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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

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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 $\geq$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 $\geq$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 $\geq$5 and women with a score $\geq$4 should undergo early intervention programs to prevent subsequent deterioration.

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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-

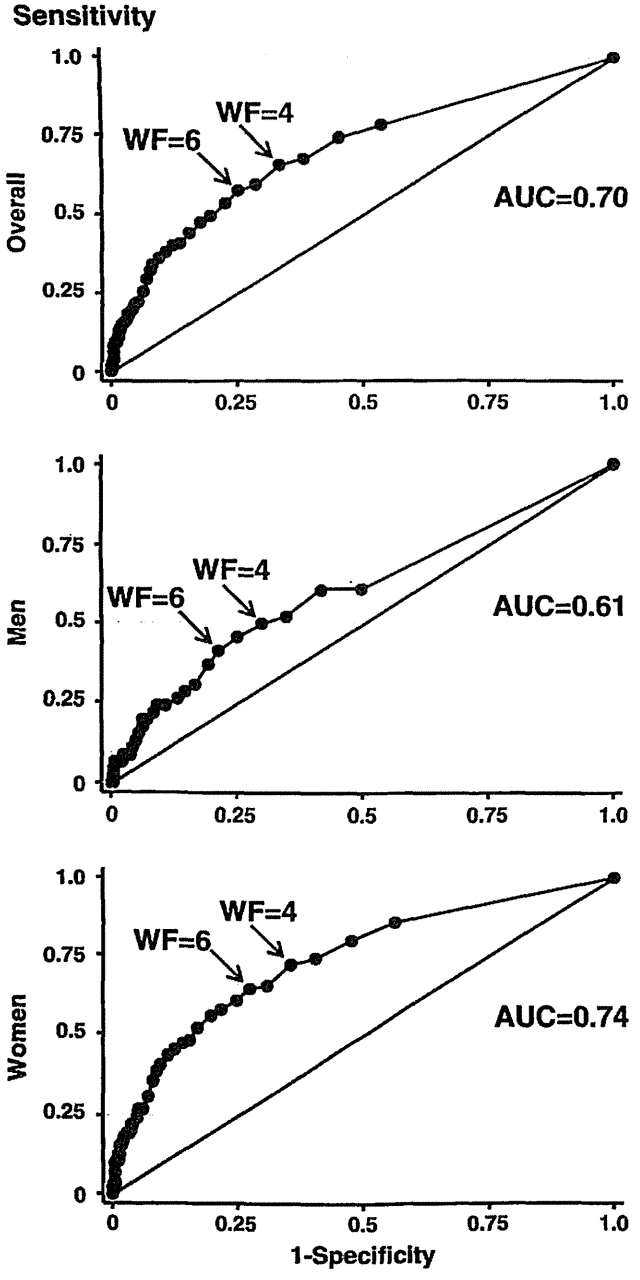

Fig. 1 Receiver operating characteristic (ROC) curve analysis for discriminating the occurrence group of certified need of care in the overall population, in men, and in women. *AUC* area under ROC curve, *WF* WOMAC (Western Ontario and McMaster Universities Osteoarthritis Index) function score

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 ≥ 2 was 47.0 % in men and 70.2 % in women, respectively, in subjects aged 60 years and older in Japanese population-based cohorts. Therefore, women are more likely than men to be affected by knee osteoarthritis and have difficulties in physical function of the lower extremities, leading to higher scores on the WOMAC function scale. Another reason for the sex differences may be the weaker muscle strength in women; muscle strength in men is higher than that in women in all decades of life [14], which may obscure the association in men, as muscle strength has been reported to be inversely associated with the WOMAC domains [15].

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

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

There are some limitations in the present study. First, we could not obtain information on causes of certified need of care in the LTCI system. Therefore, we could not analyze the direct association of each causing condition with measured factors, and could not determine the risk factors for occurrence of certified need of care with respect to each causing condition. The Japanese government reported that the top five leading causes of certified need of care were cerebral stroke, dementia, asthenia, osteoarthritis, and fall-related fracture, comprising 71.6 % of all causes in 2010 [10]. Based on these data, most of the causes of incident certification in the present

study are inferred to be among the top five leading conditions. Additional studies are necessary to identify those direct associations. Second, participants at baseline in the present study were those who could walk to the survey site and could understand and sign an informed consent form. Since those who could not were not included in the analyses, the study participants do not truly represent the general population due to health bias, which should be taken into consideration when generalizing the results of the present study.

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

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Conflict of interest There are no conflicts of interest.

