 years using a questionnaire on the presence and absence of pain [25], which is higher than the values

Table 4. Association of onset of pain and physical functional disability with age, BMI, grip strength, and KL grade.

	Onset of pain			Onset of physical functional disability		
	Adjusted OR	95% CI	p value	Adjusted OR	95% CI	p value
Men						
Age (+ 1 year)	–	–	–	1.05	1.02–1.08	0.0011
BMI (+ 1kg/m²)	–	–	–	–	–	–
Grip strength (+ 1kg)	–	–	–	1.01	0.97–1.04	0.628
KL grade						
KL 0/1	–	–	–	1		
KL 2	–	–	–	1.02	0.60–1.72	0.9504
KL 3/4	–	–	–	2.7	1.14–6.69	0.0274
Women						
Age (+ 1 year)	1.02	1.003–1.04	0.023	1.05	1.03–1.07	< 0.0001
BMI (+ 1kg/m²)	1.08	1.03–1.15	0.0047	1.08	1.02–1.14	0.0141
Grip strength (+ 1kg)	0.99	0.96–1.02	0.4977	0.96	0.92–0.99	0.0152
KL grade						
KL 0/1	1			1		
KL 2	1.09	0.74–1.61	0.6593	0.84	0.56–1.25	0.4035
KL 3/4	1.42	0.79–2.55	0.2337	1	0.54–1.82	0.9894

Multiple logistic regression analysis was used with significant variables ($p < 0.01$) in univariate models as explanatory variables.
BMI, body mass index; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

found in the present study. This discrepancy between our study and the Chingford study may be partly explained by age differences in addition to different estimations for pain and racial differences, because mean age was 52 years in the Chingford study compared with 67 years in the present study. Furthermore, we first found that approximately 40% men and women had onset of physical functional disability and approximately 15% men and women had resolution of physical functional disability. To our knowledge, no other community-based studies have described longitudinal patterns of physical functional disability, and the present study was the first to clarify the onset and resolution of physical functional disability using WOMAC.

Pain is the principal clinical symptom of knee OA [5], but, although much effort has been devoted to defining knee pain, the correlation with radiographic severity of the knee OA is not as strong as one would expect [2,6–8]. In the present study, we examined onset of pain according to KL grade using WOMAC. In men and women without knee OA (KL 0/1), more than 30% subjects had onset of pain. In addition, 50% of men and women with KL 3/4 knee OA had onset of pain, meaning that 50% did not have onset of pain despite having severe radiographic knee OA. In fact, in the present study, radiographic knee OA was not significantly associated with onset of pain in men, and after adjustment, the significant association of knee OA with onset of pain disappeared in women. These findings indicate that pain may arise from a variety of structures other than joint cartilage, such as menisci, synovium, ligaments, bursae, bone and bone marrow [26–30]. In addition, in the present study, the risk for onset of pain was higher with higher BMI rather than knee OA in women, indicating knee pain may be prevented by reducing obesity.

In the present study, we also examined the association of knee OA with the resolution of pain, and found that around 30% of men and women without knee OA had resolution of knee pain, which was a similar rate to onset of pain, and only 7% of men and 15% of women with severe knee OA had resolution of knee pain. These findings indicate that around 90% of subjects with severe knee OA had continuous knee pain. There were significant associations of resolution of pain with KL grade. Considering the results of onset of pain, severe knee OA may lead to difficulties with resolution of pain rather than onset of pain, particularly in men. In addition, after adjustment, resolution of pain was significantly associated with lower BMI and higher grip strength, which is a useful marker of muscle function and sarcopenia [15], rather than radiographic knee OA, indicating that improvement of obesity and performing muscle exercises may help make pain disappear. In addition, the significant association of BMI and grip strength remained after adjustment for treatment of knee OA, indicating that reducing obesity and performing muscle exercises may be as important as treatment to achieve resolution of pain due to knee OA.

We also found that severe knee OA was a risk factor for physical functional disability, particularly in men, despite the finding that severe knee OA was not significantly associated with onset of pain in men. Severe knee OA was not significantly associated with onset of physical functional disability after adjustment for age in women, despite the finding that severe knee OA was significantly associated with onset of pain. This discrepancy between gender may be partly explained by the idea that women are more susceptible to pain. In fact, our previous study showed that the prevalence of knee pain in women with KL 0/1, 2 and 3/4 knee OA was significantly higher than that in men with KL 0/1, 2 and 3/4 knee OA, respectively[2]. In addition, risk factors for onset of physical functional disability were higher BMI and weaker grip strength rather than knee OA in women in the present study. Grip strength is a useful marker of muscle function and sarcopenia [15]. A previous study also showed that grip strength is related to total muscle [19]. Results in the present study indicate that onset of physical functional disability may be prevented by improvement of obesity and muscle exercises.

In the present study, physical functional disability disappeared in 20% of women without knee OA, whereas physical functional disability disappeared only in 5% of women with severe knee OA. The association of knee OA with resolution of physical functional

Table 5. Association of resolution of pain and physical functional disability with age, BMI, grip strength, and KL grade.

