

## IMPACT OF BACK MUSCLE STRENGTH AND AGING ON LOCOMOTIVE SYNDROME IN COMMUNITY LIVING JAPANESE WOMEN

KENICHI HIRANO<sup>1</sup>, SHIRO IMAGAMA<sup>2</sup>, YUKIHARU HASEGAWA<sup>2</sup>,  
NORIMITSU WAKAO<sup>3</sup>, AKIO MURAMOTO<sup>2</sup> and NAOKI ISHIGURO<sup>2</sup>

<sup>1</sup>*Department of Orthopaedic Surgery, Nagoya Daiichi Red Cross Hospital  
3-35, Michishita-cho, Nakamura-ku, Nagoya, 453-8511, Japan*

<sup>2</sup>*Department of Orthopaedic Surgery, Nagoya University Graduate School of Medicine  
65, Tsurumai-cho, Showa-ku, Nagoya, 466-8560, Japan*

<sup>3</sup>*Department of Orthopaedic Surgery, Aichi Medical University  
1-1, Yazakokarimata, Nagakute, 480-1195, Japan*

### ABSTRACT

The Japanese Orthopaedic Association has proposed the term locomotive syndrome (LS) to designate a condition of individuals in high-risk groups with musculoskeletal disease who are highly likely to require nursing care. This study investigates the influence of spinal factors on LS in Japanese females. A total of 187 women  $\geq 50$  years old were enrolled in the study. Those answering yes to at least one of the 7 categories in the self-assessment checklist for LS were defined as having LS. We evaluated lateral lumbar radiographs, sagittal parameters, sagittal balance using the spinal inclination angle (SIA) as an index, spinal range of motion (ROM) as determined with SpinalMouse<sup>®</sup>, back muscle strength (BMS), and body mass index (BMI). Age, BMI, BMS, SIA, sacral slope angle (SSA), and lumbar spinal ROM showed significant correlations with LS. Multiple logistic regression analysis indicated that an increase in age (OR 1.054,  $p < 0.05$ ) and a decrease in BMS (OR 0.968,  $p < 0.01$ ) were significantly associated with LS. Age had significant negative correlations with BMS, SSA, thoracic and lumbar spinal ROM, and it had positive correlations with BMI, SIA, and lumbar kyphosis. BMS had significant negative correlations with age, SIA, thoracic and lumbar kyphosis, and it had positive correlations with SSA, lumbar and total spinal ROM. An increase in age and a decrease in BMS may be the most important risk factors for LS in Japanese women. Back muscle strengthening and spinal ROM exercises could be useful for improving the status of an individual suffering from LS.

Key Words: back muscle strength; locomotive syndrome; osteoporosis; musculoskeletal disease; female

### INTRODUCTION

The Japanese population is aging very rapidly. In 2009, the average lifespan of a Japanese male and female were 79.59 and 86.44 years, respectively; among the highest lifespans in the world. Moreover, people aged 65 years or older accounted for 22.7% of the Japanese population in 2009. Japanese society could be considered a super-aged society. By 2055 the elderly are

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Corresponding author: Shiro Imagama, MD, PhD

Department of Orthopaedic Surgery, Nagoya University Graduate School of Medicine,  
65, Tsurumai-cho, Showa-ku, Nagoya, 466-8560, Japan

Tel: +81-52-741-2111, Fax: +81-52-744-2260, E-mail: imagama@med.nagoya-u.ac.jp

expected to account for 40.5% of the country's total population.<sup>1)</sup>

The Japanese Orthopaedic Association (JOA) has proposed the term “locomotive syndrome” (LS) to designate a condition in people from high-risk groups with musculoskeletal disease who are highly likely to require nursing care at some point.<sup>1,2)</sup> This syndrome is caused by weakening of the musculoskeletal organs such as bone, joint, and muscle. The loss of function in these organs leads to walking or self-transportation disabilities, which may ultimately force people suffering from this syndrome to seek outside care and support. To prevent this disabling condition, individuals must maintain healthy musculoskeletal organs.

The specific characteristics of LS are yet to be known. Major musculoskeletal diseases which may lead to LS include osteoporosis, spondylosis, and osteoarthritis. The spinal column, which strongly regulates posture, is one of the major and most important components affected by osteoporosis and spondylosis, and to investigate the relationship between spinal factors and LS is essential. Our current study aimed to investigate the influence of spinal curvature, range of motion and other factors on LS in Japanese women.

