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ORIGINAL ARTICLE

Association of physical activities of daily living with the incidence of certified need of care in the long-term care insurance system of Japan: the ROAD study

Toru Akune · Shigeyuki Muraki · Hiroyuki Oka · Sakae Tanaka · Hiroshi Kawaguchi · Fumiaki Tokimura · Hideyo Yoshida · Takao Suzuki · Kozo Nakamura · Noriko Yoshimura

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Abstract

Background The present study aimed to investigate association of physical activities of daily living with the incidence of certified need of care in the national long-term care insurance (LTCI) system in elderly Japanese population-based cohorts.

Methods Of the 3,040 participants in the baseline examination, we enrolled 1,773 (699 men, 1,074 women) aged 65 years or older who were not certified as in need of care-level elderly at baseline. Participants were followed during an average of 4.0 years for incident certification of need of care in the LTCI system. The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) was used assess function. Associated factors in the baseline examination with the occurrence were determined by multivariate Cox proportional hazards regression analysis. Receiver operating characteristic curve analysis was performed to evaluate cut-off values for discriminating between the occurrence and the non-occurrence group.

Results All 17 items in the WOMAC function domain were significantly associated with the occurrence of certified need of care in the overall population. Cut-off values of the WOMAC function score that maximized the sum of sensitivity and specificity were around 4–6 in the overall population, in men, and in women. Multivariate Cox hazards regression analysis revealed that a WOMAC function score ≥4 was significantly associated with occurrence with the highest hazard ratio (HR) for occurrence after adjusting for confounders in the overall population (HR [95 % confidence interval (CI)] 2.54 [1.76–3.67]) and in women [HR (95 % CI) 3.13 (1.95–5.02)]. A WOMAC function score ≥5 was significantly associated with the highest HR for occurrence in men [HR (95 % CI) 1.88 (1.03–3.43)].

Conclusions Physical dysfunction in daily living is a predictor of the occurrence of certified need of care. Elderly men with a WOMAC function score ≥5 and women with a score ≥4 should undergo early intervention programs to prevent subsequent deterioration.

T. Akune (✉) · S. Muraki
Department of Clinical Motor System Medicine, 22nd Century Medical and Research Center, Graduate School of Medicine, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8655, Japan
e-mail: akune-ort@h.u-tokyo.ac.jp

H. Oka · N. Yoshimura
Department of Joint Disease Research, 22nd Century Medical and Research Center, Graduate School of Medicine, University of Tokyo, Tokyo, Japan

S. Tanaka · H. Kawaguchi
Department of Sensory and Motor System Medicine, Graduate School of Medicine, University of Tokyo, Tokyo, Japan

F. Tokimura
Department of Orthopaedic Surgery, Tokyo Metropolitan Geriatric Hospital, Tokyo, Japan

H. Yoshida
Research Team for Promoting Independence of the Elderly, Tokyo Metropolitan Institute of Gerontology, Tokyo, Japan

T. Suzuki
Research Institute, National Center for Geriatrics and Gerontology, Aichi, Japan

K. Nakamura
National Rehabilitation Center for Persons with Disabilities, Saitama, Japan

Introduction

Japan is a super-aged society experiencing an unprecedented aging of the population. The proportion of the population aged 65 years or older was 23 % in 2010, and is expected to reach 30.1 % in 2024 and 39 % in 2051 [1]. This leads to an increasing proportion of disabled elderly requiring support or long-term care, imposing enormous economic and social burdens on the country. The Japanese Government started the national long-term care insurance (LTCI) system in 2000 based on the Long-Term Care Insurance Act [2]. The aim was to certify need of care-level elderly and to provide suitable care services according to the level of care required [7 levels, including requiring support (levels 1 and 2) and requiring long-term care (levels 1–5)]. The total number of certified need of care-level elderly was reported to be 5 million in 2011 [2]. Certification of need of care in the national LTCI system is an important outcome in Japan not only because of its massive social and economic burdens, but also because it is urgently necessary to reduce risk and decrease the number of disabled elderly requiring care in their activities of daily living (ADLs). It is critically important to accumulate epidemiologic evidence, including identification of predictors, to establish evidence-based prevention strategies. However, no studies have determined the association of physical ADLs with the incidence of certified need of care in the national LTCI system using large-scale, population-based cohorts. The objective of the present study was to investigate the association of physical ADLs with the incidence of certified need of care in the national LTCI system and determine its predictors in elderly participants of large-scale, population-based cohorts of the research on osteoarthritis/osteoporosis against disability (ROAD) study.

Subjects and methods

Participants

The analysis was based on data collected from cohorts established in 2005 for the ROAD study. Details of the cohorts have been reported elsewhere [3, 4]. Briefly, a baseline database was created from 2005 to 2007, which included clinical and genetic information on 3,040 residents of Japan (1,061 men, 1,979 women). Participants were recruited from resident registration listings in three communities, namely, an urban region in Itabashi, Tokyo, and rural regions in Hidakagawa and Taiji, Wakayama. Participants in the urban region in Itabashi were recruited from those of a cohort study [5] in which the participants were randomly drawn from the register database of Itabashi ward residents, with a response rate in the age group >60 years of 75.6 %. Participants in the rural regions in Hidakagawa and Taiji were recruited from resident registration lists, with response rates in the groups aged >60 years of 68.4 and 29.3 %, respectively. Inclusion criteria were the ability to (1) walk to the survey site, (2) report data, and (3) understand and sign an informed consent form. For the present study, we enrolled 1,773 participants (699 men, 1,074 women; mean age 75.4 years) aged 65 years or older who were not certified as in need of care-level elderly in the national LTCI system at baseline. All participants provided written informed consent, and the study was conducted with approval from the ethics committees of the participating institutions.

Baseline procedures

Participants completed an interviewer-administered questionnaire containing 400 items that included lifestyle information, such as smoking habits, alcohol consumption, and physical activity. At baseline, anthropometric measurements, including height and weight, were taken, and body mass index (BMI) [weight (kg)/height^2 (m^2)] was estimated based on the measured height and weight.

Assessment of physical ADLs

We used the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) for assessment of physical ADLs. The WOMAC is a health status instrument, consisting of three domains: pain, stiffness, and physical function. We used the WOMAC function domain to evaluate physical ADLs. It consisted of 17 items: assessing difficulties in descending stairs, ascending stairs, rising from sitting, standing, bending to floor, walking on a flat surface, getting in/out of car/bus, going shopping, putting on socks/stockings, rising from bed, taking off socks/stockings, lying in bed, getting into/out of bath, sitting, getting on/off toilet, heavy domestic duties, and light domestic duties. Each item in the domain is graded on either a 5-point Likert scale (scores of 0–4) or a 100-mm visual analog scale [6, 7]. In the present study, we used the Likert scale (version LK 3.0). Items were rated from 0 to 4; 0, no difficulty; 1, mild difficulty; 2, moderate difficulty; 3, severe difficulty; 4, extreme difficulty. The domain score ranges from 0 to 68. Japanese versions of the WOMAC have been validated [8].

Certification of need of care in the LTCI system

The nationally uniform criteria for long-term care need certification was established objectively by the Japanese Government, and certification of need of care-level elderly is determined based on evaluation results by the Certification Committee for Long-term Care Need in municipalities in accordance with basic guidelines formulated by the Government. The process of eligibility for certification of need of care in the LTCI system was described in detail by Chen et al. [9]. An elderly person who requires help with ADLs or the caregiver contacts the municipal government to request official certification of care needs. After the application, a trained official visits the home to assess the current physical status of the elderly person, including presence or absence of muscle weakness or joint contracture of limbs, and difficulties in sitting-up, standing-up, maintaining sitting or standing position, transferring from one place to another, standing on one leg, walking, bathing, dressing, and other ADLs. Mental status, including dementia, also is assessed. These data are analyzed to calculate a standardized score for determination of the level of care needs (certified support, levels 1–2; or long-term care, levels 1–5). In addition, the primary physician of the applicant assesses physical and mental status, including information on diseases causing ADL disability and the extent of disabilities caused by them. Finally, the Certification Committee for Long-term Care Need reviews the data and determines the certification and its level.

