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ORIGINAL ARTICLE

Examination of factors that lead to the transition of community-dwelling older adults to a state requiring support and care : A longitudinal study on factors influencing locomotive syndrome

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Abstract

Objective: This study aimed to clarify the factors that influence the temporal changes in the severity of the locomotive syndrome in community-dwelling older adults.

Methods: A cohort of 544 community residents who underwent physical examinations for two consecutive years were assessed for various parameters related to physical motor function and body composition, health-related quality of life (QOL) using questionnaires, activities of daily living, and dietary intake through surveys. The participants were divided into four groups based on the changes in the severity of the locomotive syndrome over time, and the factors that influenced the changes in the locomotive degree were examined.

Results: The factors identified as the causes of locomotive syndrome in healthy individuals were as follows: (1) high lower leg circumference, high bone density, and insufficient nutritional intake and insufficient nutritional intake; (2) diminished physical functions, including reduced walking speed and increased stumble frequency; and (3) psychological factors assessed in the 36-Item Short Form Survey (SF-36), and (4) time spent on medical consultations and treatments. The factors that alleviated locomotive syndrome included (1) protein intake and (2) psychological factors assessed in the SF-36.

Conclusion: Mobility of community-dwelling elderly is influenced by aging, nutritional status, physical function, and psychological factors. Vegetable protein intake and psychological health may contribute to improvement. These factors can help design interventions to maintain mobility.

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Key words: Older adults; living in the community; locomotive syndrome; care.

Introduction

The proportion of older adults aged ≥65 years in Japan is steadily increasing, with the older adult population in Aomori Prefecture reaching 34.9% in 2022[1]. The number of people requiring long-term support or care is also increasing. Factors such as, locomotive syndrome, and

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frailty contribute significantly to the demand for long-term care and support for older adults. Frailty and its causes encompass physical, cognitive, psychological, and social problems[2]. Locomotive syndrome, marked by a decline in the degree of independence in performing the activities of daily living (ADLs) due to locomotor organ-related diseases and disabilities, is closely related to frailty and sarcopenia, contributing to the need for long-term support and care[3-5].

Locomotive syndrome may be accompanied by pain due to aging, osteoporosis[6], and musculoskeletal diseases such as lumbar spinal stenosis and knee osteoarthritis[6, 7]. Chronic pain in the shoulders, hips, and knees is associated with the severity of the locomotive syndrome[8]. Therefore, the deliberate repetition of lifestyle habits that avoid pain-inducing exercise exacerbates the severity of the locomotive syndrome, and psychological factors are believed to play a role in this context. Locomotive syndrome is further influenced by high body mass index (BMI)[9, 10], exercise habits[9, 11], irregular eating habits[10, 11], smoking[12], drinking habits[10, 13], and high blood pressure[11].

Locomotive syndrome is greatly influenced by locomotor disorders and diseases, and daily exercise habits; however, the relationship extends beyond motor function to include nutritional status and mental and psychological factors. However, these studies only showed the relationship of the syndrome with individual elements, prompting the need for an exploration of multifactorial relationships. This includes considerations of nutritional status, social participation, and the impact of ADLs. Limited reports exist that specifically examine the factors influencing the symptoms of the locomotive syndrome, especially in terms of ADLs. Within this context, we believe that this study will contribute to preventing conditions that necessitate long-term support and care by preventing locomotive syndrome in the context of ADLs within the community.

The Iwaki Health Promotion Project Health Checkup (referred to as Iwaki Health Checkup)[14] is a large-scale health checkup for residents in collaboration with multiple professionals and is participated by several residents of the Iwaki district of Hirosaki City. We believe that elucidating these questions through the analysis of accumulated data across various fields will yield solutions to the challenges posed by locomotive syndrome.

This study aimed to investigate the status of locomotive syndrome and identify combinations of factors that significantly influence changes in the severity of the locomotive syndrome over time, including motor function, psychological factors, nutritional status, social participation, mental factors, and ADL factors.

Participants and Methods

1. Participants

A total of 846 residents of Iwaki District, Hirosaki City, who underwent the Iwaki Health Checkup for two consecutive years (2018 and 2019) were selected for this study. After excluding those who had missing data, only 544 individuals were analyzed. In accordance with the regulations of the Hirosaki University COI Data Management Committee, we ensured that the participants could easily comprehend the research topic and its outline by providing opt-out options. Additionally, the participants were afforded the opportunity to decline the utilization of their data.

This study was approved by the Hirosaki University Graduate School of Medicine Ethics Review Board and conducted in accordance with the ethical guidelines of the Declaration of Helsinki (approval number: 2023-111).

2. Methods

Data for this study were obtained through the use of a self-administered questionnaire conducted prior to the Iwaki Health Checkup in 2018 and 2019. The questionnaire covered various aspects, including health-related quality of life (QOL), depression/depressive state, dietary habits, physical motor function, and body composition measured during health checkups.

1) Self-administered questionnaire survey

a) Baseline

Key demographic information such as sex, age at the time of participation in 2019, most recent educational background, past medical history, hospitalization history, and surgical history were collected. Additionally, the participants' medical history in terms of bone and joint diseases, osteoporosis, and diabetes was explored.

The assessment of hospitalization history focused on whether the participants had previously required hospitalization for illness treatment. In relation to surgical history, the participants were asked about any previous surgeries undergone to treat an illness.

b) Medications status

We surveyed whether the participants were currently taking medications to treat illnesses or sleeping pills following the diagnoses of diabetes mellitus, osteoporosis, and rheumatoid arthritis by a doctor. Based on existing studies, diseases known to affect locomotive syndrome were selected for this survey. Notably, supplements and over-the-counter drugs were excluded from consideration.

c) Lifestyle habits

The participants were asked about their smoking and drinking frequency, exercise habits, and time spent on ADLs.

