Prevalence of symptomatic lumbar spinal stenosis and its association with physical performance in a population-based cohort in Japan: the Wakayama Spine Study

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Objective: The purpose of this study was to investigate the prevalence of symptomatic lumbar spinal stenosis (LSS) and to clarify the association between symptomatic LSS and physical performance using magnetic resonance imaging (MRI) in a population-based cohort.

Design: This cross-sectional study was performed as a part of the Research on Osteoarthritis/osteoarthritis Against Disability (ROAD) in Japan and 1,009 subjects (335 men, 674 women, mean age 66.3 years, age range 21–97 years) were analyzed. An experienced orthopedic surgeon obtained the medical history and performed the physical testing for all participants. Symptomatic LSS diagnostic criteria required the presence of both symptoms and radiographic LSS findings. A 6-m walking time, chair standing time, and one-leg standing time were obtained from all participants.

Results: The prevalence of symptomatic LSS was 9.3% (95% confidence interval [CI]: 7.7–11.3) overall, 10.1% (CI: 7.4–13.8) in men and 8.9% (CI: 7.0–11.3) in women. There was a difference in the prevalence with increasing age by gender. The LSS prevalence showed little difference with age greater than 70 years for men, but the LSS prevalence for women was higher with increasing age. Among physical performance measures, 6-m walking time at a maximal pace was significantly associated with symptomatic LSS (P = 0.03).

Conclusion: The prevalence of symptomatic LSS was approximately 10% in a cohort resembling the general Japanese population. A 6-m walking time at a maximal pace was a more sensitive index than walking at a usual pace in assessing decreased physical performance associated with symptomatic LSS.

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Subjects with three different degenerative musculoskeletal disorders (knee osteoarthritis, hip osteoarthritis, and symptomatic LSS) who were scheduled for either joint replacement or spinal decompression surgery, walking ability was limited in all three groups compared to healthy controls. However, patients with symptomatic LSS showed the greatest restrictions in walking ability. In another report regarding subjects with symptomatic LSS in an orthopedic clinical practice, subjects in the healthy group showed greater functional mobility than those in the symptomatic LSS group. The subjects included in the previous studies had enough symptoms to have visited the hospital, however, the association of physical performance measures with symptomatic LSS in subjects with minor symptoms who do not visit the hospital has not been well characterized. Although there may be a latent diminished physical functioning in symptomatic LSS with even minor radiographic changes and symptoms, there have been no population-based studies on symptomatic LSS that have included people with minor signs and symptoms of LSS.

Symptomatic LSS in this study was diagnosed by the presence of both clinical symptoms and radiographic LSS findings consistent with the clinical presentation. The aim of the present study was to clarify the prevalence of symptomatic LSS by gender and age strata with the clinical presentation. The aim of the present study was to clarify the prevalence of symptomatic LSS by gender and age strata.

Methods

Participants

The present study, entitled “the Wakayama Spine Study: population-based cohort”, was a population-based study for degenerative spinal disease and performed in a subcohort of the large-scale population-based cohort study called Research on Osteoarthritis/osteoporosis Against Disability (ROAD). ROAD is a nationwide, prospective study of bone and joint diseases consisting of population-based cohorts established in several communities in Japan. As a detailed profile of the ROAD study has already been described elsewhere, only a brief summary is provided here.

To date, creation of a baseline database including clinical and genetic information for 3,040 inhabitants (1,061 men, 1,979 women) in the age range of 23–95 years (mean, 70.6 years) has been completed. Participants were recruited from listings of resident registrations in three communities: an urban region in Itabashi, Tokyo; a mountainous region in Hidakagawa, Wakayama; and a coastal region in Taiji, Wakayama. All participants provided written informed consent, and the study was conducted with the approval of ethical committees of the University of Tokyo and the Tokyo Metropolitan Institute of Gerontology.

Participants completed an interviewer-administered questionnaire of 400 items that included lifestyle information such as smoking habits, alcohol consumption, family history, past history, physical activity, reproductive variables, and health-related quality of life (QOL). Anthropometric measurements included height, weight, bilateral grip strength, and body mass index (BMI) (weight [kg]/height2 [m2]). The ankle-brachial index (ABI) was measured using PWV/ABI (OMRON Co., Kyoto, Japan) for all participants. A timed 6-m walk at the participant’s usual pace in a hallway was recorded to measure physical performance. Similarly, 6-m walking time at a maximal pace was measured. The time taken for five consecutive chair rises without the use of hands was also recorded. One-leg standing time with each leg was measured using a stopwatch (upper limit, 60 s) and the time adopted was the mean value of both legs.