Follow-up and definition of incident certified need of care

After the baseline ROAD survey, participants who were not certified as in need of care-level elderly at baseline were followed for incident certification of need of care in the LTCI system. Incident certified need of care was defined as the incident certified 7 levels, including requiring support (levels 1–2) and requiring long-term care (levels 1–5). Information on the presence or absence of certification of need of care and its date of occurrence were collected by the resident registration listings in three communities every year up to 2010, and were used for analyses in the present study.

Statistical analysis

All statistical analyses were performed using STATA statistical software (STATA, College Station, TX, USA). Differences in values of the parameters between the two groups were tested for significance using the unpaired Student's t test, the Mann–Whitney's U test, and Chi-square test. We used receiver operating characteristic (ROC) curve analysis to determine a cut-off value of the WOMAC function score for discriminating two distinct groups: an occurrence and a non-occurrence group of certified need of care. Cut-off values were determined that maximized the sum of sensitivity and specificity. Factors associated with the occurrence of certified need of care were determined using Cox proportional hazards regression analysis; hazard ratios (HRs) and 95 % confidence intervals (CIs) were determined after adjusting for region, age, sex, and BMI. Smoking habit and alcohol consumption were not included as confounders because they were not significantly associated with the incidence of certified need of care.

Results

Of the 1,773 participants who were not certified as in need of care-level elderly at baseline, information on

Table 1 Baseline characteristics of population at risk for the certified need of care in the LTCI system

	Men	Women
No. of subjects	699	1,074
Age (years)	75.6 (5.1)	75.2 (5.3)
Height (cm)	160.9 (6.0)	147.9 (6.0)[b]
Weight (kg)	59.4 (9.1)	50.0 (8.3)[b]
BMI (kg/m^2)	22.9 (2.9)	22.8 (3.4)
Smoking (%)	21.0	3.2[c]
Alcohol consumption, %	61.2	23.0[c]
WOMAC function domain		
Descending stairs, pts[a]	0 (0, 0, 1, 1)	0 (0, 0, 1, 2)[d]
Ascending stairs, pts[a]	0 (0, 0, 1, 1)	0 (0, 0, 1, 2)
Rising from sitting, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 1, 1)[d]
Standing, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 1, 1)[d]
Bending to floor, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 1, 1)
Walking on a flat surface, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 0, 1)
Getting in/out of car/bus, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 1, 1)[d]
Going shopping, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 0, 1)[d]
Putting on socks/stockings, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 0, 1)[d]
Rising from bed, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 0, 1)[d]
Taking off socks/stockings, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 0, 1)[d]
Lying in bed, pts[a]	0 (0, 0, 0, 0)	0 (0, 0, 0, 1)[d]
Getting into/out of bath, pts[a]	0 (0, 0, 0, 0)	0 (0, 0, 0, 1)[d]
Sitting, pts[a]	0 (0, 0, 0, 0)	0 (0, 0, 0, 0)[d]
Getting on/off toilet, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 1, 2)[d]
Heavy domestic duties, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 0, 1)[d]
Light domestic duties, pts[a]	0 (0, 0, 0, 1)	0 (0, 0, 0, 1)[d]
Total, pts[a]	1 (0, 0, 5, 12)	2 (0, 0, 8, 17)[d]

Except where indicated otherwise, values are mean (SD)

LTCI long-term care insurance system, *BMI* body mass index, *WOMAC* the Western Ontario and McMaster Universities Arthritis Index

[a] Median (10, 25, 75, and 90 percentile)

[b] $P < 0.05$ vs men by unpaired Student's t test

[c] $P < 0.05$ vs men by Chi-square test

[d] $P < 0.05$ vs men by Mann–Whitney U test

Table 2 Association of physical activities of daily living with the occurrence of certified need of care in the LTCI system

Physical activity	Overall population		Men		Women	
	HR (95 % CI)	*P* value	HR (95 % CI)	*P* value	HR (95 % CI)	*P* value
Descending stairs, pts	1.47 (1.26, 1.72)	<0.001	1.29 (0.96, 1.74)	0.089	1.56 (1.30, 1.87)	<0.001
Ascending stairs, pts	1.47 (1.25, 1.73)	<0.001	1.29 (0.93, 1.77)	0.123	1.55 (1.29, 1.86)	<0.001
Rising from sitting, pts	1.58 (1.34, 1.88)	<0.001	1.38 (0.95, 1.99)	0.092	1.67 (1.37, 2.03)	<0.001
Standing, pts	1.64 (1.41, 1.91)	<0.001	1.39 (1.02, 1.90)	0.037	1.73 (1.45, 2.06)	<0.001
Bending to floor, pts	1.57 (1.32, 1.85)	<0.001	1.61 (1.15, 2.27)	0.006	1.57 (1.29, 1.90)	<0.001
Walking on a flat surface, pts	1.57 (1.30, 1.90)	<0.001	1.25 (0.88, 1.77)	0.22	1.78 (1.41, 2.23)	<0.001
Getting in/out of car/bus, pts	1.76 (1.47, 2.10)	<0.001	1.60 (1.14, 2.26)	0.007	1.85 (1.50, 2.29)	<0.001
Going shopping, pts	1.72 (1.46, 2.03)	<0.001	1.55 (1.14, 2.11)	0.005	1.81 (1.48, 2.21)	<0.001
Putting on socks/stockings, pts	1.60 (1.33, 1.92)	<0.001	1.41 (0.98, 2.03)	0.065	1.71 (1.37, 2.12)	<0.001
Rising from bed, pts	1.68 (1.40, 2.03)	<0.001	1.41 (0.98, 2.02)	0.066	1.83 (1.47, 2.29)	<0.001
Taking off socks/stockings, pts	1.64 (1.37, 1.98)	<0.001	1.48 (1.01, 2.16)	0.046	1.72 (1.39, 2.13)	<0.001
Lying in bed, pts	1.82 (1.44, 2.30)	<0.001	1.96 (1.13, 3.40)	0.017	1.79 (1.38, 2.32)	<0.001
Getting into/out of bath, pts	1.71 (1.43, 2.04)	<0.001	1.64 (1.15, 2.33)	0.006	1.75 (1.43, 2.15)	<0.001
Sitting, pts	2.21 (1.73, 2.82)	<0.001	1.92 (1.14, 3.22)	0.014	2.32 (1.75, 3.06)	<0.001
Getting on/off toilet, pts	1.87 (1.52, 2.29)	<0.001	1.51 (1.00, 2.27)	0.05	2.09 (1.63, 2.68)	<0.001
Heavy domestic duties, pts	1.27 (1.09, 1.49)	0.003	1.20 (0.89, 1.62)	0.238	1.33 (1.10, 1.60)	0.003
Light domestic duties, pts	1.68 (1.41, 2.01)	<0.001	1.49 (1.07, 2.07)	0.019	1.80 (1.45, 2.24)	<0.001

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

LTCI long-term care insurance system

certification of need of care could be obtained in 1,760 (99.3 %) during the average 4.0-year follow-up. Fifty-four men and 115 women were certified as in need of care-level elderly in the national LTCI system, whereas, 1,591 remained uncertified during the follow-up period. The average period for the certification was 2.3 years. Among the above 54 men and 115 women, those who were certified as requiring long-term care level 1, 2, 3, 4, and 5 were 7, 9, 2, 4, 3 men, and 12, 17, 9, 4, 4 women, respectively. One hundred and twenty-six participants died and eight moved away. Incidence of certified need of care in the LTCI system was 2.3/100 person-years in the overall population, and 2.0/100 person-years in men and 2.5/100 person-years in women. Table 1 shows the baseline characteristics of the population at risk for occurrence of certified need of care in the LTCI system. The score of each item in the WOMAC function domain was significantly higher in women than in men in almost all items.