	Resolution of pain			Resolution of physical functional disability		
	Adjusted OR	95% CI	p value	Adjusted OR	95% CI	p value
Men						
Age (+ 1 year)	–	–	–	0.95	0.90–0.9985	0.0443
BMI (+ 1kg/m^2)	0.92	0.80–1.04	0.1994	–	–	–
Grip strength (+ 1kg)	–	–	–	1.02	0.96–1.09	0.526
KL grade						
KL 3/4	1			–	–	–
KL 2	2.37	0.52–16.8	0.3042	–	–	–
KL 0/1	5.18	1.32–34.6	0.0378	–	–	–
WOMAC at baseline						
Pain	0.63	0.46–0.80	0.001	–	–	–
Physical function	–	–	–	–	–	–
Women						
Age (+ 1 year)	0.99	0.96–1.02	0.6031	0.98	0.95–1.02	0.4081
BMI (+ 1kg/m^2)	0.88	0.80–0.96	0.0034	0.93	0.84–1.02	0.1358
Grip strength (+ 1kg)	1.08	1.02–1.14	0.014	1.09	1.02–1.16	0.0123
KL grade						
KL 3/4	1			1		
KL 2	1.34	0.66–2.79	0.4312	3.04	1.15–9.62	0.0362
KL 0/1	1.71	0.79–3.77	0.1797	2.52	0.89–8.34	0.0997
WOMAC at baseline						
Pain	0.66	0.53–0.78	<0.0001	–	–	–
Physical function	–	–	–	0.87	0.78–0.93	0.0009

Multiple logistic regression analysis was used with significant variables ($p<0.01$) in univariate model as explanatory variables.
BMI, body mass index; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; KL, Kellgren Lawrence grade.

disability remained significant after adjustment. This means that in women without knee OA, pain may occur, but it may disappear more easily. In addition, grip strength was also associated with resolution of physical functional disability after adjustment, indicating that muscle exercises may help make physical functional disability disappear.

The present study showed gender differences in the associations of knee OA with pain and physical functional disability. In women, knee OA was significantly associated with onset of pain and physical functional disability as well as their resolution, whereas in men, there were no significant association of knee OA with onset of pain and resolution of physical functional disability. Our previous cross-sectional study also showed that the odds ratio of knee pain for KL 3/4 knee OA was approximately twice as high in women as in men[2]. These findings may be partly explained by the lower muscle mass in women compared with men. In men, muscular strength may obscure the associations of knee OA with pain and physical functional disability.

In conclusion, the present longitudinal study revealed the onset rate of pain and physical functional disability as well as their resolution rate using WOMAC. In addition, severe knee OA was significantly associated with onset of pain and physical functional disability as well as their resolution, particularly in women. Furthermore, we also clarified that BMI and grip strength were associated with onset of pain and physical functional disability as well as their resolution in women.

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Conflict of interest

None.

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Supplementary material available online

Supplementary Tables 1-4.

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ORIGINAL ARTICLE

Prevalence of hallux valgus and risk factors among Japanese community dwellers

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Abstract
Background To investigate the prevalence and severity of radiographically detected hallux valgus (HV) as well as associated risk factors among Japanese residents of Miyagawa, a mountain village located in the center of Mie Prefecture.
Methods The height, weight and body mass index (BMI) of 403 participants (male $n = 135$, female $n = 268$) recruited from among the residents of Miyagawa Village, Japan aged $\geq$65 years were measured, and baseline data, including age, sex and medical history were obtained from interviews and questionnaires. Knee osteoarthritis (KOA) was determined from radiographs of the feet and knees, and osteoporosis was determined by measuring bone mineral density. Hallux valgus, defined as angulation of the big toe at the first metatarsophalangeal joint of >20°, was classified as: mild (20°–30°), moderate (30°–40°) or severe (>40°). Risk factors for HV were calculated using multivariate logistic regression analysis that included age, sex, obesity (BMI $\geq$25), KOA, osteoporosis, Heberden's nodes and low back pain as variables.
Results The overall prevalence of definite radiographic HV was 22.8 % (184/806), and mild, moderate and severe HV was found in 66.3, 27.2 and 6.5 % of the participants, respectively. Hallux valgus was found in at least one foot in 120 (29.8 %) of the participants and the prevalence significantly differed between females with and without HV and KOA (odds ratios: 2.54 and 1.71, respectively).
Conclusions The prevalence of definite radiographic HV was 29.8 %. Female sex and KOA were significantly associated with increased risk for radiographic HV.

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Introduction

Hallux valgus (HV) is a common deformity in adults that is characterized by abnormal angulation, rotation and lateral deviation of the big toe at the first metatarsophalangeal joint [1, 2]. Wearing footwear causes individuals with HV pain and difficulty in walking [3], and many such patients require orthosis and/or surgery [4, 5]. Understanding the associated risk factors is very important to prevent HV and determine the ratio of individuals with HV. However, the community prevalence of HV estimated by epidemiological studies varies between 21 and 70 % [6–10]. This variation is partly attributable to differences in study populations and unclear definitions of HV, with the terms "hallux valgus" and "bunion" specifically causing confusion. Most epidemiological HV studies have used a self-check sheet or footprint rather than X-rays to detect HV [11] and very few community-based studies have incorporated such radiographic imaging [12]. We initiated a cohort study in 1997 to investigate the epidemiology of knee osteoarthritis (KOA) [13–15] and osteoporosis [16]. The present study of HV started from the seventh (2009) and eighth (2011) biennial examinations.

