Journal of Bone and Mineral Metabolism (2019) 37:1058–1066
https://doi.org/10.1007/s00774-019-01012-0

ORIGINAL ARTICLE

Prevalence and co-existence of locomotive syndrome, sarcopenia, and frailty: the third survey of Research on Osteoarthritis/Osteoporosis Against Disability (ROAD) study

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Received: 13 February 2019 / Accepted: 19 May 2019 / Published online: 20 June 2019

Abstract

This study aimed to estimate the prevalence of locomotive syndrome, sarcopenia, and frailty and clarify their co-existence in a population-based cohort. The third survey of Research on Osteoarthritis/Osteoporosis Against Disability (ROAD) study was conducted between 2012 and 2013, examining 963 subjects (aged ≥ 60 years; 321 men, 642 women). Locomotive syndrome, sarcopenia, and frailty were defined using three tests proposed by Japanese Orthopaedic Association, Asian Working Group for Sarcopenia criteria, and Fried's definition, respectively. Prevalence of locomotive syndrome stages 1 and 2 were 81.0% (men, 80.4%; women, 81.3%) and 34.1% (men, 30.5%; women, 35.8%), respectively, and those of sarcopenia and frailty were 8.7% (men, 9.7%; women, 8.3%) and 4.5% (men, 2.8%; women, 5.3%), respectively. Locomotive syndrome stage 1, sarcopenia, and frailty co-existed in 2.1%; 6.5% had locomotive syndrome stage 1 and sarcopenia, 2.4% had locomotive syndrome stage 1 and frailty, while none had sarcopenia and frailty. Locomotive syndrome stage 1 presented alone in 70.0%, sarcopenia in 0.1%, and no frailty. The remaining 18.9% had none of these conditions. Co-existence of locomotive syndrome stage 2, sarcopenia, and frailty was observed in 2.0%; 5.0% had locomotive syndrome stage 2 and sarcopenia, 2.2% had locomotive syndrome stage 2 and frailty, and 0.1% had sarcopenia and frailty. Locomotive syndrome stage 2, sarcopenia, and frailty alone, presented in 24.9%, 1.7%, and 0.2%, respectively. The remaining 64.0% had none of these conditions. Most subjects with sarcopenia and/or frailty also had locomotive syndrome. Preventing locomotive syndrome may help prevent frailty and sarcopenia and subsequent disability.

Keywords Disability · Locomotive syndrome · Sarcopenia · Frailty · Co-existence

Introduction

According to the recent National Livelihood Survey by the Ministry of Health, Labour, and Welfare, Japan, frailty is the third leading cause of disability requiring support or long-term care, followed by dementia and cardiovascular disease

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00774-019-01012-0) contains supplementary material, which is available to authorized users.

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[1]. Fried et al. first defined frailty as a clinical syndrome comprising five variables: unintentional weight loss, self-reported exhaustion, low physical activity, weakness (low grip strength), and slowness (low walking speed) [2]. Older persons with three or more of these five factors are considered frail, those with one or two as pre-frail, and those with none as non-frail or robust.

Sarcopenia (SP) is characterized by generalized loss of skeletal muscle mass as well as muscle strength and/or function, causing multiple adverse health outcomes, including physical disability, poor quality of life, and mortality [3–8]. The European Working Group on Sarcopenia in Older People (EWGSOP) developed a practical clinical definition as well as diagnostic criteria for SP in 2010, and a revised version (EWGSOP2) was published in 2018 [8, 9]. After the publication of the EWGSOP consensus criteria, the Asian Working Group for Sarcopenia (AWGS) established diagnostic cut-off values for Asian populations [10]. Two of the three SP criteria, namely, muscle strength and function, overlap with two of the five criteria of frailty, suggesting that SP and frailty are strongly associated.

