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ORIGINAL ARTICLE

Is musculoskeletal pain related to locomotive syndrome even in young and middle-aged adults?

Toshihiro Kato[a,b], Akinobu Nishimura[b], Makoto Ohtsuki[c], Yusuke Wakasugi[c], Rie Nagao-Nishiwaki[d], Aki Fukuda[e], Ko Kato[e] and Akihiro Sudo[f]

[a]Department of Rehabilitation, Suzuka Kaisei Hospital, Kameyama, Japan; [b]Department of Orthopaedic and Sports Medicine, Mie University Graduate School of Medicine, Tsu City, Japan; [c]Faculty of Health Science, Department of Clinical Nutrition, Suzuka University of Medical Science, Suzuka, Japan; [d]Faculty of Health Science, Department of Nursing, Suzuka University of Medical Science, Suzuka, Japan; [e]Department of Orthopaedic Surgery, Suzuka Kaisei Hospital, Kameyama, Japan; [f]Department of Orthopaedic Surgery, Mie University Graduate School of Medicine, Tsu City, Japan

ABSTRACT

Objectives: Locomotive syndrome (LS) is the leading cause of persons needing long-term care in old age and is characterized by locomotive organ impairment including musculoskeletal pain. The aim was to examine the association between musculoskeletal pain and LS in young and middle-aged persons.

Methods: A total of 836 participants (male 667, female 169; mean age 44.4 years) were examined in this cross-sectional study. The LS was evaluated by three screening tools: the two-step test, the stand-up test, and the 25-question Geriatric Locomotive Function Scale. Musculoskeletal pain, exercise habits, physical function (walkability and muscle strength), and physical activity were also assessed.

Results: The LS was found in 22.8% of participants. The number with musculoskeletal pain was significantly higher in those with the LS. A significant correlation was found between the degree of musculoskeletal pain and exercise habits. Less regular exercise was significantly associated with higher LS prevalence. Physical activity and function were greater in participants with more regular exercise.

Conclusions: Musculoskeletal pain was significantly related to LS even in young and middle-aged persons. The present results suggest that control of musculoskeletal pain and improvement of exercise habits in young and middle-aged persons might help prevent the LS.

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Introduction

In recent years, Japan has rapidly become a super-aging society. The elderly population aged 65 years or older accounted for 27.3% of the entire population in 2016, and this percentage is expected to reach 39.9% in 2060 [1]. As a consequence, the number of people who need long-term care has also increased, and the cost of long-term care in 2016 was 2.8 times that in 2010 [2]. Research on labor and health by the Ministry of Health has shown that musculoskeletal system disorders (fractures caused by falls and joint disease) account for 23.2% of the total cases needing long-term care [3]. In 2007, locomotive syndrome (LS) was proposed by the Japanese Orthopedic Association [4] and defined as locomotive organ impairment that encompasses osteoporosis, osteoarthritis, spondylosis, and sarcopenia, which may occur with aging and may lead to the need for long-term care.

The percentage of community-dwelling elderly people with chronic knee pain and low back pain has been reported to be 53.2% and 52.5%, respectively [5]. Musculoskeletal pain is associated with impaired quality of life because of low physical activity levels and decreases in physical function [6]. Previous studies claimed that musculoskeletal pain is significantly related to the LS [7,8]. However, most previous studies of the LS have been conducted in community-dwelling elderly people [9–11], and there have been few published data about the LS in young and middle-aged adults [12,13]. From these studies [12,13], not a small number of young or middle-aged adults had the LS. Moreover, very little is known about the relationship between musculoskeletal pain and LS in young and middle-aged adults. Treatment approaches for pain with normal joints and mild osteoarthritis in young and middle-aged adults are easier and more efficient than those for pain with advanced osteoarthritis in old-age.

From this viewpoint, the status of musculoskeletal pain in young and middle-aged adults can play an important role in addressing the prevention of locomotive organ impairment and the need for long-term care in the future. The purpose of this study was to examine the associations among musculoskeletal pain, physical function, exercise habits, and LS in young and middle-aged adults.

CONTACT Akinobu Nishimura meiten@clin.medic.mie-u.ac.jp Department of Orthopaedic and Sports Medicine, Mie University Graduate School of Medicine, 2-174 Edobashi, Tsu City 514-8507, Japan

Materials and methods

This cross-sectional study was performed at five companies that were recruited by the public health department of Mie prefecture, Japan, between December 2015 and February 2018. The five companies included two drug companies (company A, 250 day-shift employees; company B, 124 day-shift employees), an office equipment manufacturing company (Company C, 258 day-shift employees), a chemical company (Company D, 275 day-shift employees), and an electronics company (Company E, 215 day-shift employees). Participants were excluded if they could not walk without aids (t-cane, crutch, wheelchair, etc.), had some sort of injury that would hinder exercise at the time of this survey, and were not able to participate in all assessments of the LS. Participation rates for companies A, B, C, D, and E were 74.4% (186/250), 77.4% (96/124), 75.2% (194/258), 83.3% (229/275), and 60.9% (131/215), respectively. In total, 836 (667 male, 169 female) workers participated in this study, and the response rate was 74.4% (836/1122). The participants consisted of various white-collar (75.6%) and blue-collar (24.6%) workers. This study met the guideline of the 2008 Helsinki Declaration of Human Rights and was approved by the Institutional Review Board of the author's affiliated institutions (approval number: No. 1574 at Mie University, No. 241 at the Suzuka University of Medical Science). Written, informed consent was obtained from each participant prior to study participation.

