

Locomotive syndrome: clinical perspectives

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Abstract: The deterioration of locomotive components, which comprise bones, joints, and intervertebral discs, and muscles and nerves, can lead to symptoms such as pain, limitations in the range of joint mobility, malalignment, impaired balance, and difficulty walking. Locomotive syndrome (LoS) was proposed by the Japanese Orthopedic Association in 2007 as a concept for people who are at a high risk of developing a musculoskeletal ambulation disability attributed to locomotor organs. Although many international articles related to LoS have been published, an international consensus of this concept seems to be lacking. This review article on LoS introduces the concept, the related assessment methods, and the condition's prevalence based on the most up-to-date literature, and discusses discrimination from frailty and sarcopenia, relevance to musculoskeletal problems, management plan, and future directions. Familiarity with recent evidence would be useful for the health care providers in an aging society to educate individuals with LoS or pre-LoS and to maintain their well-being and prevent them from requiring long-term care.

Keywords: locomotive syndrome, long-term care, frailty, sarcopenia, functional disability, osteoarthritis, spondylosis, osteoporosis

Introduction

As the number of elderly people needing nursing care is increasing annually and in response to the heavy financial burden this has imposed on the Japanese society, the Japanese government has introduced a new insurance system called Long-term Care Insurance in 2000 to cope with the rapid increase in the aging population.¹ In this context, three professional Japanese medical societies related to musculoskeletal disorders – the Japanese Orthopedic Association (JOA), the Japanese Society for Musculoskeletal Medicine (formerly the Japanese Society for Musculoskeletal Rehabilitation), and the Japanese Clinical Orthopedic Association – proposed a new concept called musculoskeletal ambulation disability symptoms in 2006 to describe a condition characterized by unstable balance or difficulty walking.² Locomotive syndrome (LoS) was described by the JOA in 2007 as a wider range of disabilities than musculoskeletal ambulation disability symptoms.^{2,3}

Although awareness of the concept of LoS has increased in Japan⁴ and numerous reports on LoS have been published in international journals during the past decade, as determined by a MEDLINE search, these reports have been limited to Japanese institutes and a few articles from other countries have been published, with the exception of a report from Brazil.⁵ This review article on LoS introduces the concept, the related assessment methods, and the condition's prevalence based on previous literature, and discusses discrimination from frailty and sarcopenia, relevance to musculoskeletal problems, management plan, and future directions. The authors reviewed the available literature, reports, and surveys related to LoS available in PubMed/MEDLINE and Google Scholar, on websites, and from other sources up to December 2017.

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Review of literature

Concept of LoS

LoS is proposed as a disorder that predominantly affects people who are at a high risk of developing a musculoskeletal ambulation disability attributed to locomotor organ diseases.³ According to the recent literature, LoS is also defined as a condition in which mobility functions, such as sit-to-stand or gait, are reduced because of locomotive organ impairment.⁴ In LoS, the locomotive system consists of three main components: 1) bones, 2) joints and intervertebral discs, and 3) muscles and nerves. Thus, musculoskeletal ambulation diseases, such as osteoporosis, osteoporosis-related fractures, osteoarthritis (OA), spondylosis, sarcopenia, and neural disorders, are often included in this category.^{4,6} The deterioration of locomotive components or interrelated discordance of the locomotive system can lead to symptoms such as pain, a limitation in the range of joint mobility, malalignment, impaired balance, and difficulty walking^{4,6} (Figure 1). Notably, the condition referred to as “sarcopenia” in a diagram is not the same as “sarcopenia” as defined by the European Working Group or the Asian Working Group.

Degenerative changes in the locomotive organ begin before middle age. For instance, according to Cheung et al ~40% of people under 30 years of age and 90% of people over 55 years of age present with intervertebral disc degeneration of the lumbar spine.⁷ A cohort study conducted in Japan has revealed estimated prevalences of radiographic

knee OA and lumbar spondylosis of 25.3 and 37.9 million, respectively.⁸ However, as the normal aging process and pathologic changes are often difficult to distinguish based on radiographic degeneration,^{9,10} health education has been an essential component in promoting health and preventing disease.¹¹

Assessment of LoS

Several assessment methods have been proposed to examine elderly people with a functional decline and to establish an operational definition of LoS.^{5,12–18}

Initially, when the concept of LoS was proposed, seven self-check statements were prepared to determine whether the patient presented with an element of LoS.⁵ Several international research articles have adopted this assessment to determine the presence or absence of LoS over the past decade. However, this assessment has been used only for self-encouragement as an accessible term known as loco-check,¹⁹ but not for the operational definition of LoS according to the official announcement by the JOA (<https://locomo-joa.jp/locomo/>).