Moreover, in the above-mentioned National Livelihood Survey, osteoporotic fractures and falls were ranked the fourth, while osteoarthritis was ranked the fifth cause of disability requiring support or long-term care [1]. Musculoskeletal diseases including osteoporosis and osteoarthritis can affect mobile function, activities of daily living, and consequently, the quality of life. In this context, the Japanese Orthopaedic Association (JOA) proposed the term 'locomotive syndrome' to designate a condition requiring nursing care or the risk of developing such a condition, following a decline in mobility resulting from one or more disorders of the locomotive organs, which include the bones, joints, muscles, and nerves [11]. The weakness of locomotive organs causes difficulty in mobility—defined as the ability to stand, walk, run, climb stairs, and perform other physical functions essential to daily life. Therefore, to assess the risk of developing locomotive syndrome, in 2013, the JOA proposed the following three tests as candidate indices: the two-step test, stand-up test, and 25-question geriatric locomotive function scale (GLFS) [12]. Furthermore, the JOA determined the clinical decision limits of these indices for assessing the risk of locomotive syndrome [13].

To prevent disability, it is important to examine epidemiological indices, such as the prevalence of diseases that result in disability. Since older people are known to have multiple disorders that could cause disability, any effort to draft prevention and management strategies must begin by considering mutual associations of the causes of disability. However, little information is available regarding interaction between the diseases leading to disability, such as locomotive syndrome, SP, and frailty because only a few population-based studies have yet been conducted in this context.

The Research on Osteoarthritis/Osteoporosis Against Disability (ROAD) study began in 2005–2007 and is a prospective cohort study that aims to elucidate the environmental and genetic background of bone and joint diseases. It was designed to examine the extent to which risk factors of these diseases are related to clinical features, laboratory and radiographic findings, bone mass and geometry, lifestyle, nutritional factors, anthropometric and neuromuscular measurements, as well as fall propensity [14, 15]. The 3-year follow-up (second survey) of the ROAD study was conducted on individuals of the same communities in 2008–2010, the 7-year follow-up (third survey) in 2012–2013, and the 10-year follow-up (fourth survey) in 2015–2016.

In the present study, we examined the co-existence of locomotive syndrome, SP, and frailty, based on the data of individuals in whom all measurements relevant to the diagnosis of such disorders were collected in the third survey of the ROAD study conducted in 2012–2013.

Materials and methods

Study participants

The present study was conducted in the ROAD study cohorts that were established in 2005. The ROAD study is a national, prospective study of osteoarthritis that consists of population-based cohorts from several communities in Japan. Details of the cohort profiles have been reported elsewhere [14, 15]. Briefly, a baseline database was created between 2005 and 2007 that included the clinical and genetic information of 3040 residents. This included 1061 men and 1979 women with a mean age of 70.3 [standard deviation (SD), 11.0] years. The mean age of men was 71.0 (SD, 10.7) years and that of women was 69.9 (SD, 11.2) years. Subjects were recruited from resident registration listings in three communities with diverse backgrounds: 1350 subjects from an urban region in Itabashi, Tokyo; 864 subjects from a mountainous region in Hidakagawa, Wakayama; and 826 subjects from a coastal region in Taiji, Wakayama.

After the baseline study, a second survey was conducted in the same communities from 2008 to 2010 [16]. This was followed by the third survey, which was conducted between 2012 and 2013 [17, 18] and only included the cohorts in the mountainous and coastal regions. These were composed of 1575 participants (513 men, 1,062 women) in whom physical examination for locomotive syndrome [19], SP, and frailty was performed. Among them, 1336 subjects (438 men, 898 women) completed the questionnaire as well as all measurements required for the assessment of locomotive syndrome, SP, and frailty. Of these, we selected subjects aged ≥ 60 years based on the AWGS criteria for SP [10].

Consequently, 963 participants (321 men and, 642 women) were included in the current study.

All participants provided written informed consent before inclusion. The study was approved by the institutional ethics committees of the University of Tokyo (No. 1264 and No. 1326) and Wakayama Medical University (No. 373).

Examinations of the third survey of the ROAD study

Assessment of locomotive syndrome

As mentioned above, we used the following three tests proposed by the JOA [12].