With regard to the time spent on ADLs[15], we utilized the questionnaire from the Basic Survey on Social Life conducted by the Ministry of Internal Affairs and Communications to evaluate the participants' personal errands, meals, commute to work/school, means of transportation (excluding commute to work/school), schoolwork, housework, nursing/caregiving, childcare, shopping, watching television/ listening to the radio/ reading the newspaper/reading magazines, rest/relaxation, learning/self-development/training, hobbies/entertainment, sports, volunteer activities/social participation activities, relationships/relationships, medical visits/recuperation, and other items. The participants were instructed to record the mean daily hours dedicated to each activity within a week. The time spent per week, derived from the participants' responses, was recorded as the time spent on ADLs (hours/week).

d) MOS 36-Item Short-Form Health Survey

QOL was evaluated using the 36-Item Short-Form Health Survey (SF-36)[16, 17], a scale designed for measuring health-related quality of life (HRQOL). The sub-items of the SF-36, including physical functioning (PF), role physical (RP), bodily pain (BP), general health (GH), vitality (VT), social functioning (SF), role emotional (RE), and mental health (MH), were rated from 0 to 100 points. The SF-36 provides a comprehensive evaluation of HRQOL, where higher scores indicate better HRQOL.

e) Lubben Social Network Scale-6

Social isolation was assessed using the Lubben Social Network Scale-6 (LSNS-6)[18, 19], a scale that screens social isolation in older adults. Scores ranged from 0 to 30 points, with higher scores indicating a larger social network and scores below 12 indicating social isolation. Data were categorized into the presence or absence of social isolation using the total score, or a cutoff score of ≤12 points was used for further analysis.

f) Dietary Survey (Brief-type self-administered Diet History Questionnaire)

To evaluate habitual dietary intake, the Brief-type self-administered Diet History

Questionnaire (BDHQ) was employed[20, 21], a simple self-administered dietary intake. The estimated daily intake (kcal, g/day) was determined for BDHQ crude data: estimated energy requirement (EER), energy (EN), weight (W), water (WTR), protein (PRT), animal protein, vegetable protein (VPRT), such as lipids, animal fats (FAT), vegetable fats (VFAT), and carbohydrates (CHO).

g) Locomo 25 items

Locomo 25[22] is a self-administered questionnaire encompassing domains such as body pain, difficulty in movement, activities of daily living, daily activities, social activities, and anxiety. A score of <7 points was indicative of a healthy status, 7–15 points denoted locomotive syndrome stage 1, 16–23 points denoted locomotive syndrome stage 2, and ≥ 24 points denoted locomotive syndrome stage 3.

h) Status of stumbles and falls

We conducted a questionnaire to ascertain the frequency of stumbles and falls among participants in the previous year. The participants were asked to indicate the number of times they stumbled or almost fell in their daily lives. Furthermore, the participants were asked to specify the total number of falls in their daily lives.

2) Measurement items

a) Baseline data

The patient's height, body W, waist size, and lower leg circumference were measured as baseline data. The circumference of the lower leg was measured at the position with the maximum circumference on both sides. The maximum value between the two sides was then utilized for analysis.

b) Physical function

To evaluate physical function, grip strength (left and right), long sitting posture, leg flexion/extension strength, TUG test, and maximum 10-meter walking time (10mWT) were measured. These items were measured twice, and the average values were calculated for each parameter.

Grip strength was measured using a grip dynamometer while the participant was in an upright position, alternating between the left and right sides. Decimal numbers were disregarded. To measure leg flexion and extension muscle strength, the participants sat on a measurement table, securing their pelvis and thighs with a belt to ensure that the knee joint was flexed at a 90° angle. The arm cushion of the measuring table was positioned to touch the upper part of the ankle joint. Using a tensiometer, the maximum isometric muscle strength for knee flexion and extension was measured twice for each participant. The timed-up-and-go (TUG) test comprised measuring the time (seconds) required for a participant to walk a 3-meter walking path with maximum effort from a seated position on a chair, and then turn around and sit down again (in seconds) twice. In the 10mWT, a 3-meter walking path was set up before and after a 10-meter walking path. The time (seconds) to walk along the middle of the 10-meter path with maximum effort was measured twice. In the 2018 checkup, measurements were performed using a stopwatch; during the 2019 checkup, measurements were performed using the gait measuring device Otasha 21 (Yagami Inc.). The average time for both the TUG test and 10mWT were calculated for each year, 2018 and 2019, based on the two measurements.

c) Bone density measurement

The Osteo Sono-Assessment Index (OSI) of the calcaneus was measured using the quantitative ultrasound method, while the bone density was calculated as the percentage of the average OSI for young adults, commonly referred to as the T-score[23, 24]. In principle, the measurement was performed on the right calcaneus, and the left calcaneus was used only when measurement could not be performed on the right calcaneus.

d) Stand-up test

The stand-up test was performed to evaluate the locomotive syndrome stage[25]. Locomotive syndrome stage 1 was identified if the participant was unable to stand up from a 40-cm platform with one leg but was able to stand up from a 20-cm platform with both legs. Locomotive syndrome stage 2 was identified if the participant was unable to stand up from a 20-cm platform with both legs but was able to stand up from a 30-cm platform. Locomotive syndrome stage 3 was identified if the participant was unable to stand up from a 30-cm platform with both legs. In cases other than those mentioned above, the patient was considered healthy.

e) Two-step test

A two-step test[26] was conducted to evaluate the locomotive syndrome.