## MATERIALS AND METHODS

The subjects were healthy Japanese volunteers who attended a local government's “basic health checkup” in 2010. This checkup has been held annually in the town of Yakumo for 30 years (Yakumo study) and comprises voluntary orthopedic and physical function examinations as well as internal medical examinations and psychological tests. Every year, an announcement outlining the aims of the health screening program is mailed to the inhabitants, and participants confirm by return mail.

The inclusion criteria were defined as: 1) Japanese women aged  $\geq 50$  years; 2) individuals who underwent radiographs of the lumbar spine, SpinalMouse® (Idiag, Volkswill, Switzerland) measurements, and physical examination (back muscle strength, body mass index (BMI)) during the “basic health checkup”; and 3) individuals who were informed about this study and consented to participate in it. SpinalMouse® is a noninvasive, computer-assisted device measuring spinal shape and mobility using surface-based measurements. Individuals could not participate if they had severe disability walking and standing or dysfunction of the central or peripheral nervous systems.

Among 650 subjects who underwent this checkup in 2010, 414 (average 66.3 years, range 39–90 years) underwent orthopedic and physical function examinations. Of those 414 subjects, 315 (115 males, 200 females) underwent radiographs of the lumbar spine, SpinalMouse® measurements, and physical examination (back muscle strength, BMI). We excluded anyone less than 50 years old, so the current study included 187 Japanese women, with an average age of 68.0 years (range 50–89 years; SD 8.3). All subjects performed a self-assessment checklist for locomotive syndrome and an examination to determine back muscle strength and BMI. The Committee on Ethics in Human Research of Nagoya University approved the study protocol.

### *Self-assessment checklist for locomotive syndrome*

The Japanese Orthopaedic Association (JOA) developed a self-assessment checklist for LS in 2007 (Table 1),<sup>1)</sup> which we used with all subjects in our current study. By JOA criteria, an individual answering in the affirmative to any of the seven categories in the checklist may have LS. Our current study followed those guidelines. The numbers of subjects who answered yes to each category in the checklist are shown in Table 3.

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**Table 1** A self-assessment checklist for locomotive syndrome<sup>1</sup>

categories	
1	You cannot put on a pair of socks while standing on one leg
2	You stumble or slip in your house.
3	You need to use a handrail when going upstairs
4	You cannot get across the road at a crossing before the traffic light changes.
5	You have difficulty walking continuously for 15 min.
6	You find it difficult to walk home carrying a shopping bag weighing about 2 kg (e.g., two 1-l milk packs).
7	You find it difficult to do housework requiring physical strength (e.g., use of a vacuum cleaner to clean the rooms, putting futons into and taking them out of the closet, etc.).

*Radiographic measurement*

Participants stood in a neutral standing position for the lumbar spine radiographs, and we measured the lumbar kyphosis angle (Cobb angle between T12 and S1) and the sacral slope angle using the lateral lumbar radiograph. In this study, lumbar kyphosis angle was used instead of lumbar lordosis angle.

*Measurement of spinal curvature and range of motion*

Spinal curvature and range of motion (ROM) were evaluated using SpinalMouse<sup>®</sup>. Intraclass coefficients of 0.92–0.95 have been determined for curvature measurement with SpinalMouse<sup>®</sup>.<sup>3)</sup> In the current study, we measured the angles three times at each position: neutral standing position, maximum bending position, and maximum extension position; the average of the three measurements in each position was used. The evaluation items included the spinal inclination angle between straight line from T1 to S1 and true vertical, thoracic kyphosis angle (Cobb angle between T1 and T12), lumbar kyphosis angle (Cobb angle between T12 and S1), sacral slope angle, thoracic ROM, lumbar ROM and total spinal ROM. Spinal inclination reflected a forward, stooped posture. All spinal data could be measured and then calculated automatically and easily using the SpinalMouse<sup>®</sup> apparatus. We correlated the lumbar kyphosis angle and sacral inclination angle with lumbar radiographs to confirm the reproducibility of Spinal Mouse<sup>®</sup> measurements.

*Measurement of back muscle strength*

We determined back muscle strength from the maximal isometric strength of the trunk muscles in a standing posture with 30 degrees lumbar flexion using a digital back muscle strength meter (T.K.K.5402, Takei Co., Japan).<sup>4)</sup> The average force from two trials was recorded. The maximum strength in each trial had a high reproducibility ( $r=0.990$ ,  $p<0.0001$ ). All subjects were assessed by one examiner who was blinded to the results of other evaluations.

