The Japanese Orthopaedic Association has proposed the term *locomotive syndrome* 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 locomotive syndrome in Japanese men. A total of 105 men older than 50 years were enrolled in the study. Those answering *yes* to least 1 of 7 categories in a self-assessment checklist for locomotive syndrome were defined as having locomotive syndrome. The authors evaluated lateral lumbar radiographs, sagittal parameters, sagittal balance using the spinal inclination angle as an index, spinal range of motion as determined with SpinalMouse (Idiag, Volkerswill, Switzerland), back muscle strength, and body mass index. Age, back muscle strength, and spinal inclination angle significantly correlated with locomotive syndrome. Multiple logistic regression analysis indicated that a decrease in back muscle strength (odds ratio, 0.964; *P* < .01) and an increase in spinal inclination angle (odds ratio, 1.232; *P* < .05) were significantly associated with locomotive syndrome. Back muscle strength had significant negative correlations with age and spinal inclination angle. Spinal inclination angle had significant negative correlations with back muscle strength and lumbar and total spinal range of motion and significant positive correlations with age, body mass index, sacral slope angle, and lumbar kyphosis. A decrease in back muscle strength and an increase in spinal inclination angle may be the most important risk factors for locomotive syndrome in Japanese men. Back muscle strengthening and spinal range of motion exercises could be useful for improving the symptoms of locomotive syndrome.
The Japanese population is aging rapidly. In 2009, the average lifespans of a Japanese man and woman were 79.59 and 86.44 years, respectively, which are 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 expected to account for 40.5% of the country’s total population.\(^1\)

The Japanese Orthopaedic Association (JOA) has proposed the term locomotive syndrome to designate a condition in people from high-risk groups with musculoskeletal disease who are highly likely to require nursing care at some point.\(^1\)\(^3\) This syndrome is caused by weakening of the musculoskeletal organs such as bones, joints, and muscles. The loss of function in these organs leads to walking or self-transportation disabilities, which may ultimately force people with this syndrome to seek outside care and support. To prevent this disabling condition, individuals must maintain healthy musculoskeletal organs.

The specific characteristics of locomotive syndrome are not yet known. Major musculoskeletal diseases that may lead to locomotive syndrome include osteoporosis, spondylolisthesis, and osteoarthritis. Although the spinal column, which strongly regulates posture, is one of the major components affected by osteoporosis and spondylolisthesis, the authors found no other report investigating the relationship between spinal factors and locomotive syndrome among men. This goal of this study was to investigate the influence of spinal curvature, range of motion (ROM), and other factors on locomotive syndrome in Japanese men.

**Materials and Methods**

The study group comprised healthy Japanese men who attended a local government basic health checkup in 2010. This checkup has been held annually in the town of Yakumo for 30 years and includes voluntary orthopedic and physical function examinations, internal medical examinations, and psychological tests.

Inclusion criteria included: (1) Japanese men aged older than 50 years; (2) men who underwent radiographs of the lumbar spine, SpinalMouse (Idiag, Volkswill, Switzerland) measurements, and physical examination (back muscle strength and body mass index [BMI]) during the basic health checkup; and (3) men who consented to participate in this study. SpinalMouse is a noninvasive, computer-assisted device measuring spinal shape and mobility using surface-based measurements. Individuals could not participate with this diagnostic technique if they had severe walking or standing disabilities or dysfunction of the central or peripheral nervous systems.

Of 650 individuals who underwent the checkup in 2010, four hundred fourteen (average age, 66.3 years; age range, 39-90 years) underwent orthopedic and physical function examinations. Of those 414 individuals, 315 (115 men and 200 women) underwent radiographs of the lumbar spine, SpinalMouse measurements, and physical examination. Women and anyone younger than 50 years were excluded. The final study group comprised 105 Japanese men with an average age of 69.5 years (range, 50-90 years; SD, 8.2). All participants 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 JOA developed a self-assessment checklist for locomotive syndrome in 2007 (Table 1)\(^1,\)\(^2\) which was administered to all participants in the current study. By JOA criteria, an individual answering in the affirmative to any of the 7 categories in the checklist may have locomotive syndrome. The current study followed those guidelines. The number of participants who answered in the affirmative to each category in the checklist are shown in Table 1.

**Radiographic Measurement**

Participants stood in a neutral standing position for the lumbar spine radiographs. Lumbar kyphosis angle (Cobb angle between T12 and S1) and sacral slope angle were measured using lateral lumbar radiographs.
Measurement of Spinal Curvature and Range of Motion

Spinal curvature and ROM were evaluated using SpinalMouse. Intraclass coefficients of 0.92 to 0.95 have been determined for curvature measurement with SpinalMouse.\(^4\) In the current study, each angle was measured 3 times each in a neutral standing position, maximum bending position, and maximum extension position; the average of the 3 measurements was used. Evaluation included spinal inclination angle between a 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 were measured and calculated automatically using the SpinalMouse. Lumbar kyphosis angle and sacral inclination angle were correlated with lumbar radiographs to confirm the reproducibility of SpinalMouse measurements.