The maximum two-step length was measured twice, and the maximum value was divided by height, which was defined as the two-step value. A two-step value of ≥1.3 indicated a healthy status, 1.1–1.3 denoted locomotive syndrome stage 1, 0.9–1.1 denoted locomotive syndrome stage 2, and <0.9 denoted locomotive syndrome stage 3.

f) Body composition

In terms of body composition, limb musculoskeletal mass, body WTR content, and extracellular WTR content were measured following the impedance method using InBody-770 (manufactured by InBody Japan). The extracellular WTR ratio was calculated from the body WTR content and extracellular WTR content. If the extracellular WTR ratio was ≥4.0, the patient was judged to have edema[27].

g) Presence of locomotive syndrome

The presence or absence of locomotive syndrome was determined by performing Locomo 25, a stand-up test, and a two-step test according to the criteria[3] proposed by the Japanese Orthopedic Association. If any single item aligned with locomotive syndrome stages 1–3, the participant was considered to have locomotive syndrome.

Statistical analysis

The participants were divided into four groups based on the change in locomotive syndrome from 2018 to 2019. ① Individuals who were judged to have no locomotive syndrome in 2018 and 2019 were defined as the maintaining health group (MH group). ② Individuals who were judged to have no locomotive syndrome in 2018 but developed it in 2019 were classified as the locomotive syndrome decline group (LD group). ③ Individuals who were judged to have locomotive syndrome in 2018 but no locomotive syndrome in 2019 were classified as the locomotive syndrome improvement group (LI group). ④ Individuals who had locomotive syndrome in 2018 and 2019 were classified as the maintaining locomotive syndrome group (ML group).

First, a one-way analysis of variance (ANOVA) and Kruskal-Wallis test were performed to explore the differences in the 2018 values of each item and the magnitude of change from 2018 to 2019 (computed by subtracting the 2018 values from the 2019 values) among the four study groups.

Subsequently, we investigated the factors influencing the changes in locomotive syndrome.

Second, among those who were judged to have no locomotive syndrome in 2018, individuals who did not have locomotive syndrome (MH group) after 1 year were compared with those who had locomotive syndrome (LD group) after 1 year. Multiple logistic regression analysis was performed using the division between the MH group and LD group as the dependent variable and the items for which significant differences were found in the above analysis as the independent variables.

Third, individuals who did not have locomotive syndrome in 2018 but had it in 2019 (LD group) were compared with those who had locomotive syndrome in 2018 but not in 2019 (LI). This analysis may help in thoroughly understanding the factors that influence changes in locomotive syndrome. Furthermore, a multiple logistic regression analysis was performed using the division between the LD and LI groups as the dependent variable and the items for which significant differences were found in the above analysis as the independent variables.

SPSS Ver. 24 (IBM Japan) was used to perform all statistical analyses, and the significance level for all tests was set at 5%.

Result

1. Analysis participants

The analysis participants included 201 in the MH group, 56 in the LD group, 48 in the LI group, and 239 in the ML group.

2. Results of intergroup comparisons based on changes in locomotive syndrome

The analysis of variance revealed significant differences in the following items during the 2018 health checkup when comparing the four groups ($p<0.05$): age, height, body W, grip strength (right/left), leg flexion/extension strength, TUG test, 10mWT, BDHQ EER/EN/CHO, SF-36 PF/RP/BP/GH/RE, bone density, LSNS-6, daily life commuting to work/school, childcare time, shopping time, and medical examination/recuperation time. In terms of the magnitude of change from 2018 to 2019, significant differences were observed in body W, leg flexion/extension strength, BDHQ (EER, EN, W, and WTR), and SF-36 (PF, RP, BP, GH, and VT) ($p<0.05$). Tables 1 and 2 present the descriptive statistical values for all groups and each group concerning the variables with significant differences found in the analysis of variance and related items.

3. Comparison between MH group and LD group

First, we explored the factors that cause healthy people to transition from a healthy state to locomotive syndrome. The results of the multiple logistic regression analysis with the MH and LD groups as dependent variables are shown in Table 3. Explanatory variables included items showing significant differences in the analysis of variance and related variables (age, height, weight, grip strength, lower limb flexor strength, lower limb extensor strength, TUG test, 10mWT, BDHQ, SF-36, and daily life time). The dependent variables, the MH group and LD group, were analyzed with the MH group coded as 0 and the LD group coded as 1.

As a result of the multiple logistic test of the MH group and LD group, the following items from the 2018 health checkup were extracted: age, SF-36 PF/SF/RP, 10mWT, BDHQ VPRT, lower leg circumference, consultation and treatment time in daily life, bone density, and number of stumbles. Additionally, the amount of change in body W; SF-36 BP, VT, and SF; and 10mWT from 2018 to 2019. The risk of developing locomotive syndrome increases when the 2018 age (odds ratio = 1.07), SF-36 RP (odds ratio = 1.06), 10mWT (odds ratio = 2.73), lower leg circumference (odds ratio = 1.17), daily life time consultation/recuperation time (odds ratio = 2.18), bone density (odds ratio = 1.04), and number of stumbles (odds ratio = 1.23) are higher. The risk of developing locomotive syndrome decreases when the 2018 SF-36 PF (odds ratio = 0.95) and SF (odds ratio = 0.97), and BDHQ VPRT (odds ratio = 0.93) are lower.

