Japan College of Rheumatology
MODERN RHEUMATOLOGY

http://informahealthcare.com/mor
ISSN 1439-7595 (print), 1439-7609 (online)

Mod Rheumatol, 2014; 24(6): 966–973

DOI: 10.3109/14397595.2014.883055

informa healthcare

ORIGINAL ARTICLE

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

Shigeyuki Muraki[1], Toru Akune[1], Keiji Nagata[2], Yuyu Ishimoto[2], Munehito Yoshida[2], Fumiaki Tokimura[3], Sakae Tanaka[4], Hiroyuki Oka[5], Hiroshi Kawaguchi[4], Kozo Nakamura[6], and Noriko Yoshimura[5]

[1]*Department of Clinical Motor System Medicine, 22nd Century Medical & Research Center, Faculty of Medicine, the University of Tokyo, Tokyo, Japan,* [2]*Department of Orthopaedic Surgery, Wakayama Medical University, Wakayama, Japan,* [3]*Department of Orthopaedic Surgery, Tokyo Metropolitan Geriatric Medical Center, Tokyo, Japan,* [4]*Department of Orthopaedic Surgery, Faculty of Medicine, the University of Tokyo, Tokyo, Japan,* [5]*Department of Joint Disease Research, 22nd Century Medical & Research Center, Faculty of Medicine, the University of Tokyo, Tokyo, Japan, and* [6]*National Rehabilitation Center for Persons with Disabilities, Saitama, Japan*

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

Received 9 September 2013
Accepted 10 January 2014
Published online 24 February 2014

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.

Correspondence to: Shigeyuki Muraki, MD, PhD, Department of Clinical Motor System Medicine, 22nd Century Medical & Research Center, Faculty of Medicine, the University of Tokyo, Tokyo, Japan. Tel: + 81-3-5800-9178. Fax: + 81-3-5800-9179. E-mail: murakis-ort@h.u-tokyo.ac.jp

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.

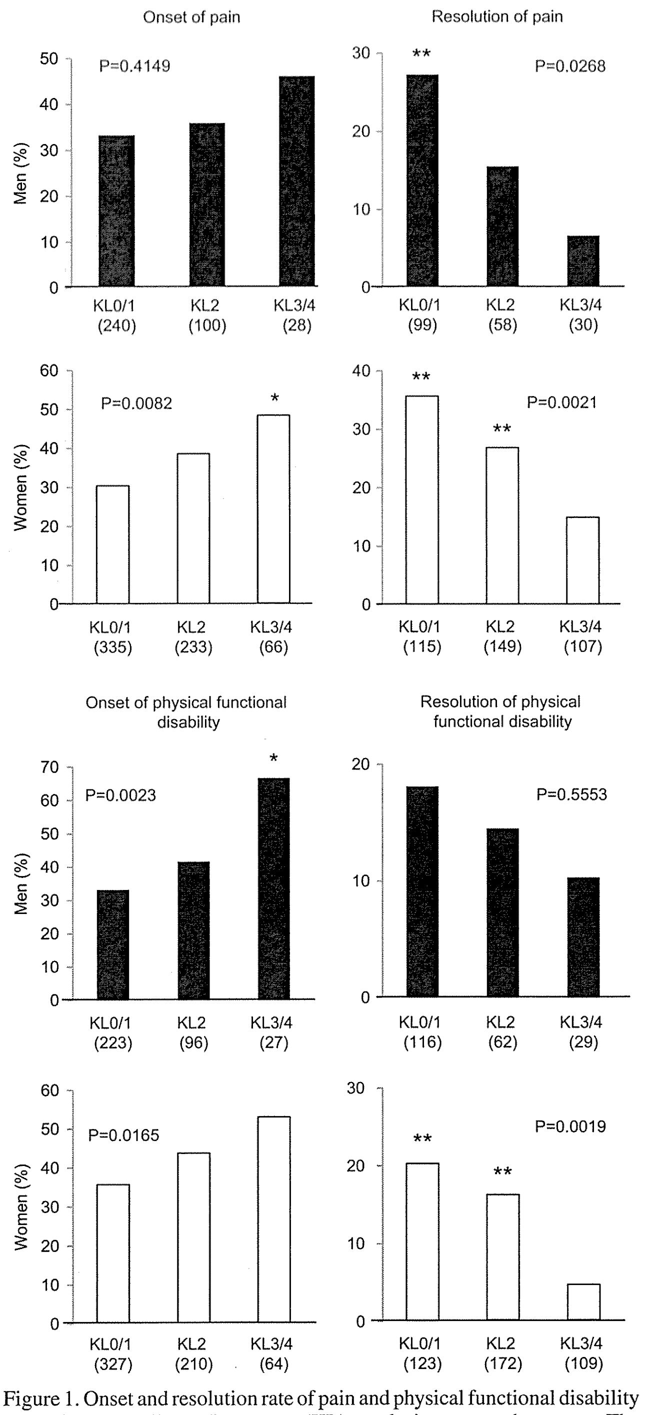

Figure 1. Onset and resolution rate of pain and physical functional disability according to Kellgren Lawrence (KL) grade in men and women. The number of subjects in each subgroup is shown in brackets. Chi-square test was used to determine the association of KL grade with onset of pain and physical functional 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/m^2)	–	–	–	–	–	–
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/m^2)	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.

Acknowledgements

This study was supported by Grants-in-Aid for Scientific Research (S19109007, B20390182, C20591737, C20591774), for Young Scientists (A18689031), and for Exploratory Research (19659305) from the Japanese Ministry of Education, Culture, Sports, Science and Technology, H17-Men-eki-009, H18-Choujyu-037, H20-Choujyu-009, H21-Chouju-Wakate-011 and H22-Chouju-Wakate-007 from the Ministry of Health, Labor and Welfare, Research Aid from the Japanese Orthopaedic Association (JOA-Subsidized Science Project Research 2006-1 & 2010-2), and Grant No.166 from the Japan Orthopaedics and Traumatology Foundation.

The authors thank Dr. Yamamoto, Dr. Ishibashi, Dr. Anamizu and members of Department of Orthopaedics, and Mr. Kutsuma and other members of Department of Radiology at Tokyo Metropolitan Geriatric Medical Center; Mrs. Tomoko Takijiri and other members of the Public Office in Hidakagawa Town; and Mrs. Tamako Tsutsumi, Mrs. Kanami Maeda and other members of the Public Office in Taiji Town, for their assistance in the location and scheduling of participants for examinations.

Conflict of interest

None.