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Clinical Study

The prevalence of cervical myelopathy among subjects with narrow cervical spinal canal in a population-based magnetic resonance imaging study: the Wakayama Spine Study

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Abstract

BACKGROUND CONTEXT: A narrow cervical spinal canal (CSC) is a well-known risk factor for cervical myelopathy (CM). However, no epidemiologic data of the CSC based on a population-based cohort are available.

PURPOSE: The purpose of the study was to investigate the age-related differences in CSC diameters on plain radiographs and to examine the associated magnetic resonance imaging (MRI) abnormalities including cervical cord compression and increased signal intensity (ISI) as well as the clinical CM with the narrow CSC.

STUDY DESIGN/SETTING: This was a cross-sectional study.

PARTICIPANT SAMPLE: Data were obtained from the baseline survey of the Wakayama Spine Study that was performed from 2008 to 2010 in a western part of Japan. Finally, a total of 959 subjects (319 men and 640 women; mean age, 66.4 years) were included.

OUTCOME MEASURES: The outcome measures included in the study were the CSC diameter at C5 level on plain radiographs, cervical cord compression and ISI on sagittal T2-weighted MRI, and physical signs related to CM (eg, the Hoffmann reflex, hyperreflexia of the patellar tendon, the Babinski reflex, sensory and motor function, and bowel/bladder symptoms).

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METHODS: The age-related differences of CSC diameters in men and women were investigated by descriptive statistics. The prevalence of MRI abnormalities and clinical CM was compared among the groups divided by the CSC diameter (less than 13, 13–15, and 15 mm or more). In addition, a logistic regression analysis was performed to determine the association of the CSC diameter with cervical cord compression/clinical CM after overall adjustment for age, sex, and body mass index.
RESULTS: The CSC diameter was narrower with increasing age in both men and women. The prevalence of cervical cord compression, ISI, and the clinical CM was significantly higher in the narrower CSC group. The prevalence of cervical cord compression, ISI, and CM among subjects with CSC diameter less than 13 mm was 38.0%, 5.4%, and 10.1%, respectively. In the logistic model, the CSC diameter was a significant predictive factor for the clinical CM ($p<.0001$).
CONCLUSIONS: This study firstly confirmed the age-related differences in CSC diameters and the significant association of the narrow CSC diameter with CM in a population-based cohort.

Keywords: Cervical spine; Spinal canal stenosis; Cervical myelopathy; Magnetic resonance imaging; Population-based cohort; Epidemiology

Introduction

In cervical spinal disorders such as cervical myelopathy (CM) and spinal cord injury, developmental cervical spinal canal (CSC) stenosis has been considered as an effective predictor of clinical outcome [1,2]. The spinal cord area should be evaluated after comparing with data obtained from asymptomatic subjects of each age group. Age-dependent data are required because the spinal cord may change with age, just as the cerebrum decreases in size with age in elderly subjects. The spinal canal should also be considered in asymptomatic subjects when treating cervical spinal disorders because patients with a tight spinal canal are more susceptible to spinal cord damage. However, the prevalence of spinal cord disorders and CM among patients with CSC of narrow diameter is not known. To date, few studies have focused on age-related differences in the cervical spinal cord and CSC [3,4]. Recent advances in magnetic resonance imaging (MRI) have made it possible to noninvasively obtain clear images of the cervical spinal cord, thereby making evaluation of traumatic spinal cord injury and cervical cord compression more applicable in routine practice. This study was undertaken to clarify age-related differences in the cervical spinal cord and CSC using magnetic resonance imaging (MRI) to establish the basis for morphometric evaluation of patients with cervical spinal cord disorders. More specifically, the purposes of this study were to investigate age-related changes of the CSC in a population-based cohort in Japan and to examine the associated MRI abnormalities including cervical cord compression and increased signal intensity (ISI) as well as the clinical CM with the narrow CSC diameters.