Measurement of Back Muscle Strength

Back muscle strength from the maximal isometric strength of the trunk muscles was measured in a standing posture with 30° lumbar flexion using a digital back muscle strength meter (TKK 5402; Takei Scientific Instruments Co Ltd, Tokyo, Japan).\(^5\) The average force from 2 trials was recorded. The maximum strength in each trial had a high reproducibility (r=0.990; P<0.0001). All participants were assessed by one examiner (A.M.) who was blinded to the results of other evaluations.

Statistical Analysis

All data (mean±SD) were analyzed using SPSS version 19 statistical software (SPSS Inc, Chicago, Illinois). Pearson’s correlation coefficient analysis or Spearman’s correlation coefficient analysis was used to determine correlations between variables. Logistic regression analyses (univariate and multiple) were used for analyzing risk factors for locomotive syndrome. Variables were included in the multiple model if the univariate analysis P value was <.25. P values <.05 were considered statistically significant.

RESULTS

Evaluation of the SpinalMouse data revealed a significant correlation between lumbar radiographic data and lumbar kyphosis angle (r=.672; P<.0001) and sacral slope angle (r=.551; P<.0001). This confirmed the reliability of the SpinalMouse measurements of these angles, and the data were then used in further analysis.

Mean values for study participants’ ages and measured variables are listed in Table 2. Thirty-one men were defined as having locomotive syndrome. The correlations between each category of locomotive syndrome, the self-assessment checklist, and other variables in the participants were also evaluated (Table 3). Among the measured variables, age, back muscle strength, and spinal inclination angle showed significant correlations with locomotive syndrome and categories 1, 3, and 6 of the 7 self-assessment checklist categories.

When univariate logistic regression analysis was performed with the presence of locomotive syndrome as a dependent variable and the other estimated variables were selected as independent variables, age, back muscle strength, and spinal inclination angle were identified as significantly affecting the presence of locomotive syndrome (Table 4). Multiple logistic regression analysis with the selected variables from the univariate analyses revealed back muscle strength and spinal inclination angle to be significant indices of locomotive syndrome (Table 5). These results from multiple logistic regression analysis showed that a decrease in back muscle strength and an increase in the spinal inclination angle represent important risk factors for locomotive syndrome in Japanese men.
Correlations between variables were also evaluated. Back muscle strength had significant negative correlations with age and spinal inclination angle. Spinal inclination angle had significant negative correlations with back muscle strength, lumbar spinal ROM, and total spinal ROM, and it had positive correlations with age, BMI, sacral slope angle, and lumbar kyphosis angle (Table 6).

### DISCUSSION

The concept of locomotive syndrome is relatively new, and to the authors’ knowledge, few clinical studies focus on locomotive syndrome. The origin of locomotive syndrome is multifold; above all, degenerative spondylosis, osteoporosis, and osteoarthritis of the knee are the major musculoskeletal diseases involved.1-3 Many middle-aged and elderly people experience some type of spinal disorder. The current study investigated the influence of spinal curvature, ROM, and other factors on locomotive syndrome in Japanese men. To the authors’ knowledge, this is the first study focusing on spinal factors as a contributor of locomotive syndrome among Japanese men.

The current study demonstrated that decreased back muscle strength and increased spinal inclination may be important risk factors for locomotive syndrome in Japanese men. These 2 indices were mutually correlated, and both were correlated with aging. Moreover, spinal in-
clination angle had significant negative correlations with lumbar spinal ROM and total spinal ROM, and it had positive correlations with age, BMI, sacral slope angle, and lumbar kyphosis angle.

Therefore, increased lumbar kyphosis leads to increased spinal inclination and is indirectly correlated with decreased back muscle strength. A previous study reported that lumbar 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, may be a symptom of locomotive syndrome. The current study’s results are consistent with that study.

The current study’s results 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 (Table 6). Among participants in the current study, those with locomotive syndrome had weaker back muscle strength and a larger spinal inclination than those without locomotive syndrome. 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.

Increased lumbar kyphosis in the elderly also causes sagittal imbalance of the spine, and its most prominent clinical feature is a stooped trunk and difficulty walking. Walking difficulty is a representative symptom in locomotive syndrome, and maintaining the ability to walk is essential to avoiding locomotive syndrome. Sagittal imbalance may be linked to spinal compression fracture due to forward loading.