MRI

A mobile MRI (Exelart 1.5 T, Toshiba, Tokyo, Japan) unit was used in the present study, and total spinal MRI was performed for all participants on the same day as the examination. MRI exclusion criteria included presence of a cardiac pacemaker, claustrophobia, or other contraindications. The participants were positioned in supine during the MRI, and those with rounded backs used triangular pillows under their head and knees. The imaging protocol included sagittal T2-weighted fast spin echo (FSE) (repetition time [TR]: 4,000 ms/echo, echo time [TE]: 120 ms, field of view [FOV]: 300 × 320 mm), and axial T2-weighted FSE (TR: 4,000 ms/echo, TE: 120 ms, FOV: 180 × 180 mm). Sagittal images were taken for the entire spine, but axial images were done at each lumbar intervertebral level (L1-2–L5/S1) parallel to the vertebral endplates.

Symptomatic LSS diagnosis

An experienced orthopedic surgeon (YI) consistently took the medical history and performed the physical testing for all the participants in this study. The history included information on the...
presence of low back, buttock and leg pain, the area of pain or other discomfort, the presence of IC and its distance, and a modified Zurich Claudication Questionnaire (excepting six items about satisfaction and a history of lumbar surgery for symptomatic LSS). Physical examinations included symptoms induced by lumbar extension, symptoms improved or induced with lumbar flexion, floor finger distance (cm), peripheral circulation (good or poor), a straight leg raising test, manual muscle testing of both upper and lower extremities, tendon reflex testing for both upper and lower extremities, and Babinski reflex testing. In addition, the MRI study of the entire spine was performed on all participants on the same day as the physical examination.

The diagnostic criteria for symptomatic LSS used in the present study were based on the LSS definition from the North American Spine Society (NASS) guideline, which requires presentation of both LSS symptoms and radiographic signs of LSS. The orthopedic surgeon (YI) made the diagnosis of symptomatic LSS using this definition. The diagnosis for LSS symptoms required one or more of the following symptoms: pain, numbness and neurological deficits in the lower extremities and buttocks, and bladder/bowel dysfunction. The symptom characteristics should be induced or exacerbated with walking or prolonged standing and relieved with lumbar flexion, sitting and recumbency. The severity of radiographic LSS was assessed by qualitative measurements, which were performed by a well-experienced orthopedic surgeon (YI) and images were provided on films. The features assessed for LSS included severity of central, lateral recess, and foraminal stenosis, rated as four grades: none, mild, moderate and severe. The lateral recess was defined, as per Fardon and Millette, as extending from the medial edge of the facet to the edge of the neural foramen. We applied the general guideline classification of a mild stenosis as narrowing of the normal area by one-third or less, moderate stenosis as narrowing between one-third and two-thirds, and severe stenosis as narrowing of more than two-thirds. Central and lateral recess stenosis was rated on the axial images and foraminal stenosis on the sagittal images. We used the most severe side for the rating of lateral and foraminal stenosis at each level. The same observer scored 50 randomly selected lumbar MRI films more than 1 month after the first reading to evaluate the intraobserver variability of the severity rating. Two experienced orthopedic surgeons also scored 50 different lumbar MRI films (YI & KN) for interobserver variability. The interobserver variability was confirmed by a kappa analysis which dichotomized radiographic LSS severity as no/mild stenosis vs moderate/severe stenosis, and showed sufficient reliability for assessment of central, lateral and foraminal stenosis (0.77, 0.70 and 0.65, respectively). Interobserver variability was also sufficient for assessment using the kappa analysis (0.71, 0.65 and 0.65, respectively).

Radiographic LSS also required the severity to be more than moderate and the radiographic finding needs to be consistent with the symptoms as outlined above. An experienced orthopedic surgeon (YI) made the final diagnosis of symptomatic LSS using this definition, which requires presentation of both LSS symptoms and radiographic LSS findings. There were no participants with LSS symptoms due to tumor, inflammatory, or traumatic pathologies.

Statistical analysis

All statistical analyses were performed using JMP version 8 (SAS Institute Japan, Tokyo, Japan). Differences in age, height, weight, BMI, 6-m walking time at a usual pace, 6-m walking time at a maximal pace, chair standing time, and one-leg standing time between men and women were examined by the non-paired Student’s t-test. The non-paired Student’s t-test was also used to compare age between participants with and without symptomatic LSS. The prevalence of symptomatic LSS was also compared between men and women by the chi-square test. Differences in physical performance measures (6-m walking time at a usual pace, 6-m walking time at a maximal pace, chair standing time, and one-leg standing time) between participants with and without symptomatic LSS were examined by the non-paired Student’s t-test. Furthermore, logistic regression analysis was used to estimate the odds ratios (ORs) of physical performance measures (6-m walking time at a usual pace, 6-m walking time at a maximal pace, chair standing time, and one-leg standing time) for symptomatic LSS after adjustment for age, gender, and BMI.