Participants and methods

Participants

The present study is a part of "The Wakayama Spine Study: a population-based cohort," which was a large-scale population-based MRI study. Because a detailed profile of the Wakayama Spine Study has already been described elsewhere, only a brief summary is provided here [5,6]. The Wakayama Spine Study was conducted between 2008 and 2010 in a mountainous region in Hidakagawa, Wakayama, and a coastal region in Taiji, Wakayama. From inhabitants of the Hidakagawa and Taiji regions, 1,063 potential study subjects were recruited for MRI examinations. Among those 1,063 candidates, 52 declined the examination; therefore, 1,011 inhabitants were registered in the present study. Among those 1,011 participants, individuals with MRI-sensitive implanted devices (such as a pacemaker) and other disqualifiers were excluded. Ultimately, the cervical spine was scanned with MRI in 985 participants. Four participants who had undergone a previous cervical operation were excluded from the analysis, and another four participants whose MRI interpretation was difficult because of poor image quality were also excluded. After these exclusions, the present study had 977 participants. Radiographic evaluation of the cervical spine was also performed in 959 of the subjects. In total, both MRI and radiographic results were available for 959 participants (319 men and 640 women) with an age range of 21 to 97 years (mean, 67.3 years for men and 65.9 years for women). The participants completed an interviewer-administered questionnaire of 400 items that included lifestyle information; and anthropometric and physical performance measurements were taken. All study participants provided informed consent, and the study design was approved by the appropriate ethics review boards.

Anthropometric measurements included height (meter), weight (kilogram), and body mass index (BMI; weight [kilogram]/height^2 [m^2]). Medical information concerning neck pain, sensory disturbances, the Hoffmann reflex, the Babinski reflex, and the deep tendon reflex of the patellar tendon was gathered by an experienced orthopedic surgeon. The Hoffmann reflex was elicited with the hand in a neutral position by flicking the distal phalanx of the middle finger and observing flexion of the distal phalanx of the thumb [7,8].

The Babinski reflex was elicited by firmly sweeping from the lateral part of the sole to the base of the toes with a pointed end of a reflex hammer and observing the hallux extensor response [9,10]. Hyperreflexia of the patellar tendon, a positive Hoffmann reflex, and a positive Babinski reflex were defined as aggravation on both sides. A myelopathic sign was defined as the presence of hyperreflexia of the patellar tendon, Hoffmann reflex, or Babinski reflex.

Measurements of CSC diameter and canal-to-body ratio on radiographs

All subjects also underwent lateral radiography with their neck in the neutral position. They were told by an X-ray technician to look straight ahead in a relaxed position. The radiographic data were scanned and calibrated using the ruler, which was put on the film. The sagittal spinal canal diameter at the C5 level was measured as the shortest distance from the midpoint between the vertebral body's superior and inferior end plates to the spinolaminar line. The canal-to-body ratio (CBR) was obtained by dividing the diameter of the spinal canal by that of the vertebral body to assess the tightness of the spinal canal and also to eliminate the magnification effect of radiographs.

Magnetic resonance imaging

An MRI scan of the cervical spine was obtained for each participant using a 1.5-T Excelart imaging system (Toshiba, Tokyo, Japan). All scans were taken in the supine position, except for participants with a rounded back, who used a triangular pillow under their heads and knees. The imaging protocol included a sagittal T2-weighted fast spin-echo pulse sequence (repetition time: 4,000 ms; echo time: 120 ms; and field of view: 300 × 320 mm) and an axial T2-weighted fast spin-echo pulse sequence (repetition time: 4,000 ms; echo time: 120 ms; and field of view: 180 × 180 mm).

MRI measures

Midsagittal T2-weighted images were assessed by an experienced orthopedic surgeon (Keiji Nagata), who was blinded to participants' clinical status.

Evaluation of cervical cord compression

Cervical cord compression was defined as compression with an anterior and/or a posterior component of the spinal cord [6]. Cervical cord compression was evaluated at each intervertebral level from C2–C3 to C7–T1.

Evaluation of signal intensity of the spinal cord

Increased signal intensity was defined as a high-intensity area in contrast with the adjacent isointensity portion of the spinal cord [11]. The ISI was evaluated in the area from C2 to T1.

Measurement of spinal cord diameter

The spinal cord diameter was measured manually at the midpoint of the C5 vertebral body level using the imaging software OsiriX (http://www.osirix-viewer.com/).

Definition of clinical CM

Myelopathy is defined clinically by the presence of myelopathic signs (eg, the Hoffmann reflex, hyperreflexia of the patellar tendon, and the Babinski reflex), usually accompanied by bilateral sensory deficits or sensory level and bowel/bladder symptoms. Among participants with myelopathic signs, cervical cord compression was the essential condition for diagnosing CM.

Statistical analyses

A comparison of baseline characteristics between sexes was performed using the Student *t* test. Differences in the CSC diameter, vertebral body, spinal cord, and CBR among men and women were determined using the Student *t* test. One-way analysis of variance was used to evaluate the differences in CSC diameter, vertebral body, spinal cord, and CBR among different age groups. The chi-square test was used to assess the presence of ISI among different age groups.