With regard to the amount of change from

Table 1. Value of each measured item in 2018 by change in locomotion level

		Item	Subjects n=544	MH group n=201	LD group n=56	LI group n=48	ML group n=239
2018		Age*	53.1 ± 14.4	47.8 ± 13.7	56.0 ± 12.6	53.0 ± 14.5	62.0 ± 13.3
		Height (cm)*	162.1 ± 8.5	163.4 ± 8.9	162.2 ± 8.1	162.0 ± 8.0	159.2 ± 8.7
		Weight (kg)*	52.3 ± 14.3	46.8 ± 13.7	55.0 ± 12.6	52.0 ± 14.5	61.0 ± 13.3
		Grip strength：right (kg)*	31.3 ± 9.3	33.5 ± 9.6	30.6 ± 9.3	31.6 ± 8.6	29.0 ± 8.8
		Grip strength：left (kg)*	30.5 ± 9.4	32.4 ± 9.9	30.4 ± 9.7	30.7 ± 8.5	28.0 ± 8.6
		Leg flexion strength (N)*	72.5 ± 27.4	79.5 ± 29.2	72.1 ± 25.6	72.8 ± 27.4	64.0 ± 23.7
		Leg extension strength (N)*	156.9 ± 67.0	171.9 ± 71.3	160.5 ± 69.3	158.8 ± 63.6	135.5 ± 58.2
		TUG test (sec)*	4.4 ± 0.7	4.1 ± 0.5	4.4 ± 0.6	4.4 ± 0.6	4.9 ± 1.1
		10mWT (sec)*	3.7 ± 0.8	3.5 ± 0.6	3.9 ± 0.8	3.7 ± 0.6	4.2 ± 0.9
	BDHQ	EER (kcal/a day)*	2180.1 ± 301.8	2261.1 ± 323.5	2171.4 ± 275.3	2165.7 ± 284.7	2051.4 ± 260.4
		EN (kcal/a day)*	1890.1 ± 569.4	1918.2 ± 541.3	1732.0 ± 468.3	2023.5 ± 598.0	1841.3 ± 608.1
		W (g/a day)	2134.3 ± 682.7	2135.2 ± 666.6	1977.3 ± 571.4	2341.7 ± 705.1	2095.1 ± 709.4
		WTR (g/a day)	1728.1 ± 585.7	1723.0 ± 578.0	1606.9 ± 494.2	1908.7 ± 604.3	1697.1 ± 599.1
		PRT (g/a day)	71.7 ± 26.3	71.3 ± 23.8	65.4 ± 21.4	76.4 ± 31.1	72.3 ± 28.4
		APRT (g/a day)	41.6 ± 20.7	41.0 ± 18.5	38.3 ± 17.1	43.9 ± 24.6	42.0 ± 21.5
		VPRT (g/a day)	30.1 ± 9.5	30.3 ± 9.2	27.2 ± 8.0	32.5 ± 10.6	30.3 ± 10.2
		FAT (g/a day)	54.7 ± 20.0	55.3 ± 18.9	50.5 ± 16.4	58.3 ± 21.2	53.7 ± 21.1
		AFAT (g/a day)	26.4 ± 12.2	26.4 ± 10.9	24.0 ± 9.7	28.2 ± 14.1	25.9 ± 13.0
		VFAT (g/a day)	28.3 ± 10.4	28.8 ± 10.3	26.5 ± 9.1	30.1 ± 10.1	27.8 ± 10.8
		CHO (g/a day)*	247.6 ± 80.6	254.3 ± 81.0	223.1 ± 76.7	259.7 ± 78.9	242.1 ± 81.0
	SF-36	PF*	91.7 ± 13.2	97.0 ± 8.4	92.5 ± 8.9	92.4 ± 10.3	80.8 ± 18.6
		RP*	93.3 ± 14.1	96.3 ± 10.9	95.5 ± 11.6	93.4 ± 11.3	85.0 ± 19.7
		BP*	71.6 ± 21.7	76.6 ± 19.2	75.6 ± 16.2	65.0 ± 23.2	63.9 ± 22.3
		GH*	61.2 ± 16.3	64.8 ± 15.5	63.0 ± 15.8	60.4 ± 16.3	54.5 ± 16.2
		VT	63.1 ± 18.0	63.7 ± 17.1	64.9 ± 18.7	62.9 ± 18.4	61.0 ± 18.9
		SF	92.1 ± 15.7	94.3 ± 12.6	87.5 ± 22.7	93.0 ± 12.9	90.7 ± 16.1
		RE*	93.1 ± 15.7	94.4 ± 13.7	92.3 ± 15.3	95.0 ± 15.8	88.1 ± 20.2
		MH	74.4 ± 17.3	75.1 ± 16.0	75.8 ± 16.4	74.9 ± 18.0	72.4 ± 18.2
		Bone density：T score (%)*	94.3 ± 12.4	95.1 ± 10.8	96.7 ± 13.8	95.9 ± 16.6	91.1 ± 12.0
		LSNS-6*	20.7 ± 11.4	21.4 ± 11.1	20.2 ± 8.4	19.7 ± 10.4	19.3 ± 12.6
	Daily life time (hour/day)	Personal affairs	6.9 ± 0.6	7.0 ± 0.3	6.8 ± 1.0	7.0 ± 0.0	6.9 ± 0.5
		Mealtime	7.0 ± 0.4	7.0 ± 0.0	6.9 ± 0.9	7.0 ± 0.0	7.0 ± 0.2
		Commuting time*	3.8 ± 2.8	4.3 ± 2.7	4.1 ± 2.9	3.5 ± 3.0	3.1 ± 3.0
		Travel time (excluding commuting time)	3.1 ± 2.7	3.4 ± 2.7	2.9 ± 2.7	2.9 ± 2.7	2.9 ± 2.8
		School hours	0.1 ± 0.5	0.1 ± 0.4	0.0 ± 0.0	0.2 ± 0.9	0.1 ± 0.6
		Housework	4.9 ± 3.0	4.8 ± 2.9	4.9 ± 3.1	5.4 ± 2.8	5.0 ± 2.9
		Nursing and care	0.4 ± 1.4	0.3 ± 1.2	0.5 ± 1.7	0.5 ± 1.6	0.5 ± 1.7
		Childcare*	1.2 ± 2.6	1.8 ± 3.0	0.9 ± 2.4	1.4 ± 2.8	0.7 ± 2.0
		Shopping*	2.5 ± 1.8	2.4 ± 1.8	2.7 ± 2.1	2.2 ± 1.5	2.8 ± 1.9
		TV, radio, newspaper, magazine	6.6 ± 1.5	6.5 ± 1.5	6.6 ± 1.5	6.6 ± 1.5	6.7 ± 1.4
		Vacation & Relaxation	4.9 ± 1.5	5.1 ± 2.7	4.3 ± 3.1	5.2 ± 2.8	4.7 ± 3.1
		Learning, self-development, training	0.5 ± 1.6	0.4 ± 1.4	0.4 ± 1.0	0.6 ± 1.6	0.7 ± 1.8
		Hobbies & Entertainment	1.9 ± 2.5	1.9 ± 2.6	1.6 ± 2.4	1.7 ± 2.6	1.9 ± 2.6
		Sport	0.7 ± 1.6	0.8 ± 1.6	0.6 ± 1.3	0.8 ± 2.0	0.6 ± 1.5
		Volunteer & Social Participation	0.1 ± 0.5	0.1 ± 0.5	0.1 ± 0.3	0.1 ± 0.5	0.1 ± 0.6
		Socializing	0.5 ± 1.0	0.5 ± 0.9	0.4 ± 0.6	0.5 ± 1.1	0.8 ± 1.4
		Consultation, Recuperation*	0.3 ± 0.6	0.2 ± 0.5	0.4 ± 0.7	0.3 ± 0.7	0.4 ± 0.9
		Other	0.0 ± 0.2	0.0 ± 0.2	0.0 ± 0.2	0.0 ± 0.0	0.0 ± 0.2