We then investigated association of each item in the WOMAC function domain with the occurrence of certified need of care in the LTCI system (Table 2). All 17 items in the WOMAC function domain were significantly associated with the occurrence of the certified need of care in the overall population and in women. In men, standing, bending to floor, getting in/out of car/bus, going shopping, taking off socks/stockings, lying in bed, getting into/out of bath, sitting, and light domestic duties were significantly associated with the occurrence of certified need of care, whereas other ADLs were not. In addition, the value of HR for each item in the association was higher in women than in men in 15 of 17 items.

Next we determined cut-off values of total score of the WOMAC function domain for discriminating two groups: an occurrence and a non-occurrence group of certified need of care using ROC curve analysis. The area under ROC curve was 0.70 in the overall population, 0.61 in men, and 0.74 in women (Fig. 1). The cut-off value of the WOMAC function score that maximized the sum of sensitivity and specificity was 6, 5, and 6 in the overall population, in men, and in women, respectively. In addition, the sensitivity/specificity was 57.3/75.0 % in the overall population, 45.7/75.0 % in men, and 64.4/72.6 % in women, respectively (Table 3). Furthermore, the cut-off value by which the sum was the second largest was 4 in the overall population, 4 in men, and 4 in women, and the sensitivity/specificity was 65.3/66.7 % in the overall population, 50.0/70.0 % in men, and 72.1/64.5 % in women, respectively (Table 3).

Because ROC curve analysis is a univariate analysis, we performed multivariate Cox hazards regression analysis to determine the cut-off value of the WOMAC function score for best discriminating between an occurrence and a non-

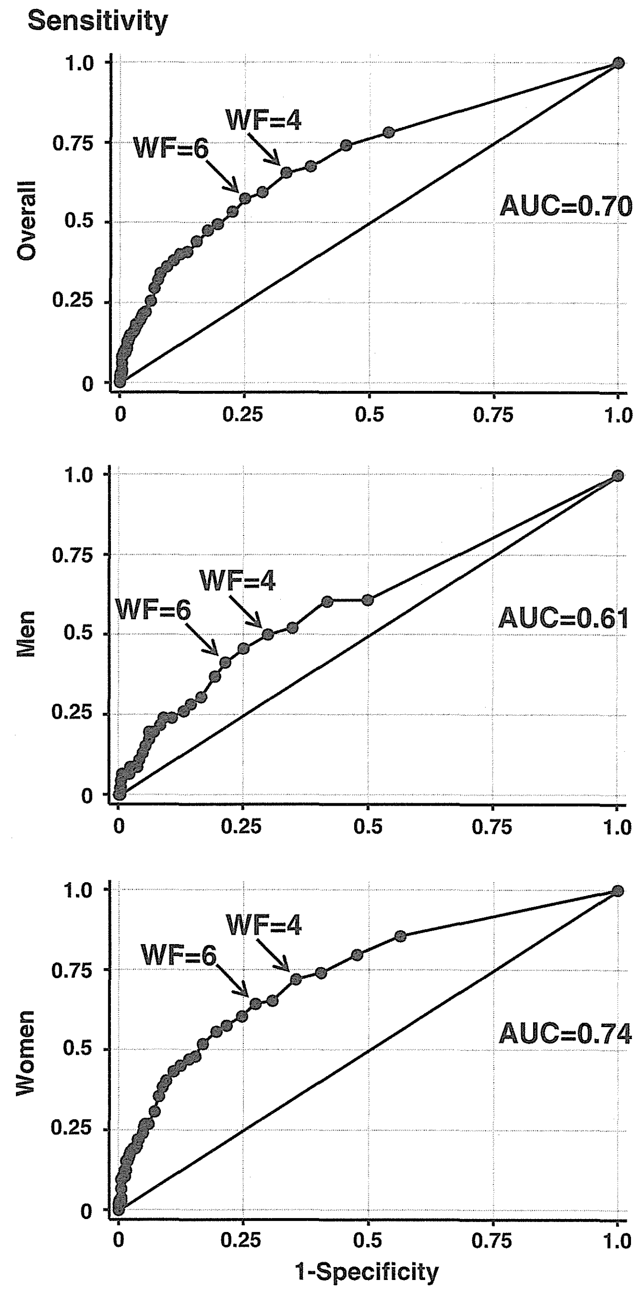

Fig. 1 Receiver operating characteristic (ROC) curve analysis for discriminating the occurrence group of certified need of care in the overall population, in men, and in women. *AUC* area under ROC curve, *WF* WOMAC (Western Ontario and McMaster Universities Osteoarthritis Index) function score

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Discussion

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

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

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

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

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

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

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

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

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

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Conflict of interest There are no conflicts of interest.

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Original Article

Relationship Between Physical Activity and Chronic Musculoskeletal Pain Among Community-Dwelling Japanese Adults

Masamitsu Kamada[1,2,3,4], Jun Kitayuguchi[3], I-Min Lee[4], Tsuyoshi Hamano[5], Fumiaki Imamura[6], Shigeru Inoue[7], Motohiko Miyachi[1], and Kuninori Shiwaku[8]

[1]Department of Health Promotion and Exercise, National Institute of Health and Nutrition, Shinjuku-ku, Tokyo, Japan
[2]Japan Society for the Promotion of Science, Chiyoda-ku, Tokyo, Japan
[3]Physical Education and Medicine Research Center UNNAN, Unnan, Shimane, Japan
[4]Division of Preventive Medicine, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, USA
[5]Center for Community-based Health Research and Education (COHRE), Organization for the Promotion of Project Research, Shimane University, Izumo, Japan
[6]MRC Epidemiology Unit, Institute of Metabolic Science, University of Cambridge School of Clinical Medicine, Cambridge, UK
[7]Department of Preventive Medicine and Public Health, Tokyo Medical University, Shinjuku-ku, Tokyo, Japan
[8]Department of Environmental and Preventive Medicine, Shimane University School of Medicine, Izumo, Shimane, Japan

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ABSTRACT

Background: Both little and excessive physical activity (PA) may relate to chronic musculoskeletal pain. The primary objective of this study was to characterize the relationship of PA levels with chronic low back pain (CLBP) and chronic knee pain (CKP).

Methods: We evaluated 4559 adults aged 40–79 years in a community-based cross-sectional survey conducted in 2009 in Shimane, Japan. We used self-administered questionnaires to assess sociodemographics and health status: PA was assessed by the International Physical Activity Questionnaire, and CLBP and CKP were assessed by a modified version of the Knee Pain Screening Tool. We examined relationships of PA with prevalence of CLBP and CKP using Poisson regression, controlling for potential confounders.