For categorical data, the chi-square test was used to assess the presence of significant differences among different diameters of the CSC. For continuous outcomes, the analysis of variance test was used to assess differences among different diameters of the CSC. In addition, to determine the association of ISI, CSC diameter, and CBR with cervical cord compression and CM, logistic regression analysis was used after overall adjustment for age, sex, and BMI. All statistical tests were performed at a significance level of .05 (two-sided). Data analyses were performed using JMP, version 8 (SAS Institute, Inc, Cary, NC, USA).

Results

Characteristics of the participants

The baseline characteristics of the 977 participants, including data for anthropometric measurements and physical performance, are listed in Table 1. There was no

Table 1
Characteristics of men and women participating in the present study

Characteristic	Men	Women
N	319	640
Age, y	67.3±13.8	65.9±13.3
Height, cm	164.6±7.2**	151.6±7.2
Weight, kg	64.4±11.6**	53.0±9.4
Body mass index, kg/m^2	23.7±3.4*	23.1±3.7
Grip strength, kg	37.9±9.1**	23.9±5.9

Note: Significantly different from women by the Student *t* test (*p<.01; **p<.001).

Values are the mean±standard deviation.

Table 2
Radiographic and MRI measures stratified by gender and age strata

Age strata	Radiographic measures: Diameter of cervical spinal canal (mm)	Radiographic measures: Canal-to-body ratio	MRI measures: Increased signal intensity, N (%)	MRI measures: Diameter of spinal cord (mm)
Men				
Overall	14.8±1.3	0.82±0.12	15 (4.6)	6.9±0.9
<50 y	15.2±1.3	0.86±0.09	2 (5.2)	7.3±0.8
50–59 y	14.8±1.7	0.85±0.13	4 (6.9)	7.1±0.9
60–69 y	14.9±1.2	0.82±0.11	3 (4.5)	6.9±0.7
70–79 y	14.8±1.2	0.82±0.11	2 (2.3)	6.9±0.8
≥80 y	14.4±1.1	0.79±0.12	4 (5.5)	6.6±0.9
Women				
Overall	14.1±1.2	0.92±0.13	11 (1.7)	6.8±0.9
<50 y	14.5±1.3	0.99±0.14	1 (1.1)	6.9±0.9
50–59 y	14.4±1.3	0.96±0.12	1 (0.0)	7.0±0.7
60–69 y	14.1±1.1	0.91±0.12	0 (0)	6.8±0.8
70–79 y	13.9±1.1	0.89±0.12	6 (3.5)	6.8±0.9
≥80 y	13.8±1.0	0.86±0.12	3 (2.5)	6.7±0.9

Note: Otherwise indicated, values are mean±standard deviation for each age strata in men and women.

significant difference in age between sexes. Height, weight, and BMI were significantly higher in men than in women.

Age and sex differences of CSC diameter, CBR, ISI, and spinal cord diameter

Table 2 lists the age-related differences in diameters of the CSC, the CBR on radiograph, ISI, and spinal cord diameter on MRI in men and women among different age groups. The CSC diameter was significantly narrower with age in women ($p<.0001$). In men, the CSC diameter had a tendency to be narrower with age, but it was not significantly different in women. The mean diameter of the CSC was not significantly different between men and women. The diameter of the vertebral body was significantly higher in men and women with increasing age ($p<.0001$). The mean CBR in men and women was 0.82 and 0.92, respectively, and it was significantly higher in women than in men at the C5 vertebral level. The CBR was significantly lower with increasing age in both sexes (men, $p=.0004$; women: $p<.0001$).

The prevalence of ISI in all participants was 2.7% (4.6% in men and 1.7% in women) and was significantly higher in men than in women ($p=.007$). The prevalence of ISI was not significantly different with age between sexes. The diameter of the spinal cord was significantly lower with increasing age in both sexes (men, $p=.0012$; women, $p=.0068$). The mean diameter of the spinal cord was not significantly different between men and women.