The present cross-sectional study investigates the prevalence of radiographic HV and associated risk factors

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among Japanese inhabitants of Miyagawa. Whether having radiographic HV affected their quality of life (QOL) was determined using the Japanese version of the EuroQol 5D (EQ-5D) questionnaire [17, 18].

Materials and methods

Individuals aged ≥65 years were recruited from among the inhabitants of Miyagawa, a mountain village located in the center of the Mie Prefecture, Japan. The population of this village was 3,364 in the year 2012, and 1,522 residents met the age criterion. The study that started in 1997 was designed to determine factors associated with KOA and osteoporosis by analyzing data from a representative sample of a rural elderly population every 2 years. The present study analyzes data from the seventh and eighth biennial examinations in 2009 and 2011, respectively.

The Ethics Committee for Human Research at our institution approved this study, and written informed consent was obtained from all participants before enrollment.

Baseline data were obtained at one-to-one interviews using standard questionnaires designed by orthopedic surgeons. These data included information about age, sex, medical history, cigarette smoking, and health-related QOL determined from the EQ-5D questionnaire. Height and body weight were measured, and body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2) at the baseline assessment. Obesity was defined as BMI >25. Bunions and callosities were identified by palpation. Pain was determined by applying pressure to the bunion. The location of callosities was categorized from maps of the soles of the feet. Heberden's nodes were located by visual inspection and palpation.

The EQ-5D is a standardized, characterized instrument for assessing the course of health processes [17] that was translated into Japanese for the present study. The EQ-5D contains a self-assessment section in which participants provide a description of their health status from the viewpoints of mobility, self-care, daily activities, pain (discomfort and anxiety) and depression. They selected the most appropriate of three statements about each of the five QOL dimensions to indicate their current health status. Each statement represents an increasing degree of severity. The results were coded and converted to utility scores using a table of values [18].

Other medical examinations consisted of radiography of the feet and knees and measurement of bone mineral density (BMD) at the distal third of the non-dominant side radius using dual energy X-ray absorptiometry (DCS-600EX; Aloka, Tokyo, Japan). Osteoporosis was defined as 2.5 standard deviations (SD) of BMD below that of the young adult mean (YAM) of a healthy young adult of the same sex.

Fully extended anteroposterior (AP) radiographs of both knees while standing were scored for radiographic KOA according to the Kellgren Lawrence (K/L) grading system [19]. Confirmed radiographic KOA was defined as a K/L grade of ≥2.

Foot X-rays were taken from participants standing upright with both feet on the cassette as described by Saltzman [20]. The standardized radiographic projection was indicated for weight-bearing views, in which the X-ray beam was inclined at 20° at a distance of 40 in., and centered between the bilateral feet. The hallux valgus angle (HVA), which is formed by the bone axes of the first metatarsal and the first proximal phalanx, and the M1-M2 angle formed by the bone axes of the first and second metatarsals on all radiographs, were consistently measured by the same examiner (AN) [21] and analyzed using Image J version 1.37 software (National Institutes of Health, Bethesda, MD, USA). The HVA value was taken as the mean of three determinations.

Hallux valgus was defined as an HV angle >20°, according to the Japanese Orthopaedic Society criteria and severity was classified as mild (20°–30°), moderate (30°–40°) or severe (>40°) [22].

Statistical analysis

Means ± standard deviations (SD) were calculated for variables unless otherwise noted. Risk factors for HV were determined from multivariate logistic regression analysis that included age, sex, obesity, KOA, osteoporosis, Heberden's nodes and low back pain as variables. The relationship between HVA and the M1-M2 angle was assessed using Pearson's correlation coefficient. The relationship between the severity of HV and of KOA (except total knee arthroplasty) was assessed using the Spearman rank correlation coefficient. Risk factors for HV are summarized as odds ratios (OR) with 95 % confidence intervals (CI). The EQ-5D values for normal feet or for each grade of HV were determined using a one-way ANOVA with Dunnett's post hoc test.

Significance at the level of 5 % was taken for all tests. All data were statistically analyzed using PASW Statistics for Windows version 18 (SPSS Inc, Chicago, IL, USA).

Results

A total of 314 (105 men, 209 women) and 221 (74 men, 147 women) elderly residents participated in the seventh and eighth Miyagawa studies, respectively, of whom 130 participated in both. Two residents declined X-ray examinations, and thus data from 403 (overall mean age: 75.5 ± 6.4 years, range: 65–94 years, female: 75.8 ± 6.6 years, male: 75.4 ± 6.3 years) participants (806 feet) who fulfilled the study criteria were analyzed. None of the participants had a history of surgically treated HV.

Table 1 shows the distribution of HV severity in the 806 feet. The overall prevalence of definite radiographic HV was 22.8 % (184/806), and 11.6 % (28/270) and 41.1 % (156/536) in men and women, respectively. The ratios of residents with mild, moderate and severe HV were 66.3 % (122/184), 27.2 % (50/184) and 6.5 % (12/184), respectively. The HV was bilateral in 64 (15.9 %), unilateral in 56 (13.9 %), and on at least one side in 120 (29.8 %) of the participants.