*The items with significant differences and their related items are listed ($p<0.05$)

MH group: the maintaining health group, LD group: the locomotive syndrome decline group

LI group: the locomotive syndrome improvement group, ML group: the maintaining locomotive syndrome group

Table 2. Value of change in each measure from 2018 to 2019 by change in locomotion level

		Item	Subjects n=544	MH group n=201	LD group n=56	LI group n=48	ML group n=239
The amount of change from 2018 to 2019		Weight (kg)*	8.7 ± 20.7	13.5 ± 20.7	7.1 ± 20.8	9.0 ± 19.8	−1.1 ± 20.4
		Leg flexion strength (N)*	87.5 ± 44.9	97.1 ± 47.7	82.1 ± 47.7	85.4 ± 40.8	76.9 ± 39.9
		Leg extension strength (N)*	−88.8 ± 48.9	−95.9 ± 50.3	−92.1 ± 49.6	−90.5 ± 48.7	−77.5 ± 45.5
	BDHQ	EER (kcal/day)*	−8.3 ± 24.1	−8.9 ± 34.6	−7.0 ± 5.6	−12.1 ± 35.4	−8.9 ± 5.4
		EN (kcal/day)*	−48.7 ± 416.9	−25.7 ± 363.8	62.7 ± 309.6	−152.3 ± 422.0	−45.2 ± 449.3
		W (g/day)*	−5.2 ± 486.7	31.8 ± 455.6	67.5 ± 372.4	−218.4 ± 524.1	−10.5 ± 503.2
		WTR (g/day)*	5.4 ± 419.1	37.4 ± 401.9	55.1 ± 330.1	−186.4 ± 450.7	−0.4 ± 424.2
		PRT (g/day)	−2.0 ± 19.8	−1.2 ± 16.9	3.2 ± 16.1	−6.7 ± 22.7	−2.3 ± 20.9
		APRT (g/day)	−1.3 ± 16.2	−0.6 ± 14.0	2.3 ± 14.1	−4.3 ± 18.7	−2.0 ± 16.9
		VPRT (g/day)	−0.7 ± 7.4	−0.6 ± 6.8	0.9 ± 6.3	−2.4 ± 7.9	−0.4 ± 7.9
		FAT (g/day)	−1.0 ± 7.4	−0.3 ± 14.2	1.9 ± 13.2	−5.4 ± 18.0	−0.8 ± 15.1
		AFAT (g/day)	−0.5 ± 10.4	−0.2 ± 8.9	1.7 ± 8.5	−2.6 ± 12.5	−0.4 ± 10.6
		VFAT (g/day)	−0.4 ± 8.2	−0.1 ± 8.4	0.2 ± 7.4	−2.8 ± 8.8	−0.4 ± 7.6
		CHO (g/day)	−7.1 ± 65.8	−3.5 ± 59.0	5.4 ± 55.4	−17.5 ± 73.2	−6.7 ± 69.7
	SF-36	PF*	−0.7 ± 12.0	0.2 ± 10.9	−5.4 ± 12.7	1.8 ± 9.0	−2.2 ± 14.6
		RP*	−1.7 ± 14.8	−0.9 ± 13.5	−8.8 ± 18.2	2.0 ± 10.6	−4.1 ± 19.6
		BP*	−1.2 ± 22.7	1.0 ± 21.0	−11.5 ± 19.2	6.9 ± 29.5	−3.7 ± 22.7
		GH*	−1.6 ± 12.7	−1.6 ± 12.1	−5.3 ± 12.4	1.2 ± 15.4	−0.7 ± 12.1
		VT*	−1.6 ± 15.3	0.0 ± 16.0	−6.9 ± 17.0	−0.1 ± 15.5	−2.7 ± 13.1
		SF	−0.9 ± 16.2	−1.7 ± 15.7	4.2 ± 20.4	−0.8 ± 15.8	−1.9 ± 16.9
		RE	−0.6 ± 16.2	0.1 ± 15.1	−2.2 ± 16.9	−4.2 ± 16.9	−1.5 ± 17.2
		MH	0.8 ± 14.6	1.3 ± 14.0	−0.5 ± 13.3	−2.2 ± 19.7	0.7 ± 12.8

*The items with significant differences and their related items are listed ($p<0.05$)
MH group: the maintaining health group, LD group: the locomotive syndrome decline group
LI group: the locomotive syndrome improvement group, ML group: the maintaining locomotive syndrome group

2018 to 2019, the risk of developing locomotive syndrome increases when the amount of change in SF-36 SF (odds ratio = 1.04) increases. The amount of risk of developing locomotive syndrome increases when the amount of change in body W (odds ratio = 0.98), SF-36 BP (odds ratio = 0.97) and VT (odds ratio = 0.96) decreases.