In this study, the participants completed a questionnaire before undergoing physical function tests. The questionnaire asked about age, sex, musculoskeletal pain, exercise habits, physical activity, and the 25-question Geriatric Locomotive Function Scale (GLFS-25). Musculoskeletal pain was defined by asking the following question about nine anatomical areas (neck, shoulder, upper extremity, lumbar region, hip, knee, ankle, foot, and other): have you experienced pain on most days (and continuously on at least one day) in the past month, in addition to the current pain? Participants who answered 'yes' in an anatomical area were considered to have musculoskeletal pain there [14]. As an assessment of exercise habits, the stages of exercise behavior changes were assessed using 5 items referring to actual exercise behavior performed both in the past and currently, and the condition of readiness for those exercise behaviors [15]. Participants were divided into stages as follows, according to The Process of Change Questionnaire developed by Oka [16]: (1) Precontemplation, (2) Contemplation, (3) Preparation, (4) Action, and (5) Maintenance. In precontemplation, people have no desire to change their exercise behavior and do not understand the need. They are not intending to change within 6 months. In contemplation, people understand the need but are not taking action. In preparation, people do exercise, but not regularly (more than twice a week). In action, people do regular exercise, but they are within 6 months of starting. In maintenance, people have been exercising regularly for more than 6 months. Physical activity was assessed using the International Physical Activity Questionnaire Short Form (IPAQ-SF) [17], which asks about the duration (minutes) and frequency (days) of walking (equivalent to 3.3 metabolic equivalents (METs)), moderate-intensity activities (equivalent to 4.0 METs), and vigorous-intensity activity (equivalent to 8.0 METs). An overall total physical activity MET-minutes/week (total physical activity) score can be computed as Total physical activity MET-minutes/week = sum of the total (Walking + Moderate + Vigorous) MET-minutes/week score. This total physical activity score was evaluated according to the 'Guidelines for Data Processing and Analysis of the International Physical Activity Questionnaire (IPAQ)' [18].

Physical functions were assessed using knee-extension force, gait speed, and step length. The knee-extension force was measured using the LocomoScan (ALCARE Co., Ltd.; Tokyo, Japan). A trial was performed for each leg, and the mean value of both legs was normalized by the subject's weight. The gait speed and step length were analyzed by WalkWay (Walk Way MW 1000; Anima, Tokyo, Japan). Anthropometric measures included height and weight, which were measured using the InnerScan 50V (TANITA Co., Tokyo, Japan). The body mass index (BMI) was calculated as weight (kg)/height (m^2). Q3

To evaluate the LS, the two-step test, stand-up test, and GLFS-25 were used [4]. The two-step test measures stride length. Participants start in a standing posture and then move two steps forward with maximum stride while being careful not to lose balance. The two-step score is calculated by normalizing the maximal length of the two steps taken for the subject's height. The stand-up test is performed with stools that are 10, 20, 30, and 40 cm in height. Participants are asked to stand up on one or both legs from each stool. The order of difficulty, from easy to difficult, is in the order of double-leg stand-up from 40, 30, 20, and 10-cm-high stools, followed by single-leg stand-up from 40, 30, 20, and 10-cm-high stools.

The GLFS-25 was developed by Seichi et al. [19]. It is a self-administered, comprehensive measure consisting of 25 items referring to the previous month in four subscales: pain (4 items), activities of daily living (16 items), social function (3 items), and mental health status (2 items). Each item is graded on a five-point scale from no impairment (0 point) to severe impairment (4 points), and the total score was used for determining the LS-risk level.

The risk of LS was determined according to Nakamura's report [4]. Participants who met all three of the following criteria were considered to not have the LS (LS stage 0): (a) two-step score $\geq$1.3; (b) ability to stand-up on a single-leg from a 40-cm-high stool with each of the legs in the stand-up test; and (c) GLFS-25 score <7. Participants who met any of the following three criteria were diagnosed as having LS stage 1: (a) two-step score <1.3; (b) difficulty standing-up on a single-leg from a 40-cm-high stool with each of the legs in the stand-up test; and (c) GLFS-25 score $\geq$7. Participants who met any of the following three criteria were diagnosed as having LS stage 2: (a) two-step score <1.1; (b) difficulty standing-up on both legs from a 20-cm-high stool in the stand-up test; and (c) GLFS-25 score $\geq$16. Participants were thus classified as No-LS (LS stage 0) or LS

(LS stage 1 or 2), and independent variables were compared between the groups.