Figure 1 shows that HVA significantly correlated with the M1-M2 angle (Pearson's correlation coefficient (r) = 0.762, $p < 0.001$).

Table 2 shows relationships between each risk factor and the prevalence of HV. The prevalence of females significantly differed between groups with and without HV ($p = 0.003$, OR: 2.54, 95 % CI: 1.38–4.66) and KOA ($p = 0.028$, OR: 1.71, 95 % CI: 1.06–2.76).

The incidences of bunions on normal feet and on feet with mild, moderate and severe HV were 2.7 % (17/622), 28.7 % (35/122), 54.0 % (27/50), and 91.7 % (11/12), respectively (Fig. 2a). The incidences of painful bunions on normal feet and on feet with mild, moderate and severe HV were 0.3 % (2/622), 5.7 % (6/122), 8.0 % (4/50), and 16.7 % (2/12), respectively. The rate of painful bunions on all those with HV was 6.5 % (12/184). The incidences of callosities located on the balls (the first metatarsal head) of both normal feet and on feet with mild, moderate and severe HV were 3.2 % (20/622), 7.4 % (9/122), 2.0 % (1/50), and 0 % (0/12), respectively. On the other hand, the incidences of callosities located on the second, third, and fourth metatarsal heads of normal feet and of feet with mild, moderate and severe HV

Table 1 Distribution of hallux valgus severity

Participants	Normal	Mild	Moderate	Severe
Men	242	22	5	1
Women	380	100	45	11
Total	622	122	50	12

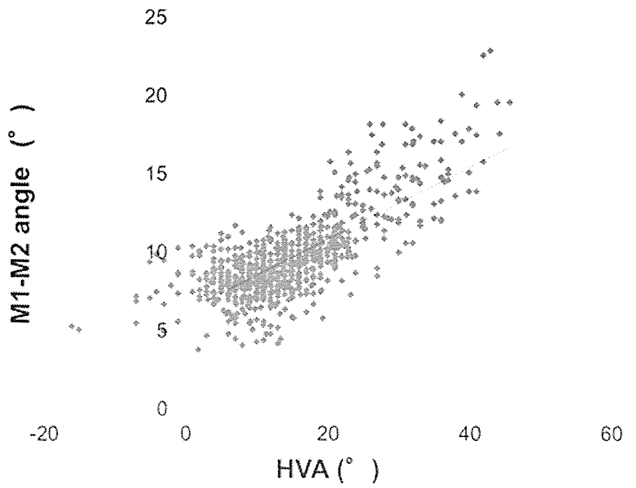

Fig. 1 Relationship between hallux valgus (*HVA*) angle and M1-M2 angle

Table 2 Comparison of individuals with and without radiographic hallux valgus

	HV ($n = 120$)	No HV ($n = 283$)	p	95 % CI	OR
Age (years)	76.1 ± 6.9	75.3 ± 6.1	0.66	0.97–1.05	1.01
Gender	M21; F99	M114; F169	0.003*	1.38–4.66	2.54
Obesity	+30/−90	+81/−282	0.23	0.38–1.22	0.73
KOA	+73/−47	+115/−168	0.03†	1.06–2.76	1.71
Osteoporosis	+66/−54	+123/−160	0.80	0.65–1.74	1.07
Heberden's nodes	+67/−53	+118/−165	0.13	0.90–2.27	1.43
Low back pain	+53/−67	+146/−137	0.10	0.44–1.08	0.68

HV hallux valgus, *KOA* knee osteoarthritis, *CI* confidence interval, *OR* odds ratio. Age is shown as mean ± SD. * $p < 0.01$, † $p < 0.05$

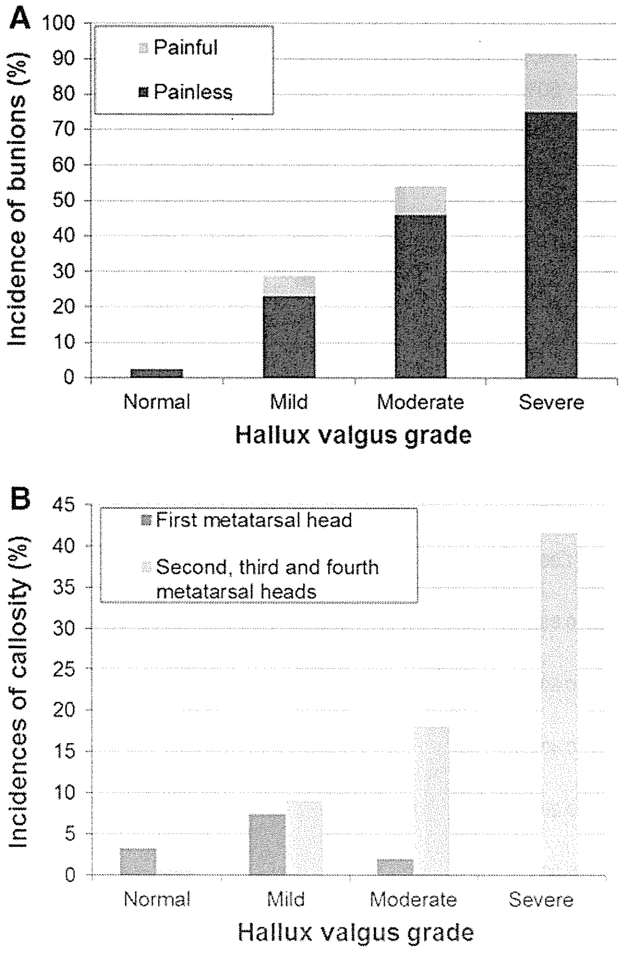

Fig. 2 Incidence of painful (*gray*) and painless (*black*) bunions (**a**) and callosities (**b**)

were 0.6 % (4/622), 9.0 % (11/122), 18.0 % (9/50) and 41.7 % (5/12), respectively (Fig. 2b).