Results: CLBP and CKP were both prevalent (14.1% and 10.7%, respectively) and associated with history of injury, medication use, and consultation with physicians. PA was not significantly related to CLBP or CKP ($P > 0.05$) before or after adjustment for potential confounders. For example, compared with adults reporting moderate PA (8.25–23.0 MET-hours/week), prevalence ratios for CKP adjusted for sex, age, education years, self-rated health, depressive symptom, smoking, chronic disease history, and body-mass index were 1.12 (95% confidential interval [CI] 0.84–1.50) among those with the lowest PA and 1.26 (95% CI 0.93–1.70) among those with the highest PA (P quadratic = 0.08). The prevalence ratios were further attenuated toward the null after additional adjustment for history of injury, medication use, and consultation (P quadratic = 0.17).

Conclusions: This cross-sectional study showed that there were no significant linear or quadratic relationships of self-reported PA with CLBP and CKP. Future longitudinal study with objective measurements is needed.

Key words: exercise; musculoskeletal pain; arthritis; epidemiology; public health

INTRODUCTION

Musculoskeletal disorders are a major burden on individuals, health systems, and society, contributing meaningfully to indirect costs[1] and disability worldwide.[2] Further, chronic musculoskeletal pain (CMP), a major symptom of musculoskeletal disorders,[3–6] worsens quality of life and physical functioning later in life.[7,8] In the United States, 28.8% of men and 26.6% of women reported feeling some pain.[9] The lifetime risk of low back pain in Japan is estimated to be 83%.[10] However, despite its importance to public health, evidence linking lifestyle to CMP remains to be established.

Physical activity (PA), including exercise therapy, is recommended as a non-pharmacological intervention for

Address for correspondence. Masamitsu Kamada, Department of Health Promotion and Exercise, National Institute of Health and Nutrition, 1-23-1 Toyama, Shinjuku-ku, Tokyo, 162-8636, Japan (e-mail: kamada@gakushikai.jp).

CMP.[11,12] Pharmacological treatments, including nonsteroidal anti-inflammatory drugs, are also commonly prescribed. Considering the expense of prescriptions and side effects of such treatments,[13] increasing PA should receive greater priority both as a therapeutic agent and as preventative action against CMP. However, the relationship between PA levels and CMP has not been established yet.

Recently, both too little PA and too much PA were found to be hazardous to spinal health,[14,15] indicating a U-shaped relationship between PA and chronic low back pain (CLBP). However, few studies have examined the dose-response relationship between PA and CMP.[15–18]

When examining the relationship between PA and CMP, weight status and musculoskeletal injury need to be accounted for, since adiposity is an established risk factor for knee osteoarthritis and CMP.[19–22] Among overweight individuals, excessive PA may cause high physical load on the knee joint, leading to chronic knee pain (CKP).[23] This mechanism suggests that excess PA may cause CMP, especially among overweight adults. Injury is also an established risk factor for CMP.[23,24] Excess PA increases the probability of experiencing injury,[25,26] and musculoskeletal injury may reduce PA levels,[27,28] potentially leading to weight gain.[29] For these reasons, it is important to consider both weight status and injury history when investigating the association of PA with CMP. To our knowledge, a history of injury has been accounted for only in studies examining the risk of knee osteoarthritis,[23,30,31] while studies of the relationship between PA and CMP in the general population typically have not taken injury history into account. In addition, adults who have history of injury are likely to take medications and consult physicians, and these pain management factors may also affect pain itself as well as daily habits (such as PA). Thus, consideration of these factors is also important.

To fill the gap in knowledge on the potential role of PA in the development of CMP, we examined cross-sectional associations of PA with CLBP and CKP among adults in a community-based survey in Japan, taking into account potential confounding by body weight, history of joint injuries, and pain management factors. We also examined *post hoc* how these factors could influence associations between common demographic variables with CLBP and CKP.

METHODS

Data collection

We cross-sectionally evaluated observations from an ongoing community-based intervention study for community-level improvement in levels of PA.[32] In October 2009, invitation letters, consent forms, and questionnaires were mailed to 6000 residents randomly selected from the city registry in Unnan City (population 43 520, area 553.4 km^2), a rural mountainous region in Shimane, Japan. Men and women aged 40 to 79 years were invited to participate; excluded were those in assisted living facilities, those who required long-term care, and those who could not complete the questionnaires by themselves. We took a pragmatic approach to increase our survey response rate, including the use of personalised and relatively short questionnaires[33] and sending postcard reminders to non-responders.

A total of 4559 adults (76.0%) responded to the initial survey of the trial and were considered eligible for the present study. Written informed consent was obtained from each participant. This study was approved by the research ethics committee of the Physical Education and Medicine Research Center UNNAN (H21-10-13-1).

Measures

Sex and age were derived from the city registry, and other sociodemographic variables were obtained from self-administered questionnaires. We inquired about weight and height (used for calculating body mass index [BMI] in kg/m^2), years of education, self-rated health (very good, good, poor, or very poor),[34] depressive symptom (yes or no),[35] smoking (never, past, or current), and chronic disease history (hypertension, hyperlipidaemia, diabetes, hyperuricaemia, stroke, heart disease, kidney and urologic diseases, liver disease, gastrointestinal disease, endocrine disease, or cancer). These covariates were selected because they previously have been reported to be associated with PA, musculoskeletal morbidity, or both.[23,36]

Musculoskeletal pain

CLBP and CKP were assessed using a questionnaire (available as web-only supplemental material eQuestionnaire 1) that has questions similar to those in the Knee Pain Screening Tool (KNEST), except for questions about use of health services (which were not examined in this study).[37,38] The KNEST was previously developed to screen and identify individuals who have knee pain in a general population. CLBP and CKP were defined as current pain (ie, episodes of pain at the time of the questionnaire) that had lasted longer than 3 months in the past year.[39] We assessed the test-retest reliability of CLBP and CKP in study subjects by mailing the questionnaire twice to 500 randomly-selected adults aged 40–84 years, separated by an interval of 10 days. These were individuals living in Unnan who were not invited to participate in the main trial/survey. Evaluating the 206 respondents (response rate 41.2%; mean and standard deviation [SD] of age 63.4 and 11.9 years; 51.4% women) to both questionnaires, we observed moderate reliability (Cohen's kappa 0.49 for CLBP and 0.72 for CKP).

We also obtained information on a visual analogue scale (VAS) for intensity of pain. We defined "severe chronic pain" as chronic pain with a VAS pain score ≥75 on a 100-point scale.[40] However, the prevalence of severe chronic pain was low (low back: $n = 96$, 2.4%; knee: $n = 83$, 2.0%) in this general population. Thus, we were unable to analyze this outcome in detail in the current study. We also asked about a history of low back injury and knee injury, medication use, and consultation with physicians for low back or knee pain. These factors were included in analyses as dichotomous variables (yes or no for each item).

Physical activity

We used the Japanese short version of the International Physical Activity Questionnaire (IPAQ),[41] for which external reliability and validity have been reported elsewhere.[42,43] The IPAQ asks separate questions about time spent on walking, moderate physical activity (MPA), and vigorous physical activity (VPA) in a typical week.