In 2008, a research group of the Ministry of Health, Labor, and Welfare in Japan²⁰ established a diagnostic tool for LoS by organizing a group of six experts, who developed the 25-question Geriatric Locomotive Function Scale (GLFS-25). This scale is a tool to assess difficulty and disability in daily activities related to locomotive organs.¹²

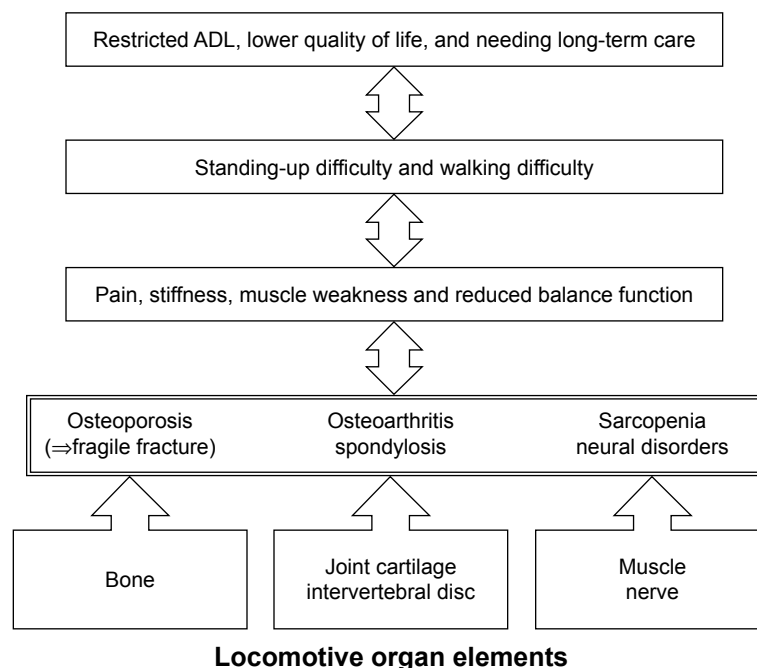


Figure 1 A concept of locomotive syndrome.
Abbreviation: ADL, activities of daily living.

Table 1 Reference values of physical performance tests for LoS

References	Samples	Test items	Main findings
Yoshimura et al ¹³	≥40 years, 826 men, 1,642 women	Hand grip strength One-leg standing time 6MWT	<ul style="list-style-type: none"> • Mean values for hand grip strength, waking time for 6 m at usual pace, and fast pace for men were 32.7 kg, 5.6 and 3.7 s, respectively, and those for women were 32.7 kg, 5.6 and 3.7 s, respectively • Median values for one-leg standing time were 14 s for men and 12 s for women • There were significant associations between the presence of disability and walking speed
Muramoto et al ¹⁴	≥40 years, 128 men, 230 women	Hand grip strength One-leg standing time Timed up-and-go test 10 m gait time Back muscle strength Maximum stride	<ul style="list-style-type: none"> • Hand grip strength, one-leg standing time, and timed up-and-go test proved to be reliable performance tests to evaluate the severity of LoS
Muramoto et al ¹⁵	≥60 years, 128 men, 230 women	Same as above	<ul style="list-style-type: none"> • When using a GLFS-25 score (≥16), reference values for timed up-and-go test, one-leg standing time, back muscle strength, 10 m gait time, maximum stride, and grip strength in men were 6.7 and 21 s, 78 kg, 5.5 s, 119 cm, and 34 kg, respectively, and those for women were 7.5 and 15 s, 40 kg, 6.2 s, 104 cm, and 22 kg, respectively
Nakamura et al ¹⁶	≥65 years, 126 women	Hand grip strength One-leg standing time Seated toe touch 6MWT	<ul style="list-style-type: none"> • When using a GLFS-25 score (≥16), the threshold for discriminating LoS was 15 s for one-leg standing time, 4.8 s for normal 6MWT, and 3.6 s for fast 6MWT. Of these variables, one-leg standing time <15 s was most strongly associated with LoS
Seichi et al ¹⁷	≥65 years, 261 men, 619 women	The average of one-leg standing time obtained for both legs (IA-OLS)	<ul style="list-style-type: none"> • When using a GLFS-25 score (≥16), the optimal cutoff for IA-OLS time was 19 s for individuals aged ≤70, 10 s for individuals aged >70 and ≤75, and 6 s for individuals aged >75