References

1. Sharma L, Kapoor D. Epidemiology of osteoarthritis. In: Moskowitz RW, Altman RD, Hochberg MC, Buckwalter JA, Goldberg VM, editors. Osteoarthritis: Diagnosis and Medical/Surgical Management. 4th ed. Philadelphia: Lippincott Williams & Wilkins; 2007. pp. 3–26.
2. Muraki S, Oka H, Akune T, Mabuchi A, En-yo Y, Yoshida M, et al. Prevalence of radiographic knee osteoarthritis and its association with knee pain in the elderly of Japanese population-based cohorts: The ROAD study. Osteoarthritis Cartilage. 2009;17(9):1137–43.
3. Yoshimura N, Muraki S, Oka H, Mabuchi A, En-yo Y, Yoshida M, et al. Prevalence of knee osteoarthritis, lumbar spondylosis and osteoporosis in Japanese men and women: The Research on Osteoarthritis/osteoporosis Against Disability (ROAD). J Bone Miner Metab. 2009;27(5):620–8.
4. Ministry of Health, Labour and Welfare. The outline of the results of National Livelihood Survey 2007. August 2013. Available at http://www.mhlw.go.jp/toukei/list/20-19-1.html.
5. Linaker CH, Walker-Bone K, Palmer K, Cooper C. Frequency and impact of regional musculoskeletal disorders. Baillieres Clin Rheumatol. 1999;13(2):197–215.
6. Duncan R, Peat G, Thomas E, Hay E, McCall I, Croft P. Symptoms and radiographic osteoarthritis: not as discordant as they are made out to be? Ann Rheum Dis. 2007;66(1):86–91.
7. Hannan MT, Felson DT, Pincus T. Analysis of the discordance between radiographic changes and knee pain in osteoarthritis of the knee. J Rheumatol. 2000;27(6):1513–7.
8. Neogi T, Felson D, Niu J, Nevitt M, Lewis CE, Aliabadi P, et al. Association between radiographic features of knee osteoarthritis and pain: results from two cohort studies. BMJ. 2009;339:b2844.
9. Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. J Rheumatol. 1988;15(12):1833–40.
10. Thumboo J, Chew LH, Soh CH. Validation of the Western Ontario and McMaster University osteoarthritis index in Asians with osteoarthritis in Singapore. Osteoarthritis Cartilage. 2001;9(5):440–6.
11. Woo J, Lau E, Lee P, Kwok T, Lau WC, Chan C, et al. Impact of osteoarthritis on quality of life in a Hong Kong Chinese population. J Rheumatol 2004;31(12):2433–8.
12. Dillon CF, Rasch EK, Gu Q, Hirsch R. Prevalence of knee osteoarthritis in the United States: arthritis data from the Third National Health and Nutrition Examination Survey 1991-94. J Rheumatol. 2006;33(11): 2271–9.
13. Jordan JM, Helmick CG, Renner JB, Luta G, Dragomir AD, Woodard J, et al. Prevalence of knee symptoms and radiographic and symptomatic knee osteoarthritis in African Americans and Caucasians: the Johnston County Osteoarthritis Project. J Rheumatol. 2007;34(1):172–80.
14. Yoshida S, Aoyagi K, Felson DT, Aliabadi P, Shindo H, Takemoto T. Comparison of the prevalence of radiographic osteoarthritis of the knee and hand between Japan and the United States. J Rheumatol. 2002;29(7):1454–8.
15. Roubenoff R. Sarcopenia: a major modifiable cause of frailty in the elderly. J Nutr Health Aging. 2000;4(3):4140–2.
16. Bohannon RW. Hand-grip dynamometry predicts future outcomes in aging adults. J Geriatr Phys Ther. 2008;31(1):3–10.
17. Sirola J, Rikkonen T, Tuppurainen M, Jurvelin JS, Kroger H. Association of grip strength change with menopausal bone loss and related fractures: a population based follow-up study. Calcif Tissue Int. 2006;78(4):218–26.
18. Kerr A, Syddall HE, Cooper C, Turner GF, Briggs RS, Sayer AA. Does admission grip strength predict length of stay in hospitalised older patients? Age Ageing 2006;35(1):82–4.
19. Wind AE, Takken T, Helders PJ, Engelbert RH. Is grip strength a predictor for total muscle strength in healthy children, adolescents, and young adults? Eur J Pediatr. 2010;169(3):281–7.
20. Yoshimura N, Muraki S, Oka H, Kawaguchi H, Nakamura K, Akune T. Cohort profile: Research on osteoarthritis/osteoporosis against disability (ROAD) study. Int J Epidemiol. 2010;39: 988–95.
21. Kellgren JH, Lawrence JS (eds.). The Epidemiology of Chronic Rheumatism: Atlas of Standard Radiographs of Arthritis. Oxford, England: Blackwell Scientific; 1963.
22. Barr S, Bellamy N, Buchanan WW, Chalmers A, Ford PM, Kean WF, et al. A comparative study of signal versus aggregate methods of outcome measurement based on the WOMAC Osteoarthritis Index. J Rheumatol 1994;21(11):2106–12.
23. Hashimoto H, Hanyu T, Sledge CB, Lingard EA. Validation of a Japanese patient-derived outcome scale for assessing total knee arthroplasty: comparison with Western Ontario and McMaster Universities osteoarthritis index (WOMAC). J Orthop Sci. 2003; 8(3):288–93.
24. Muraki S, Akune T, Oka H, Ishimoto Y, Nagata K, Yoshida M, et al. Incidence and risk factors for radiographic knee osteoarthritis and knee pain in Japanese men and women: a longitudinal population-based cohort study. Arthritis Rheum. 2012;64(5):1447–56.
25. Soni A, Kiran A, Hart DJ, Leyland KM, Goulston L, Cooper C, et al. Prevalence of reported knee pain over twelve years in a community-based cohort. Arthritis Rheum 2012;64(4):1145–52.
26. Saito T, Koshino T. Distribution of neuropeptides in synovium of the knee with osteoarthritis. Clin Orthop Relat Res. 2000;376: 172–82.

27. Bollet AJ. Edema of the bone marrow can cause pain in osteoarthritis and other diseases of bone and joints. Ann Intern Med. 2001;134(7):591–3.
28. Teichtahl AJ, Wluka AE, Morris ME, Davis SR, Cicuttini FM. The relationship between the knee adduction moment and knee pain in middle-aged women without radiographic osteoarthritis. J Rheumatol. 2006;33(9):1845–8.
29. Thorp LE, Sumner DR, Wimmer MA, Block JA. Relationship between pain and medial knee joint loading in mild radiographic knee osteoarthritis. Arthritis Rheum. 2007;57(7):1254–60.
30. Felson DT, Niu J, Guermazi A, Roemer F, Aliabadi P, Clancy M, et al. Correlation of the development of knee pain with enlarging bone marrow lesions on magnetic resonance imaging. Arthritis Rheum. 2007;56(9):2986–92.

Supplementary material available online

Supplementary Tables 1-4.

Japan College of Rheumatology
MODERN RHEUMATOLOGY

http://informahealthcare.com/mor
ISSN 1439-7595 (print), 1439-7609 (online)

Mod Rheumatol, 2014; 24(2): 250–257

DOI: 10.3109/14397595.2013.854063

informa healthcare

ORIGINAL ARTICLE

Development and evaluation of a video exercise program for locomotive syndrome in the elderly

Hiroshi Hashizume[1], Noriko Yoshimura[2], Keiji Nagata[1], Nobuyuki Miyazaki[1], Yuyu Ishimoto[1], Ryoko Nishiyama[1], Hiroyuki Oka[2], Hiroshi Yamada[1], and Munehito Yoshida[1]

[1]*Department of Orthopaedic Surgery, Wakayama Medical University, Wakayama City, Wakayama, Japan, and* [2]*Department of Joint Disease Research, 22nd Century Medical and Research Center, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan*

Abstract

Objectives. To develop and evaluate an exercise program that the elderly could sustainably perform in the community or at home to recover from locomotive syndrome.
Methods. We produced 2 types of teaching media, video and pamphlet, describing 10 physical and mobility training exercises. The pilot study examined changes in pulse rate, percutaneous oxygen saturation (SpO_2), and the Borg scale rating of perceived exertion in 20 elderly volunteers. Separately, 120 elderly subjects were recruited and divided into 3 groups according to the teaching medium (video, group V; pamphlet, group P; none, group C). Before and 3 months after the intervention, visual analog scale (VAS) scores of low back and knee pain, single-leg standing time, 6-m walking time, Roland–Morris Disability Questionnaire, Oswestry Disability Index, Short Form-8, and 25-question Geriatric Locomotive Function Scale were evaluated.
Results. Pulse-rate changes before and after exercise did not exceed 20 %, and SpO_2 changes were within 4 points in all cases. The Borg scale ranged between 11 and 14. The intergroup comparison revealed the advantage of the video program in improving the VAS of low back pain, left-leg standing time, and 6-m walking time.
Conclusion. A video exercise program can potentially aid recovery from locomotive syndrome in the elderly.

Keywords

DVD video, Elderly, Exercise program, Locomotive syndrome, Low back pain

History

Received 14 November 2012
Accepted 6 March 2013
Published online 30 March 2013

Introduction

Population aging is occurring in countries worldwide, but it is most advanced in highly developed countries. The population of Japan in particular is aging very rapidly. According to an estimate by the Ministry of Internal Affairs and Communications released on October 1, 2007, 29,005,000 people (22.7 % of the total population) in Japan were 65 years old or older [1]. The United Nations has therefore labeled Japan a "superaged" society. Aging is associated with an increased risk of problems related to physical mobility. By 2006, the number of elderly persons in Japan needing nursing care had increased to 4,300,000; orthopedic problems are unquestionably one of the main reasons for this need [2]. According to the Comprehensive Survey of Living Conditions conducted in 2007 by the Japan Ministry of Health, Labour and Welfare, the most frequent symptom in both men and women 65 years old or older was low back pain [3]. Joint disease is also a major cause of the need for long-term care; in a large-scale population-based cohort study, the number of patients in Japan with knee osteoarthritis (KOA) was estimated to be approximately 25 million [4].

To increase society's awareness of this problem, the Japanese Orthopaedic Association (JOA) has proposed the concept of *locomotive syndrome*, a condition in which the elderly receive care services, or are at high risk of soon requiring care services, because of difficulty with physical mobility [2, 5]. The earliest possible intervention is required to prevent the need for long-term care among individuals with locomotive syndrome.

Many reports indicated that exercise is effective for most disorders affecting mobility, including low back pain and knee disease [6, 7]. However, few reports have investigated the efficacy of exercise for the elderly, especially from the point of view of preventing locomotive syndrome. Because the elderly often have multiple diseases that affect their mobility, studies to develop tools for the early detection of locomotive syndrome are ongoing. Investigations of specific methods for teaching exercise to the elderly are also underway.

The purposes of this study are to (1) develop an exercise program that the elderly could sustainably perform in the community or at home, (2) investigate which medium of exercise instruction (video or pamphlet) is superior, and (3) determine the parameter that is most useful for evaluating the effectiveness of this intervention for locomotive syndrome.

Methods

For this study, "elderly" was defined according to the Japan Ministry of Health, Labour and Welfare's definition of 65 years old or older. The study was conducted after approval from the ethics review board and consent from the participants were obtained.

Correspondence to: Hiroshi Hashizume, Department of Orthopaedic Surgery, Wakayama Medical University, 811-1 Kimiidera, Wakayama City, Wakayama 649-6122, Japan. Tel: +073-441-0645. Fax: +073-448-3008. E-mail: hashizum@wakayama-med.ac.jp

Development of the exercise program for the elderly

Exercise program

Ten types of exercises that an elderly person could perform without excess load on the musculoskeletal system or cardiopulmonary function were selected from widely known physical and mobility training exercises. The exercises were combined into a single exercise program comprising 2 distinct parts:

(A) Mobility training for fall prevention (Fig. 1a)

1. Stepping (40 s)
2. Single-leg standing with eyes open (10 s/cycle × 4)
3. Squatting (10 s/cycle × 10)
4. Quadriceps femoris training (5 s/bilateral side × 5)

(B) Muscle training to prevent/improve low back pain (Fig. 1b)

1. Muscle training of the hips and pelvis (10 s/cycle × 8)
2. Exercises for back flexibility (10 s/cycle × 5)
3. Abdominal muscle training (10 s/cycle × 5)
4. Back muscle training (5 s/cycle × 3)
5. Stretching of the lumbar spine (30 s/cycle × 2)
6. Rounding the back like a cat (10 s)

Teaching materials

Two types of teaching media were produced (Fig. 2). One was a DVD video of exercise demonstration by 2 instructors with background music and commentary. The other was a pamphlet including the same content as the DVD video but consisting of photographs and descriptions. In the video, the rhythm was regulated so that 4 beats of the background music lasted for 5 s.