Two-step test This test measured length of the stride to assess walking ability, including muscle strength, balance, and flexibility of the lower limbs. The procedure of the two-step test was as follows [12]: (1) subjects determined the starting line and stood with the toes of both feet behind it; (2) subjects were instructed to take two long steps (as long as possible), and then align both feet; and (3) the length of the two steps from the starting line to the tips of the subject's toes, where he/she stopped, was measured. The two-step test score was calculated using the following formula: length of the two steps (cm)/height (cm).

Stand-up test This test was used to assess leg strength by having the subject stand up on one or both legs from seats at four specified heights: 40, 30, 20, and 10 cm. The subject stood up from each seat (in descending order of height) first with both legs and then with one leg. If the subject could stand without leaning back to gain momentum and could maintain this posture for 3 s, he/she was considered to have passed that height test [12]. In the present study, a subject was considered to have failed this test if he/she was unable to stand on one leg (right or left) from a height of 40 cm.

25-question GLFS The 25-question GLFS was developed by Seichi et al. [20] and is a self-administered, comprehensive measure consisting of 25 items. These include four questions regarding history of pain during the last month, 16 questions concerning activities of daily living during the last month, three questions on social functions, and two questions pertaining to mental health status during the last month. These 25 items are graded on a five-point scale, from no impairment (0 points) to severe impairment (4 points) and arithmetically added to obtain a total score (minimum = 0, maximum = 100). Thus, a higher score is associated with worse locomotive function. Validity of the scale has been assessed and a cut-off point of 16 was determined to have the highest sensitivity and specificity in indicating disability resulting from locomotive syndrome (Supplemental Table 1) [12].

Based on the results of these tests, the clinical decision limits proposed by JOA for categorizing locomotor syndrome were as follows [13].

The criteria for locomotive syndrome stage 1 were as follows: (1) a two-step test score < 1.3, (2) difficulty rising on one leg from a 40-cm-high seat in the stand-up test (either leg), and (3) a 25-question GLFS score ≥ 7. When a subject met any of these conditions, he/she was diagnosed with locomotive syndrome stage 1, indicating the beginning of decline in mobility.

The criteria for locomotive syndrome stage 2 were as follows: (1) a two-step test score < 1.1, (2) difficulty rising on both legs from a 20-cm-high seat in the stand-up test, and (3) a 25-question GLFS score ≥ 16. Any participant who met these conditions was diagnosed with locomotive syndrome stage 2, indicating progression towards decline in mobility.

Assessment of SP

We defined SP based on the following recommended cut-off values of skeletal muscle mass according to the AGWS report [10]:

1. Age 60 or 65 years as the age for SP diagnosis according to the definitions of elderly in each country;
2. Low appendicular skeletal muscle mass: 7.0 kg/m^2 for men and 5.7 kg/m^2 for women using bioimpedance analysis;
3. Low handgrip strength: < 26 kg for men and < 18 kg for women;
4. Low gait speed: usual gait speed ≤ 0.8 m/s.

In the present study, we considered subjects ≥ 60 years old as having SP if they had a low skeletal muscle mass with either low handgrip strength or low gait speed. Handgrip strength, walking speed, and muscle mass were measured as follows.

Handgrip strength and walking speed Handgrip strength was measured using a handgrip dynamometer (Toei Light Co., Ltd., Saitama, Japan). Both hands were tested, and the larger value was noted as the maximum muscle strength. As an index of muscle function, the usual walking speed was measured. The time (in seconds) taken to walk 6 m at normal walking speed in a hallway was manually assessed using a stopwatch, and the usual gait speed was calculated.

Skeletal muscle mass Skeletal muscle mass was measured with bioimpedance analysis [21–25] using the Body Composition Analyzer MC-190 (Tanita Corp., Tokyo, Japan). We used the protocol described by Tanimoto et al. [26, 27], which has been validated by Nemoto et al. [28]. Appendicular skeletal muscle mass is the sum of the muscle mass of

the arms and legs. Absolute appendicular skeletal muscle mass was converted to a skeletal muscle mass index by dividing the appendicular skeletal muscle mass by height in meters squared (kg/m^2).