Prevalence of MRI measures and CM among different diameters of the CSC

Anthropometric measures such as CSC diameter were found to be significantly different according to age (Table 3). Regarding MRI measures, significant differences between different CSC diameters were found with respect to cervical cord compression ($p<.0001$), ISI ($p<.0001$), and spinal cord diameter ($p<.0001$), except for ISI in women. The prevalence of cervical cord compression, ISI, and CM in subjects with a CSC diameter less than 13 mm was 61.9%, 23.8%, and 4.8% in men, respectively. Meanwhile, the prevalence of cervical cord compression, ISI, and CM among female subjects with a CSC diameter less than 13 mm was 33.3%, 1.9%, and 11.1%, respectively. Multiple logistic regression analysis was performed to estimate the predictive factors for CM in MRI and radiographic measurements after adjustment for age, sex, and BMI (Table 4). As an overall result, ISI, CSC diameter, and CBR were significant predictive factors for CM ($p<.01$). There was a positive association between cervical cord compression and spinal cord diameter, whereas spinal cord diameter itself was not a significant predictive factor for CM.

Discussion

The present study is the first population-based study to clarify the normal value of the diameter of the CSC and its association with cervical cord compression, ISI, and CM in Japanese men and women. We clarified that the CSC diameter was narrower with age in both men and women in the population-based cohort. The prevalence of the clinical CM was significantly higher in the narrower CSC group. Furthermore, in the logistic model, the CSC diameter was a significant predictive factor for clinical CM.

In this study, the CSC and vertebral body diameters were measured using plain radiographs because the posterior longitudinal ligament could not be distinguished from the vertebral body on MRI. There have been several reports on the diameter of the CSC. Porter et al. [12] reported that canal size did not appear to change significantly with biomechanical stress and aging. Meanwhile, Goto et al. [3] and Kato et al. [4] reported that the younger generation (younger than 40 years of age) had a statistically wider CSC. Our result was consistent with the latter reports. Why do younger persons have a wider CSC than elderly persons? There are two possible reasons for the differences in CSC diameter between generations. First, the CSC diameter becomes narrower with aging. A CSC with a small diameter is primarily a developmental and not a degenerative phenomenon. However, Hukuda and Kojima [13] reported that the diameter of the vertebral body was wider in older people compared with younger people. Those morphologic changes of the vertebral component may affect the diameter of the CSC. Second, the changes in Japanese eating habits and physique in the past few decades may have contributed to the changes in the diameter of the CSC. The variation of CSC diameter with different generation may be a limited phenomenon in Japan. However, we believe the results prompt future investigations into the various factors affecting the CSC dimensions, apart from aging.

Table 3
Prevalence of MRI measures and cervical myelopathy among different diameter of cervical spinal canal

Factors	Diameter of cervical spinal canal (mm)			p value
	<13	13–15	≥15	
Men				
N	21	162	136	
Age, y	69.5±12.0	69.1±12.8	64.9±14.9	.027
Height, cm	163.7±5.6	163.6±6.8	165.8±7.7	.025
Weight, kg	67.6±10.5	61.7±10.6	67.0±12.3	.0002
Body mass index, kg/m^2	25.2±3.3	23.0±3.2	24.2±3.4	.0006
MRI measures				
Cervical cord compression, N (%)	13 (61.9)	58 (35.8)	22 (16.2)	<.0001
Increased signal intensity, N (%)	5 (23.8)	9 (5.6)	1 (0.7)	<.0001
Diameter of spinal cord (mm)	6.2±0.5	6.8±0.8	7.2±0.8	<.0001
Cervical myelopathy, N (%)	1 (4.8)	2 (1.2)	0 (0)	.09
Women				
N	108	383	149	
Age, y	68.7±13.3	67.2±12.8	60.4±13.4	<.0001
Height, cm	149.1±7.2	151.4±7.1	153.9±6.7	<.0001
Weight, kg	49.8±8.1	53.2±9.6	54.8±9.4	.0001
Body mass index, kg/m^2	22.4±3.2	23.2±3.7	23.2±3.8	.12
MRI measures				
Cervical cord compression, N (%)	36 (33.3)	92 (24.0)	11 (7.4)	<.0001
Increased signal intensity, N (%)	2 (1.9)	8 (2.1)	0 (0)	.21
Diameter of spinal cord (mm)	6.5±0.9	6.9±0.8	7.0±0.8	<.0001
Cervical myelopathy, N (%)	12 (11.1)	12 (3.1)	0 (0)	<.0001

MRI, magnetic resonance imaging.

Note: For categorical data, the chi-square test was used to assess the presence of significant differences among different diameters of the cervical spinal canal.

For continuous outcomes, comparison was made by the analysis of variance test differences among different diameters of the cervical spinal canal.