Estimation of the physical load from the DVD video exercise

Twenty volunteers (age range 65–88 years) who used a day hospital service were asked to perform the video exercises for 15 min. Changes in pulse rate and percutaneous oxygen saturation (SpO_2) before (within 5 min of starting) and after (within 60 s of finishing) the exercise were measured. The Borg scale rating of perceived exertion (RPE, range 6–20) was also recorded to measure the subjective intensity level of the physical activity [8].

Evaluation of the efficacy of the exercise program

Participants and sampling in groups

One hundred twenty elderly residents (age range 65–85 years, mean 72.2 years) of Hashimoto City were recruited by open

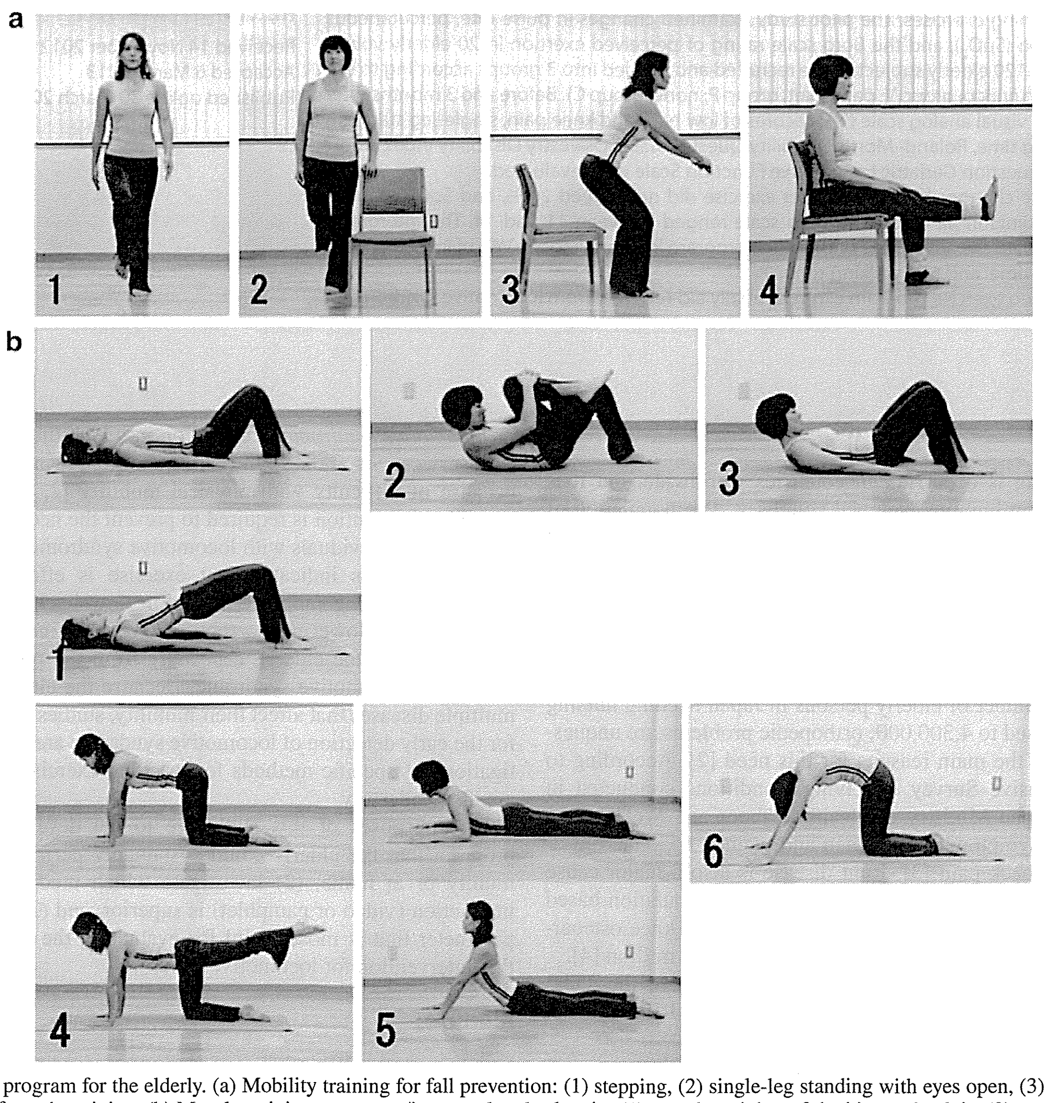

Fig. 1 Exercise program for the elderly. (a) Mobility training for fall prevention: (1) stepping, (2) single-leg standing with eyes open, (3) squatting, and (4) quadriceps femoris training. (b) Muscle training to prevent/improve low back pain: (1) muscle training of the hips and pelvis, (2) exercises for back flexibility, (3) abdominal muscle training, (4) back muscle training, (5) stretching of the lumbar spine, and (6) rounding the back like a cat

Fig. 2 Two types of teaching media produced for the participants. (a) DVD jacket cover. (b) Example of the instructions in the pamphlet: (1) stepping (*top*), (2) single-leg standing with eyes open (*middle*), and (3) squatting (*bottom*)

invitation. Hashimoto City is located between the mountains and a dormitory town of Osaka. In 2008, elderly people constituted 22.3 % of the approximately 69,000-resident population.

The participants were divided randomly into the following 3 groups by a member of the city staff: (1) group V participants performed the exercises while watching the video; (2) group P participants performed the exercises while reading the pamphlet; and (3) group C participants did not perform the exercises. Participants were allowed to change groups when requested because of a family relationship or friendship. Finally, there were 43, 41, and 36 participants in groups V, P, and C, respectively. Participants in groups V and P were instructed to perform all exercises twice a day. The period of intervention was set at 3 months.

Radiographic assessment

All participants underwent radiographic examination at the start of the intervention to assess degenerative changes in their knee joints or lumbar spine. KOA and lumbar spondylosis (LS) were defined as grade ≥2 on the Kellgren–Lawrence scale [9]; i.e., radiographic findings of definite osteophytes and definite narrowing of the joint space or intervertebral space were defined as grade 2. Osteoporosis (OP) of the lumbar spine was defined as sparse or absent longitudinal trabeculae in the vertebral body in accordance with the criteria proposed by the Japanese Society for Bone and Mineral Research [10]. Vertebral fracture was assessed by a quantitative method using lateral radiographs of the lumbar spine (L1–L5), according to the Japanese Society of Bone and Mineral Research criteria [10]. Wedge appearance was defined as a site at which the anterior height of the vertebra was ≤75 % of the posterior height. Biconcave appearance occurred if the height of the central part of the vertebra was ≤80 % of that of the anterior or posterior parts of the vertebra. Crush appearance was indicated if the heights of the anterior, central, and posterior parts of an axial vertebra were all reduced to ≤80 % of the normal values.

Clinical assessment

Clinical assessments of the participants were performed at the start of the intervention. Anthropometric measurements included height, weight, and body mass index [BMI; weight (kg)/height (m^2)]. To evaluate physical performance, the single-leg standing time for each leg was measured using a stopwatch (upper limit, 60 s). Six-meter walking times with normal steps and quick steps were also measured using a stopwatch. These measurements were performed by members of the local government staff who were blinded to the intervention groups. At the same time, the participants completed several types of self-report questionnaires. Presence of pain was assessed by a questionnaire asking the participants if they had experienced low back pain or knee pain lasting more than 24 h within the previous month. The participants were also asked to rate the intensity of their current pain pertaining to the lower back or knee joints by using a visual analog scale (VAS, range 0–100). For the assessment of functional disability, participants completed the Oswestry Disability Index (ODI, Japanese version; range 0–100) [11]; for the assessment of low back pain, the Roland–Morris Disability Questionnaire (RDQ, Japanese version; range 0–24) [11–13] was used. The participants completed the Short Form-8 health survey (SF-8, Japanese version) [14] for assessment of health-related quality of life. The physical component summary (PCS) and mental component summary (MCS) scores of this instrument were calculated using the norm-based scoring system [14]. The 25-question Geriatric Locomotive Function Scale (GLFS-25, Japanese version) was used to detect locomotive syndrome [15]. The GLFS-25 is a self-administered, relatively comprehensive measure consisting of 25 items. These 25 items are graded on a 5-point scale, ranging from no impairment (0 points) to severe impairment (4 points), and the scores are then added together to produce a total (range 0–100). We set the cutoff score for identifying locomotive syndrome at 16, according to the currently accepted criteria [15].

The same clinical assessments, excluding anthropometric measurements or the presence of pain, were performed at the end (after 12 weeks) of the intervention. In addition, the participants in groups V and P recorded their daily level of exercise during the intervention. When a subject performed all of the exercises once, a score of 2 was given. One point was given if some of the exercises were performed, and a score of 0 was given if the subject did not perform any exercises. Because the participants in the 2 groups were instructed to perform all of the exercises twice daily, the possible range of daily points was 0–4. The exercise achievement summary scale was calculated using the following formula: (sum of the daily points/4 × number of days) × 100.