Figure 3 shows that the severity of HV and of KOA significantly correlated ($\rho = 0.228$ and $p < 0.001$).

The EQ-5D utility scores of individuals with normal feet and with mild, moderate and severe HV were 0.855, 0.872, 0.809 and 0.769, respectively, with no significant differences among the groups (Fig. 4).

Discussion

The results of this cross-sectional study indicated a 29.8 % prevalence of radiographic HV among residents in a single village. Roddy et al. [2] reported a 28.4 % prevalence of self-reported HV among 4,249 patients in two general practices. On the other hand, Cho et al. [12] found

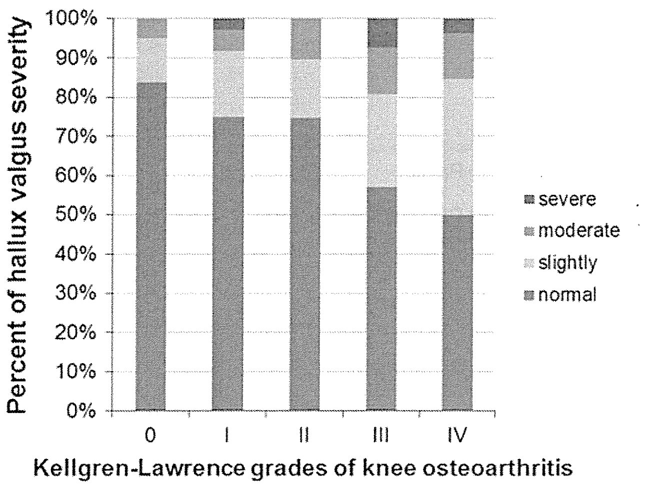

Fig. 3 Relationship between severity of hallux valgus and of knee osteoarthritis

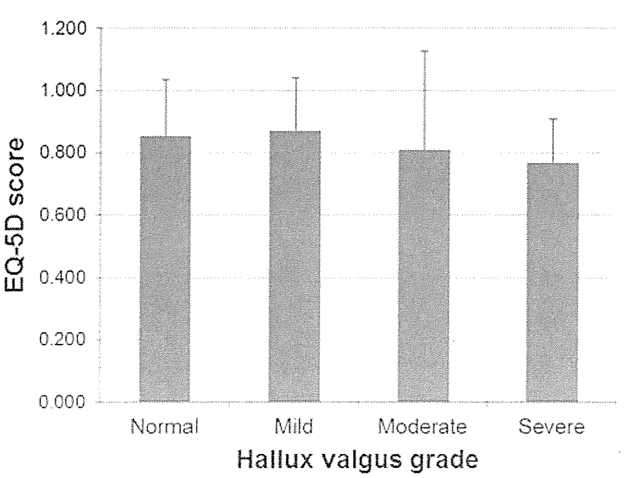

Fig. 4 EQ-5D utility scores of hallux valgus severity. Severity does not significantly differ between groups

radiographic HV in 364 (64.7 %) of 563 individuals. The reason for this higher value is their wider definition of radiographic HV as >15°, compared with our definition of >20°. Severe HV (>25°) was also found in 48 (13.2 %) individuals. Given these diagnostic criteria for HV, the prevalence was similar in both studies.

Badlissi [11] identified HV in 37.1 % of 784 individuals in a community-based study and found no association with foot pain or function, whereas 9.9 % of individuals studied by Cho et al. [12] reported foot pain. On the other hand, Menz et al. [23] identified foot pain in 20–30 % of community-dwelling elderly individuals. Although foot pain was not assessed in the present study, bunions and callosities, which are the main cause of pain associated with HV, were investigated. The rate of painful bunions on all those with HV in the present study was 6.5 % (12/184), which closely correlated with the severity of HV. The rates of painful bunions and callosities were higher in feet with HV than in normal feet. The locations of callosities changed from the ball of the foot to the second, third and fourth metatarsal heads according to the severity of HV. The likely reason for this is that the load center of the foot moves from the ball of the foot to the second, third and fourth metatarsal heads as HV severity progresses.

Risk factors for HV in some countries have been reported. Our results concurred with the findings of many reports indicating that female sex increases risk for HV [2, 12, 24–26], but contradicted those of Roddy et al. [2], who reported that HV is closely associated with age. However, their study participants were much younger than those in the present study (>30 vs >65 years). Our results suggested that HV is less likely to occur in the elderly. We also found that osteoporosis, which is considered a typical musculoskeletal disease of the elderly, and low back pain, which is associated with osteoporosis, were not associated with HV.