Results

Table I shows the characteristics of 1,009 participants (335 men and 674 women, mean age 66.3 years, age range of 21–97 years) including age, anthropometric measurements, and physical performance in the present study. Two-thirds of the 1,009 participants were women. Mean age was not significantly different between men and women. BMI was significantly lower in women than in men (P = 0.005). Physical performance measures of the 6-m walking time at a usual pace and at a maximal pace were significantly shorter in men than in women (P < 0.05 for both), while chair standing time and one-leg standing time were not significantly different between men and women.

The prevalence of radiographic LSS findings was much greater than the prevalence of symptomatic LSS for the participants in this study. The percentage of participants with moderate or severe radiographic central stenosis was 76.5% (95% confidence interval [CI]: 73.7–79.0) in total, while the prevalence of symptomatic LSS was 9.3% (95% CI: 7.7–11.3) in total, 10.1% (CI: 7.4–13.8) in men, and 8.9% (CI: 7.0–11.3) in women. There was no significant difference between men and women (P = 0.52). The prevalence in men less than 39 years, 40–49, 50–59, 60–69, 70–79, and 80 years and older was 0%, 3.8% (CI: 0.7–18.9), 9.8% (CI: 4.6–19.8), 11.8% (CI: 6.1–21.5), 11.7% (CI: 6.7–19.8), and 10.7% (CI: 5.6–19.7), respectively, while that in women was 0%, 1.4% (CI: 0.2–7.3), 5.7% (CI: 2.8–11.3), 9.3% (5.7–14.8), 11.9% (CI: 7.9–17.5), and 13.3% (CI: 8.4–20.6), respectively (Fig. 2). The prevalence of both genders

<table>
<thead>
<tr>
<th>Table I Characteristics of participants</th>
<th>Total</th>
<th>Men</th>
<th>Women</th>
<th>P value for gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of participants</td>
<td>1009</td>
<td>335</td>
<td>674</td>
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</tr>
<tr>
<td>Age group (years)</td>
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</tr>
<tr>
<td>≤39</td>
<td>30</td>
<td>11</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>40–49</td>
<td>100</td>
<td>26</td>
<td>74</td>
<td></td>
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<tr>
<td>50–59</td>
<td>184</td>
<td>61</td>
<td>123</td>
<td></td>
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<tr>
<td>60–69</td>
<td>229</td>
<td>68</td>
<td>161</td>
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<td>70–79</td>
<td>271</td>
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<td>≥80</td>
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<td>75</td>
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<tr>
<td>Demographic characteristics</td>
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<td></td>
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<tr>
<td>Age, years</td>
<td>66.3±13.6</td>
<td>67.3±13.8</td>
<td>65.9±13.4</td>
<td>0.11</td>
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<td>Height, cm</td>
<td>155.9±9.4</td>
<td>164.5±7.1</td>
<td>151.6±7.2</td>
<td>&lt;0.0001</td>
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<tr>
<td>Weight, kg</td>
<td>56.8±11.5</td>
<td>64.4±11.7</td>
<td>53.1±9.4</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>23.3±3.6</td>
<td>23.7±3.5</td>
<td>23.1±3.6</td>
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<tr>
<td>Physical performance</td>
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<td></td>
</tr>
<tr>
<td>Six-meter walking time at a usual pace, s</td>
<td>5.7±2.2</td>
<td>5.5±1.5</td>
<td>5.8±2.4</td>
<td>0.04</td>
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<tr>
<td>Six-meter walking time at a maximal pace, s</td>
<td>3.9±1.4</td>
<td>3.6±1.1</td>
<td>4.0±1.6</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Chair standing time, s</td>
<td>8.9±4.0</td>
<td>8.8±3.4</td>
<td>8.9±4.2</td>
<td>0.61</td>
</tr>
<tr>
<td>One-leg standing time, s</td>
<td>36.0±23.7</td>
<td>35.7±24.0</td>
<td>36.1±23.6</td>
<td>0.92</td>
</tr>
</tbody>
</table>

Non-paired t-test was used to determine differences in demographic characteristics and measurements of physical performance between men and women. Values are the means ± standard deviation.
Values are the means and 95% CI. BMI showed that 6-m walking time at a maximal pace was significantly associated with symptomatic LSS (OR: 1.17, 95% CI: 1.01–1.34). The physical performance measures of 6-m walking time at a usual pace, chair standing time, and one-leg standing time were not significantly associated with symptomatic LSS (OR: 1.04, 95% CI: 0.94–1.13, OR: 1.03, 95% CI: 0.97–1.09 and OR: 1.00, 95% CI: 0.98–1.01, respectively).