We estimated total weekly PA by multiplying the reported duration (hours) per week of walking, MPA, and VPA by their Metabolic Equivalent of Tasks (METs; walking = 3.3 METs; MPA = 4.0 METs; and VPA = 8.0 METs) to obtain estimated energy expenditure in MET-hours per week.[41] Using these values, total moderate-to-vigorous physical activity (MVPA) was defined as 7 days × (3.3 METs × walking hours/day + 4.0 METs × MPA hours/day + 8.0 METs × VPA hours/day). The internal reliability over 10 days of the IPAQ was tested within our study, and found to be acceptable (Spearman correlation $r = 0.64$ among adults aged 40–84 years in the forementioned reliability study). In a validation study conducted among a sample of 95 subjects (40 men and 55 women) aged 62 to 85 (mean [SD], 74.9 [4.5]) years living in Unnan, we compared energy expenditure derived from the IPAQ with that objectively measured by a uniaxial accelerometer (Lifecorder, Suzuken Co., Ltd., Nagoya, Japan[44,45]). The validity ($r = 0.33$) was comparable to that observed in other studies.[42,43]

Statistical analyses

We compared the prevalence of CLBP and CKP in adults with different PA levels, estimating prevalence ratios (PR) by multivariable-adjusted Poisson regression.[46] Poisson regression was used because the prevalence of CLBP and CKP was relatively high (>10% each). We examined CLBP and CKP separately as well as simultaneously using generalized estimating equations because these outcomes were correlated (kappa = 0.20).[47]

We evaluated total MVPA levels both continuously and categorically. To define categories, we chose an MVPA cutpoint of 8.25, corresponding to the WHO recommendation of 2.5 hours/week of MVPA (brisk walking in this case).[48] For those with ≥8.25 MET-hours/week, we used tertiles within this sufficiently active group to determine further cutpoints (23.1, 75.4). Thus, the participants were divided into five categories: 0, 0.01–8.24, 8.25–23.00, 23.01–75.39, and ≥75.40 MET-hours/week. The adjusted PR and 95% confidence intervals (CIs) were then estimated using the middle category (8.25–23.0 MET-hours/week) as the reference category to assess potential non-linear relationships between MVPA and CMP.

When we evaluated MVPA as a continuous variable, we truncated the variable at the 95th percentile value (180 MET-hours/week) and log-transformed the variable to minimize effects of outliers and right-skewed distribution; analyses without truncation and log-transformation produced similar results, although whether the homoscedasticity assumption was met was uncertain (data not shown). In the regression analyses, we separately tested linear and quadratic relationships between MVPA and CMP.

We adjusted for the following potential confounders: sex, age, years of education, self-rated health, depressive symptoms, smoking habit, and chronic disease history (Model 1). In a separate model, we further adjusted for BMI (Model 2), past history of joint injuries (Model 3), and medication use and consultation with physicians (Model 4). Prevalence ratios by each covariate were additionally evaluated. We also assessed whether excess PA was associated with CKP, especially among adults with greater weight, by testing for an interaction between MVPA and BMI for CKP prevalence, and by examining joint categories of BMI (<20, 20–24.9, and ≥25 kg/m^2) and MVPA (<8.25, 8.25–39.59, and ≥39.6 MET-hours/week). For these analyses, we used the median value of MVPA in adults with sufficient PA (39.5 MET-hours/week) for the cutpoint. We further assessed interactions between MVPA and history of injuries (low back or knee) for the combined outcome of either CLBP or CKP. While a prior review recommended exclusion of adults previously experiencing joint injuries in such analyses,[23] our sample size would have been substantially reduced by excluding adults with a history of injury (33% of total). In a sensitivity analyses, we examined only adults without such a history and findings were little changed. Thus, in the present analyses, we included them, treating history of injury as a potential confounder and an effect-modifier.

We examined the associations of the different PA intensities with CLBP and CKP. In these analyses, VPA, MPA, and walking (in minutes per week) were entered into the same model simultaneously. Categorical and continuous analyses were performed separately for each PA intensity.

Missing information was imputed to minimize bias due to missing information and repeated four times, under the assumption that values were missing at random.[49,50] Each imputation was based on regression models including variables used in the main regression analyses. The five imputed datasets were analysed independently and combined for inference, accounting for variability of imputation.[49,50] We also repeated our analyses evaluating adults with complete information only, including 3329 participants. Analyses (two-sided $\alpha < 0.05$) were carried out using SAS version 9.3 (Cary, NC, USA).

Table 1. Characteristics of adults in a community-based survey in Shimane, Japan, 2009 (n = 4559)

	Total	Participants who had CLBP	Participants who had CKP
Number of participants	4559	605	471
Physical activity[a]			
MVPA, MET-hours/week	10.6 (0–46.2)	11.6 (0–49.5)	11.6 (0–56.3)
Vigorous physical activity, min/week	0 (0–0)	0 (0–0)	0 (0–10)
Moderate physical activity, min/week	0 (0–40)	0 (0–40)	0 (0–60)
Walking, min/week	120 (0–420)	120 (0–420)	123 (0–510)
Men, %	46.3	49.9	39.5
Age, years	60.9 (10.6)	62.8 (10.6)	65.9 (10.0)
40s, %	17.6	13.2	7.0
50s, %	26.8	24.3	20.4
60s, %	29.8	29.6	28.5
70s, %	25.8	32.9	44.2
Self-rated health			
Excellent or good, %	81.8	61.6	68.9
Education status, years	11.4 (2.4)	11.2 (2.4)	10.8 (2.3)
Chronic disease history, %[b]	62.0	68.4	64.8
Depressive symptom, %	47.6	52.4	72.8
Smoking			
Past smoker, %	8.8	11.4	9.2
Current smoker, %	16.9	18.9	9.6
Body mass index, kg/m^2	22.5 (3.1)	22.7 (3.2)	23.6 (3.1)
Past low back injury, %	23.2	45.1	29.1
Past knee injury, %	16.0	24.1	42.5
Medication use for low back pain, %	18.5	50.2	35.5
Medication use for knee pain, %	11.8	20.6	51.0
Consultation with physicians for low back pain, %	16.3	43.7	26.9
Consultation with physicians for knee pain, %	11.6	17.7	53.0

CLBP, chronic low back pain; CKP, chronic knee pain; MET, metabolic equivalent; MVPA, moderate-to-vigorous physical activity.
Means (standard deviations) for continuous variables and proportions for categorical variables are presented unless stated otherwise.
[a]Median (interquartile range).
[b]Reporting history of any of the following diseases: hypertension, hyperlipidemia, diabetes, hyperuricemia, cerebrovascular disease, heart disease, kidney and urologic diseases, liver disease, gastrointestinal disease, endocrine disease, cancer.

RESULTS

Of the 4559 participants, 46.3% were men, and participants had a mean (SD) age of 60.9 (10.6) years (Table 1). The median (interquartile range) level of MVPA was 10.6 (0–46.2) MET-hours/week. A total of 55% engaged in the recommended level of MVPA (≥8.25 MET-hours/week), whereas 25.6% did not engage in any MVPA. Adults with greater MVPA were more likely to be men, older, smokers, less educated, less depressed, and more likely to have prevalent chronic diseases and history of low back or knee injury (all $P < 0.05$); however, MVPA was not associated with BMI ($P = 0.7$) (data not shown).

CLBP was present in 14.1% of adults ($n = 605$), CKP was present in 10.7%, and both pain conditions were present in 3.7%. Fair or poor self-rated health, history of injury, medication use, and consultation with physicians were significantly associated with CLBP (Table 2). The relationship between MVPA and CLBP was not significant ($P > 0.10$ for both linear and quadratic associations). Although CKP was more prevalent in adults with the lowest (0 MET-hours/week) and the highest (≥75.4 MET-hours/week) PA (10.8% and 12.2%, respectively) than in those with average PA (9.7% in those with 8.25–23.0 MET-hours/week), PRs adjusted for potential confounders including BMI (Model 2) were not significantly different from 1.00 (lowest MVPA: PR 1.12, 95% CI 0.84–1.50; highest PA: PR 1.26, 95% CI 0.93–1.70) (Table 3). The non-significant quadratic association between PA and CKP ($P = 0.08$) in Model 2, further attenuated (to $P = 0.17$) in Model 4 after additional adjustment for history of injury and pain management (ie, medication use and consultation) (Figure 1). The pattern of results were similar to the above results with CLBP and CKP evaluated separately when we evaluated CLBP and CKP together as a combined outcome (P quadratic trend > 0.3; data not shown).