Statistical analyses

JMP9 (SAS Institute Inc., Cary, NC, USA) and IBM SPSS Statistics 18 (International Business Machines Corp., Armonk, NY, USA) statistical software were used for the statistical analyses in this study. To compare the baseline data among the 3 groups, a chi-square test for independence was used for proportional variables (sex and prevalence). One-factor analysis of variance (ANOVA) was performed for parametric variables (age, VAS, single-leg standing time, and 6-m walking time). A Kruskal–Wallis rank test was performed for nonparametric data (RDQ, ODI, PCS, MCS, and GLFS-25). For intragroup comparisons between baseline and 3 months after the intervention, a paired *t* test was used for parametric data (age, VAS, single-leg standing time, and 6-m walking time) and a Wilcoxon signed-rank test was used for nonparametric data (RDQ, ODI, PCS, MCS, and GLFS-25). A Mann–Whitney *U* test was applied to compare the exercise achievement summary scale scores between groups V and P. The intervention effect (the change of each parameter) was also compared. In advance of the comparison, split-plot ANOVA was performed to assess inter- and intragroup differences by using repeated values of VAS; single-leg standing time; 6-m walking time; and PCS, MCS, RDQ, ODI, and GLFS-25 scores as objective factors and group as an explanatory factor. Mauchly's sphericity test was used to validate the equality of the variances for repeated measures of the 3 groups. Subsequently, Scheffé's *F* post hoc pairwise multiple-comparison test was performed to assess the significance of the mean differences between the groups. In cases in which the baseline parameters significantly differed among the groups, analysis of covariance (ANCOVA) was applied in which the baseline value was added as a covariate. A value of $p < 0.05$ was considered significant.

Results

Physical load of the DVD video exercise

All 20 elderly participants with locomotive disability and/or concomitant internal disease completed the 15-min DVD video exercise program. Pulse-rate changes before and after exercise did not exceed 20 %, and SpO_2 changes were within 4 points in all cases. The RPE scores were 11 (light), 12, 13 (somewhat hard), and 14 for 5, 12, 2, and 1 participants, respectively. No participants had a score of 15 (hard) or higher for the intensity of the exercises (Table 1).

Efficacy of the exercise program

Table 2 presents the age, anthropometric measurements, prevalence of bone and joint diseases, and SF-8 summary scores (i.e.,

Table 1. Physical load of the DVD video exercise in 20 volunteers

			Concomitant chronic diseases		Pulse rate (bpm)		SpO_2 (%)		
No.	Age (years)	Sex	Musculoskeletal disease	Internal disease	Before EX	After EX	Before EX	After EX	RPE
1	78	Female	LBP	HT, bronchial asthma	74	78	95	95	12
2	71	Female	LBP	DM	88	84	93	92	12
3	69	Female	LBP	HT	92	91	96	96	13
4	73	Female	LBP		78	76	95	93	11
5	66	Female		Hyperlipemia	88	84	92	92	12
6	74	Female	KOA	HT	84	90	96	94	12
7	66	Male		HT, cerebral infarction	89	92	95	95	11
8	88	Male	LBP	HT, arrhythmia	81	83	94	92	12
9	65	Male	LSS		76	88	95	92	12
10	80	Male		LBP, KOA arrhythmia	78	92	95	91	14
11	83	Female	LBP	Cerebral infarction	77	79	97	97	11
12	82	Male	LBP	HT	80	84	97	96	12
13	80	Male	LBP	Parkinson's disease	80	88	94	96	12
14	69	Male	LSS	HT	85	87	96	96	12
15	73	Male	LBP	DM	72	68	97	95	11
16	78	Female	LBP	HT, arrhythmia	85	89	93	93	12
17	77	Male	LBP	Vertigo	63	72	97	97	11
18	79	Male		HT, bronchitis, angina pectoris	69	72	95	97	12
19	75	Male	LBP	Bronchial asthma	82	96	90	90	13
20	70	Male	LBP, HOA		86	86	97	95	12

Perceived exertion ratings of 12–14 suggest that physical activity was performed at a moderate level of intensity

LBP low back pain, *LSS* lumbar spinal stenosis, *KOA* knee osteoarthritis, *HOA* hip osteoarthritis, *HT* hypertension, *DM* diabetes mellitus, *bpm* beats per minute, *EX* exercise, SpO_2 percutaneous oxygen saturation, *RPE* Borg rating of perceived exertion scale (range 6–20); RPE 11, "light" intensity; RPE 13, "somewhat hard" intensity; RPE 15, "hard" intensity

Table 2. Characteristics of 120 elderly participants

	Men	Women
Number of subjects	32	88
Age (years)	74.1 ± 5.4	71.6 ± 4.3
Height (cm)	164.5 ± 4.7	151.4 ± 4.9
Body weight (kg)	67.2 ± 9.1	53.1 ± 7.7
Body mass index (kg/m^2)	24.8 ± 2.6	23.1 ± 3.0
Prevalence		
Musculoskeletal pain		
Low back pain	26/31 (83.9 %)	58/86 (67.4 %)
Knee pain	11/31 (35.5 %)	32/86 (37.2 %)
Radiographic findings		
LS	28/31 (90.3 %)	71/86 (82.6 %)
KOA	16/32 (48.4 %)	67/86 (77.9 %)
OP of the lumbar spine	1/31 (3.2 %)	38/86 (44.2 %)
VF of the lumbar spine	1/31 (3.2 %)	11/86 (12.8 %)
Locomotive syndrome	8/31 (25.8 %)	36/88 (40.9 %)
Short Form-8 summary scores		
PCS	46.1 (40.9–49.3)	45.3 (41.2–49.6)
MCS	52.1 (49.6–55.7)	53.0 (48.3–55.3)

PCS and MCS presented as median (25–75 %). Locomotive syndrome was indicated by the 25-question Geriatric Locomotive Function Scale when the total score was ≥16 points

LS lumbar spondylosis, *KOA* knee osteoarthritis, *OP* osteoporosis, *VF* vertebral fracture, *PCS* physical component scale, *MCS* mental component scale

Table 3. Characteristics of the participants in the 3 intervention groups

	Group V	Group P	Group C
Number of subjects	43	41	36
Age (years)	72.9 ± 5.1	70.9 ± 3.9	73.1 ± 4.9
Gender (male:female)	18:25*	7:34	7:29
Body mass index (kg/m^2)	23.5 ± 3.0	23.5 ± 2.6	23.5 ± 3.3
Prevalence			
Musculoskeletal pain			
Low back pain	32/42 (76.2 %)	30/40 (75.0 %)	22/35 (62.9 %)
Knee pain	15/42 (35.7 %)	15/41 (36.6 %)	12/36 (33.3 %)
Radiographic findings			
LS	36/40 (90.0 %)	32/41 (78.0 %)	31/36 (86.1 %)
KOA	25/40 (62.5 %)	30/41 (73.2 %)	27/36 (75.0 %)
OP of the lumbar spine	10/40 (25.0 %)	18/41 (43.9 %)	11/36 (30.6 %)
Locomotive syndrome	17/42 (40.5 %)	15/41 (36.6 %)	12/36 (33.3 %)

Locomotive syndrome was indicated by the 25-question Geriatric Locomotive Function Scale when the total score was ≥16 points

Group V video exercise group, *Group P* pamphlet exercise group, *Group C* control group, *LS* lumbar spondylosis, *KOA* knee osteoarthritis, *OP* osteoporosis

*$p < 0.05$

PCS and MCS) in men and women. These data are used to verify the characteristics of the participants in the "Discussion."

The participants' characteristics by group are presented in Table 3. The mean age and BMI of the participants did not differ significantly among the 3 groups. There was a bias in the sex distribution among the 3 groups ($p = 0.0453$). At the start of the intervention, the prevalence of low back and knee pain did not differ significantly among the groups. No significant differences were observed among the groups regarding the prevalence of LS, KOA, and OP, although there was a tendency of a relatively higher prevalence of OP in group P. In total, 17 of 42 participants in group V, 15 of 41 participants in group P, and 12 of 36 participants in group C were diagnosed with locomotive syndrome. The prevalence of locomotive syndrome was not significantly different among the groups.

The follow-up rates (proportion of the participants who completed the 3-month intervention) were 88.4, 90.2, and 83.3 % for groups V, P, and C, respectively. One woman in group P withdrew from the study because she sustained a vertebral body fracture during her daily activities. Furthermore, 1 woman in group C withdrew because she was awaiting surgery for cervical spondylotic myelopathy. Another 13 participants withdrew from the study for personal reasons. No participants in group V or group P withdrew because of the difficulty of the exercise itself. The exercise achievement summary scale score in group V (median = 74.1 %, 25–75 percentile = 58.0–91.7 %) was significantly higher ($p = 0.0015$) than that in group P (median = 53.2 %, 25–75 percentile = 35.9–73.8 %). There was no significant difference in the exercise achievement summary scale score between men (median = 69.6 %, 25–75 percentile = 40.4–91.1 %) and women (median = 64.7 %, 25–75 percentile = 39.1–81.2 %).