**Discussion**

The present study is the first to clarify the prevalence of symptomatic LSS by gender and age strata and the association of symptomatic LSS with physical performance measures using a population-based cohort. The prevalence of symptomatic LSS was found to be 9.3% in the general Japanese population, 10.1% in men, 8.9% in women, and there were no significant differences between genders. Interestingly, although the prevalence in women was higher with increasing age, the prevalence in men was the highest at 60–69 years, and little difference in prevalence was seen in men aged 60–69 years to 80 years or older. The prevalence of radiographic LSS was much greater than the prevalence of symptomatic LSS, with only a small proportion of participants with radiographic LSS actually showing symptoms suggestive of the clinical syndrome. The 6-m walking time at a maximal pace was significantly associated with symptomatic LSS, while the 6-m walking time at a usual pace was not.

We have identified no previous studies of symptomatic LSS prevalence. Johnsson et al. reported that the incidence of symptomatic LSS was 50/million person-years in southern Sweden in a study of patients who consulted the orthopedic department in two cities. However, as the author of that report described, the incidence of symptomatic LSS could be underestimated, because the study did not include patients with minor symptoms who did not visit the hospital. This study is the first to clarify the prevalence of symptomatic LSS using a population-based cohort study.

Reported differences in prevalence of symptomatic LSS between men and women are mixed. Verbiest reported a preponderance of symptomatic LSS in men as compared to women among his patients diagnosed by clinical symptoms and myelography. However, Getty reported an equal gender distribution of symptomatic LSS prevalence in a series in which subjects were treated surgically for symptomatic LSS. It is important to note that the subjects in those studies were patients who visited hospitals. In the present study, differences in the prevalence of symptomatic LSS between men and women in the general population were clarified. The prevalence of symptomatic LSS in men was slightly higher than in women, but there was no significant difference between genders. There was a difference in distribution of symptomatic LSS between men and women. The prevalence in women was higher with increasing age, but that in men was the highest at 60–69 years and

**Table II**

<table>
<thead>
<tr>
<th>Physical performance</th>
<th>Total</th>
<th>LSS</th>
<th>Non-LSS</th>
<th>P value</th>
<th>Men</th>
<th>LSS</th>
<th>Non-LSS</th>
<th>P value</th>
<th>Women</th>
<th>LSS</th>
<th>Non-LSS</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of participants</td>
<td>94</td>
<td>915</td>
<td></td>
<td></td>
<td>34</td>
<td>301</td>
<td></td>
<td>60</td>
<td>614</td>
<td></td>
<td></td>
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<tr>
<td>Physical performance</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Six-meter walking time at a usual pace, s</td>
<td>6.3 ± 2.7</td>
<td>5.6 ± 2.1</td>
<td>0.003</td>
<td>6.0 ± 1.6</td>
<td>5.4 ± 1.5</td>
<td>0.03</td>
<td>6.5 ± 3.1</td>
<td>5.7 ± 2.3</td>
<td>0.02</td>
<td>6.5 ± 3.1</td>
<td>5.7 ± 2.3</td>
<td>0.02</td>
</tr>
<tr>
<td>Six-meter walking time at a maximal pace, s</td>
<td>4.5 ± 2.1</td>
<td>3.8 ± 1.3</td>
<td>&lt;0.0001</td>
<td>3.9 ± 1.1</td>
<td>3.6 ± 1.1</td>
<td>0.09</td>
<td>4.8 ± 2.4</td>
<td>3.9 ± 1.5</td>
<td>&lt;0.0001</td>
<td>4.8 ± 2.4</td>
<td>3.9 ± 1.5</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Chair standing time, s</td>
<td>10.1 ± 4.0</td>
<td>8.8 ± 3.9</td>
<td>0.002</td>
<td>9.7 ± 2.8</td>
<td>8.7 ± 3.4</td>
<td>0.10</td>
<td>10.3 ± 4.6</td>
<td>8.8 ± 4.1</td>
<td>0.008</td>
<td>10.3 ± 4.6</td>
<td>8.8 ± 4.1</td>
<td>0.008</td>
</tr>
<tr>
<td>One-leg standing time, s</td>
<td>27.9 ± 23.5</td>
<td>36.8 ± 23.6</td>
<td>0.0005</td>
<td>27.7 ± 25.4</td>
<td>36.7 ± 23.7</td>
<td>0.04</td>
<td>28.0 ± 22.6</td>
<td>36.9 ± 23.5</td>
<td>0.006</td>
<td>28.0 ± 22.6</td>
<td>36.9 ± 23.5</td>
<td>0.006</td>
</tr>
</tbody>
</table>

Values are the means ± standard deviation.