Regarding MRI measurements, the prevalence of cervical cord compression and ISI among persons with a CSC diameter less than 13 mm, which was considered to be developmental canal stenosis [14], was 61.9% and 23.8% in men and 33.3% and 1.9% in women, respectively. Above all, a CSC diameter less than 13 mm was observed in more than 10% of the participants. Of those with a CSC diameter less than 13 mm, cervical cord compression (ie, the preliminary step in the development of CM) was also observed in 61.9% of men and 33.3% of women. From these results, the number of people who have a risk for CM was considered quite high in the general population. Countee and Vijayanathan [15] reported that congenital stenosis in men with a cervical canal diameter of 14 mm or less was associated with quadriplegia after trauma. In the present study, we noted that the narrower the diameter of the CSC, the higher the prevalence of ISI. Of note, the distribution of prevalence between men and women was different. Increased signal intensity was seen in approximately 10% of men younger than 60 years, whereas it was seen in only 1% of women younger than 60 years, and was relatively higher in older people. In the present study, the prevalence of the clinical CM was significantly higher in the narrower CSC group. The result may show that patients with a narrowed spinal canal are more likely to develop CM. Further longitudinal studies are needed to clarify the causal

Table 4
The odds ratio and 95% confidence interval of increased signal intensity, diameter of spinal cord, diameter of cervical spinal canal, and canal-to-body ratio for cervical myelopathy

Variables	Cervical cord compression		Cervical myelopathy	
	OR* (95% CI)	p value	OR (95% CI)	p value
Age, y (+10 y)	23.6 (9.62–60.0)	<.0001	11.0 (1.15–133.9)	.047
Women (vs. men)	1.41 (1.03–1.92)	.032	4.33 (1.50–18.4)	.018
Body mass index, kg/m^2 (+1 SD)	2.12 (0.87–5.16)	.095	1.04 (0.94–1.15)	.41
Increased signal intensity positive	18.8 (6.87–66.4)	<.0001	6.32 (1.36–21.8)	.007
Diameter of spinal cord, mm (−1 mm)	1.40 (1.17–1.68)	.0002	1.46 (0.93–2.31)	.11
Diameter of cervical spinal canal, mm (−1 mm)	1.67 (1.45–1.93)	<.0001	2.73 (1.83–4.23)	<.001
Canal-to-body ratio (−10%)	1.85 (1.60–2.16)	<.0001	2.12 (1.47–3.16)	.0001

OR, odds ratio; CI, confidence interval; SD, standard deviation.

* OR was calculated by multiple logistic regression analysis after adjustment for age, gender, and body mass index.

relationship between narrowed spinal canal and CM. In addition, we clarified the positive association between cervical cord compression and spinal cord diameter, whereas the diameter of the spinal cord itself was not a significant predictive factor for CM. This may indicate that the spinal cord can become atrophied in individuals with cervical cord compression or in those who have a congenitally narrow spinal cord.

The present study also clarified the difference in age- and sex-related changes in the CSC diameter and CBR. The CSC has been the focus as a risk factor for CM [14,16]. However, in recent years, the CBR rather than CSC diameter has been reported to be a useful predictor for CM because of a magnification error resulting from the focus-to-film distance and the object-film distance on MRI [17]. However, Blackley et al. [18] showed that there is currently a poor correlation between the CBR and the true sagittal diameter of the spinal canal on computed tomography scans because of the wide normal variations in the diameter of the vertebral body. Therefore, the characteristics of the variations between the CSC diameter and the CBR should be considered. Of note, the present study found the CSC diameter to be higher in men than in women. However, the CBR was higher in women than in men, which is the reason for the increased diameter of the vertebral body in men. Therefore, the differences between the sexes should be taken into account when considering the CBR as a risk factor for CM.

Study limitations

The present study had several limitations. First, although more than 1,000 participants were included in the present study, these participants may not represent the general population because they were recruited from only two areas of Japan. However, anthropometric measurements were compared between the participants of the present study and the general Japanese population [19], and no significant differences in BMI were found between the participants in the present study and the Japanese population at large in both sexes (BMI [standard deviation] in men: 23.71 kg/m^2 [3.41 kg/m^2] and 23.95 kg/m^2 [2.64 kg/m^2], p=.33, respectively; BMI [standard deviation] in women: 23.06 kg/m^2 [3.42 kg/m^2] and 23.50 kg/m^2 [3.69 kg/m^2], p=.07, respectively). Second, the distribution of the CSC diameter applies to only a small portion of the Japanese population and cannot be extrapolated to other populations.

Conclusions

This study confirmed the significant association of the narrow CSC diameter with CM in a population-based cohort. The results prompt future studies to look into the various factors affecting the dimensions of the CSC, apart from aging.

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