Changes in the evaluation items before and after the intervention are presented in Table 4. Group V included more physically inferior participants than the other 2 groups at baseline. During the 3 months, different responses to the intervention were observed in each group. In group V, significant improvements were observed in the VAS score for low back pain, single-leg standing time (both right and left legs), 6-m walking time (both with normal steps and with quick steps), and PCS score. In group P, significant improvements were observed in the single-leg standing time (left leg) and PCS and RDQ scores. In group C, no significant change was observed in any parameter during the 3 months.

Thereafter, the changes in each parameter were compared among groups V, P, and C (Table 5). Split-plot ANOVA revealed a significant interaction for the VAS of low back pain, single-leg standing time (left leg), and 6-m walking time for both normal and quick steps among the 3 groups. The baseline values of the 6-m walking time (with both normal and quick steps) and PCS score were significantly different among the 3 groups. ANOVA revealed significant differences in changes in the VAS of low back pain, left-leg standing time, 6-m walking time (both with normal steps and with quick steps), and PCS score among the groups. Statistical differences were observed in these parameters excluding the PCS score after adjustment by the covariate (i.e., baseline value) in ANCOVA. Moreover, statistical differences were similarly observed in the same parameters (VAS of low back pain: $p = 0.0471$; left-leg standing time: $p = 0.0205$; 6-m walking time with normal steps: $p = 0.0155$; 6-m walking time with quick steps: $p = 0.0422$) when gender was added as a covariate.

During the 3 months, the numbers of locomotive syndrome participants who withdrew from the study were 0, 2, and 3 in groups V, P, and C, respectively. In total, 6 of 17 participants in group V, 3 of 13 participants in group P, and 0 of 9 participants in group C recovered from locomotive syndrome after the intervention.

Discussion

As stated in the "Introduction" the increasing number of elderly persons who need nursing care is becoming an urgent social issue in many countries. At the beginning of this study, we indicated 3 purposes for conducting an exercise intervention to recover from locomotive syndrome.

The first purpose of this study was to develop an exercise program that the elderly could sustainably perform in the community or at home. It was intended that the video exercise program in this study would be performed without difficulty by the elderly and would thus improve their physical performance and prevent the need for long-term care. Each exercise that we selected has been conventionally used for patients, depending on their condition. The

Table 4. Changes in the evaluation items before and after intervention

	Group V ($n = 38$)		Group P ($n = 37$)		Group C ($n = 30$)	
	Baseline	3 months later	Baseline	3 months later	Baseline	3 months later
Visual analog scales						
Low back pain	38.5 ± 22.3	25.6 ± 18.0**	32.7 ± 21.2	31.5 ± 27.7	28.2 ± 26.4	22.3 ± 24.3
Knee pain	19.5 ± 19.5	21.8 ± 23.2	19.8 ± 17.3	14.8 ± 15.7	21.6 ± 23.1	16.9 ± 17.5
Single-leg standing time						
Right leg (s)	33.7 ± 22.9	42.8 ± 21.8*	42.6 ± 22.7	42.4 ± 22.1	38.2 ± 25.0	38.9 ± 23.4
Left leg (s)	27.0 ± 22.5	39.3 ± 23.5**	37.7 ± 21.9	45.0 ± 19.3*	32.9 ± 23.4	34.9 ± 22.3
6-m walking time						
Normal steps (s)	5.7 ± 0.7	5.4 ± 0.9*	4.9 ± 1.1	5.3 ± 1.0*	5.1 ± 1.1	5.2 ± 1.0
Quick steps (s)	4.4 ± 0.6	4.2 ± 0.6**	3.8 ± 0.7	3.9 ± 0.7	4.1 ± 0.8	3.9 ± 0.6
Short Form-8 summary scores						
PCS	42.5 (38.6–47.9)	44.1 (40.4–49.1)*	45.1 (41.0–48.8)	47.9 (42.8–51.8)*	49.1 (44.8–52.1)	48.6 (43.5–52.7)
MCS	52.9 (49.0–55.7)	53.9 (48.3–56.7)	53.0 (49.3–56.3)	54.3 (51.4–56.4)	52.8 (47.2–55.2)	52.8 (48.0–55.2)
RDQ score	4.0 (2.0–9.0)	4.0 (0.0–11.0)	3.5 (0.0–7.3)	2.0 (0.0–6.5)*	2.0 (0.0–5.5)	1.0 (0.0–5.0)
ODI (% disability)	17.8 (7.2–30.6)	17.8 (6.7–30.6)	17.8 (8.9–23.9)	14.4 (5.0–24.4)	13.3 (3.3–22.2)	11.1 (2.8–21.7)
GLFS-25 score	14.0 (6.0–27.3)	10.0 (5.5–20)	10.0 (5.5–23)	7.0 (4.0–19.5)	10.0 (5.0–16.0)	9.0 (4.0–17.0)

Visual analog scales, single-leg standing time, and 6-m walking time presented as mean ± standard deviation. Short Form-8 summary scores, RDQ score, ODI, and GLFS-25 score presented as median (25–75 %)

Group V video exercise group, *Group P* pamphlet exercise group, *Group C* control group, *PCS* physical component scale, *MCS* mental component scale, *RDQ* Roland–Morris Disability Questionnaire, *ODI* Oswestry Disability Index, *GLFS-25* the 25-question Geriatric Locomotive Function Scale

*$p < 0.05$, **$p < 0.01$

first half of the program consists of quadriceps femoris exercise and fall-prevention exercises, which are reported to be effective for KOA [16]. The latter half of the program consists of exercises for low back pain. Many studies have confirmed the effectiveness of these exercises [6, 17]. The current exercise program was intended to improve general physical performance with the aim of preventing locomotive syndrome because the elderly often have multiple diseases affecting their mobility. During the development of the program, the first consideration was to avoid an excessive burden on the cardiopulmonary function of the participants. The pilot study, which examined the physical load on 20 elderly volunteers, demonstrated that pulse-rate changes before and after exercise did not exceed 20 % and that the SpO_2 change was within 4 points in all the cases. The RPE scores were 11–14 for all participants. These results confirmed that the video exercise program provided a moderate physical load for most of the elderly participants without imposing an excessive cardiopulmonary burden.

The second purpose of this study was to determine which medium of exercise instruction (video or pamphlet) is superior. We investigated the short-term efficacy of the exercise program with regard to physical performance in elderly participants and compared the effectiveness of the different teaching media. Several studies have used a video exercise program for frail elderly individuals [18, 19]. The superiority of video programs over written instructions has been reported for shoulder exercises [20] and for educating candidates for back surgery [21] and total knee arthroplasty [22]. Therefore, we expected that the video exercise program would relieve participants of body pain and improve their physical performance better than the pamphlet exercise program at the beginning of this study. In fact, the exercise achievement summary scale score in group V was significantly higher than that in group P. This finding indicated that the video exercise program provides greater motivation for participants than does the pamphlet exercise program. Moreover, intergroup comparisons of changes in the parameters after 3 months revealed statistically significant differences among the groups.

The third purpose of this study was to determine which parameter is most useful for evaluating the effectiveness of this intervention in preventing locomotive syndrome. We used the single-leg standing and 6-m walking tests as indices of physical performance to evaluate the effect of exercise on the elderly participants. The single-leg standing test has been reported to be a useful index for

Table 5. Intergroup comparison of the change of each parameter

	Interaction	Baseline value	Effect of intervention	
	Split-plot ANOVA *p* value	ANOVA *p* value	ANOVA *p* value	ANCOVA *p* value
Visual analog scales				
Low back pain	**0.027**	0.250	**0.037**	
Knee pain	0.266	0.892	0.182	
Single-leg standing time				
Right leg	0.150	0.154	0.150	
Left leg	**0.024**	0.069	**0.009**	
6-m walking time				
Normal steps	**<0.001**	**<0.001**	**<0.001**	**0.022**
Quick steps	**0.001**	**0.001**	**0.001**	**0.040**
Short Form-8 summary scores				
PCS	0.088	**0.016**	**0.014**	0.426
MCS	0.798	0.316	0.230	
RDQ score	0.436	0.454	0.099	
ODI (% disability)	0.803	0.669	0.297	
GLFS-25 score	0.347	0.690	0.508	

Values in bold are statistically significant

ANOVA analysis of variance, *ANCOVA* analysis of covariance, *PCS* physical component scale, *MCS* mental component scale, *RDQ* Roland–Morris Disability Questionnaire, *ODI* Oswestry Disability Index, *GLFS-25* the 25-question Geriatric Locomotive Function Scale examining elderly populations [23]. Moreover, gait velocity has been reported to be sensitive to changes in mobility in frail elderly individuals [23–25]. Although the observation period of this study was short, the values of the 2 measurements revealed significant improvement, at least in group V. These 2 measurements may be useful indices for evaluating short-term effects on physical performance (mobility and static balance) in elderly individuals.