Assessment of frailty

With regard to the diagnostic criteria for frailty, Fried et al. first defined frailty as a clinical syndrome composed of five variables: unintentional weight loss, self-reported exhaustion, low physical activity, weakness (low grip strength), and slowness (low walking speed) [2]. Older persons with three or more of these five factors are considered frail.

In the present study, unintentional weight loss and self-reported exhaustion were defined using the Kihon Checklist, which is a questionnaire created and validated by the Ministry of Health and Welfare in Japan to identify older adults at a higher risk of requiring long-term healthcare [29]. Among the 25 yes/no questions in the Kihon Checklist, unintentional weight loss was defined as a positive answer to question 11: 'Have you lost 2 kg or more in the past 6 months?' The presence of self-reported exhaustion was defined as a positive answer to question 25: 'In the last 2 weeks, have you felt tired without a reason?' The presence of low physical activity was defined as a negative answer to question 1: 'Do you go out at least once a week?'

To measure weakness, low grip strength was established according to a sex-specific cut-off of the maximum muscle strength of the subject according to the AWGS criteria (< 26 kg, men; < 18 kg, women) [10]. To measure slowness, each participant's 6-m normal walking speed (m/s) was calculated. Low walking speed was defined as ≤ 0.8 m/s according to the AWGS criteria [10].

Statistical analysis

All statistical analyses were performed using STATA statistical software (STATA Corp., College Station, Texas, USA). Differences in proportions were compared using the Chi-square test. Continuous variables were compared using the analysis of variance for multiple groups or Scheffé's least-significant-difference test for pairs of groups. A P value of < 0.05 was considered statistically significant.

Results

Background characteristics of participants

As mentioned earlier, 963 subjects (321 men and 642 women) completed the questionnaire as well as all measurements for assessment of locomotive syndrome, SP, and frailty. Background characteristics of these 963 subjects are shown in Table 1.

Table 1 Background characteristics of the participants

Variables	Total	Men	Women	P value (men vs women)
Number of subjects	963	321	642	–
Age [years], mean (SD)	72.2 (7.6)	72.9 (8.0)	71.9 (7.3)	0.061
Height [cm], mean (SD)	154.4 (9.0)	163.2 (6.7)	150.1 (6.5)	< 0.0001****
Weight [kg], mean (SD)	54.9 (10.6)	62.1 (10.5)	51.3 (8.6)	< 0.0001****
Body mass index [kg/m^2], mean (SD)	22.9 (3.4)	23.3 (3.2)	22.8 (3.4)	0.032*
Two-step test score, mean (SD)	1.18 (0.21)	1.20 (0.19)	1.18 (0.22)	0.152
Stand-up test (40 cm, one leg), failure (%)	49.7	48.6	50.3	0.616
Stand-up test (20 cm, two legs), failure (%)	10.3	5.3	12.8	< 0.001***
25-question geriatric locomotive function scale score ≥ 7	26.3	21.2	28.8	0.011*
25-question geriatric locomotive function scale score ≥ 16	13.1	11.5	13.9	0.311
Grip strength [kg], mean (SD)	29.0 (9.0)	38.5 (7.7)	24.3 (5.0)	< 0.0001****
Walking speed [m/s], mean (SD)	1.05 (0.29)	1.03 (0.29)	1.05 (0.30)	0.271
Skeletal muscle mass index [kg/m^2], mean (SD)	6.56 (1.04)	7.55 (1.02)	6.07 (0.63)	< 0.0001****
Prevalence of locomotive syndrome stage 1 (%)	81.0	80.4	81.3	0.727
Prevalence of locomotive syndrome stage 2 (%)	34.1	30.5	35.8	0.102
Prevalence of sarcopenia	8.7	9.7	8.3	0.467
Prevalence of frailty	4.5	2.8	5.3	0.078

SD standard deviation

*P < 0.05; ***P < 0.001; ****P < 0.0001

Prevalence of locomotive syndrome stages 1 and 2

The prevalence rates of locomotive syndrome stage 1 according to age group stratifications of 60–64, 65–69, 70–74, 75–79, and ≥ 80 years were 62.7%, 75.6%, 80.9%, 93.3%, and 93.2%, respectively (men, 68.8%, 70.9%, 76.8%, 94.4%, and 89.9%, for 60–64, 65–69, 70–74, 75–79, and ≥ 80 years, respectively; women, 59.5%, 77.4%, 82.9%, 92.7%, and 95.5%, for 60–64, 65–69, 70–74, 75–79, and ≥ 80 years, respectively). The prevalence tended to be significantly higher with age ($P < 0.001$), but there was no significant difference between the sexes ($P = 0.73$).