Differences in continuous variables of anthropometric characteristics and background data between the No-LS and the LS groups were evaluated using the *t*-test, and the Chi-squared test was used to evaluate categorical variables. The Cochran–Armitage trend test was used to examine the presence of a linear trend between the LS and exercise habits. Adjusted standardized residuals were calculated, and stages that contributed to significant differences were determined based on an absolute value of 1.96. Logistic regression analysis was used to examine the associations among musculoskeletal pain, exercise habits, and the LS in young and middle-aged adults after adjusting for age, sex, and BMI. In this analysis, exercise habits were categorized as (1) Precontemplation, (2) Contemplation, (3) Preparation, (4) Action, and (5) Maintenance. Adjusted odds ratios (ORs), 95% confidence intervals (CIs), and standardized partial regression coefficient (β) values were calculated. The correlations among physical function, physical activity, and exercise habits were evaluated by multiple linear regression analysis adjusting for age, sex, and BMI. All data were analyzed using the Statistical Package for the Social Sciences (SPSS ver. 23; SPSS, Armonk, NY, USA), and they are expressed as means ± standard deviation. Significance was determined at a level of 5% for all tests.

Results

Anthropometric characteristics and background data of each group are shown in Table 1. The mean age of the 836 participants was 44.4 ± 10.3 years, and 169 (20.2%) participants were female. Of all participants, 22.8% were evaluated as having the LS (21.0% of males and 30.2% of females), with 157 having LS stage 1 and 34 having LS stage 2. The percentage of females was significantly higher than that of males in the LS group. Age and BMI were significantly greater in the LS group than in the No-LS group.

Figure 1 shows the prevalence of musculoskeletal pain in the nine anatomical areas, and 59.0% of persons had experienced musculoskeletal pain somewhere in their body. The common sites of pain were, in descending order, the neck (9.0% of No-LS and 24.6% of LS), shoulder (8.1% of No-LS and 23.0% of LS), lumbar region (16.4% of No-LS and 25.7% of LS), and knee (6.0% of No-LS and 12.0% of LS). The prevalence of neck, shoulder, lumbar, hip, and knee pain was significantly higher in the LS group than in the No-LS group. The total number of pain sites was

Table 1. Anthropometric characteristics and background data of each group.

		Total ($n = 836$)	No-LS ($n = 645$)	LS ($n = 191$)	*p*-Value
Age (years)		44.4 ± 10.3	43.8 ± 10.2	46.3 ± 10.3	**.003
Sex (*n*, %)	Male	667 (79.8%)	527 (81.7%)	140 (73.3%)	
	Female	169 (20.2%)	118 (18.3%)	51 (26.7%)	*.011
Height (cm)		168.1 ± 7.8	168.4 ± 7.5	167.1 ± 8.8	.085
Weight (kg)		67.1 ± 11.5	66.9 ± 11.0	67.9 ± 13.1	.348
BMI (kg/m^2)		23.7 ± 3.3	23.5 ± 7.5	24.2 ± 3.7	*.024
Occupation (*n*, %)	White collar	631 (75.6%)	494 (76.6%)	137 (71.7%)	
	Blue collar	205 (24.6%)	151 (23.4%)	54 (28.3%)	.170
Smoking (*n*, %)	Current smoker	207 (24.8%)	151 (23.4%)	56 (29.3%)	.097
AD (*n*, %))	Daily	196 (23.5%)	146 (22.6%)	50 (26.2%)	.310

*$p < 0.05$; **$p < .01$; ***$p < .001$.
Data presented as means ± standard deviation for age, height, weight, and body mass index (BMI). The differences in the values of age, height, weight, and BMI between the two groups were tested for significance using the *t*-test, and those of sex, occupation, smoking, and alcohol drinking (AD) were tested by the chi-squared test.
No-LS: locomotive syndrome stage 0; LS: locomotive syndrome stage 1 or 2; BMI: body mass index; AD: alcohol drinking; *n*: number.

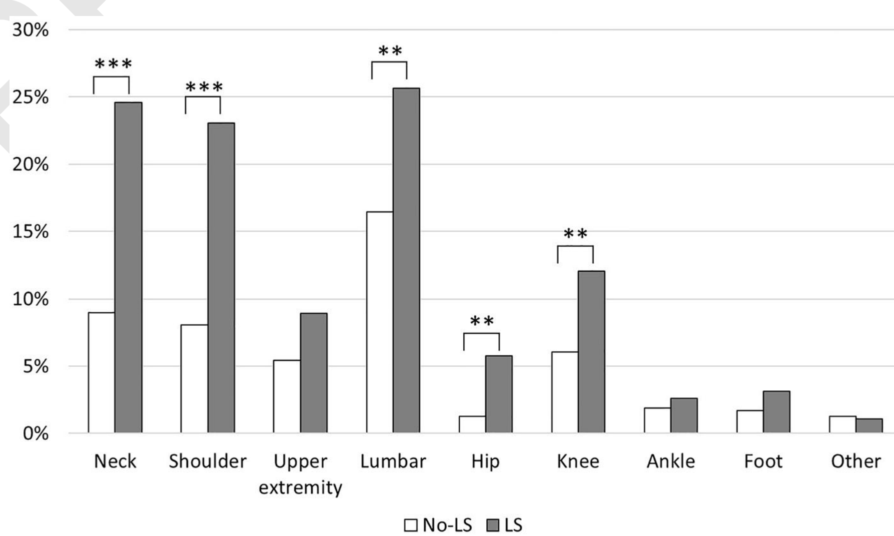

Figure 1. Prevalence of musculoskeletal pain in each anatomical area by group. No-LS: locomotive syndrome stage 0; LS: locomotive syndrome stage 1 or 2. *$p < .05$; **$p < .01$; ***$p < .001$.