Associations of age and history of injury with CLBP and CKP were found, but these associations attenuated when adjusted for medical treatment and consultation. A significant positive association of BMI with CKP, but not CLBP, persisted; per 5 kg/m^2, PRs were 1.03 (95% CI 0.91–1.17) for CLBP and 1.28 (95% CI 1.11–1.48) for CKP, based on Model 4 (Tables 2 and 3). History of injury was also associated with each CMP outcome: PR 1.60 (95% CI 1.35–1.90) for CLBP and PR 1.67 (95% CI 1.35–2.07) for CKP (Tables 2 and 3).

Table 2. Cross-sectional associations of energy expended on moderate to vigorous physical activity with chronic low back pain among Japanese adults ($n = 4559$)

	Adults with CLBP, %	PR (95% CI)[a]			
		Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]
PA levels, MET-hours/week					
0	14.9	0.94 (0.72–1.23)	0.93 (0.71–1.22)	0.95 (0.73–1.24)	0.93 (0.72–1.21)
0.1–8.24	12.8	0.86 (0.66–1.13)	0.86 (0.65–1.13)	0.89 (0.68–1.18)	0.86 (0.66–1.13)
8.25–23.0	15.0	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)
23.1–75.3	13.7	0.94 (0.68–1.31)	0.94 (0.67–1.30)	0.95 (0.69–1.32)	0.98 (0.72–1.33)
≥75.4	16.1	1.09 (0.84–1.41)	1.10 (0.851.42)	1.04 (0.80–1.35)	1.02 (0.79–1.32)
P for linearity		0.14	0.13	0.30	0.20
P for quadratic		0.29	0.28	0.53	0.87
Sex, female	13.2	0.99 (0.82–1.19)	1.01 (0.84–1.21)	1.07 (0.89–1.28)	0.93 (0.78–1.12)
Age					
50s	12.5	1.16 (0.88–1.52)	1.16 (0.88–1.52)	1.18 (0.90–1.55)	1.13 (0.86–1.49)
60s	14.0	1.33 (1.00–1.78)	1.34 (1.01–1.79)	1.39 (1.05–1.86)	1.19 (0.89–1.60)
70s	19.0	1.62 (1.19–2.20)	1.64 (1.21–2.24)	1.63 (1.20–2.23)	1.26 (0.92–1.74)
Self-rated health, fair or poor	30.3	2.59 (2.18–3.08)	2.59 (2.18–3.08)	2.36 (1.98–2.81)	1.75 (1.46–2.09)
Education years, per year	—[e]	0.98 (0.94–1.03)	0.99 (0.95–1.03)	0.99 (0.95–1.03)	1.01 (0.96–1.05)
Chronic disease history	15.6	1.03 (0.86–1.22)	1.01 (0.85–1.21)	1.01 (0.85–1.21)	1.03 (0.86–1.23)
Depressive symptom	15.2	1.06 (0.90–1.26)	1.07 (0.90–1.27)	1.01 (0.86–1.20)	1.03 (0.86–1.23)
Smoking					
Past smoker	18.2	1.29 (0.98–1.70)	1.30 (0.99–1.71)	1.23 (0.93–1.62)	1.17 (0.88–1.54)
Current smoker	15.9	1.23 (0.98–1.55)	1.25 (0.99–1.57)	1.21 (0.96–-1.52)	1.14 (0.91–1.44)
BMI, per 5 kg/m^2	—[e]	—[f]	1.09 (0.97–1.23)	1.07 (0.95–1.22)	1.03 (0.91–1.17)
History of low back injury	27.6	—	—	2.38 (2.03–2.79)	1.60 (1.35–1.90)
Medication use for LBP	40.9	—	—	—	2.66 (2.17–3.27)
Consultation for LBP	39.8	—	—	—	1.88 (1.54–2.29)

BMI, body mass index; CI, confidence interval; CLBP, chronic low back pain; LBP, low back pain; MET, metabolic equivalent; PA, physical activity; PR, prevalence ratio.
[a]Model 1 adjusted for sex, age, education years, self-rated health, chronic disease history, depressive symptom, and smoking. Reference categories were male, 40s of age, excellent or good self-rated health, no chronic disease history, no depressive symptom, and never smoker. Linear and quadratic relationships were tested separately.
[b]Model 2 adjusted for variables in the Model 1 and BMI.
[c]Model 3 adjusted for variables in the Model 2 and history of joint injuries (two indicator variables for injury of the knee and of the low back; yes, no for each).
[d]Model 4 adjusted for variables in the Model 3 and pain management (medication use and consultation with physicians).
[e]Prevalence is not shown for continuous variable.
[f]Not included in the models.

The interaction between BMI and MVPA levels for CKP was not significant ($P > 0.9$ for linear and quadratic trends). When BMI and total MVPA levels were examined jointly, a non-significant U-shaped relationship between MVPA and CKP was observed in the high-BMI category (Model 4, Figure 2). The interaction between MVPA and joint injuries was also not significant ($P = 0.88$).

When we evaluated PA of different intensities, VPA, MPA, and walking were neither linearly nor non-linearly significantly associated with CLBP and CKP evaluated separately (all $P > 0.05$; data not shown) or with CLBP and CKP evaluated simultaneously as a combined outcome (Table 4).

All of these results from multiple imputed analyses were similar to those from complete-case analyses, with the exception of the complete-case analyses having less precision and wider confidence intervals; the variability of 5-time imputation was <10% of total variance (data not shown), while the variability due to multiple imputation was incorporated into estimations of precision and significant testing in all presented analyses.

DISCUSSION

This study examined the associations of PA with CLBP and CKP among middle-aged and older Japanese. We found that there were no significant cross-sectional relationships of PA with CLBP and CKP. While neither a U-shaped association nor interactions by body mass and prior injury were statistically significant, our analysis indicate the importance of accounting for body mass, history of injury, medication use, and consultation with physicians in research on PA and CMP.

Few previous studies have examined a potential non-linear relationship between PA and CMP, especially for CKP. Some studies suggested U-shaped relationships between PA and CLBP.[15,17,18] An occupational cohort study showed that the lowest and highest tertiles of minutes of MVPA yielded statistically significantly higher risks of low back pain than the middle tertile.[18] However, our cross-sectional investigation did not detect any significant linear or quadratic associations of PA and CLBP or CKP.

Table 3. Cross-sectional associations of energy expended on moderate to vigorous physical activity with chronic knee pain among Japanese adults (*n* = 4559)