Abbreviations: 6MWT, 6 m walking time; GLFS-25, 25-question Geriatric Locomotive Function Scale; IA-OLS, individual average of one-leg standing time obtained for both legs; LoS, locomotive syndrome.

Indeed, most research articles have adopted the GLFS-25 to determine both the presence and severity of LoS, regardless of the age of the subjects. Subsequently, several functional measures, such as hand grip strength, one-leg standing time, and 6 m walking time, were proposed to evaluate LoS¹³⁻¹⁷ (Table 1). Although these methods seemed to be valuable, none was adopted as an official performance test for assessing LoS. Alternatively, Ogata et al have proposed two physical performance tests to evaluate the motor function in people with LoS, including the two-step test and the stand-up test.¹⁸ Currently, the two-step test, the stand-up test, and the GLFS-25 have been officially introduced to diagnose people with LoS^{4,21} (Table 2). In the proposed assessments, although two clinical stages of LoS have been defined for assessing the severity of locomotive symptoms, recent

literature typically uses stage 2 LoS to determine whether the subject has LoS.

Two-step test

The subject begins the test in an upright posture and moves forward for a maximum of two strides without losing his or her balance. If the subject succeeds in holding the final standing position for longer than 3 s without any additional steps, the test is regarded as complete. The test is performed twice, and the best result is recorded. The distance is subsequently standardized according to the subject's height.¹⁸ If the value of this test is <1.3 or 1.1, the subject is regarded as having stage 1 LoS or stage 2 LoS, respectively.^{4,21}

Stand-up test

Subjects are asked to stand from stools of varying heights with a single leg or both legs. The stools range from 10 to 40 cm in height, increasing in 10 cm increments. The test is first performed with both legs using the easiest size, namely, the 40 cm stool, and then using increasingly difficult sizes, with every 10 cm downward step, followed by a single leg standing test performed in the same manner. If the subject succeeds in holding the final standing position for longer than 3 s without any additional steps, the test is regarded

Table 2 Operational definition for locomotive syndrome

	Stage 1	Stage 2
Two-step test	<1.3	<1.1
Stand-up test	Impossible to stand up from 40 cm height stool with one leg	Impossible to stand up from 20 cm height stool with both legs
GLFS-25 score	≥7	≥16

Abbreviation: GLFS-25, 25-question Geriatric Locomotive Function Scale.

as complete.¹⁸ If the trial with the 40 cm tall stool using a single leg is not completed, the subject is regarded as having stage 1 LoS, and if the trial with the 20 cm tall stool using both legs is not completed, the subject is regarded as having stage 2 LoS.^{4,21}

The 25-question Geriatric Locomotive Function Scale

The GLFS-25 is a self-reported comprehensive measure that consists of 25 questions that refer to experiences in the preceding month. The scale addresses four dimensions with 25 questions: 4 questions regarding pain, 16 questions regarding activities of daily living, 3 questions regarding social functions, and 2 questions regarding mental health status. Each of the questions is rated on an ordinal scale of 0–4 points, with higher scores indicating a symptom or a medical condition of greater severity. In previous studies, the GLFS-5 was also introduced as a quick five-item version of the GLFS-25 using a cluster analysis. The total score is assumed to represent a quantitative evaluation of the difficulties and disabilities in daily life activities related to locomotive organs. The cutoff scores for identifying LoS were set to 16 for the total score (ranging from 0 to 100 points) for GLFS-25 and 6 for the total score (ranging from 0 to 20 points) for GLFS-5, respectively.¹² On the other hand, a GLFS-25 score of ≥ 7 is regarded as stage 1 LoS and a GLFS-25 score of ≥ 16 is regarded as stage 2 LoS.^{4,21}