Table 2. Prevalence of the locomotive syndrome by exercise habit stage.

	Exercise habit stage				
	1 ($n = 212$)	2 ($n = 238$)	3 ($n = 194$)	4 ($n = 37$)	5 ($n = 155$)
No-LS					
Number (n)	159	166	159	32	129
Prevalence rate (%)	75.0%	69.7%	82.0%	86.5%	83.2%
Adjusted standardized residual	−0.9	−3.2**	1.8	1.4	2.0*
LS					
Number (n)	53	72	35	5	26
Prevalence rate (%)	25.0%	30.3%	18.0%	13.5%	16.8%
Adjusted standardized residual	0.9	3.2**	−1.8	−1.4	−2.0*

*$p < .05$. **$p < .01$.
Ordered chi-squared test was used to calculate adjusted standardized residuals, and stages that contributed to significant differences were determined based on an absolute value of 1.96.
No-LS: locomotive syndrome stage 0; LS: locomotive syndrome stage 1 or 2.

Table 3. Relationships between the locomotive syndrome and musculoskeletal pain, physical functions, exercise habits, and physical activity score.

Independent variable	No-LS ($n = 645$)	LS ($n = 191$)	OR	95% CI	p-Value
Age (years)	43.8 ± 10.2	46.3 ± 10.3	1.022	1.004–1.040	.016*
Sex, male/female	527/118	140/51	1.802	1.183–2.746	.006**
BMI (kg/m^2)	23.5 ± 7.5	24.2 ± 3.7	1.071	1.016–1.129	.011*
Total number of pain sites (n)	0.51 ± 0.83	1.08 ± 1.14	1.768	1.494–2.093	<.001***
Knee-extension force (% weight)	80.8 ± 21.1	74.1 ± 21.9	0.986	0.978–0.995	.003**
Gait speed (cm/s)	129.5 ± 19.3	124.1 ± 19.9	0.989	0.974–1.004	.146
Step length (%height)	39.4 ± 4.1	38.4 ± 4.4	0.990	0.924–1.060	.772
Exercise habit stages, 1/2/3/4/5	159/166/159/32/129	53/72/35/5/26	0.873	0.764–0.996	.044*
Total physical activity score (MET-minutes/week)	1085.5 ± 1648.4	1103.2 ± 1936.9	1.000	1.000–1.000	.244

*$p < .05$; **$p < .01$; ***$p < .001$.
Ordered logistic regression was used to examine the associations between LS and musculoskeletal pain, physical functions, exercise habits, and physical activity score after adjusting for age, sex, and BMI. Exercise habits were categorized as 1: Precontemplation, 2: Contemplation, 3: Preparation, 4: Action, and 5: Maintenance.
No-LS: locomotive syndrome stage 0; LS: locomotive syndrome stage 1 or 2; BMI: body mass index; OR: odds ratio; CI: confidence interval.

Table 4. Comparisons of musculoskeletal pain, physical functions, exercise habits, and physical activity scores between locomotive syndrome stages 1 and 2.

Independent variable	LS1 ($n = 157$)	LS2 ($n = 34$)	OR	95% CI	p-Value
Age (years)	46.4 (9.9)	45.9 (12.2)	0.854	0.343–2.130	.736
Sex, male/female	114/43	8/26	0.999	0.959–1.039	.942
BMI	24.1 (3.7)	24.5 (3.9)	1.001	0.899–1.114	.985
Total number of pain sites	1.01 (1.1)	1.44 (1.3)	1.383	1.011–1.891	.042*
Knee-extension force, % weight	0.75 (0.2)	0.71 (0.3)	0.498	0.075–3.305	.471
Gait speed	125.5 (19.8)	117.7 (19.7)	1.005	0.973–1.037	.777
Step length, %height	0.39 (0.04)	0.37 (0.04)	0	0.000–9.335	.095
Stages of exercise behavior changes, 1/2/3/4/5	41/60/31/3/22	12/12/4/2/4	0.937	0.684–1.285	.688
Total physical activity score	340.5 (731.1)	618.8 (1126.3)	1.000	1.000–1.001	.249

*$p < .05$.
Ordered logistic regression analysis was used to examine the associations between LS and musculoskeletal pain, physical functions, exercise habits, and physical activity score after adjusting for age, sex, and BMI. Exercise habits were categorized as 1: Precontemplation, 2: Contemplation, 3: Preparation, 4: Action, and 5: Maintenance.
No-LS: locomotive syndrome stage 0; LS: locomotive syndrome stage 1 or 2; BMI: body mass index; OR: odds ratio; CI: confidence interval.

significantly higher in the LS group than in the No-LS group (0.5 ± 0.8 vs. 1.1 ± 1.1, $p < .001$).

Table 2 shows the rates of LS according to the stages of exercise behavior changes. The prevalence of the LS was 25.0%, 30.3%, 18.0%, 13.5%, and 16.8% in participants divided into the Precontemplation, Contemplation, Preparation, Action, and Maintenance stages, respectively. As the exercise behavior stage progressed, the prevalence of LS tended to decrease ($p = .004$ for trend). A significantly high LS prevalence in the contemplation stage and a low LS prevalence in the maintenance stage contributed to this significant trend.