This study had several limitations. First, the grouping of the participants was not perfectly randomized. Group V included more physically inferior participants than the other 2 groups. We permitted group changes as requested by the participants because they were recruited from a community-based population. It was difficult to place couples and friends in different groups without the risk of information leakage. The short period (3 months) of the intervention/observation was another limitation of this study. If the aim of the study is to prevent the need for care in elderly individuals, then a longer observation time is necessary. Further investigation is necessary regarding the long-term effects on society, such as changes in medical costs and the number of elderly individuals requiring nursing care. Regarding the static balance exercise, the significant improvement in the single-leg standing time after 3 months may be surprising especially because our exercise program contains only a short (i.e., 10 s/cycle × 4) single-leg standing exercise. The JOA and the Japanese Clinical Orthopaedic Association (JCOA) recommend the one-leg standing balance exercise for 1 min to prevent falls and hip fractures [26, 27]. A systematic review concerning falls prevention suggests that greater relative effects are observed in programs that include exercises that challenge balance (exercises conducted while standing in which people aim to stand with their feet closer together or on 1 leg, minimize the use of their hands to assist, and practice controlled movements of the center of gravity), use a higher intensity of exercise, and do not include a walking program [28]. A Cochrane review including 94 studies of balance exercise in the elderly suggests that the more effective programs ran 3 times a week for 3 months and involved dynamic exercise in standing [29]. We believe our results do not contradict the summary of the 2 systematic reviews. Moreover, we speculate that the improvement of our participants in a short time may be due to the mildness of locomotive disability among the participants. Our participants were community-dwelling elderly subjects, whereas the subjects in the JOA and JCOA reports were clinic patients [26, 27]. We may need to verify the possibility that the participants were healthy apart from their locomotive disability because the participants of this study were community-dwelling individuals who were recruited by open invitation. However, the data presented in Table 2 suggest that the participants were not particularly healthy with respect to their musculoskeletal conditions. The mean ages of the male and female participants of the current study were 74.1 and 71.6 years, respectively. In a study of a large-scale population-based cohort in Japan, Yoshimura et al. [4] found that the prevalences of KOA, LS, and lumbar OP in the group aged 70–79 years were 48.2, 85.3, and 3.6 %, respectively, among men and 71.9, 75.1, and 29.8 %, respectively, among women. Muraki et al. [30, 31] reported that, among the radiological osteoarthritis-affected subjects, one-fourth of the male participants and one-third of the female participants experienced pain. The national standard values (median) of PCS and MCS scores were 47.5 and 53.1, respectively, for men, and 47.3 and 53.6, respectively, for women (age range 70–75 years) [14]. Although careful judgment is required when comparing our data with those of previous studies, it may be safely said that our participants constituted a typical group for their age with respect to their mobility, rather than a particularly healthy volunteer group.

In conclusion, this study confirmed the safety of the exercise program we developed and indicated that the video exercise program provides greater motivation to participants than does the pamphlet exercise program. Moreover, this study demonstrated that our exercise program may improve low back pain and functional disability in participants. The single-leg standing and 6-m walking tests are possibly useful indices for evaluating the short-term effects of exercise on balance and mobility in the elderly. Although these results are preliminary, we believe that this study provides fundamental information for future studies.

Acknowledgments

This work was supported by the consigned research fund of Wakayama Prefecture Nos. B-21006 and B-22014. The authors thank Dr. Hiroaki Terashita of Mikimachi Terashita Orthopaedic Clinic for his precise advice in planning this study and Mr. Yoshihisa Kitaoka and other members of the public office in Hashimoto City for their assistance in selecting locations and scheduling participants for examinations.

Conflict of interest

The video exercise program in this study was developed with technical cooperation from Wakayama Telecasting Corp (WTV). WTV developed a commercial DVD video containing this exercise program under the editorial supervision of M.Y. and H.H. However, none of the authors received any benefits from the company.

References

1. Statistics Bureau. Current population estimates as of October 1, 2007. Available at: http://www.stat.go.jp/english/data/jinsui/2007np/index.htm. Accessed Mar 13, 2012.
2. Nakamura K. A "super-aged" society and the "locomotive syndrome". J Orthop Sci. 2008;13:1–2.
3. Ministry of Health, Labour and Welfare. Comprehensive survey of living conditions. 14. Rate of Persons with subjective symptoms (per 1000 population) by type of symptoms, sex and age group (multiple answer), 2007. Available at: http://www.mhlw.go.jp/english/database/db-hss/cslc-tables.html. Accessed Mar 13, 2012.
4. Yoshimura N, Muraki S, Oka H, Mabuchi A, En-Yo Y, Yoshida M, et al. Prevalence of knee osteoarthritis, lumbar spondylosis, and osteoporosis in Japanese men and women: the research on osteoarthritis/osteoporosis against disability study. J Bone Miner Metab. 2009;27:620–8.
5. Nakamura K. Locomotive syndrome: disability-free life expectancy and locomotive organ health in a "super-aged" society. J Orthop Sci. 2009;14:1–2.
6. Hayden JA, van Tulder MW, Malmivaara A, Koes BW. Exercise therapy for treatment of non-specific low back pain. Cochrane Database Syst Rev. 2005;3:CD000335.
7. Richmond J, Hunter D, Irrgang J, Jones MH, Levy B, Marx R, et al. Treatment of osteoarthritis of the knee (nonarthroplasty). J Am Acad Orthop Surg. 2009;17:591–600.
8. Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc. 1982;14:377–81.
9. Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. Ann Rheum Dis. 1957;16:494–502.
10. Orimo H, Hayashi Y, Fukunaga M, Sone T, Fujiwara S, Shiraki M, et al. Diagnostic criteria for primary osteoporosis: year 2000 revision. J Bone Miner Metab. 2001;19:331–7.
11. Fujiwara A, Kobayashi N, Saiki K, Kitagawa T, Tamai K, Saotome K. Association of the Japanese Orthopaedic Association score with the Oswestry Disability Index, Roland-Morris Disability Questionnaire, and short-form 36. Spine. 2003;28:1601–7.
12. Suzukamo Y, Fukuhara S, Kikuchi S, Konno S, Roland M, Iwamoto Y, et al. Validation of the Japanese version of the Roland-Morris Disability Questionnaire. J Orthop Sci. 2003;8:543–8.
13. Nakamura M, Miyamoto K, Shimizu K. Validation of the Japanese version of the Roland-Morris Disability Questionnaire for Japanese patients with lumbar spinal disorders. Spine. 2003;28:241–8.
14. Fukuhara S, Suzukamo Y. Manual of the SF-8 Japanese version: Institute for Health Outcomes and Process Evaluation Research, Kyoto, 2004 (in Japanese).
15. Seichi A, Hoshino Y, Doi T, Akai M, Tobimatsu Y, Iwaya T. Development of a screening tool for risk of locomotive syndrome in the elderly: the 25-question Geriatric Locomotive Function Scale. J Orthop Sci. 2012;17:163–72.

16. Roddy E, Zhang W, Doherty M. Aerobic walking or strengthening exercise for osteoarthritis of the knee? A systematic review. Ann Rheum Dis. 2005;64:544–8.
17. Rainville J, Hartigan C, Martinez E, Limke J, Jouve C, Finno M. Exercise as a treatment for chronic low back pain. Spine J. 2004;4:106–15.
18. Vestergaard S, Kronborg C, Puggaard L. Home-based video exercise intervention for community-dwelling frail older women: a randomized controlled trial. Aging Clin Exp Res. 2008;20:479–86.
19. Haines TP, Russell T, Brauer SG, Erwin S, Lane P, Urry S, et al. Effectiveness of a video-based exercise programme to reduce falls and improve health-related quality of life among older adults discharged from hospital: a pilot randomized controlled trial. Clin Rehabil. 2009;23:973–85.
20. Reo JA, Mercer VS. Effects of live, videotaped, or written instruction on learning an upper-extremity exercise program. Phys Ther. 2004;84:622–33.
21. Phelan EA, Deyo RA, Cherkin DC, Weinstein JN, Ciol MA, Kreuter W, et al. Helping patients decide about back surgery: a randomized trial of an interactive video program. Spine. 2001;26:206–11.
22. Lin PC, Lin LC, Lin JJ. Comparing the effectiveness of different educational programs for patients with total knee arthroplasty. Orthop Nurs. 1997;16:43–9.
23. van Iersel MB, Munneke M, Esselink RA, Benraad CE, Olde Rikkert MG. Gait velocity and the Timed-Up-and-Go test were sensitive to changes in mobility in frail elderly patients. J Clin Epidemiol. 2008;61:186–91.
24. Shinkai S, Watanabe S, Kumagai S, Fujiwara Y, Amano H, Yoshida H, et al. Walking speed as a good predictor for the onset of functional dependence in a Japanese rural community population. Age Ageing. 2000;29:441–6.
25. Guralnik JM, Ferrucci L, Simonsick EM, Salive ME, Wallace RB. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. N Engl J Med. 1995;332:556–61.
26. Sakamoto K, Nakamura T, Hagino H, Endo N, Mori S, Muto Y, et al. Effects of unipedal standing balance exercise on the prevention of falls and hip fracture among clinically defined high-risk elderly individuals: a randomized controlled trial. J Orthop Sci. 2006;11:467–72.
27. Kita K, Hujino K, Nasu T, Kawahara K, Sunami Y, Japanese Clinical Orthopaedic Association, Committee on Musculoskeletal Rehabilitation. A simple protocol for preventing falls and fractures in elderly individuals with musculoskeletal disease. Osteoporos Int. 2007;18:611–9.
28. Sherrington C, Whitney JC, Lord SR, Herbert RD, Cumming RG, Close JC. Effective exercise for the prevention of falls: a systematic review and meta-analysis. J Am Geriatr Soc. 2008;56:2234–43.
29. Howe TE, Rochester L, Neil F, Skelton DA, Ballinger C. Exercise for improving balance in older people. Cochrane Database Syst Rev. 2011;11:CD004963.
30. Muraki S, Oka H, Akune T, Mabuchi A, En-Yo Y, Yoshida M, et al. Prevalence of radiographic lumbar spondylosis and its association with low back pain in elderly subjects of population-based cohorts: the ROAD study. Ann Rheum Dis. 2009;68:1401–6.
31. Muraki S, Oka H, Akune T, Mabuchi A, En-yo Y, Yoshida M, et al. Prevalence of radiographic knee osteoarthritis and its association with knee pain in the elderly of Japanese population-based cohorts: the ROAD study. Osteoarthr Cartil. 2009;17:1137–43.