Akai et al recently evaluated the relationships between the GLFS-25 score and 46 variables in multiple dimensions, including demographic background, living environment, health status, medical history and comorbidity, locomotive organ problems, clinical symptoms, laboratory tests, X-ray findings, and motor functional assessment. Eleven variables were identified. The authors reported that the GLSF-25 score showed an increasing negative correlation with each variable in the following order:²²

- Use of a walking aid
- Daily tasks are bothersome to complete
- Weakness of the triceps surae muscle
- Sensory changes in the lower leg
- Muscle weakness in the anterior tibial muscle
- Difficulty seeing
- Knee joint pain
- Difficulty hearing
- Low back pain
- Sense of powerlessness
- Weakness of the quadriceps muscle

Prevalence

Two nationwide surveys reported the prevalence of LoS in people aged ≥ 40 years in Japan using the cutoff ≥ 16 for the GLFS-25 score. The estimated prevalence of LoS was 7.9% in men and 12.3% in women in 2010²³ and 10.8% in men and 12.9% in women in 2014.²⁴ Moreover, Yoshimura et al investigated the prevalence of LoS using the new indices of the two-stage definition in 2013 and revealed that the estimated prevalence of stage 1 LoS (GLFS-25 score ≥ 7) was 18.8% in men and 24.5% in women and of stage 2 LoS (GLFS-25 score ≥ 16) was 9.0% in men and 11.4% in women.²¹ Based on these reports, the prevalence of LoS, as defined by the cutoff score (≥ 16) for GLFS-25, consistently increases in patients aged ≥ 70 years, and women in all generations are more likely to develop LoS (Table 3).

Discussion

Conceptual differences between frailty, sarcopenia, and LoS

Considerable overlap exists among frailty, sarcopenia, and LoS, particularly in terms of the physical aspect of functional decline. However, each concept develops in different circumstances.

Frailty is conceptually characterized as a clinically vulnerable state in older adults that results from an age-associated decline in multiple organ systems,^{25–27} whereas sarcopenia and LoS mainly focus on muscle capacity. Frailty includes a variety of functional deficits that occur during aging, such as comorbid illnesses, psychological vulnerability, self-reported disability, and poor quality of life. Two major definitions of frailty have emerged over the past several years: the frailty phenotype, which is known as Fried's definition,²⁵ and the frailty index.²⁶ Moreover, further definitive criteria have also been described in the literature.²⁷

The term sarcopenia was initially proposed in 1989.^{28,29} This disorder has been recognized as the loss of muscle function and the loss of muscle mass with aging. According to the European Working Group, sarcopenia requires the presence of either a low gait speed or low grip strength prior to the loss of muscle mass,³⁰ and this algorithm was adopted by the Asian Working Group for sarcopenia, with some differences in the cutoff values.³¹ Therefore, distinctive feature of sarcopenia seems to have a definitive algorithm to clarify this condition.

Although the concepts seem to differ from each other, substantial overlap in the physical aspect of functional decline exists among these three syndromes. In fact, with respect to

Table 3 Estimated prevalence of locomotive syndrome in Japan

Demographics			Two-step test		Stand-up test		GLFS-25 score	
			Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2
Kimura et al ²³	40s	Men	None				None	8.0%
		Women						8.9%
	50s	Men						7.9%
		Women						10.4%
	60s	Men						6.0%
		Women						10.5%
	70s	Men						10.8%
		Women						20.8%
Seichi et al ²⁴	40s	Men	None				None	4.4%
		Women						4.8%
	50s	Men						7.2%
		Women						8.3%
	60s	Men						11.5%
		Women						12.5%
	70s	Men						21.1%
		Women						27.5%
Yoshimura et al ²¹	40s	Men	21.1%	2.6%	15.8%	2.6%	10.8%	0.0%
		Women	31.8%	1.2%	12.9%	0.0%	8.3%	2.4%
	50s	Men	34.6%	3.7%	15.9%	0.0%	7.4%	1.2%
		Women	31.8%	3.1%	23.6%	1.0%	13.0%	4.2%
	60s	Men	49.3%	8.8%	47.8%	3.7%	12.0%	6.0%
		Women	52.4%	12.4%	33.9%	5.5%	19.7%	4.6%
	70s	Men	71.7%	23.9%	78.0%	2.9%	19.9%	8.1%
		Women	78.3%	30.4%	56.2%	13.1%	31.6%	15.1%