	Adults with CKP, %	PR (95% CI)[a]			
		Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]
PA levels, MET-hours/week					
0	10.8	1.15 (0.86–1.54)	1.12 (0.84–1.50)	1.14 (0.85–1.53)	1.14 (0.85–1.53)
0.1–8.24	9.9	1.02 (0.74–1.41)	0.99 (0.72–1.37)	0.98 (0.70–1.39)	0.98 (0.71–1.34)
8.25–23.0	9.7	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)
23.1–75.3	10.3	1.09 (0.78–1.50)	1.06 (0.77–1.47)	1.03 (0.73–1.43)	0.97 (0.70–1.34)
≥75.4	12.2	1.26 (0.93–1.71)	1.26 (0.93–1.70)	1.19 (0.88–1.60)	1.15 (0.85–1.56)
P for linearity		0.53	0.43	0.79	1.00
P for quadratic		0.07	0.08	0.09	0.17
Sex, female	12.1	1.22 (0.98–1.52)	1.31 (1.05–1.64)	1.25 (1.00–1.56)	0.98 (0.79–1.22)
Age, years					
50s	8.0	1.85 (1.24–2.76)	1.88 (1.26–2.80)	1.84 (1.23–2.74)	1.51 (1.01–2.26)
60s	10.3	2.23 (1.49–3.32)	2.30 (1.54–3.44)	2.24 (1.50–3.34)	1.75 (1.16–2.62)
70s	19.1	3.77 (2.51–5.68)	4.14 (2.75–6.22)	3.56 (2.37–5.37)	2.06 (1.36–3.13)
Self-rated health, fair or poor	18.7	1.67 (1.36–2.06)	1.65 (1.34–2.03)	1.51 (1.22–1.86)	1.21 (0.98–1.49)
Education years	—[e]	0.96 (0.92–1.01)	0.97 (0.93–1.01)	0.97 (0.93–1.01)	1.01 (0.96–1.05)
Chronic disease history	12.7	1.18 (0.96–1.47)	1.07 (0.86–1.33)	1.06 (0.86–1.32)	0.98 (0.79–1.22)
Depressive symptom	11.2	1.19 (0.98–1.44)	1.24 (1.02–1.51)	1.20 (0.99–1.46)	1.17 (0.97–1.41)
Smoking					
Past smoker	11.1	1.11 (0.77–1.60)	1.15 (0.80–1.66)	1.17 (0.82–1.69)	1.17 (0.82–1.67)
Current smoker	6.0	0.73 (0.52–1.02)	0.78 (0.55–1.09)	0.80 (0.57–1.12)	0.87 (0.62–1.23)
BMI per 5 kg/m^2	—[e]	—[f]	1.68 (1.47–1.91)	1.57 (1.37–1.80)	1.28 (1.11–1.48)
History of knee injury	29.0	—	—	3.23 (2.65–3.94)	1.67 (1.35–2.07)
Medication use for KP	49.4	—	—	—	2.99 (2.29–3.89)
Consultation for KP	51.5	—	—	—	3.11 (2.44–3.96)

BMI, body mass index; CI, confidence interval; CKP, chronic knee pain; KP, knee pain; MET, metabolic equivalent; PA, physical activity; PR, prevalence ratio.
[a]Model 1 adjusted for sex, age, education years, self-rated health, chronic disease history, depressive symptom, and smoking. Reference categories were male, 40s of age, excellent or good self-rated health, no chronic disease history, no depressive symptom, and never smoker. Linear and quadratic relationships were tested separately.
[b]Model 2 adjusted for variables in the Model 1 and BMI.
[c]Model 3 adjusted for variables in the Model 2 and history of joint injuries (two indicator variables for injury of the knee and of the low back; yes, no for each).
[d]Model 4 adjusted for variables in the Model 3 and pain management (medication use and consultation with physicians).
[e]Prevalence is not shown for continuous variable.
[f]Not included in the models.

Both positive and negative effects of excess PA on knee joint are conceivable. A systematic review concluded that there was strong evidence for an inverse relationship between PA and cartilage defects of the knee joint.[51] However, the authors also concluded that there was a positive relationship between tibiofemoral osteophytes and PA. The results of previous studies on PA and joint health have been inconsistent, and many of the prior studies did not assess non-linear relationships or were too underpowered to do so.[51] Therefore, future longitudinal investigations examining a potential non-linear relationship between PA and CMP are of value.

Our results also showed the importance of taking into account BMI, past injuries, and factors related to pain management, which were all significantly associated with CMP. Higher BMI level in this study was significantly associated with higher prevalence of CKP but not CLBP, in line with the postulation that a greater body mass causes physical burden on the knee joint.[23] Our failure to show an interaction of PA and BMI on CKP may reflect the limited statistical power of the present study and also the limited range of BMI in our population, which predominantly comprised normal-weight adults with BMI < 25 kg/m^2 (80%). Only a few prior studies took a history of injury into account.[18,23] One third of the adults in our study reported a history of injury, and we observed a significant positive association of history of injury with CMP; it is possible that prior excess PA could have caused joint injury, which led to CMP. On the other hand, PA is recommended as a non-pharmacological intervention for CMP.[11,12] Thus, adults who had history of injury, and possibly CMP, might engage in more PA for treatment and rehabilitation.

Our results showed that there were strong associations of CMP with medication use and consultation with physicians and that adjusting for these factors attenuated the quadratic association between PA and CKP. As seeking medications and undergoing outpatient treatment is directly associated with not only pain but also PA, these results are plausible. Our findings thus emphasize that future research on the relationship between PA and CMP should consider effects of BMI, injury, and pain management factors.

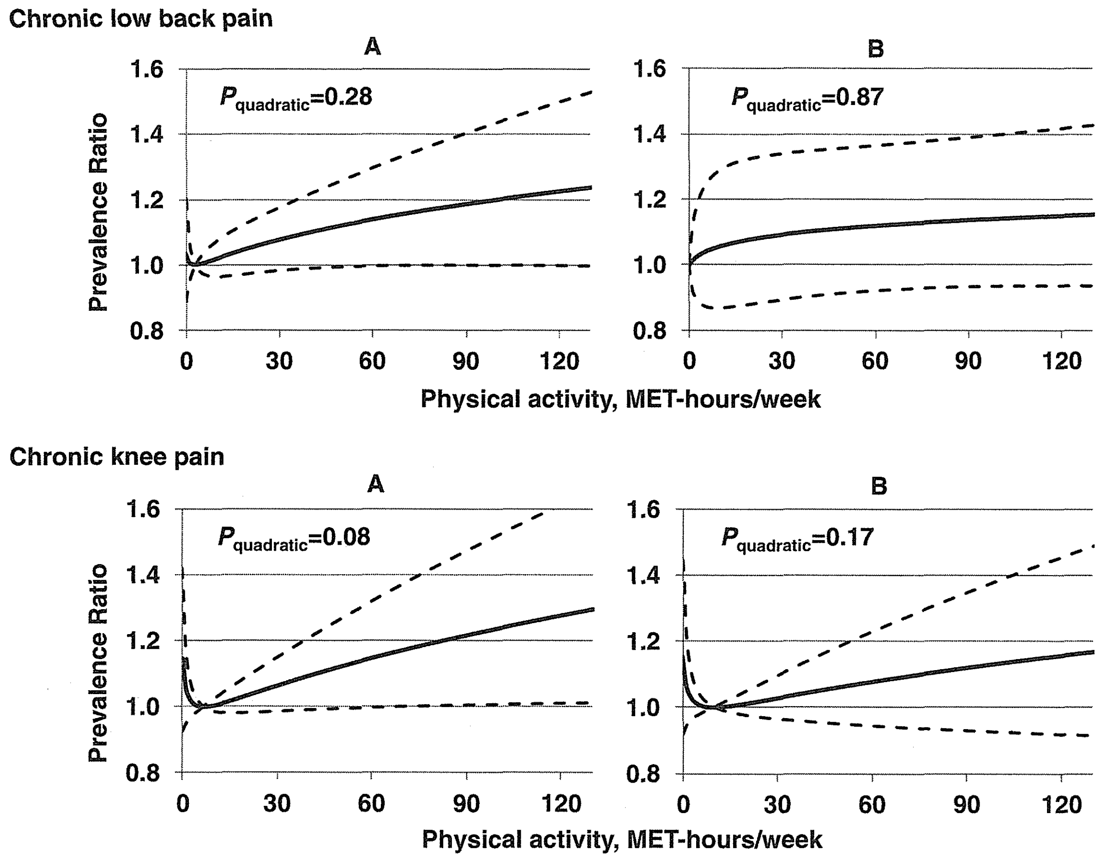

Figure 1. Associations between moderate-to-vigorous physical activity and the prevalence of chronic low back pain and chronic knee pain among Japanese adults ($n = 4559$). Solid lines represent prevalence ratios (PRs), and dashed lines indicate 95% confidence intervals estimated by Poisson regression, estimated by a quadratic function of physical activity levels (metabolic equivalent of task [MET]-hours/week). Panels on the left (A) display PR adjusted for sex, age, education years, self-rated health, depressive symptoms, smoking habit, chronic disease history, and body mass index; while on the right (B), PRs are further adjusted for history of joint injuries, medication use, and consultation with physicians for pain management. The reference value for each was fixed to the values giving the lowest prevalence of each outcome. P for each quadratic function is displayed.