The results for the relationships between the LS and musculoskeletal pain, physical functions, exercise habits, and physical activity score are shown in Table 3. The variables that emerged as predictors of the LS were female sex (OR = 1.802, 95% CI 1.183–2.746, $p = .006$), older age (OR = 1.022, 95% CI 1.004–1.040, $p = .016$), higher BMI (OR = 1.071, 95% CI 1.016–1.129, $p = .011$), the larger total number of pain sites (OR = 1.768, 95% CI 1.494–2.093, $p < .001$), lower knee-extension force (OR = 0.256, 95% CI 0.105–0.623, $p = .003$), and lower stage of exercise habits (OR = 0.873, 95% CI 0.764–0.996, $p = .044$). In addition, musculoskeletal pain emerged as a factor in the comparison of LS stage 1 and LS stage 2 (OR = 1.383, 95% CI 1.011–1.891, $p = .042$) (Table 4), and it also emerged as a factor related to the LS in the maintenance stage (OR = 1.668, 95% CI 1.075–2.586, $p = .022$) (Table 5).

Table 6 shows the correlations between physical function measures and exercise habits after adjusting for age, sex, and BMI. Knee-extension force ($\beta = 0.091$), gait speed ($\beta = 0.105$), step length ($\beta = 0.113$), and total physical

Table 5. Relationships between the locomotive syndrome and musculoskeletal pain, physical functions, and physical activity score in participants in the maintenance stage.

Independent variable	No-LS ($n = 129$)	LS ($n = 26$)	OR	95% CI	p-Value
Age (years)	44.2 ± 10.0	45.6 ± 12.1	1.007	0.960–1.057	.760
Sex, male/female	116/13	20/6	2.856	0.833–9.793	.095
BMI (kg/m^2)	23.8 ± 2.7	23.4 ± 4.4	0.987	0.843–1.155	.867
Total number of pain sites (n)	0.53 ± 0.83	1.00 ± 1.14	1.668	1.075–2.586	.022*
Knee-extension force (% weight)	83.0 ± 21.0	81.0 ± 19.6	0.602	0.062–5.889	.663
Gait speed (cm/s)	129.9 ± 20.0	131.2 ± 21.0	1.025	0.986–1.066	.206
Step length (%height)	39.8 ± 4.2	39.1 ± 4.8	0.000	0.000–36.352	.117
Total physical activity score (MET-minutes/week)	2237.9 ± 1865.5	2097.1 ± 1659.1	1.000	1.000–1.000	.931

*$p < .05$.
Ordered logistic regression was used to examine the associations between LS and musculoskeletal pain, physical functions, and physical activity score after adjusting for age, sex, and BMI.
No-LS: locomotive syndrome stage 0; LS: locomotive syndrome stage 1 or 2; BMI: body mass index; OR: odds ratio; CI: confidence interval.

Table 6. Correlations between exercise habits and physical functions and physical activity score.

	Exercise habit stage						
	1 ($n = 212$)	2 ($n = 238$)	3 ($n = 194$)	4 ($n = 37$)	5 ($n = 155$)	p-Value	Standard partial regression coefficient
Age (years)							
Sex							
BMI							
Knee-extension force (% weight)							
Crude	78.3 ± 20.3	77.0 ± 21.6	80.2 ± 22.4	81.8 ± 23.8	82.7 ± 20.9		
Adjusted	78.2 ± 20.4	76.9 ± 20.1	80.0 ± 20.9	81.3 ± 20.7	83.1 ± 21.2	.007**	0.091
Gait speed (cm/s)							
Crude	125.4 ± 19.4	127.4 ± 19.5	129.8 ± 18.7	134.0 ± 21.1	130.1 ± 20.3		
Adjusted	125.3 ± 19.5	127.2 ± 19.5	129.9 ± 19.5	134.4 ± 19.5	130.4 ± 19.5	.003**	0.105
Step length (%height)							
Crude	38.4 ± 3.9	39.2 ± 4.3	39.7 ± 4.1	39.4 ± 4.6	39.7 ± 4.3		
Adjusted	38.4 ± 4.4	39.1 ± 4.6	39.8 ± 4.2	39.5 ± 4.3	39.7 ± 3.7	.001**	0.113
Total physical activity score (MET-minutes/week)							
Crude	764.1 ± 1746.0	817.7 ± 1874.5	905.4 ± 1042.0	956.4 ± 732.8	2214.3 ± 1839.2		
Adjusted	787.6 ± 1626.8	843.3 ± 1628.9	882.6 ± 1626.6	918.8 ± 1626.5	2180.3 ± 1630.2	<.001***	0.259

*$p < .05$; **$p < .01$; ***$p < .001$.
Ordered multiple linear regression analysis was used to examine the associations between exercise habits and physical functions and physical activity scores after adjusting for age, sex, and BMI. The exercise habits were categorized as 1: Precontemplation, 2: Contemplation, 3: Preparation, 4: Action, and 5: Maintenance.
No-LS: locomotive syndrome stage 0; LS: locomotive syndrome stage 1 or 2; BMI: body mass index.

activity score ($\beta = 0.259$) were significantly correlated with exercise habits.