The prevalence rates of locomotive syndrome stage 2 according to age group stratifications of 60–64, 65–69, 70–74, 75–79, and ≥ 80 years were 10.3, 20.4, 22.5, 50.0, and 69.5%, respectively (men, 10.9, 12.7, 18.8, 42.6, and 60.8%, for 60–64, 65–69, 70–74, 75–79, and ≥ 80 years, respectively; women, 9.9, 23.2, 24.3, 53.2, and 75.7%, for 60–64, 65–69, 70–74, 75–79, and ≥ 80 years, respectively). Similarly, the prevalence tended to be significantly higher with age ($P < 0.001$), but there was no significant difference between the sexes ($P = 0.10$).

Prevalence of SP

SP prevalence rates according to age group stratifications of 60–64, 65–69, 70–74, 75–79, and ≥ 80 years were 1.1%, 1.0%, 3.4%, 7.9%, and 31.1%, respectively (men, 1.6%, 1.8%, 4.4%, 13.0%, and 24.1%, for 60–64, 65–69, 70–74, 75–79, and ≥ 80 years, respectively; women, 0.8%, 0.7%, 2.9%, 5.7%, and 36.0%, for 60–64, 65–69, 70–74, 75–79, and ≥ 80 years, respectively). The prevalence of SP, similar to that of locomotor syndrome, tended to be significantly higher with age ($P < 0.001$), but there was no significant difference between the sexes ($P = 0.47$).

Prevalence of frailty

The prevalence of frailty in the 60–64, 65–69, 70–74, 75–79, and ≥ 80 age groups was 0.0%, 1.0%, 1.9%, 7.9%, and 12.1%, respectively (men, 0.0%, 0.0%, 1.5%, 5.6%, and 6.3%, for 60–64, 65–69, 70–74, 75–79, and ≥ 80 years, respectively; women, 0.0%, 1.4%, 2.1%, 8.9%, and 16.2%, for 60–64, 65–69, 70–74, 75–79, and ≥ 80 years, respectively). The prevalence of frailty was significantly higher with age ($P < 0.001$), but there was no significant difference between the sexes ($P = 0.08$).

Co-existence of locomotive syndrome stage 1, SP, and frailty

Table 2 shows the prevalence according to the combination of the presence/absence of locomotive syndrome stage 1, SP, and frailty. It reveals that co-existence of locomotive syndrome stage 1, SP, and frailty was observed in 2.1% of this population; 6.5% had locomotive syndrome stage 1 and SP, 2.4% had locomotive syndrome stage 1 and frailty; however, none of the subjects were observed to have SP and frailty. Locomotive syndrome stage 1 occurred separately in 70.0%, SP in 0.1%, and frailty in none. The remaining 18.9% did not have locomotive syndrome stage 1, SP, or frailty.

Co-existence of locomotive syndrome stage 2, SP, and frailty

Table 3 shows the prevalence according to the combination of the presence/absence of locomotive syndrome stage 2, SP, and frailty. Co-existence of locomotive syndrome stage 2, SP, and frailty was observed in 2.0% of the subjects; 5.0% had locomotive syndrome stage 2 and SP, 2.2% had locomotive syndrome stage 2 and frailty, and only 0.1% of the subjects had SP and frailty. Locomotive syndrome stage 2,