4. Comparison between the LD group and LI group

Next, to explore the factors that cause changes in people with locomotive syndrome decline and people with locomotive syndrome improvement, the results of the multiple logistic regression analysis with the LD and LI groups as dependent variables are shown in Table 4. Explanatory variables included items showing significant differences in the analysis of variance and related variables (age, height, weight, grip strength, lower limb flexor strength, lower limb extensor strength, TUG test, 10mWT, BDHQ, SF-36, and daily life time). The dependent variables, the LD group and LI group, were analyzed with the LI group coded as 0 and the LD group coded as 1. Following the multiple logistic regression analysis of the LD and LI groups, the BDHQ VPRT and SF-36 BP were extracted as items for 2018. Furthermore, the magnitude of change in SF-36 BP and VT from 2018 to 2019 were extracted. The risk of transitioning to locomotive syndrome decline increases when the 2018 SF-36 BP (odds ratio = 1.03) increases. The risk of transitioning to locomotive syndrome decline increases when the 2018 BDHQ VPRT (odds ratio = 0.94) decreases.

In terms of the amount of change from 2018 to 2019, the risk of developing locomotive syndrome increases when the amount of change in SF-36 BP (odds ratio = 0.97) and VT (odds ratio = 0.97) decreases.

Table 3. Factors affecting differences between MH and LD groups

dependent	independent (2018)	b	SE	Wald	p	odds ratio	95%CI Lower	Upper
MH(0)/LD(1)	intercept	−13.54	4.25	10.13	0.00	0.00		
	Age	0.06	0.02	15.25	0.00	1.07	1.03	1.10
	SF36：PF	−0.05	0.02	8.94	0.00	0.95	0.91	0.98
	SF36：RP	0.06	0.02	6.56	0.01	1.06	1.01	1.11
	SF36：SF	−0.03	0.01	7.14	0.01	0.97	0.95	0.99
	10mWT	1.01	0.33	9.13	0.00	2.73	1.42	5.25
	BDHQ：VPRT	−0.08	0.03	8.42	0.00	0.93	0.88	0.98
	Calf circumference	0.15	0.06	5.91	0.02	1.17	1.03	1.32
	Daily life time：consultation, recuperation	0.78	0.36	4.70	0.03	2.18	1.08	4.41
	Bone density (T score)	0.04	0.02	5.23	0.02	1.04	1.01	1.07
	Stumbling frequency	0.21	0.09	4.94	0.03	1.23	1.02	1.48

model chi square test p<0.01; Hosmer&Lemeshow's test p=0.409

dependent	independent (change from 2018 to 2019)	b	SE	Wald	p	odds ratio	95%CI Lower	Upper
MH(0)/LD(1)	interceppt	−1.25	0.27	20.60	0.00	0.29		
	Weight (kg)	−0.02	0.01	4.26	0.04	0.98	0.96	1.00
	SF36_BP	−0.03	0.01	12.99	0.00	0.97	0.95	0.98
	SF36_VT	−0.04	0.01	12.48	0.00	0.96	0.93	0.98
	SF36_SF	0.04	0.01	8.47	0.00	1.04	1.01	1.06
	10mWT	−0.60	0.36	2.79	0.09	0.55	0.27	1.11

model chi square test p<0.01; Hosmer&Lemeshow's test p=0.729

b: β estimate, SE: standard error, Wald: Wald statistics, df: degree of freedam, CI: confidence interval

MH group: the maintaining health group, LD group: the locomotive syndrome decline group

Dependent Variable: MH (0) / LD (1)

Independent Variables: Age, Height, Weight, Grip strength, Leg flexion strength, Leg extension strength, TUG test, 10mWT, BDHQ, SF-36, Daily life time

Discussion

1. Comparison between the MH group and LD group

When comparing the MH group and LD group, the subject's age in 2018; SF-36 PF, SF, and RP; 10mWT; BDHQ VPRT; lower leg circumference; daily life consultation/recuperation time; bone density; and the number of stumbles were associated with locomotive syndrome decline. Furthermore, the amount of change in body W; SF-36 BP, VT, and SF; and 10mWT from 2018 to 2019 were also associated with the decline.

The decline in physical ability and walking ability due to aging increases the risk of developing locomotive syndrome. The 10mWT is used as an index to evaluate walking ability and basic physical movement ability. The risk of locomotive syndrome increased as the 10mWT slowed down. A decrease in walking ability or maintaining a low walking speed signifies sustained low physical capacity, resulting in limitations in social engagement. In older adults, the risk of locomotive syndrome increases as the opportunities for social participation and exercise diminish. Moreover, a lower frequency of stumbles is associated with a reduced risk of injury from falls. It is considered that the MH group, with a high level of satisfaction with their physical function, is less likely to experience a change toward locomotive syndrome, as it leads to maintaining a high level of physical activity and continued social participation. The results also revealed that a minimal amount of change in body W corresponds to a higher risk of developing locomotive syndrome. A high BMI