Discussion

In the present study, the relationships among musculoskeletal pain, physical function, exercise habits, and the LS were investigated in young and middle-aged adults who worked in companies. The present study showed that, first, the prevalence of musculoskeletal pain was higher in the LS group than in the No-LS group, and it was an important factor related to the LS. Second, for the prevalence rate of the LS classified according to exercise habits, lower stages of exercise were associated with a high prevalence rate of the LS, and exercise habits were one of the independent factors related to the LS. Finally, physical function and physical activity were significantly correlated with exercise habits.

Musculoskeletal pain is one of the most important factors in LS and the only factor of all the factors in this study that was associated with worsening of the LS stage. Yoshimura et al. [20] reported that the prevalence of knee pain was 32.7% (male 27.9% and female 35.1%), and that of low back pain was 37.7% (male 34.2% and female 39.4%) at 60 years or older in their cohort study. However, the average age of their subjects was 66.2 years. Matsudaira et al. [21] reported their epidemiological data on musculoskeletal symptoms in Japanese workers from their teens to 60s. Their subjects included nurses, office workers, sales/marketing personnel, and transportation workers, similar to the present participants. In Matsudaira et al.'s report, low back pain was the most prevalent work-related disease in Japanese workers. In the present study, low back pain was the most prevalent among nine anatomical site pains, which is consistent with the previous study [21]. Yoshimura reported that knee osteoarthritis and lumbar spondylosis as causes of pain co-existed in 42.0% of people [5]. Chiba et al. [22] reported that pain associated with the knee joint and lumbar spinal stenosis affected the GLFS-25 score. Several studies reported that, because the spine and knee joint play key roles in supporting the trunk upright, lumbar and/or lower extremity pain is the primary factor in locomotive disabilities [23]. Musculoskeletal pain is reported to be associated with lower extremity muscle strength [24] because it leads to inactivity [25]. From the present results, even in young and middle-aged adults, the LS was also related to musculoskeletal pain, as in elderly persons with LS.

Yoshimura et al. [26] reported the LS prevalence rate and the relationship between LS and exercise habits in the general Japanese population aged 20–69 years using the iOS application. In their study, the LS was more common in those who performed exercise less frequently than in those who performed exercise more frequently. Nishimura et al. [27] reported that people who exercised regularly in middle age had better physical function during their old age, and regular exercise in middle age appeared to protect against the LS in old age. These reports showed that good lifestyle habits including exercise are important for preventing the LS. In the present study, regular exercise was assessed by the stages of exercise behavior changes, which are used to treat diabetes mellitus [28], for smoking cessation [29], and to deal with stress [30]. In the present study, exercise was an independent factor related to the LS, and the LS prevalence rate was significantly higher in participants in the contemplation stage than in participants in other stages. For participants in the contemplation stage, it is important to provide information about the benefits of higher physical activity and the approach to improving exercise self-efficacy [31].

On the other hand, the LS prevalence rate was significantly lower in participants in the maintenance stage, the highest stage of exercise behavior, than among participants in other stages. The prevalence of the LS was relatively lower in participants in the action stage than in the maintenance stage in the present study, but not significantly so. The adjusted standardized residuals are calculated from the expected and observed values; the values may have been affected because there were fewer people in the action stage than in the other groups. Even in the maintenance stage, which should be the most desirable exercise habit stage, musculoskeletal pain was associated with the LS in the present study. The maintenance stage is the highest stage of this classification, so participants in the maintenance stage might include participants who have vigorous exercise habits. Some previous reports [32,33] showed that athletes had an increased prevalence of osteoarthritis, especially in their lower limbs. This might mean that some vigorous exercises might lead to osteoarthritis. Of the physical functioning factors in the present study, the total physical activity score was the most associated with improvement of the exercise habit. It is also important to advise participants in the maintenance stage about appropriate exercises. Several interventional studies for workers reported that chronic low back pain and work posture are improved by interventions according to their stage [34,35]. In the future, it is possible that interventions tailored to each stage could be effective for the prevention of the LS.

In the previous study of elderly people, good exercise habits were effective to maintain physical function [36]. In the present study, the physical function and total physical activity score adjusted by age, sex, and BMI correlated with exercise habit, and the average knee-extension force was significantly worse in the LS group than in the no-LS group. In general, age-related decreases of locomotor system function (which predisposes to compromised movement patterns [37] and loss of muscle strength [38]) lead to decreased walking ability. Therefore, good exercise habits are important to prevent and improve LS.

This study has several limitations that should be considered. First, the number of participants in this study was relatively small. In particular, the number of female participants was smaller than in previous epidemiological studies. Second, this was an occupational field-based, not population-based study design. Moreover, the participants in this study were workers. Therefore, caution should be exercised when generalizing these results to the general population of the same generation. Third, the current examination was not compulsory, but voluntary. Thus, participants in this study tended to be interested in their health and might be healthier than those who did not participate in this study (selection bias). Finally, in this study, participants who could not do physical function tests at the time of the survey were excluded for safety considerations.