Abbreviation: GLFS-25, 25-question Geriatric Locomotive Function Scale.

walking difficulty, which is a common disability shared by patients with the three syndromes, a large body of evidence has suggested that gait speed is associated with mortality in older adults.^{32,33} Moreover, mental disorders among elderly people were recently found to be associated with sarcopenia^{34,35} and LoS.^{36,37} Therefore, the clinical features of the three conditions are closely linked to each other.

Frailty and sarcopenia can be used to describe the condition of people who show a functional decline that is diagnosed based on several definitive criteria, whereas the concept of disability in LoS remains ambiguous. This ambiguity occurs because LoS includes not only people with a severe disability, but also individuals who are predicted to develop the syndrome in the future.⁶ The early detection of problems related to health and interventions plays a crucial role in helping older people remain independent.^{38,39} According to Iwaya et al limitations in activity might first occur in sports, followed by walking, transferring, and self-care, in that order, and limitations in mobility appear to result in mild

disability.⁴⁰ The extension of mild locomotion dysfunction seems to be an additional component of LoS and, thus, can include middle-aged adults (Figure 2).

Association of LoS with musculoskeletal problems

The degeneration of locomotive organs in knee OA and lumbar spondylosis is an important contributor to LoS by definition.^{41,42} Although approximately linear relationships were observed between the prevalence of radiographic knee OA or lumbar spondylosis and age >40 years in both sexes,⁴³ the correlation between the prevalence of LoS and age did not seem to be linear. In particular, the prevalence of LoS (GLFS-25 score ≥ 16) in Japanese men in their 40s and 50s was <10% (Table 3), despite the high incidence of radiographic lumbar spondylosis.⁸ This finding may be explained by the observation that musculoskeletal pain and muscle strength are independent predictors of the severity of LoS.²² Numerous previous studies have reported the relationships

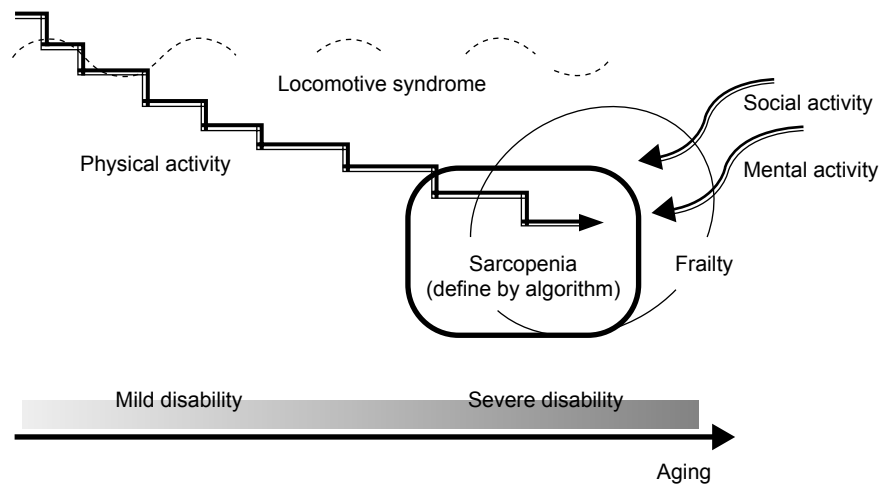


Figure 2 Mutual relationships between locomotive syndrome, frailty, and sarcopenia.

between musculoskeletal pain and LoS.^{16,44–47} Recently, biopsychosocial factors were shown to be essential components associated with not only low back pain^{48,49} but also knee pain,^{50,51} because pain is affected by actual tissue damage and psychological experience. Psychometric properties have been reported to predict pain and disability outcomes not only in patients with low back pain^{52,53} but also in patients with symptomatic knee OA.^{54,55} Thus, biopsychosocial factors should be considered when evaluating people with locomotor disabilities, particularly individuals with chronic pain conditions.