Our results support the notion that HV is associated with knee pain [2, 12, 27], the main cause of which is OA in elderly individuals. Wilder et al. [28] associated radiographically confirmed OA of the first metatarsophalangeal joint with radiographic KOA. Roddy et al. [2] concluded that HV appears to be a component of generalized OA and a likely marker of OA of the first metatarsophalangeal joint. However, the cross-sectional design of their study did not allow confirmation of this relationship ahead of the possibility that HV coexists with OA or that HV is a precursor of OA of the first metatarsophalangeal joint. Other reports [29, 30] show that most patients with HV also have cartilage degeneration of the first metatarsophalangeal joint. Knee OA has a genetic association [34], as well as a phenotypic association with factors such as weight loading (obesity) [12]. A deformity (especially of the varus type) of a person with a genetic background of KOA might proceed gradually, according to weight loading. On the other hand, valgus stress affects the first MTP joint very little when walking barefoot, but the effect is considerable when wearing shoes, especially those with pointed toes or high heels. Not all people who wear such shoes develop HV, so we believe that those who develop HV have internal factors that are related to KOA. On the other hand, Heberden's nodes that are considered hand OA [31] are thought to indicate a systemic predisposition to generalized OA [32]. However, our data showed that HV is related to KOA, but not to Heberden's nodes. Cicuttini et al. [33] found poor agreement between Heberden's nodes and radiological distal interphalangeal osteophytes in the same finger of the same hand. Heberden's nodes were defined in the present study only by inspection and palpation, and such a relationship might be revealed by X-rays of the hand. Further study is needed to clarify this issue.

Cho et al. [12] associated a high BMI with HV, whereas Roddy et al. [2] and Abhishek et al. [35] did not. The present study supports the latter finding, as an association between HV and BMI >25 (obesity) was not identified. Race, lifestyle or socioeconomic background might be involved in this contradiction.

Abhishek et al. [35] suggested that self-reported HV and big toe pain are associated with an impaired QOL, whereas HV alone is not. They also considered that the influence of HV on QOL could be explained by impaired balance [36] and gait [23]. Cho et al. [12] reported that participants with at least moderate HV (HVA >25°) had impaired general functional status on the physical function domain of the SF-36. They also found even lower general functional status among participants who had HV with foot pain than those without. Both moderate and severe HV tended to be a relatively lower EQ-5D score in the present study, but not significantly with QOL (EQ-5D). We considered only HV angle and not foot pain. This could explain the discrepancy between the previous and present results.

The present study has several potential limitations. We did not question participants about the types of shoes they wore when they were young, and so could not clarify the relationship between HV and type of shoes worn in youth. However, many inhabitants were engaged in forestry and/or agriculture because Miyagawa is a mountain village. Thus, most of them probably wore Japanese tabi socks and/or Japanese zori sandals when they were young. Both tabi socks and zori separate the big toe from the other toes and they do not have a heel. Shoes with pointed toes and high heels are risk factors for HV according to the Japanese guidelines [22]. Thus, people who wore tabi and zori in their youth might be less likely to develop HV, and because the younger generations did not wear tabi and zori even when they were young and often wore high-heeled shoes, the prevalence of HV might increase in the near future as they age. Participants who could visit the hospital were generally healthier than non-participants. The statistical significance of the risk factors might be relatively low. The EQ-5D is a standardized instrument used as a measure of health outcome, so it is not foot-specific like the self-administered foot evaluation questionnaire (SAFE-Q) [37], which might reveal significant differences. This study was cross-sectional and not longitudinal. Only two of the 130 participants who participated in both the seventh and eighth Miyagawa studies were free of HV (HVA <20) at the seventh study but had HV by the eighth (data not shown). Thus, a longitudinal study was impossible at this time. Further investigations of more participants over a longer term are planned, as the study will continue every 2 years.

Conclusion

This cross-sectional epidemiological study identified a 22.8 % prevalence of definite radiographic HV in a rural Japanese village. The ratios of mild, moderate and severe HV were 66.3, 27.2 and 6.5 %, respectively, and 15.9 and 13.9 % of participants had bilateral and unilateral HV, respectively. Furthermore, both female sex and KOA were identified as risk factors for radiographic HV.

Conflict of interest The authors declare that they have no conflict of interest.

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Spinal sagittal contour affecting falls: Cut-off value of the lumbar spine for falls

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ABSTRACT

Spinal deformities reportedly affect postural instability or falls. To prevent falls in clinical settings, the determination of a cut-off angle of spinal sagittal contour associated with increase risk for falls would be useful for screening for high-risk fallers. The purpose of this study was to calculate the spinal sagittal contour angle associated with increased risk for falls during medical checkups in community dwelling elders. The subjects comprised 213 patients (57 men, 156 women) with a mean age of 70.1 years (range, 55–85 years). The upright and flexion/extension thoracic kyphosis and lumbar lordosis angles, and the spinal inclination were evaluated with SpinalMouse®. Postural instability was evaluated by stabilometry, using the total track length (LNG), enveloped areas (ENV), and track lengths in the lateral and anteroposterior directions (X LNG and Y LNG, respectively). The back extensor strength (BES) was measured using a strain-gauge dynamometer. The relationships among the parameters were analyzed statistically. Age, lumbar lordosis, spinal inclination, LNG, X LNG, Y LNG, and BES were significantly associated with falls ($P < 0.05$). Multivariate logistic regression analyses revealed that lumbar lordosis was the most significant factor ($P < 0.01$). Univariate logistic regression analyses for falls about lumbar lordosis angles revealed that angles of 3° and less were significant for falls. The present findings suggest that increased age, spinal inclination, LNG, X LNG, Y LNG, and decreased BES and lumbar lordosis, are associated with falls. An angle of lumbar lordosis of 3° or less was associated with falls in these community-dwelling elders.