In conclusion, a cross-sectional study was performed to examine the associations among musculoskeletal pain, physical function, exercise habits, and LS in young and middle-aged adults. Musculoskeletal pain was found to be a strong risk factor for the LS, and good exercise habits may prevent the LS from maintaining or improving physical function. Therefore, control of musculoskeletal pain and improvement of physical function (mobility function and muscle strength) can play important roles in preventing locomotive organ impairments even in young and middle-aged adults. However, since this was a cross-sectional study, causal relationships cannot be inferred. In the future, it will be necessary to examine whether musculoskeletal pain, decreased physical function, and poor exercise habits are the results of the LS or the cause of the LS in a longitudinal study.

Conflict of interest

None.

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ORCID

Akinobu Nishimura http://orcid.org/0000-0003-4353-0872

References

1. National Institute of Population and Social Security Research. Population projections for Japan: 2016-2065. Available from: http://www.ipss.go.jp/pp-zenkoku/j/zenkoku2017/pp29_ReportALL.pdf [last accessed 20 Mar 2020].

2. Health and Welfare Bureau for the Elderly Ministry of Health, Labour and Welfare. Long-term care insurance system of japan. Available from: https://www.mhlw.go.jp/english/policy/care-welfare/care-welfare-elderly/dl/ltcisj_e.pdf [last accessed 20 Mar 2020].
3. Ministry of Health, Labour and Welfare. The outline of the results of National livelihood survey. Available from: http://www.mhlw.go.jp/toukei/saikin/hw/k-tyosa/k-tyosa16/dl/05.pdf [last accessed 20 Mar 2020].
4. Nakamura K, Ogata T. Locomotive syndrome: definition and management. Clin Rev Bone Miner Metab. 2016;14:56–67.
5. Hirase T, Kataoka H, Inokuchi S, Nakano J, Sakamoto J, Okita M. Factors associated with chronic musculoskeletal pain in Japanese community-dwelling older adults: a cross-sectional study. Medicine. 2017;96(23):e7069.
6. Buchman AS, Shah RC, Leurgans SE, Boyle PA, Wilson RS, Bennett DA. Musculoskeletal pain and incident disability in community-dwelling older adults. Arthritis Care Res. 2010;62(9):1287–93.
7. Arbex MCFB, Okazaki JEF, Tavares DRB, Figueiredo Bersani AL, Santos FC. Locomotive syndrome is associated with chronic pain and poor quality of life in Brazilian oldest old: LOCOMOV Project. J Orthop Sci. 2021;26(1):162–6.
8. Nakatoh S. Relationships between chronic pain with locomotive syndrome and somatic symptom disorder in general community-dwelling population: a cross-sectional evaluation of individuals aged 50 years or older undergoing primary specific health screening. Mod Rheumatol. 2019;14:1–7.
9. Fukumori N, Yamamoto Y, Takegami M, Yamazaki S, Onishi Y, Sekiguchi M, et al. Association between hand-grip strength and depressive symptoms: locomotive Syndrome and Health Outcomes in Aizu Cohort Study (LOHAS). Age Ageing. 2015;44(4):592–8.
10. Tanaka S, Ando K, Kobayashi K, Hida T, Seki T, Suzuki K, et al. Relationship between locomotive syndrome and body composition among community-dwelling middle-age and elderly individuals in Japan: the Yakumo Study. Mod Rheumatol. 2019;29(3):491–5.
11. Yamada K, Muranaga S, Shinozaki T, Nakamura K, Tanaka S, Ogata T. Age independency of mobility decrease assessed using the Locomotive Syndrome Risk Test in elderly with disability: a cross-sectional study. BMC Geriatr. 2018;18(1):28.
12. Nishimura A, Ohtsuki M, Kato T, Nagao R, Ito N, Kato K, et al. Locomotive syndrome testing in young and middle adulthood. Mod Rheumatol. 2020;30(1):178–83.
13. Yamada K, Ito YM, Akagi M, Chosa E, Fuji T, Hirano K, et al. Reference values for the locomotive syndrome risk test quantifying mobility of 8681 adults aged 20-89 years: a cross-sectional nationwide study in Japan. J Orthop Sci. 2020;25(6):1084–92.
14. Muraki S, Akune T, Oka H, En-yo Y, Yoshida M, Saika A, et al. Association of radiographic and symptomatic knee osteoarthritis with health-related quality of life in a population-based cohort study in Japan: the ROAD study. Osteoarthritis Cartilage. 2010;18(9):1227–34.
15. Prochaska JO, Velicer WF, Rossi JS, Goldstein MG, Marcus BH, Rakowski W, et al. Stages of change and decisional balance for 12 problem behaviors. Health Psychol. 1994;13(1):39–46.
16. Oka K. [Stages of change for exercise behavior and self-efficacy for exercise among middle-aged adults.] Nihon Koshu Eisei Zasshi. 2003;50(3):208–15. Japanese.
17. Murase N, Katumura T, Ueda T, Inoue S, Shimomistu T. International standardization of the physical activity energy; reliability & validity evaluation of Japanese version International Physical Activity Questionnaire. Index of Public Welfare. 2002;49:1–9.