Table 2 Co-existence of locomotive syndrome stage 1, sarcopenia, and frailty

Combination of disorders			Total		Men		Women	
Locomotive syndrome stage 1	Sarcopenia	Frailty	Number of subjects	%	Number of subjects	%	Number of subjects	%
–	–	–	182	18.9	62	19.3	120	18.7
+	–	–	674	70.0	223	69.5	451	70.2
–	+	–	1	0.1	1	0.3	0	0.0
–	–	+	0	0.0	0	0.0	0	0.0
+	+	–	63	6.5	26	8.1	37	5.8
+	–	+	23	2.4	5	1.6	18	2.8
–	+	+	0	0.0	0	0.0	0	0.0
+	+	+	20	2.1	4	1.2	16	2.5
Total			963	100.0	321	100.0	642	100.0

+ presence, − absence

Table 3 Co-existence of locomotive syndrome stage 2, sarcopenia, and frailty

Combination of disorders			Total		Men		Women	
Locomotive syndrome stage 2	Sarcopenia	Frailty	Number of subjects	%	Number of subjects	%	Number of subjects	%
–	–	–	616	64.0	215	67.0	401	62.5
+	–	–	240	24.9	70	21.8	170	26.5
–	+	–	16	1.7	7	2.2	9	1.4
–	–	+	2	0.2	1	0.3	1	0.2
+	+	–	48	5.0	20	6.2	28	4.4
+	–	+	21	2.2	4	1.2	17	2.6
–	+	+	1	0.1	0	0.0	1	0.2
+	+	+	19	2.0	4	1.2	15	2.3
Total			963	100.0	321	100.0	642	100.0

+ presence, − absence

SP, and frailty separately comprised 24.9, 1.7, and 0.2% of the population, respectively. The remaining 64.0% did not have locomotive syndrome stage 2, SP, or frailty.

Discussion

In the present study, we examined the co-existence of locomotive syndrome, SP, and frailty based on the data collected in the third survey of the ROAD study conducted in 2012–2013.

Based on the data from the ROAD study, we have reported the prevalence of locomotive syndrome stages 1 and 2, SP, and frailty separately elsewhere [17, 18, 30]. However, the prevalence of SP and frailty that we reported earlier was estimated using data from the second survey of the ROAD study conducted in 2008–2009, while that of locomotive syndrome was estimated using the data from the third survey of the ROAD study conducted in 2012–2013. In the present study, to estimate the co-existence of locomotive syndrome stages 1 and 2, SP, and frailty, we re-established the dataset to include subjects aged ≥ 60 years (since age constitutes one of the criteria of SP) with all required measurements and applied the diagnostic criteria of locomotive syndrome stages 1 and 2, SP, and frailty.

Regarding locomotive syndrome, since the JOS proposed its concept in 2007, in the second term of the National Health Promotion Movement in the twenty-first century (Health Japan 21 (second term) in 2013 declared by the Japanese government to achieve a vibrant society with healthy and spiritually rich lives according to life stages), the term 'locomotive syndrome' was adopted as one of important targets for maintenance and improvement of functions necessary for engaging in social life [31]. As health promotion activities, if the status of the locomotive organs are evaluated early and corresponding early treatments, such as maintaining favorable nutritional status and increasing the amount of physical activities, are implemented early, reduction in musculoskeletal function accompanying old age is delayed and the number of people making use of nursing care insurance in their later life is reduced. Clarifying the prevalence of locomotive syndrome and its association with SP and frailty, which are main reasons of disability of older people, is the first step of prevention and helps promote health.

In the present study, we found that most of the subjects with SP and/or frailty also had locomotive syndrome (both stages 1 and 2). Based on Tables 2 and 3, Venn diagrams (Figs. 1 and 2) were drawn to demonstrate the overlap of locomotive syndrome stages 1 and 2, SP, and frailty in subjects aged ≥ 60 years. From the view of SP, among those with SP ($n = 84$), 98.8% ($n = 83$) were diagnosed with locomotive syndrome stage 1, and among subjects with SP, 79.8% ($n = 67$) were diagnosed with locomotive syndrome stage 2. Similarly, all subjects with frailty ($n = 43$) were (100%) categorized as having locomotive syndrome stage