Table 4. Factors affecting differences between LD and LI groups

dependent	independent (2018)	b	SE	Wald	p	odds ratio	95%CI Lower	95%CI Upper
LI(0)/LD(1)	intercept	0.10	1.03	0.01	0.92	1.11		
	BDHQ : VPRT	-0.07	0.02	7.12	0.01	0.94	0.89	0.98
	SF36 : BP	0.03	0.01	6.66	0.01	1.03	1.01	1.05

model chi square test p<0.01; Hosmer&Lemeshow's test p=0.657

dependent	independent (change from 2018 to 2019)	b	SE	Wald	p	odds ratio	95%CI Lower	95%CI Upper
LI(0)/LD(1)	intercept	0.28	0.36	0.60	0.44	1.32		
	Weight (kg)	0.00	0.01	0.11	0.74	1.00	0.97	1.02
	SF36 : BP	-0.04	0.01	9.11	0.00	0.97	0.94	0.99
	SF36 : VT	-0.03	0.01	5.27	0.02	0.97	0.94	0.99
	SF36 : SF	0.02	0.01	1.71	0.19	1.02	0.99	1.05
	10mWT	-0.71	0.45	2.50	0.11	0.49	0.20	1.19

model chi square test p<0.01; Hosmer&Lemeshow's test p=0.537

b: β estimate, SE: standard error, Wald: Wald statistics, df: degree of freedam, CI: confidence interval

LI group: the locomotive syndrome improvement group, LD group: the locomotive syndrome decline group

Dependent Variable: LI(0) / LD (1)

Independent Variables: Age, Height, Weight, Grip strength, Leg flexion strength, Leg extension strength, TUG test, 10mWT, BDHQ, SF-36, Daily life time

affects locomotive syndrome, and maintaining body W while having a high BMI is a factor that leads to the development of locomotive syndrome.

The lower leg circumference is used as an indicator of the presence of muscle atrophy. The circumference of the lower leg is proportional to musculoskeletal mass and nutritional status[27]. However, the study results showed that a greater lower leg circumference is associated with a higher risk of developing locomotive syndrome. Additionally, higher bone density is linked to an increased risk of developing locomotive syndrome. The measurement of lower leg circumference in older adults is significantly influenced by the amount of bone and subcutaneous fat. If the percentage of bone and subcutaneous fat in the lower leg at the measurement site is high and muscle mass is low, the locomotive syndrome may develop despite a high lower leg circumference, but this is a matter of conjecture and requires further investigation. In terms of nutrition, a higher intake of VPRT may reduce the risk of developing locomotive syndrome. Protein intake is recommended for preventing locomotive syndrome, highlighting the importance of dietary habits that conscientiously increase VPRT intake in daily meals.

In the SF-36, a higher level of satisfaction with social functions correlates with a lower risk of developing locomotive syndrome. The risk of locomotive syndrome can be reduced by maintaining social networks without hindering interactions with family, acquaintances, and friends. Individuals who perceive no physical issues with their role functions are at a greater risk of developing locomotive syndrome. This suggests that individuals may find satisfaction in their role functions despite being less physically active. Consequently, we believe that their locomotive syndrome stage tends to be low due to the challenges they face in adopting new exercise habits or engaging in social activities. The minimal changes in body pain and vitality on the SF-36 are associated with a higher risk of developing locomotive syndrome. Persistent pain hindering work, coupled with low energy on the BDHQ and persistent fatigue without improvement, may contribute to a reduction in social activities and the amount of activity. We believe that the reduction in social activities and the amount of activity is associated with the development of locomotive syndrome. A greater amount of change in SF-36 social function is linked to a higher risk of developing locomotive syndrome. A significant improvement in social functioning may be attributed to using social support to compensate for physical function or health status declines. In such cases, increasing social activities and interactions does not necessarily indicate a health improvement.

2. Comparison of LD group and LI group

When comparing the LD group and LI group, the 2018 BDHQ VPRT and SF-36 BP were extracted as factors associated with a decrease in locomotive syndrome. Furthermore, the magnitude of change in SF-36 BP, and VT from 2018 to 2019 were also shown to be associated factors.

Less body pain based on the response to the SF-36 was a factor associated with an increased risk of locomotive syndrome. Minimal changes in body pain and vitality on the SF-36 were factors associated with improvement in locomotive syndrome. Less pain in daily life indicates that the pain experienced by the individual does not interfere with their daily life, enabling the maintenance of ADLs and social participation. However, even if there is pain, if a person can maintain an activity level that does not lead to locomotive syndrome within a manageable range, or if a person has locomotive syndrome but experiences less pain due to the chronicity of pain or decreased activity, a high score on Body Pain on the SF-36 may indicate an increased risk of locomotive syndrome. In addition, locomotive symptoms are likely to improve by maintaining a high level of vitality. A minimal change in social function, assessed based on the responses to the SF-36, has also been linked to improvements in the symptoms of the locomotive syndrome. Maintaining social interactions without altering relationships with family, friends, and peers within a manageable range that does not increase pain is considered to contribute to the improvement of locomotive syndrome symptoms.

In terms of nutrition, it is necessary to be mindful of incorporating VPRT in daily diet to improve the locomotive syndrome stage. Additionally, maintaining awareness of the appropriate protein intake is necessary to avoid loss of muscle mass resulting from insufficient intake of protein.

This study had some limitations. The participants were community-dwelling health checkup attendees and may have a higher awareness of health, which requires caution when generalizing the findings. Also, not accounting for sex differences does not adequately reflect the impact of sex differences on the risk and progression of locomotive syndrome and may introduce bias in the interpretation of results, limiting the accuracy and generalizability of the conclusions. Furthermore, since the data were collected before the COVID-19 pandemic, lifestyle changes should also be considered, necessitating further investigations with the inclusion of more recent data.