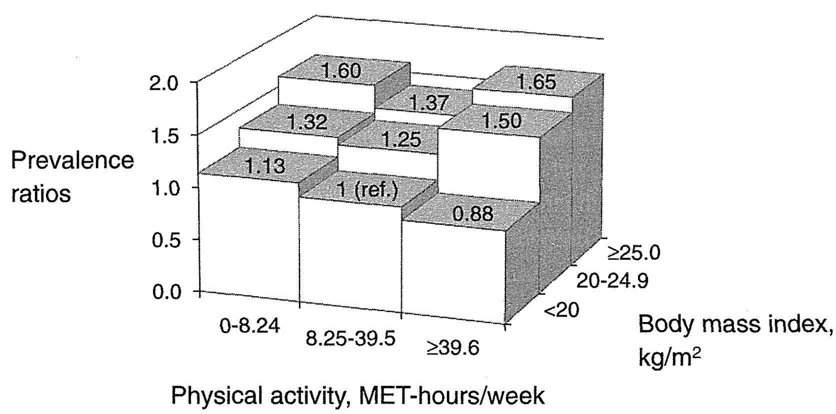

Figure 2. Associations of moderate-to-vigorous physical activity (metabolic equivalent of task [MET]-hours/week) and weight status with chronic knee pain among Japanese adults ($n = 4559$). Prevalence ratios were estimated with adjustment for sex, age, education years, self-rated health, depressive symptoms, smoking habit, chronic disease history, past joint injuries, medication use, and consultation with physicians for pain management. After adjustment, no significant prevalence ratios were observed (all $P > 0.05$). Interactions between body-mass index and physical activity levels in models, considering linear as well as non-linear associations, were also not significant (all $P > 0.1$).

Table 4. Cross-sectional associations between physical activity of different intensity and either chronic low back pain or chronic knee pain among Japanese adults (n = 4559)

Physical activity type	n	PR (95% CI)[a]			
		Model 1[b]	Model 2[c]	Model 3[d]	Model 4[e]
Vigorous PA, min/week					
0	3200	1.13 (0.80–1.59)	1.15 (0.81–1.63)	1.15 (0.83–1.59)	1.15 (0.91–1.45)
>0–40.6	453	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)
40.9–180	458	1.27 (0.84–1.90)	1.26 (0.83–1.90)	1.18 (0.80–1.75)	1.19 (0.91–1.57)
>180	448	1.05 (0.67–1.66)	1.06 (0.67–1.67)	0.98 (0.64–1.49)	0.93 (0.67–1.29)
$P_{linearity}$[f]		0.94	0.89	0.43	0.21
$P_{non\text{-}linearity}$[f]		0.93	0.83	0.97	0.45
Moderate PA, min/week					
0	2990	1.05 (0.80–1.38)	1.02 (0.78–1.33)	1.04 (0.82–1.32)	1.16 (0.88–1.53)
>0–58.8	504	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)
60.0–240	558	1.20 (0.87–1.65)	1.20 (0.88–1.63)	1.16 (0.87–1.55)	1.28 (0.96–1.69)
>240	507	1.13 (0.82–1.54)	1.14 (0.84–1.55)	1.13 (0.85–1.51)	1.29 (0.91–1.82)
$P_{linearity}$[f]		0.18	0.07	0.17	0.22
$P_{non\text{-}linearity}$[f]		0.56	0.61	0.52	0.28
Walking, min/week					
0	1271	1.10 (0.92–1.32)	1.11 (0.93–1.34)	1.09 (0.90–1.31)	1.08 (0.91–1.29)
>0–119	1055	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)
120–404	1053	1.03 (0.85–1.25)	1.04 (0.86–1.26)	1.04 (0.86–1.26)	1.06 (0.88–1.26)
>404	1180	1.11 (0.91–1.36)	1.12 (0.91–1.38)	1.11 (0.90–1.36)	1.13 (0.93–1.36)
$P_{linearity}$[f]		0.99	0.98	0.84	0.57
$P_{non\text{-}linearity}$[f]		0.08	0.06	0.13	0.18

CI, confidence interval; PA, physical activity; PR, prevalence ratio.
[a]Prevalence ratios (PR) and 95% confidence intervals were estimated by Poisson regression. We examined chronic low back pain (CLBP), chronic knee pain (CKP), or both as the outcome of interest simultaneously by generalized estimating equation that accounted for the correlations between CLBP and CKP (kappa = 0.20). The models also included all PA measures simultaneously. Correlations among these PA categories were moderate (Spearman r = 0.48 between vigorous and moderate PA; 0.31 between vigorous PA and walking; 0.28 between moderate PA and walking). For each type of physical activity, we categorized adults into four groups by treating adults with 0 min/week as a single category and by splitting the others into tertiles.
[b]Model 1 adjusted for sex, age, education years, self-rated health, chronic disease history, depressive symptom, and smoking.
[c]Model 2 adjusted for variables in the Model 1 and body mass index.
[d]Model 3 adjusted for variables in the Model 2 and history of joint injuries (two indicator variables for injury of the knee and of the low back; yes or no for each).
[e]Model 4 adjusted for variables in the Model 3 and pain management (medication use and consultation with physicians).
[f]Log-linear and quadratic relationships were tested separately, using log-transformed variables.

Globally, disability due to musculoskeletal disorders is estimated to have increased by 45% from 1990 to 2010, related to the aging of the population.[2] It remains unknown what the most effective and affordable strategies are to reduce the global burden of musculoskeletal disorders.[52] Although we detected little indication of benefits of PA for CMP, potential beneficial effects of PA on CMP still deserve discussion. Possible pathways linking greater PA to a reduced risk of CMP include but are not limited to reduction of mechanical stress through improving muscle strength, range of movement, and joint structure; improvement of blood flow to painful regions; relief of psychological stress, such as distraction and depression[7,53–55]; and elevation of tolerance to pain associated with increased serum concentrations of endocannabinoids that reduce pain sensation.[56] Our community-based research in Japan, which has one of the most aged societies in the world, provides important insights into the studies on PA and musculoskeletal health.

Our study has several limitations. In our cross-sectional study, reverse causation and recall bias might have occurred. Individuals with CMP may reduce levels of recreational PA and PA intensities, leading to null findings for MVPA and CMP. Limitations are likely to be present in our assessment of injury, because this was ascertained retrospectively. We also had a limited sample size to tease out independent relations among PA levels, CMP, and potential confounders. Future research should adopt a longitudinal design, assessing PA prior to the development of injuries or pains. Considering potential biases due to self-reported PA, objective measures of PA, as well as anthropometrics, injuries, and pain, should be incorporated in future research.

In conclusion, this cross-sectional study showed that there were no significant linear or quadratic relationships of PA with CLBP and CKP. Our findings indicate the importance of evaluating PA, CMP, body mass, injuries, and pain management factors simultaneously.

ONLINE ONLY MATERIALS

eQuestionnaire 1. Musculoskeletal pain questionnaire.
Abstract in Japanese.

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