Non-paired t-test was used to determine differences in measurements of physical performance between LSS and non-LSS.
little different in men aged 60–69 years to 80 years and older. The prevalence of lumbar spondylosis (LS) diagnosed as Kellgren/Lawrence (KL) grade two or greater (defined as osteophyte formation with and without disc space narrowing) was found to be significantly higher in men than in women. The prevalence of LS in women was found to be higher with increasing age, while that in men found little difference over 60 years.

Interestingly, these distribution patterns are similar to the prevalence of symptomatic LSS in the present study. Anatomical LSS arises from degenerative LS, and facet osteoarthritsis and/or hypertrophy, which is associated with narrowing of the space available for the neural elements. This may be one reason for the similarity between LS and symptomatic LSS prevalence.

The present study was the first to show that, among the general population, 6-m walking time at a maximal pace was significantly associated with symptomatic LSS, while 6-m walking time at a usual pace was not. This may mean that participants with symptomatic LSS appeared to have no disadvantage concerning activities of daily living compared to those without symptomatic LSS. However, when requiring greater functional reserve, such as 6-m walking time at a maximal pace, differences between participants with and without symptomatic LSS appeared. This is also the first study to indicate that tasks requiring greater functional reserve, such as walking at a maximal speed, could be a more sensitive index in assessment of decreased physical performance due to symptomatic LSS.

There are several limitations in the present study. First, although the present study included more than 1,000 participants, these participants may not represent the general population as they were recruited from only two areas. However, anthropometric measurements were compared between participants and the general Japanese population, and no significant differences were found in BMI (men: 23.71 (3.41) and 23.95 (2.64), P = 0.33; women: 23.06 (3.42) and 23.50 (3.69), P = 0.07). In addition, the proportion of current smokers and current drinkers (those who regularly smoked or drank more than one drink/month) in the general Japanese population was compared with that in the study population. Proportions of current smokers and drinkers in men and that of current drinkers in women were significantly higher in the general Japanese population than in the study population, but there were no significant differences in that of current smokers in women (smokers: men, 32.6% in the Japanese population, 25.2% in study participants, P = 0.015; women, 4.9% in the Japanese population, 4.1% in study participants, P = 0.50; drinkers: men, 73.9% in the Japanese population, 56.8% in study participants, P < 0.0001; women, 28.1% in the Japanese population, 18.8% in study participants, P = 0.0001), suggesting that it is likely that the participants (both men and women) had healthier lifestyles than the general Japanese population. Second, this is a cross-sectional study, so any causal relationship between symptomatic LSS and physical performance cannot be clarified. The Wakayama Spine Study is a longitudinal survey, so further progress will help to elucidate any causal relationships. Thirds, total walking distance/duration was not measured, and this metric for walking would likely have been of greater relevance to symptomatic LSS than speed of walking. In addition, this study only represents the Japanese population, hence, prevalence in other countries may be quite different.

In conclusion, the present study clarified that the prevalence of symptomatic LSS was about 10% in a cohort resembling the Japanese general population. There was a difference in the prevalence of symptomatic LSS distribution by age strata between men and women. The 6-m walking time at a maximal pace was a more sensitive index for assessing decreased physical performance due to LSS than the 6-m walking time at a usual pace. Further longitudinal surveys of the Wakayama Spine Study will help to further clarify the incidence and risk factors for symptomatic LSS.

Author contributions

All authors worked collectively to develop the protocols and methods described in this paper. YI, SM, KN, NO, HO, TA, and NY were principal investigators responsible for the fieldwork in the Wakayama Spine Study. YI and SM performed the statistical analysis. YI, HY, SM, KN, HH, HO, TA, MY, and NY contributed to the analysis and interpretation of results. YI wrote the report. All authors read and approved the final report.

Role of the funding source

The study sponsors played no role in the study design, the collection, analysis, and interpretation of data, writing of the report, or the decision to submit the paper for publication. The corresponding author had full access to all the data and had the final decision to submit for publication.

Conflict of interest

The authors declare that we have no conflicts of interest.

Acknowledgments

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References