Conclusion

The factors contributing to the development of locomotive syndrome in healthy encompass (1) high lower leg circumference, high bone density, and insufficient nutritional intake; (2) deterioration in physical functions, including reduced walking speed and increased frequency of stumbles; (3) psychological factors identified in the SF-36; and (4) the duration of consultations and treatments. Conversely, the factors associated with an improvement in locomotive syndrome include (1) increased protein intake and (2) positive psychological factors identified in the SF-36. Particularly in Aomori Prefecture, environmental constraints such as snowfall and frozen roads during the winter may restrict activity. Therefore, it is establish safe opportunities for exercise and social participation. Nutritionally, special attention should be given to enhancing VPRT intake in daily life. Among older adults, declining physical function and pain limit the amount of activity and reduce opportunities for social participation, leading to social isolation. To address locomotive syndrome effectively, it is crucial to cultivate sustainable exercise habits, improve lifestyle habits, and maintain and improve eating habits that revolve around the intake of plant protein, ultimately enhancing health-related QOL and alleviating body pain.

Conflict of interest

The authors declare that they have no conflicts of interest.

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References

1) Aomori Prefectural Office, Aomori Prefectural Planning and Policy Department: Population of Aomori Prefecture in 2022. https://opendata.pref.aomori.lg.jp/dataset/1740.html(reference: 10/04/2023)

2) Ono R, et al.: Reciprocal relationship between locomotive syndrome and social frailty in older adults. Geriatr Gerontol Int. 2021;21(11):981-4.

3) Nakamura K, Ogata T: Locomotive syndrome: definition and management. Clin Rev Bone Miner Metab. 2016;14(2):56-67.

4) Nishimura A, et al.: Locomotive syndrome testing in young and middle adulthood. Mod Rheumatol. 2020;30(1):178-83.

5) Iwamoto Y, et al.: Interventions to improve locomotive syndrome: a systematic review and meta-analysis of randomized controlled trials. Nagoya J Med Sci. 2023;85(2):275-88.

6) Akahane M, et al.: The impact of musculoskeletal diseases on the presence of locomotive syndrome. Mod Rheumatol. 2019;29:151-6.

7) Chiba D, 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;21:366-72.

8) Iizuka Y, et al.: Population-based study of the association of osteoporosis and chronic musculoskeletal pain and locomotive syndrome: the Katashina study. J Orthop Sci. 2015;20:1085-9.

9) Yoshimura Y, et al.: A nationwide observational study of locomotive syndrome in Japan using the ResearchKit: the Locomonitor study. J Orthop Sci. 2019;24:1094-104.

10) Ohtsuki M, et al.: Relationships between body mass index, lifestyle habits, and locomotive syndrome in young-and middle-aged adults: a cross-sectional survey of workers in Japan. J Occup Health. 2019;61:311-9.

11) Yoshinaga S, et al.: Lifestyle-related signs of locomotive syndrome in the general Japanese population: a cross-sectional study. J Orthop Sci. 2019;24:1105-9.

12) Akahane M, et al.: Lifestyle factors are significantly associated with the locomotive syndrome: a cross-sectional study. BMC Geriatr. 2017;17:241.

13) Zhu K, Prince RL: lifestyle and osteoporosis. Curr Osteoporos Rep. 2015;13:52-9.

14) Shigeyuki Nakaji, et.al.: Social innovation for life expectancy extension utilizing a platform-centered system used in the Iwaki health promotion project: a protocol paper. SAGE Open Med. 2021;19:1-13.

15) Statistics Bureau, Ministry of Internal Affairs and Communications: Overview of the 2021 Social Life Basic Survey. https://www.stat.go.jp/data/shakai/2021/gaiyou.html (Reference: 12/10/2023)

16) Fukuhara S, Bito S, Green J, Hsiao A, Kurokawa K. Translation, adaptation, and validation of the SF-36 Health Survey for use in Japan. J Clin Epidemiol. 1998;51:1037-44.

17) Fukuhara S, Ware JE, Kosinski M, Wada S, Gandek B. Psychometric and clinical tests of validity of the Japanese SF-36 Health Survey. J Clin Epidemiol. 1998;51:1045-53.

18) Lubben J, et al.: Performance of an abbreviated version of the Lubben Social Network Scale among three European community-dwelling older adult populations. Gerontologist. 2006;46:503-13.

19) Kurimoto A, et al.: Reliability and validity of the Japanese version of the abbreviated Lubben Social Network Scale. Jpn J Geriatr. 2011;48:149-57.

20) Kobayashi S, Murakami K, Sasaki S, et al. Comparison of relative validity of food group intakes estimated by comprehensive and brief-type self-administered diet history questionnaires against 16 d dietary records in Japanese adults. Public Health Nutr. 2011;14:1200-11.

21) Kobayashi S, Honda S, Murakami K, et al. Both comprehensive and brief self-administered diet history questionnaires satisfactorily rank nutrient intakes in Japanese adults. J Epidemiol. 2012;22:151-9.

22) Seichi A, et al.: Development of a screening tool for risk of locomotive syndrome in the elderly: the 25-question Geriatric Locomotive Function Scale. J Orthop Sci. 2012;17:163-72.

23) Tsuda-Futami E, et al.: An evaluation of a new gel-coupled ultrasound device for the quantitative assessment of bone. Br J Radiol. 1999;72:691-700.

24) Morita R, et al.: Quantitative ultrasound for the assessment of bone status. Osteoporos Int. 1997;7:128-34.

25) Muranaga S: Evaluation of the muscular strength of the lower extremities using the standing movement and clinical application. J Showa Med Assoc. 2001;61:362-7.

26) Muranaga S, Hirano K: Development of a convenient way to predict ability to walk, using a two-step test. J Showa Med Assoc. 2003;63(3):301-8.

27) Minoru Yamada: Management of sarcopenia in clinical setting. Jpn J Geriatr. 2021;58:175-82.