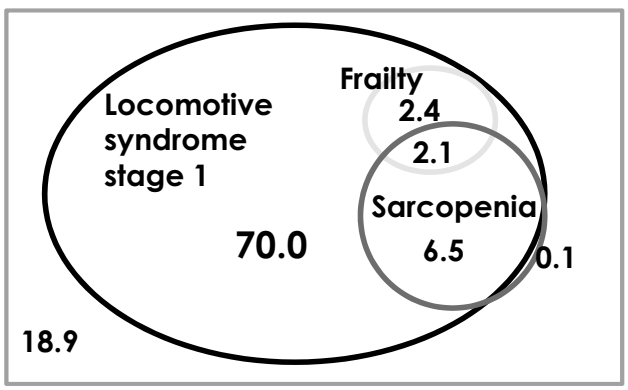

Fig. 1 Venn diagram showing co-existence of locomotive syndrome stage 1, sarcopenia, and frailty (%) in the third survey of Research on Osteoarthritis/Osteoporosis Against Disability (ROAD) study

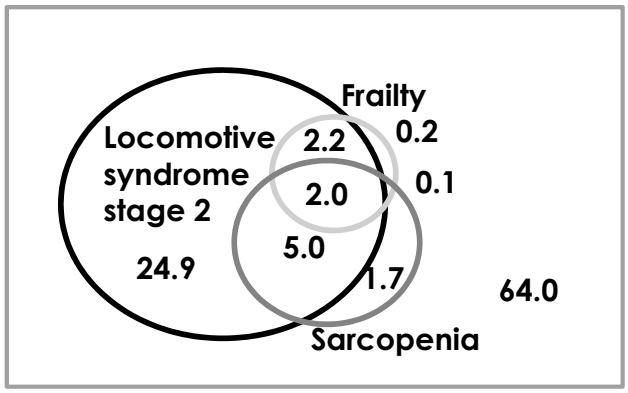

Fig. 2 Venn diagram showing co-existence of locomotive syndrome stage 2, sarcopenia, and frailty (%) in the third survey of Research on Osteoarthritis/Osteoporosis Against Disability (ROAD) study

1, and among subjects with frailty, 93.0% ($n=40$) were diagnosed with locomotive syndrome stage 2. Thus, most of the subjects with SP and/or frailty were also found to have locomotive syndrome. To the best of our knowledge, this study is the first to clarify the co-existence of locomotive syndrome, SP, and frailty using data from a population-based cohort.

As noted, almost all subjects who were diagnosed with SP and/or frailty were included under the category of locomotive syndrome stage 1. In the present study, the mean age of the subjects with locomotive syndrome stages 1 and 2 was 73.2 years and 77.0 years, respectively. Therefore, these subjects were younger than those with SP (81.2 years) or frailty (79.9 years). This suggests that the start of decline in mobility might be a precursor of SP and/or frailty. These findings indicate that for the prevention of SP and/or frailty, assessing the mobility status may be useful.

This study had several limitations. First, although the ROAD study includes a large cohort, the participants in the present study (individuals from the mountainous and coastal regions alone) may not be representative of the general population. However, in an earlier study, we compared the anthropometric measurements and lifestyle factors, such as smoking and drinking habits, between the study participants of the second survey of the ROAD study and the general Japanese population [17]. We found no significant differences between the two, except for the lower proportion of current smokers and drinkers in our study population than in the general Japanese population, suggesting that our study participants led healthier lifestyles. This selection bias should be taken into consideration when generalizing the results obtained from the present study. Second, since the definition of frailty is unestablished yet, we defined it using Fried's five measurable characteristics. However, the cut-off values of criteria such as walking speed and grip strength have not yet been established. Therefore, we defined them according to the AWGS criteria [10]. We hope that a unified definition of frailty and its cut-off values will be established in the near future to aid studies aimed at preventing disability in older people. Third, in the present study, the tests required to diagnose locomotive syndrome, SP, and frailty (including two-step test, stand-up test, handgrip strength for both hands, and the 6-m walking test for the calculation of walking speed) were performed only once. Thus, we cannot exclude the effect of incidental changes in participants' performance around the time of examination. To minimize fluctuation, future studies may consider taking repeat measurements. Finally, the present study clarified the co-existence of three conditions using the third survey of the ROAD study, we could not clarify their causal association and their influence on the future onset of disability. Further observation is required to conclude the effect of the co-existence of locomotive syndrome, SP, and frailty on the occurrence of disability.