1. Introduction

Falls that result in fractures reduce quality of life. Approximately 30% of people aged 65 years and over fall each year, and about 20% of such incidents require medical attention [1–3]. Several factors such as aging, muscle weakness, home hazards, and psychotropic medication have been reported as risk factors for falls [3]. Spinal kyphosis arises from osteoporosis, weak back muscle strength, and/or degenerative spondylosis with aging. Kyphosis, which limits the activities of daily living and impairs the quality of life, is also considered to be one of the important causes of falls [4–7]. Furthermore, postural instability, which correlates with spinal deformities, is considered to be a risk factor for falls [8–11]. Regarding the relationships between postural instability and sagittal spinal contour, a loss of lumbar lordosis affects an increasing of spinal inclination (forward stooped posture) and also correlates with postural instability and the propensity to fall [12]. Furthermore, a previous study demonstrated that a loss of lumbar lordosis, an increase in spinal inclination, and postural imbalance were significantly higher in subjects with falls than in subjects without falls or fear of falls [11]. Therefore, spinal deformities may be significant risk factors for falls. However, precise data regarding the significant factors affecting falls and the extent of spinal deformities remain unclear. Moreover, a cut-off value of sagittal spinal contour for causing falls is unknown. With the aim to identify in the clinic setting any elders who are at risk for falls, a critical cut-off angle of sagittal spinal contour associated with falls would be helpful for screening fallers. Therefore, the aims of the present study were to investigate if sagittal spinal contour factors correlated with falls, and to determine if a cut-off value of sagittal spinal contour associated with falls among community-dwelling individuals.

2. Methods

2.1. Subjects

A cross sectional study was conducted each year from 2003 to 2009. The subjects comprised 213 patients (57 men, 156 women) with a mean age of 70.1 years (range 55–85 years) who participated in medical checkups for community dwellers in Akita, Japan. All the participants were able to walk alone and did not display any apparent neurological or metabolic disorders. The history of falls within the past year was recorded by a self report questionnaire.

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Table 1
Characteristics of the 213 subjects and variables affecting falls evaluated between fallers and non-fallers.

Variables	Total ($n=213$)	Fallers ($n=29$)	Non-fallers ($n=184$)	$P^{\dagger}$
Number/percentage of women	156/73.2	24/82.8	132/71.7	
Age (years)	70.1 (7.9)	73.6 (7.7)	70.1 (9.8)	0.020*
Body weight (kg)	54.2 (8.3)	51.7 (8.7)	55.1 (9.6)	0.123
Height (cm)	153.2 (8.4)	150.6 (8.1)	153.9 (8.7)	0.197
Thoracic kyphosis (°)	34.0 (14.5)	33.3 (14.7)	34.4 (14.4)	0.396
Lumbar lordosis (°)	11.1 (15.5)	3.8 (20.5)	11.9 (14.3)	0.035*
Spinal inclination (°)	6.0 (8.4)	10.9 (12.2)	5.8 (7.9)	0.017*
Thoracic mobility (°)	22.2 (22.2)	19.2 (24.1)	22.6 (21.6)	0.421
Lumbar mobility (°)	36.9 (22.3)	35.9 (25.5)	36.4 (21.7)	0.810
Mobility of spinal inclination (°)	102.4 (33.7)	95.0 (43.2)	101.9 (32.9)	0.491
Stabilometry				
LNG (mm)	306.7 (174.8)	432.1 (282.0)	294.1 (146.0)	0.029*
ENV (mm^2)	126.9 (112.6)	188.0 (155.7)	122.0 (102.0)	0.051
X LNG (mm)	154.2 (80.1)	198.8 (116.2)	150.1 (70.5)	0.017*
Y LNG (mm)	225.7 (151.7)	336.9 (243.9)	214.5 (127.0)	0.046*
BES (kg)	14.4 (8.3)	9.0 (8.6)	14.9 (8.3)	0.001*

Notes: Values represent the mean (±SD); LNG, total track length; ENV, enveloped area; X LNG, lateral sway length; Y LNG, anteroposterior sway length; BES, back extensor strength.
* Significant difference.
† Mann–Whitney *U* test.