Osteoporos Int (2014) 25:1089–1098
DOI 10.1007/s00198-013-2489-0

ORIGINAL ARTICLE

Prevalence and progression of radiographic ossification of the posterior longitudinal ligament and associated factors in the Japanese population: a 3-year follow-up of the ROAD study

N. Yoshimura · K. Nagata · S. Muraki · H. Oka · M. Yoshida · Y. Enyo · R. Kagotani · H. Hashizume · H. Yamada · Y. Ishimoto · M. Teraguchi · S. Tanaka · H. Kawaguchi · Y. Toyama · K. Nakamura · T. Akune

Received: 14 May 2013 / Accepted: 5 August 2013 / Published online: 22 August 2013

Abstract

Summary The prevalence of radiographic cervical ossification of the posterior longitudinal ligament (OPLL) in 1,562 Japanese from a population-based cohort was 1.9 %. The presence of OPLL showed a significant association with the femoral neck bone mineral density (BMD), presence of diffuse idiopathic skeletal hyperostosis (DISH) and plasma pentosidine levels. Only one new case of radiographic OPLL was detected, but OPLL progressed in all affected subjects.

Introduction The purpose of this study was to clarify the prevalence and progression of radiographic OPLL and the associated factors, using the population-based cohort Research on Osteoarthritis/osteoporosis Against Disability (ROAD).

Methods In the ROAD study, 1,690 participants underwent X-ray examination of the entire spine and both knees. Radiographic OPLL, lumbar spondylosis, knee osteoarthritis and DISH were diagnosed by a single, well-experienced orthopaedic surgeon. An interviewer-administered questionnaire and tests for anthropometric measurements were administered, and the BMDs of the lumbar spine and proximal femur were determined. A new OPLL case was considered if heterotopic ossification in the posterior longitudinal ligament was absent at baseline but present during follow-up. Progression was defined as an increase in the maximum length or width of the ossification at follow-up over that at baseline.

Results Radiographic OPLL was detected in 30 (17 men, 13 women) of 1,562 individuals who underwent X-ray examination of the cervical spine (prevalence=1.9 %). Its prevalence was significantly higher in men than in women ($p=0.007$), but no association with age was observed. In a logistic regression analysis, OPLL showed a significant association with the femoral neck BMD, presence of DISH and plasma pentosidine levels. Only one new case of radiographic OPLL was detected, but OPLL progressed in all affected subjects.

Conclusion This population-based study clarified the prevalence of radiographic OPLL in the Japanese population as well as its progression. OPLL showed significant association with plasma pentosidine levels, BMD and DISH.

Keywords Bone mineral density · Diffuse idiopathic skeletal hyperostosis · Ossification of posterior longitudinal ligament of cervical spine · Plasma pentosidine · Prevalence · Progression

Electronic supplementary material The online version of this article (doi:10.1007/s00198-013-2489-0) contains supplementary material, which is available to authorized users.

N. Yoshimura (✉) · H. Oka
Department of Joint Disease Research, 22nd Century Medical and Research Center, Graduate School of Medicine, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8655, Japan
e-mail: YOSHIMURAN-ORT@h.u-tokyo.ac.jp

K. Nagata · M. Yoshida · Y. Enyo · R. Kagotani · H. Hashizume · H. Yamada · Y. Ishimoto · M. Teraguchi
Department of Orthopedic Surgery, Wakayama Medical University, 811-1 Kimidera, Wakayama, Wakayama 641-8509, Japan

S. Muraki · T. Akune
Department of Clinical Motor System Medicine, 22nd Century Medical and Research Center, Graduate School of Medicine, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8655, Japan

S. Tanaka · H. Kawaguchi
Department of Orthopaedic Surgery, Graduate School of Medicine, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8655, Japan

Y. Toyama
Department of Orthopaedic Surgery, School of Medicine, Keio University, 35 Shinanomachi, Shinjuku-ku, Tokyo 160-8582, Japan

K. Nakamura
National Rehabilitation Center for Persons with Disabilities, 1, Namiki 4-chome, Tokorozawa, Saitama 359-8555, Japan

Introduction

Ossification of the posterior longitudinal ligament of the spine (OPLL) is the pathological ectopic ossification of this ligament at the cervical and thoracic spine. It causes myeloradiculopathy as a result of chronic pressure on the spinal cord and nerve roots [1, 2]. Epidemiologic studies have shown a relatively high prevalence of OPLL among the Japanese, a slightly lower prevalence among East Asians and a substantially lower prevalence among whites [3, 4].

In terms of its characteristics, several epidemiological studies have reported that adult-onset obesity and diabetes mellitus (DM) are independent risk factors of OPLL [5, 6]. Further, OPLL often coincides with diffuse idiopathic skeletal hyperostosis (DISH), a systemic disorder of hyperossification. McAfee et al. [7] found that seven (50 %) of 14 patients with OPLL had DISH, and in a Japanese study, DISH was present in 27 (25 %) of 109 patients with OPLL [8].

Besides the coexistence of other disorders such as DM and DISH, little detailed information is available on the profile of OPLL in the general population. These data are important in order to characterise the disease burden. In addition, limited information is available regarding factors associated with OPLL, including biochemical markers of bone turnover, bone mineral density (BMD) values, lifestyle factors, or other coexisting disorders, such as dyslipidaemia, impairment of glucose tolerance, lumbar spondylosis (LS) and knee osteoarthritis (KOA).

Thus, the aims of the present study were to clarify the prevalence of OPLL in the Japanese population and to examine the association of OPLL with biological and environmental factors as well as coexisting disorders. For this, we used a questionnaire survey and the large, population-based cohort Research on Osteoarthritis/osteoporosis Against Disability (ROAD), which included lifestyle factors and nutrition, blood and urinary examinations, BMD measurements and X-ray examinations [9, 10].

Methods

Outline of the ROAD study

We conducted the present study using the cohorts established in 2005 for the ROAD study. The ROAD study is a nationwide, prospective study of OA comprising population-based cohorts from several communities in Japan. The details of the cohort profile have been reported elsewhere [9, 10]. Briefly, in 2005–2007, we created a baseline database that included clinical and genetic information for 3,040 residents of Japan (1,061 men, 1,979 women); the mean age (deviation [SD]) of the participants was 70.3 [11.0] years (71.0 [10.7] years for men and 69.9 [11.2] years for women). The subjects were recruited from resident registration listings in three communities with different characteristics: 1,350 subjects (465 men, 885 women) were from an urban region in Itabashi, Tokyo; 864 subjects (319 men, 545 women) were from a mountainous region in Hidakagawa, Wakayama and 826 subjects (277 men, 549 women) were from a coastal region in Taiji, Wakayama.

The participants completed an interviewer-administered questionnaire of 400 items that included lifestyle information such as occupation, smoking habits and alcohol consumption; family history; medical history; physical activity; reproductive variables and health-related quality of life. A questionnaire was prepared by modifying the one used in the Osteoporotic Fractures in Men Study [11], and some new items were added to the modified questionnaire. The participants were asked whether they took prescription medication daily or nearly every day (0 = no, 1 = yes). If participants did not know the reason for the prescribed medication, they were asked to bring their medications to the medical doctor (NY).

Anthropometric measurements included height (in centimetres), body weight (in kilograms), arm span (in centimetres), bilateral grip strength (in kilograms) and body mass index (BMI; in kilograms per square metre). Experienced orthopaedic surgeons collected medical information on systematic, local and mental status, including information on back, knee and hip pain; swelling and range of motion of the joints and patellar and Achilles tendon reflexes.

In 2008–2010, we attempted to locate and follow up all 3,040 subjects. They were invited for the second survey of the ROAD study, which included a 3-year follow-up of the same examinations as the baseline.

Subjects eligible for the present study

In the present study, we enrolled all 1,690 subjects (men, 596; women, 1,094) from mountainous and coastal areas who had enrolled in the ROAD study. In the ROAD study, X-ray examination of the cervical and thoracic spine had been performed only for these subjects and not for those from the urban region. Further, for all these 1,690 participants, the BMDs for the lumbar spine and the proximal femur had been measured using dual energy X-ray absorptiometry (Hologic Discovery; Hologic, Waltham, MA, USA) during the baseline examination. Additionally, blood and urinary examinations had also been performed for these subjects.

The study participants provided written informed consent, and the study was conducted with the approval of the ethics committees of the University of Tokyo (no. 1264 and no. 1326) and the University of Wakayama Medical University (no. 373).

Radiographic assessment

Plain radiographs were obtained for the cervical, thoracic and lumbar spine in the anteroposterior and lateral views and both knees in the anteroposterior view with weight-bearing and foot-map positioning.