Although muscle strength is also an essential factor associated with locomotor function,^{14,15,24,36,46,47,56} the impact of muscle strength on LoS may be more prominent in women than in men.¹⁵

In addition, the relationship between osteoporosis and LoS should be mentioned. Osteoporosis has a significant impact on LoS, as it influences the risk of osteoporotic fractures accompanied by low-energy trauma and occasionally results in a patient becoming bedridden. In general, bone mineral density (BMD) is assessed using dual-energy X-ray absorptiometry technology to diagnose osteoporosis.⁵⁷ According to several studies, decreased physical performance is associated with a low BMD.^{58,59} However, no study in the previous literature investigated the relationship between osteoporosis assessed by determining the BMD of the lumbar spine or the femoral neck and the presence or absence of LoS, although two reports investigating this relationship assessed the BMD of the calcaneus.^{41,45} Lumbar degenerative spondylosis occurring concomitantly with osteophytes, endplate sclerosis, facet degenerations, vertebral rotations, and possibly aortic calcifications has been reported to result in falsely elevated BMD values measured using dual-energy

X-ray absorptiometry, and thus, a discordant relationship between the BMD values for the lumbar spine and femoral neck would be observed.^{60,61} Therefore, we speculate that patients with early stage of LoS do not show decreased BMD values.

Prevention or management of LoS

Based on accumulating evidence, exercise prescriptions significantly contribute to the maintenance of functional capacity in elderly people.^{62,63} Although only one intervention trial for elderly people with LoS has been performed,⁶⁴ another exercise intervention for community-dwelling elderly people has been reported in Japan.⁶⁵ Both reports recorded significant improvements in the physical function of the participants after each intervention. The JOA has officially proposed locomotion training, called locotra, with the aim of improving and sustaining physical function in middle- and older-aged subjects.⁶⁶ Locotra consists of squatting and standing on a single leg with the eyes open, and has been shown to be effective and convenient and can improve physical function in elderly people.⁶⁷ However, further randomized controlled intervention trials are necessary to validate the evidence.

In addition to the physical interventions, a psychosocial approach should be used to maintain and encourage adherence, defined as the extent to which subjects follow the recommendations, by people with LoS. Most intervention trials generally aim to improve the study outcome immediately after each intervention; however, researchers do not typically determine whether the effect is maintained beyond the end of the intervention.⁶³ DiMatteo reported that the average nonadherence rate was 24.8% among patients with various disease conditions.⁶⁸ The World Health Organization

proposes that adherence is not only affected by disease and treatment, but also by the health care system or the provider–patient relationship, patient characteristics, and socio-economic factors.⁶⁹ According to Inoue et al a combination of psychosocial and physical interventions might significantly improve long-term GLFS-25 score and pain-related outcomes in patients with refractory chronic pain.⁷⁰ Based on recent evidence, multidisciplinary biopsychosocial rehabilitation has positive effects on pain and disabilities in patients with chronic low back pain.⁷¹ Thus, a multifaceted approach has been suggested to enhance the self-care ability of patients and enable them to maintain an exercise routine.

Future directions

The concept of LoS has become widespread in Japan. Thus, several relevant studies are underway. The LoS and Health Outcome in Aizu Cohort Study was initiated to focus on the relationships between various diseases and the function of the cervical and lumbar spine and the upper and lower extremities.⁷² Studies have reported the prevalence of cardiovascular disease, diabetes, pterygium, and depression in this population. In addition, the LoS and Health Outcome in Aizu Cohort Study has reported the relationships between future risk of falls and kyphotic posture, subjective sleep patterns, and subjective fatigue in cohort studies.^{73–75} Additional evidence would be helpful in enabling people with LoS or pre-LoS in Japan to maintain their well-being and prevent them from requiring long-term care or becoming bedridden.

Finally, we must note that with the exception of Japanese scholars, international researchers have rarely published articles related to LoS; thus, an international consensus has not yet been established. The aging of society is not a problem exclusive to Japan; thus, international collaborations are needed for the concept of LoS to be disseminated worldwide.

Disclosure

The authors report no conflicts of interest in this work.

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