In conclusion, the present study examined the co-existence of locomotive syndrome stages 1 and 2, SP, and frailty in a population-based cohort in Japan. We found that most of the subjects with SP and/or frailty were also considered to have locomotive syndrome. These results suggest that preventing locomotive syndrome may help prevent frailty and SP and subsequent disability, thereby improving the quality of life.

Acknowledgements This work was supported by Grants-in-Aid from the Ministry of Health, Labour and Welfare: H17-Men-eki-009 (Director, Kozo Nakamura), H20-Choujyu-009 (Director, Noriko Yoshimura), H23-Choujyu-002 (Director, Toru Akune), H25-Choujyu-007 (Director, Noriko Yoshimura), H25-Nanchitou (Men)-005 (Director, Sakae Tanaka), and H29-Junkankinado-Ippan-010 (Director, Etsuo Chosa). The study was also supported by Scientific Research grants 19H03895, B26293139, B23390172, B20390182, and Challenging Exploratory Research grants 18K18447, 15K15219, 24659317 to Noriko Yoshimura; Scientific Research grants B26293329, B23390356, C20591774, and Challenging Exploratory Research grants 26670307, 23659580 to Shigeyuki Muraki; Challenging Exploratory Research grants 24659666 and 21659349 and Young Scientists A18689031 to Hiroyuki Oka; Scientific Research grants B26293329, B23390357, C20591737 and Challenging Exploratory Research grants 25670293 to Toru Akune; Scientific Research grants B18H03164 to Yosuke Yamada, C18I10063 to Izumi Inoue, C18K09122 to Harumoto Yamada, and by Collaborating Research with NSF from the Ministry of Education, Culture, Sports, Science and Technology in Japan 08033011-00262 (Director, Noriko Yoshimura). The study was partly supported by grants from the Japan Agency for Medical Research and Development (19dk0110028h0003, Director, Noriko Yoshimura, 17gk0210007h0003, Director, Sakae Tanaka). Further, the study was partly supported by grants from the Japan Osteoporosis Society (Noriko Yoshimura, Shigeyuki Muraki, Hiroyuki Oka, Toru Akune), Japan Osteoporosis Foundation (2015, Noriko Yoshimura), research aids from the Japanese Orthopaedic Association (JOA-Subsidized Science Project Research 2006-1 and 2010-2, Director, Hiroshi Kawaguchi; and 2014-1, Director, Kozo Nakamura), the Japanese Society for Musculoskeletal Medicine (2015, Director, Shigeyuki Muraki; and 2017, Director, Noriko Yoshimura), Mitsui Sumitomo Insurance Welfare Foundation (2016, Director, Noriko Yoshimura), and Japan Dairy Association (2017, Director, Noriko Yoshimura). The authors wish to

thank Dr Naoki Hirabayashi of Kawakami Clinic, Hidakagawa Town; Mrs Tomoko Takijiri, Mrs Rie Takiguchi, Mrs Kyoko Maeda, Mrs Michiko Mori and other members of the public office in Hidakagawa Town; and Mrs Tamako Tsutsumi, Mrs Kanami Maeda, Mrs Megumi Takino, Mrs Shuko Okada, Mrs Kazuyo Setoh, Mrs Chika Yamaguchi, and other members of the public office in Taiji Town for their assistance in locating and scheduling participants for examinations. We would also like to thank Ms Kyoko Yoshimura, Mrs Toki Sakurai, Mrs Saeko Sahara, and Mr Noriyuki Oe for their assistance with data reduction and administration.

Compliance with ethical standards

Conflict of interest All authors have no conflicts of interest.

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