Cervical OPLL was diagnosed using plain radiographs of the cervical spine in the lateral view. OPLL was indicated by the presence of heterotopic ossification in the posterior longitudinal ligament on a lateral cervical radiograph. Radiographic OPLL was diagnosed by a single, experienced orthopaedic surgeon (KN) who was blinded to participants' clinical status. OPLL was classified into the following types: continuous, segmental and mixed. In the original OPLL classification by Tsuyama [3], it was categorised into four modes, namely continuous, segmental, mixed and localised. However, here, because of the small number of subjects in the localised category, these subjects were included in the continuous category. If OPLL was observed, the maximum length (continuous and localised type, upper limit to lower limit; segmental and mixed types, upper limit to lower limit of the longest serial region) and width of ossification were measured using the imaging software OsiriX (http://www.osirix-viewer.com/).

In addition, using radiographs of spine and knees, we determined the grade of OA. The severity of radiographic OA was determined according to the Kellgren–Lawrence (KL) grading [12] as follows: KL0, normal; KL1, slight osteophytes; KL2, definite osteophytes; KL3, joint or intervertebral space narrowing with large osteophytes and KL4, bone sclerosis, joint or intervertebral space narrowing and large osteophytes. Radiographs for each site, i.e. the vertebrae and knees, were examined by a single, experienced orthopaedic surgeon (SM) who was blinded to participants' clinical status. In the present study, the subject's KL grade was considered the maximum grade diagnosed for at least one intervertebral level of the lumbar spine or at least one knee joint.

We also investigated the presence of DISH using whole-spine X-ray films. The criterion for the definite diagnosis of DISH was the presence of four or more vertebral bodies with contiguous ligamentous ossification and calcification, which is known as Resnick and Niwayama's criterion [13]. DISH was diagnosed by a single, experienced orthopaedic surgeon (RK) who was blinded to participants' clinical status.

Blood and urine examinations

Samples were collected from the end of October to the middle of January from both mountainous and coastal areas. All blood and urine samples were extracted between 0900 and 1500 hours. The blood samples were centrifuged, and the sera and urine samples were immediately placed on dry ice and transferred to a deep freezer within 24 h. The samples were stored at −80 °C until assayed.

The blood samples were used to measure haemoglobin A1c (HbA1c, Japan Diabetes Society), serum levels of total cholesterol, uric acid and creatinine levels. The analyses were performed at the same laboratory within 24 h of collection (Osaka Kessei Research Laboratories, Inc., Osaka, Japan).

Serum levels of intact parathyroid hormone (iPTH) were measured using an electrochemiluminescence immunoassay (Roche Diagnostics GmbH, Mannheim, Germany). As a marker of bone formation, serum levels of N-terminal propeptide of type I procollagen (PINP) were measured using a radioimmunoassay (Orion Diagnostics, Espoo, Finland). The urinary levels of β-isomerised C-terminal cross-linking telopeptide of type I collagen (β-CTX), a bone resorption marker, were determined using an enzyme-linked immunosorbent assay (Fujirebio, Inc., Tokyo, Japan). Urinary β-CTX values were standardised to urinary creatinine concentrations. Plasma pentosidine levels were detected using a competitive ELISA kit (FSK pentosidine ELISA kit; Fushimi Pharmaceutical, Kagawa, Japan) as previously described [14].

Three-year follow-up and definition of OPLL occurrence and progression

In 2008–2010, the 1,690 subjects were invited to enrol in the second survey of the ROAD study, a 3-year follow-up consisting of examinations identical to those conducted at baseline. Spine and knee radiographs were also obtained at follow-up. All cervical radiographs were read by the same orthopaedic surgeon who read them at the baseline (KN), and he was again blinded to participants' clinical status. He simultaneously compared the X-ray films at the baseline and 3-year follow-up and thereby diagnosed OPLL. A new OPLL case was diagnosed if heterotopic ossification in the posterior longitudinal ligament was absent on the lateral cervical radiograph obtained at baseline but present in that obtained during follow-up. OPLL progression was defined as an increase in the maximum length or width of the heterotopic ossification during follow-up compared to that at baseline.

Statistical analysis

All statistical analyses were performed using STATA statistical software (STATA Corp., College Station, TX, USA). Differences in proportions were compared using the chi-square test. Differences in continuous variables were tested for significance using analysis of variance for multiple groups or Scheffe's least significant difference test for pairs of groups. All p values and 95 % confidence intervals (CI) are two sided.

To test the association between OPLL and potential risk factors, we used logistic regression analysis with the presence or absence of OPLL (0 = absence, 1 = presence) as an objective variable and select potential explanatory variables, in addition to basic characteristics such as age (+1 year), gender (0 = men, 1 = women) and regional differences (0 = mountainous area, 1 = coastal area). The selected associated factors were those that showed a significant (p <0.05) association with OPLL status in a simple linear analysis. To test the association between OPLL progression and associated factors, we used multivariate regression analysis with the change rate (percent per year) of the maximum length or width as an objective variable and the explanatory variables used in the above-mentioned logistic regression analysis. The explanatory variables in the logistic regression analysis and multivariate regression analysis are described in the "Results" section.

Results

Prevalence of radiographic OPLL

The X-ray radiographs of 1,562 of the 1,690 subjects (92.4 %, 520 men, 1,038 women) showed all parts of the lateral cervical spine, from C1 to C7. Among these 1,562 individuals, 30 (17 men, 13 women) were diagnosed with radiographic OPLL; thus, the prevalence of OPLL was estimated at 1.9 % (men, 3.2 %; women, 1.3 %), and it was significantly higher in men than in women (p =0.007).

Figure 1 shows the prevalence of OPLL classified by age and gender. The prevalence of OPLL was not associated with age in either men or women.

In the 30 subjects with radiographic OPLL, the OPLL was categorised into the continuous type in 13 subjects (six men and seven women, 43.3 %), the segmented type in eight (six men and two women, 26.7 %), the mixed type in seven (four men and three women, 23.3 %) and the localised type in two (one man and one woman, 6.7 %). The largest OPLL region was most commonly observed in C4 (ten individuals; 33.3 %; three men and seven women), followed by C5 (nine individuals; 33.0 %; eight men and one woman), C3 (seven individuals; 23.3 %; four men and three women), C6 (three individuals; 10.0 %; two men and one women) and C2 (one individual; 3.3 %; one woman). The largest OPLL region was not found in C1 or C7 in any subject.

The mean length and width (standard deviation, SD) of the largest region of ossification at the baseline were 27.6 (16.0) and 3.0 (1.5) mm, respectively. The values in men were 26.1 (14.5) and 2.9 (1.4) mm, and those in women were 29.6 (18.1) and 3.2 (1.5) mm, respectively; thus, no significant difference was observed between men and women in this regard.

Factors associated with OPLL

Table 1 shows the baseline characteristics of 1,562 participants with and without OPLL. Overall, subjects with OPLL tended to be taller and heavier than those without OPLL (p <0.05). Further, compared to individuals without OPLL, those with OPLL had higher plasma pentosidine levels and higher BMD values for both the lumbar spine (L2–4) and femoral neck (p <0.05).

Table 1 also shows the prevalence of LS, KOA and DISH on the basis of OPLL status. The prevalence of LS with ≥grade 2 KL and that of DISH was higher in the group with OPLL than in the one without OPLL (p <0.05), although no significant association was observed between the prevalence of KOA and the presence of OPLL.

Logistic regression analysis was performed with the OPLL status as the objective variable (0 = absence, 1 = presence). As explanatory variables, the analysis involved select associated factors that showed a significant (p <0.05) association with OPLL status in the simple linear analysis, namely, height (in centimetres), weight (in kilograms), values of plasma pentosidine (+1 μg/mL), BMD of the femoral neck (+1 SD), presence of LS based on KL grade (0 = KL grade 0 or 1, 1 = KL grade≥2) and DISH (0 = absent, 1 = present), after adjustments were made for age (years) and gender (0 = men, 1 = women). As seen from Table 2, plasma pentosidine levels, BMD of the femoral neck and the presence of DISH were found to be significant associated factors for the presence of OPLL (Table 2). Further, when BMD of the lumbar spine (L2–4) was used instead of that of the femoral neck, this factor was also found to be significantly associated with OPLL (+1 SD; odds ratio (OR), 1.52; 95 % CI, 1.05–2.20; p =0.026), but the

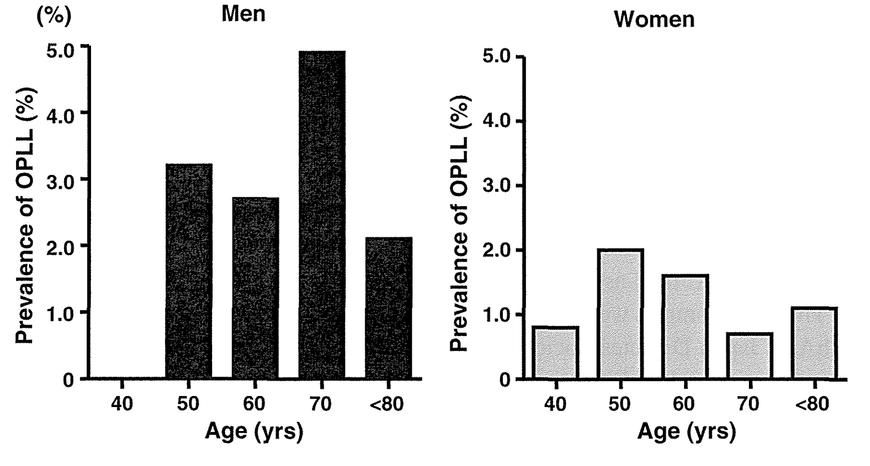

Fig. 1 Prevalence of OPLL classified by age and gender