*Statistical analysis*

All data are shown as mean  $\pm$  standard deviation (SD) and were analyzed using SPSS Ver. 19 (SPSS Inc. Chicago, IL, USA). We used Pearson's correlation coefficient analysis or Spearman's

correlation coefficient analysis for determining correlations between variables. Univariate and multiple logistic regression analyses were used for analyzing risk factors for LS. We included variables in the multiple model if the univariate analysis p value was <0.25 (multiple logistic regression stepwise method, forward selection method). Values of  $p < 0.05$  were considered statistically significant.

## RESULTS

Evaluation of the SpinalMouse® data revealed a significant correlation between the lumbar radiographic data and the lumbar kyphosis angle ( $r=0.672$ ,  $p<0.0001$ ) and sacral slope angle ( $r=0.551$ ,  $p<0.0001$ ). This confirmed the reliability of the SpinalMouse® measurements of these angles and the data were then used in further analysis.

The mean values for the age and measured variables in the study subjects are listed in Table 2. There were 80 women who were defined as having LS. The correlations between each category of LS, the self-assessment checklist and other variables in the study subjects were also evaluated (Table 3).

When univariate logistic regression analysis was performed with the presence of LS as a dependent variable and the other estimated variables selected as independent variables, we identified age, BMI, back muscle strength, spinal inclination angle, sacral slope angle, and lumbar spinal ROM as indices significantly affecting the presence of LS (Table 4). Multiple logistic regression analysis with the selected variables from the univariate analyses revealed age and back muscle strength to be significant indices of LS (Table 5). These results from multiple logistic regression analysis showed that an increase in age and a decrease in back muscle strength represent very important risk factors for LS in Japanese women.

We evaluated the correlations between variables as well (Table 6). Age had significant negative correlations with back muscle strength, sacral slope angle, thoracic and lumbar spinal ROM, and

**Table 2** Data for the study subjects

Variables	total	Groups	
		LS+ (n=80)	LS- (n=107)
Age (years)	68.0±8.3	71.1±8.6	65.7±7.3
Back muscle strength (kg)	51.6±16.8	45.3±13.9	56.3±17.2
BMI	23.4±3.2	24.1±3.2	22.9±3.1
Spinal alignment			
Spinal inclination angle (°)	3.6±4.3	4.5±5.1	2.9±3.5
Sacral slope angle (°)	12.0±7.2	10.6±7.5	13.1±6.8
Thoracic kyphosis angle (°)	41.5±10.3	43.0±11.5	40.4±9.3
Lumbar kyphosis angle (°)	-20.3±11.9	-18.4±13.2	-21.7±10.7
Spinal ROM			
Thoracic spinal ROM (°)	14.7±12.8	14.1±14.6	15.1±11.3
Lumbar spinal ROM (°)	46.2±17.1	43.1±15.7	48.6±17.7
Total spinal ROM (°)	105.6±27.6	102.5±30.0	108.0±25.6

LS: locomotive syndrome; BMI: body mass index; ROM: range of motion

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**Table 3** Correlations between each category of locomotive syndrome self-assessment checklist and other variables in the study subjects

Variables	LS	1 (n=24)	2 (n=48)	3 (n=19)	4 (n=9)	5 (n=44)	6 (n=21)	7 (n=22)
Age (years)	0.314***	0.391***	0.057	0.376***	0.038	0.163*	0.163*	0.245**
Back muscle strength (kg)	-0.308***	-0.286***	-0.125	-0.410***	-0.058	-0.138	-0.205**	-0.277***
BMI	0.183*	0.231**	0.037	0.191**	0.050	0.153*	0.104	0.080
Spinal inclination angle (°)	0.207**	0.215**	0.024	0.359***	0.040	0.063	0.174*	0.185*
Sacral slope angle (°)	-0.172*	-0.265***	-0.060	-0.290***	-0.074	-0.129	-0.085	-0.159*
Thoracic kyphosis angle (°)	0.110	0.173*	0.182*	0.142	-0.083	0.040	0.098	0.086
Lumbar kyphosis angle (°)	0.122	0.166*	-0.041	0.243**	0.096	0.064	0.090	0.100
Thoracic spinal ROM (°)	-0.052	-0.032	-0.039	0.018	-0.008	-0.108	0.058	0.109
Lumbar spinal ROM (°)	-0.170*	-0.266***	-0.079	-0.165*	-0.111	-0.092	-0.138	-0.115
Total spinal ROM (°)	-0.128	-0.221**	0.000	-0.205**	0.124	-0.009	-0.190**	-0.178*

Data represent Spearman's correlation coefficient (r) \*p<0.05, \*\*p<0.01, \*\*\*p<0.001  
 LS: locomotive syndrome, as described by any of the seven categories.