18. The IPAQ group. Guidelines for data processing and analysis of the International Physical Activity Questionnaire (IPAQ)–short and long forms. Available from: https://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnx0aGVpcGFxfGd4OjE0NDgxMDk3N-DU1YWRlZTM [last accessed 20 Mar 2020]
19. Seichi A, Hoshino Y, Doi T, Akai M, Tobimatsu Y, Iwaya T. Development of a screening tool for risk of locomotive syndrome in the elderly: the 25-question Geriatric Locomotive Function Scale. J Orthop Sci. 2012;17(2):163–72.
20. Yoshimura N, Nakamura K. Epidemiology of locomotive organ disorders and symptoms: an estimation using the population-based cohorts in Japan. Clin Rev Bone Miner Metab. 2016;14:68–73.
21. Matsudaira K, Palmer KT, Reading I, Hirai M, Yoshimura N, Coggon D. Prevalence and correlates of regional pain and associated disability in Japanese workers. Occup Environ Med. 2011;68(3):191–6.
22. Chiba D, Tsuda E, Wada K, Kumagai G, Sasaki E, Nawata A, et al. Lumbar spondylosis, lumbar spinal stenosis, knee pain, back muscle strength are associated with the locomotive syndrome: rural population study in Japan. J Orthop Sci. 2016;21(3):366–72.
23. Muraki S, Akune T, Oka H, En-Yo Y, Yoshida M, Saika A, et al. Impact of knee and low back pain on health-related quality of life in Japanese women: the Research on Osteoarthritis Against Disability (ROAD). Mod Rheumatol. 2010;20(5):444–51.
24. Kasukawa Y, Miyakoshi N, Hongo M, Ishikawa Y, Kudo D, Kijima H, et al. Lumbar spinal stenosis associated with progression of locomotive syndrome and lower extremity muscle weakness. Clin Interven Aging. 2019;14:1399–405.
25. Plooij B, Scherder EJ, Eggermont LH. Physical inactivity in aging and dementia: a review of its relationship to pain. J Clin Nurs. 2012;21(21–22):3002–8.
26. Yoshimura Y, Ishijima M, Ishibashi M, Liu L, Arikawa-Hirasawa E, Machida S, et al. A nationwide observational study of locomotive syndrome in Japan using the ResearchKit: the Locomonitor study. J Orthop Sci. 2019;24(6):1094–104.
27. Nishimura A, Ito N, Asanuma K, Akeda K, Ogura T, Sudo A. Do exercise habits during middle age affect locomotive syndrome in old age? Mod Rheumatol. 2018;28(2):334–8.
28. Tseng HM, Liao SF, Wen YP, Chuang YJ. Stages of change concept of the transtheoretical model for healthy eating links health literacy and diabetes knowledge to glycemic control in people with type 2 diabetes. Prim Care Diabetes. 2017;11(1):29–36.
29. Prochaska JO, DiClemente CC, Velicer WF, Rossi JS. Standardized, individualized, interactive, and personalized self-help programs for smoking cessation. Health Psychol. 1993;12(5):399–405.
30. Evers KE, Prochaska JO, Johnson JL, Mauriello LM, Padula JA, Prochaska JM. A randomized clinical trial of a population- and transtheoretical model-based stress-management intervention. Health Psychol. 2006;25(4):521–9.
31. Prochaska JO, Butterworth S, Redding CA, Burden V, Perrin N, Leo M, et al. Initial efficacy of MI, TTM tailoring and HRI's with multiple behaviors for employee health promotion. Prev Med. 2008;46(3):226–31.
32. Harris K, Driban JB, Sitler MR, Cattano NM, Hootman JM. Five-year clinical outcomes of a randomized trial of anterior cruciate ligament treatment strategies: an evidence-based practice paper. J Athl Train. 2015;50(1):110–2.
33. Gouttebarge V, Inklaar H, Backx F, Kerkhoffs G. Prevalence of osteoarthritis in former elite athletes: a systematic overview of the recent literature. Rheumatol Int. 2015;35(3):405–18.
34. Thanawat T, Nualnetr N. Effects of an intervention based on the Transtheoretical Model on back muscle endurance, physical function and pain in rice farmers with chronic low back pain. J Back Musculoskel Rehabili. 2017;30(4):847–56.
35. Moazzami Z, Dehdari T, Taghdisi MH, Soltanian A. Effect of an ergonomics-based educational intervention based on Transtheoretical Model in adopting correct body posture among operating room nurses. Global J Health Sci. 2015;8(7):26–34.

36. Han H, Pettee Gabriel K, Kohl HW. Application of the transtheoretical model to sedentary behaviors and its association with physical activity status. PLoS One. 2017;12(4): e0176330.
37. Beijersbergen CM, Granacher U, Vandervoort AA, DeVita P, Hortobágyi T. The biomechanical mechanism of how strength and power training improves walking speed in old adults remains unknown. Ageing Res Rev. 2013;12(2):618–27.
38. Korhonen MT, Mero AA, Alén M, Sipilä S, Häkkinen K, Liikavainio T, et al. Biomechanical and skeletal muscle determinants of maximum running speed with aging. Med Sci Sports Exerc. 2009;41(4):844–56.