2.2. Measurements of spinal sagittal contour and mobility

The parameters of sagittal spinal contour were evaluated using SpinalMouse® (Idiag, Volkerswill, Switzerland), which is a computer-assisted and non-invasive device for measuring spinal shape and mobility using surface-based techniques, and therefore reflects the shape of the dorsal trunk in appearance [13]. Measurements were accomplished by sliding this device along the spinal processes from the cephalad end of the thoracic spine to the sacrum at posterior superior iliac spine level while the subject stood with legs together. The angles of thoracic kyphosis (angle between T1 and T12), lumbar lordosis (angle between T12 and S1), and spinal inclination (angle between a straight line from T1 to S1 and the true vertical line) were evaluated. The spinal inclination reflected a forward stooped posture. All the parameters were measured in neutral standing, trunk flexion, and trunk extension positions without any support to investigate the influence of spinal mobility on the postural instability. Repetition of the measurement with the subject in trunk flexion and extension of the spine allowed measurements of spinal mobility. The mobility range of spinal inclination, which reflects the anteroposterior range of motion by the trunk, comprising the thoracic, lumbar, and sacral mobility, was also measured at maximum trunk flexion/extension. All the spinal data were measured and then calculated automatically, requiring only a short amount of time to complete the measurements. The intra-class correlation coefficients for the measurements with SpinalMouse® were 0.92–0.95 [14].

2.3. Measurement of postural instability

Stabilometry was performed using a JK-101® force platform (Unimec, Tokyo, Japan) with construction based on the strain-gauge principle. Each patient stood on the platform in a naturally upright posture with their upper limbs aligned with the sides of the body, their legs together, and their eyes open. Measurements were performed by sampling signals of the center of pressure (COP) for 20 s at a frequency of 20 Hz using a microcomputer. The following parameters indicating postural sway (imbalance) were extracted from the COP time series: total track length (LNG) indicating the sway length, enveloped area (ENV) indicating the spatial spread of the swaying, track length in the lateral direction (X LNG) indicating the lateral sway length, and track length in the anteroposterior direction (Y LNG) indicating the anteroposterior sway length. These parameters were also described and used in previous studies [12,15]. The intra-class correlation coefficients for the postural sway measurements with the stabilometer were 0.71–0.95 [16,17].

2.4. Measurement of back extensor strength

Isometric back extensor strength (BES) in the prone position was measured using a DPU-1000N Digital Force Gauge® strain-gauge dynamometer (Imada, Toyohashi, Japan). The measurements were performed twice, and the mean force was calculated. Regarding the precision of the measurements, the coefficient of variation was 2.3% [14].

2.5. Statistical analysis

All the data were analyzed using StatView® statistical software (SAS Institute, Cary, NC). To evaluate factors associated with falls, the relationships among age, body weight, height, sagittal spinal contour, spinal mobility, postural instability, and BES were analyzed using the Mann–Whitney *U* test. Since spinal posture, postural instability, and falls differ by age and sex, multivariate logistic regression analyses after adjusting for age and sex were performed for the significant variables to reveal the most significant parameters of sagittal spinal contour. Thereafter, the subjects were divided into two subgroups based on each one degree of significant sagittal spinal angle to evaluate the cut-off values. The relationships between these subgroups and falls were analyzed using univariate logistic regression analyses after adjustment for age and sex. Taking lumbar lordosis at 5° as an example of the subgroups, the subjects were divided into a 6° or more group and a 5° or less group, and analyzed as described above. The same method was applied for angles from −2° to 11°. The correlations between the variables were estimated to be absent ($r \leq 0.2$), weak ($0.2 < r \leq 0.4$), moderate ($0.4 < r \leq 0.7$), or strong ($r > 0.7$) according to the correlation coefficients. Values of $P < 0.05$ were considered statistically significant.

3. Results

The mean values for the age, body weight, height, angles of thoracic kyphosis, lumbar lordosis, and spinal inclination, thoracic and lumbar mobility, mobility of spinal inclination, parameters of postural instability, and BES are shown in Table 1. The fallers group comprised 29 subjects and the non-fallers group comprised 184 subjects.

The fallers were lighter and shorter than the non-fallers but this was not significant. The number and percentage of women were higher in the fallers group. Mann–Whitney *U* tests revealed that age, angle of lumbar lordosis, spinal inclination, LNG, X LNG, Y LNG, and BES were significantly associated with the history of falls ($P < 0.05$).

Multivariate logistic regression analyses for falls after adjustment for age and sex among the significant parameters, including angles of lumbar lordosis and spinal inclination, LNG, X LNG, Y LNG, and BES, revealed that the angle of lumbar lordosis was the only and most significant factor (Table 2). Therefore, lumbar lordosis was selected as the most significant factor among the spinal parameters. Univariate logistic regression analyses after adjustment for age and sex to evaluate the cut-off value for falls revealed

Table 2
Multivariate logistic regression analyses after adjustment for age and sex.

	Coefficient	SE	χ^2-value	*P*-value
Lumbar lordosis angle (°)	−0.049	0.022	5.167	0.023*
Spinal inclination (°)	−0.018	0.036	0.253	0.615
LNG (mm)	0.009	0.013	0.457	0.499
X LNG (mm)	−0.007	0.009	0.669	0.413
Y LNG (mm)	−0.005	0.012	0.149	0.699
BES (kg)	−0.032	0.053	0.361	0.548

Notes: SE, standard error; LNG, total track length; X LNG, lateral sway length; Y LNG, anteroposterior sway length; BES, back extensor strength.
* Statistical significance.