**Table 4** Univariate logistic regression analysis for locomotive syndrome

Variables	OR	95% CI	p
Age (years)	1.089	1.046–1.133	<0.001
BMI (kg/m <sup>2</sup> )	1.123	1.021–1.236	<0.05
Back muscle strength (kg)	0.957	0.937–0.977	<0.001
Spinal inclination angle (°)	1.09	1.014–1.172	<0.05
Sacral slope angle (°)	0.95	0.910–0.991	<0.05
Thoracic kyphosis angle (°)	1.025	0.996–1.054	0.097
Lumbar kyphosis angle (°)	1.024	0.999–1.050	0.064
Thoracic spinal ROM (°)	0.994	0.971–1.017	0.591
Lumbar spinal ROM (°)	0.981	0.964–0.998	<0.05
Total spinal ROM (°)	0.993	0.982–1.003	0.174

OR: odds ratio; CI: confidence interval

**Table 5** Multiple logistic regression analysis for locomotive syndrome

Variables	OR	95% CI	p
Age (years)	1.054	1.005–1.105	<0.05
BMI (kg/m <sup>2</sup> )	1.074	0.957–1.205	0.224
Back muscle strength (kg)	0.968	0.945–0.991	<0.01
Spinal inclination angle (°)	1.034	0.867–1.232	0.709
Sacral slope angle (°)	0.95	0.810–1.116	0.534
Thoracic kyphosis angle (°)	0.992	0.929–1.060	0.821
Lumbar kyphosis angle (°)	0.968	0.847–1.106	0.63
Lumbar spinal ROM (°)	0.993	0.969–1.017	0.546
Total spinal ROM (°)	1.002	0.988–1.016	0.796

OR: odds ratio; CI: confidence interval

**Table 6** Correlations between measured variables

Variables	Age (yrs)	BMI (kg/m <sup>2</sup> )	Back muscle strength (kg)	Spinal inclination angle (°)	Sacral slope angle (°)	Thoracic kyphosis angle (°)	Lumbar kyphosis angle (°)	Thoracic spinal ROM (°)	Lumbar spinal ROM (°)	Total spinal ROM (°)
Age (yrs)		0.146*	-0.417***	0.333***	-0.330***	0.143	0.299***	-0.154*	-0.238**	-0.053
BMI (kg/m <sup>2</sup> )			-0.121	0.233**	-0.271***	0.278***	0.188*	-0.055	-0.288***	-0.139
Back muscle strength (kg)				-0.294**	0.264***	-0.169*	-0.242**	0.040	0.191*	0.230**
Spinal inclination angle (°)					-0.291***	-0.057	0.641***	-0.154*	-0.189*	-0.184*
Sacral slope angle (°)						-0.070	-0.794***	0.045	0.372***	-0.151*
Thoracic kyphosis angle (°)							-0.349***	-0.056	-0.103	-0.222**
Lumbar kyphosis angle (°)								-0.044	-0.333***	-0.097
Thoracic spinal ROM (°)									-0.167**	-0.361***
Lumbar spinal ROM (°)										0.445***
Total spinal ROM (°)										

Data represent Pearson's correlation coefficient (r) \*p<0.05, \*\*p<0.01, \*\*\*p<0.001

it had positive correlations with BMI, spinal inclination angle, and lumbar kyphosis angle. Back muscle strength had significant negative correlations with age, spinal inclination angle, thoracic and lumbar kyphosis, and it had positive correlations with sacral slope angle, lumbar and total spinal ROM. Spinal inclination angle had significant negative correlations with back muscle strength, sacral slope angle, thoracic and lumbar, and total spinal ROM, and it had positive correlations with age and lumbar kyphosis angle.

## DISCUSSION

The concept of LS is relatively new, and as far as we know, the number of clinical studies focused on LS is very small. To educate the public and clinicians as to the concept of this syndrome, and to gain their acceptance of its use, we must be able to demonstrate the specific characteristics of LS. The origin of LS is manifold; above all, degenerative spondylosis, osteoporosis, and osteoarthritis of the knee are the major musculoskeletal diseases involved.<sup>1,2)</sup> Many elderly people suffer from some kind of spinal disorders. In the current study, we investigated the influence of spinal curvature, ROM and other factors on LS in Japanese women ( $\geq 50$  years). This is the first study that focuses on spinal factors as a contributor of LS among women.