### Table 5

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR</th>
<th>95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>0.987</td>
<td>0.908-1.073</td>
<td>.761</td>
</tr>
<tr>
<td>Back muscle strength, kg</td>
<td>0.964</td>
<td>0.943-0.987</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Spinal inclination angle, deg</td>
<td>1.232</td>
<td>1.001-1.516</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>Sacral slope angle, deg</td>
<td>1.046</td>
<td>0.943-1.159</td>
<td>.395</td>
</tr>
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<td>Thoracic kyphosis angle, deg</td>
<td>1.03</td>
<td>0.972-1.091</td>
<td>.312</td>
</tr>
<tr>
<td>Lumbar kyphosis angle, deg</td>
<td>0.984</td>
<td>0.940-1.029</td>
<td>.477</td>
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<tr>
<td>Total spinal ROM, deg</td>
<td>1.004</td>
<td>0.973-1.036</td>
<td>.805</td>
</tr>
</tbody>
</table>

**Abbreviations:** deg, degrees; CI, confidence interval; OR, odds ratio; ROM, range of motion.

### Table 6

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male, kg/m²</th>
<th>Female, kg/m²</th>
<th>Male, kg/m²</th>
<th>Female, kg/m²</th>
<th>Male, kg/m²</th>
<th>Female, kg/m²</th>
<th>Male, kg/m²</th>
<th>Female, kg/m²</th>
<th>Male, kg/m²</th>
<th>Female, kg/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
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<td>0.011</td>
<td>0.011</td>
<td>0.011</td>
<td>0.011</td>
<td>0.011</td>
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<tr>
<td>BMI, kg/m²</td>
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<td>0.090</td>
<td>0.090</td>
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<tr>
<td>Back muscle strength, kg</td>
<td>-0.260</td>
<td>-0.260</td>
<td>-0.260</td>
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<td>-0.260</td>
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</tr>
<tr>
<td>Spinal inclination angle, deg</td>
<td>0.237</td>
<td>0.237</td>
<td>0.237</td>
<td>0.237</td>
<td>0.237</td>
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<tr>
<td>Sacral slope angle, deg</td>
<td>0.155</td>
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</tr>
<tr>
<td>Thoracic kyphosis angle, deg</td>
<td>0.218</td>
<td>0.218</td>
<td>0.218</td>
<td>0.218</td>
<td>0.218</td>
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<tr>
<td>Lumbar kyphosis angle, deg</td>
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<td>0.075</td>
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<td>0.075</td>
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<td>0.075</td>
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<tr>
<td>Total spinal ROM, deg</td>
<td>0.195</td>
<td>0.195</td>
<td>0.195</td>
<td>0.195</td>
<td>0.195</td>
<td>0.195</td>
<td>0.195</td>
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</tbody>
</table>

**Abbreviations:** BMI, body mass index; deg, degrees; ROM, range of motion.

*Data represent Pearson’s correlation coefficient (r).*

P < .01.

P < .001.

P < .05.

P < .001.
on the spinal vertebrae. Individuals who maintain a posture with the head bent forward will often fall more, which leads to a deterioration of their activities of daily living and their quality of life.\(^9\)

Back muscle strength has been investigated mainly in patients with osteoporosis. Women with osteoporosis have significantly less back muscle strength than healthy women.\(^{10}\) Back muscle correlates negatively with thoracic and lumbar kyphosis and positively with sacral inclination angle and bone mineral density of the spine.\(^{10-13}\) Moreover, back muscle strength is the most important factor for quality of life in patients with postmenopausal osteoporosis\(^ {14}\) and in middle-aged and elderly men.\(^9\) This is consistent with the current study’s results demonstrating that weaker back muscle strength is an important risk factor for locomotive syndrome: osteoporosis can be a cause of locomotive syndrome, and locomotive syndrome may lead to deterioration in activities of daily living and quality of life.

Exercises may help prevent or slow the onset of locomotive syndrome. First, because individuals with locomotive syndrome have weaker back muscles, back muscle–strengthening exercises may be effective. Previous studies have reported the effectiveness of back muscle–strengthening exercises in improving the quality of life of patients with osteoporosis.\(^ {15-18}\) Second, the current study’s results showed a negative correlation between lumbar spinal ROM and spinal inclination and lumbar kyphosis angles; that is, a larger spinal ROM contributes to a lesser spinal inclination and lesser lumbar kyphosis. Previous studies reported the influence of spinal ROM on quality of life in postmenopausal patients with osteoporotic\(^ {14,19}\) and in middle-aged and elderly men.\(^9\) These results indicate that spinal ROM exercises should be included in any exercise program for individuals at risk for locomotive syndrome.

This study had some limitations. First, locomotive syndrome is a broad concept that may encompass many types of musculoskeletal diseases, so the study’s results may be less clear than if an individual disease had been investigated. Second, a full radiographic examination of the entire spine is required for a complete evaluation of sagittal balance. Unfortunately, whole spine radiographs were not obtained at the basic health checkup; therefore, the SpinalMouse was used to evaluate spinal balance. Third, the number of participants in the study was relatively small; however, the number may be sufficient for the first study demonstrating the relationship between spinal factors and locomotive syndrome among Japanese men.

**Conclusion**

Back muscle strength and spinal inclination may be the most important risk factors for locomotive syndrome among men. Lumbar kyphosis and lumbar spinal ROM are related to spinal inclination. Back muscle–strengthening and lumbar spinal ROM exercises may be useful tools for improving the symptoms of locomotive syndrome.

**References**