The present study demonstrated that aging and decreased back muscle strength may be

important risk factors for LS in women. These two indices were mutually correlated, and both were correlated with spinal inclination angle, sacral slope angle, lumbar kyphosis angle, and lumbar spinal ROM. In other words, increased spinal inclination and lumbar kyphosis are causes or consequences of decreased back muscle strength, and with aging lumbar kyphosis leads to increased spinal inclination, and decreased sacral slope angle and lumbar spinal ROM. A previous study<sup>5)</sup> reported that lumbar (not thoracic) kyphosis correlated positively with spinal inclination and all parameters of postural balance measured by stabilometry in osteoporosis patients. Postural imbalance, such as a category 1, might be one of the symptoms of LS. Our results are consistent with that study.

Our results (Table 6) suggest that, with aging, the spinal inclination increases and back muscle strength decreases with an increase in lumbar kyphosis resulting in a posture with the head bent forward. Among the subjects in the present study, those who had LS had weaker back muscle strength than those subjects without LS. Decreased back muscle strength were significantly correlated with increased spinal inclination, thoracic and lumbar kyphosis. The posture with the head bent forward leads to sagittal imbalance, which can cause a gait disorder and lead to a high risk of falling.<sup>6)</sup> Increased thoracic and lumbar kyphosis also causes sagittal imbalance of the spine and its most prominent clinical feature is a stooped trunk and difficulty walking.<sup>7)</sup> Walking difficulty is a representative symptom in LS, and maintaining the ability to walk is essential to avoiding LS. Sagittal imbalance might be linked to spinal compression fracture due to forward loading on the spinal vertebrae. Individuals that maintain a posture with the head bent forward will often fall more which leads to a deterioration of their activities of daily living (ADL) and their quality of life (QOL).<sup>8)</sup>

Back muscle strength has been investigated mainly in osteoporosis patients. Osteoporotic women had significantly lower back muscle strength than healthy women.<sup>9)</sup> Back muscle strength correlated negatively with thoracic and lumbar kyphosis and positively with sacral inclination angle and bone mineral density of the spine.<sup>9-12)</sup> Moreover, back muscle strength is the most important factor for QOL in patients with postmenopausal osteoporosis,<sup>13)</sup> and in middle-aged and elderly males.<sup>8)</sup> This is consistent with our current results demonstrating that weaker back muscles is an important risk factor for LS: osteoporosis can be a cause of LS, and LS may lead to deterioration in ADL and QOL.

Some exercises may help prevent or slow the onset of LS. First, since those with LS have weaker back muscles, back muscle strengthening exercises might be effective. Previous literature reported on the effectiveness of back muscle strengthening exercises in improving the QOL of patients with osteoporosis.<sup>14-17)</sup> Secondly, our results also showed negative correlations between age and the thoracic and lumbar spinal ROM. And our results also showed positive correlations between decreased back muscle strength and the lumbar and total spinal ROMs. That is, a larger spinal ROM contributes to increased back muscle strength. Previous literature also pointed out the influence of spinal ROM on QOL in postmenopausal osteoporotic patients<sup>13,18)</sup> and in middle-aged and elderly males.<sup>8)</sup> These results indicate that spinal ROM exercises should also be included in any exercise program for individuals at risk for LS.

There are some limitations in this study. First, this investigation is a cross-sectional study; a longitudinal study is needed for further information. Second, locomotive syndrome is a broad concept which may encompass many kinds of musculoskeletal diseases, so our results might be less clear than if we had examined an individual disease. Third, a full radiographic examination of the entire spine is required for a complete evaluation of sagittal balance. Unfortunately, we were unable to obtain whole spine radiographs in the basic health checkup, and, therefore we used the SpinalMouse<sup>®</sup> for evaluating spinal balance.

In summary, aging and decreased back muscle strength may be the most important risk factors

for LS. Increased spinal inclination, lumbar kyphosis, and decreased lumbar spinal ROM are related to decreased back muscle strength. Back muscle strengthening exercises and lumbar spinal ROM exercises could be useful tools for improving the status of a patient diagnosed with LS.

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### CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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