Psychometric Evaluation and External Validity of the Japanese Version of Lumbar Stiffness Disability Index

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Abstract:

Introduction: Long fusion surgery for adult spinal deformity may restrict activities of daily living due to lumbar stiffness. While the Lumbar Stiffness Disability Index (LSDI) can help assess lumbar stiffness, in Asia the external validity of this questionnaire has not been sufficiently examined. We performed the psychometric evaluation and external validation of the Japanese version of the LSDI (LSDI-J).

Methods: Fifty consecutive patients (14 males and 36 females; mean age 70.6 years) who underwent lumbar fusion surgery at our institution a minimum of one year after surgery and who visited the outpatient clinic between April and May 2019, were surveyed using the LSDI-J. The mean number of fusion levels was 4.4. Cronbach's alpha coefficients were calculated for internal consistency, and the intraclass correlation coefficient (ICC) was calculated to evaluate reliability. External validity was assessed by comparisons with the Oswestry Disability Index (ODI), the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ), and the lumbar range of motion (LROM) with LSDI-J scores.

Results: Cronbach's alpha coefficient was 0.652 overall, and 0.849 after excluding Question 10 due to a low response rate. The ICC was 0.824 overall and 0.851 after excluding Question 10. The correlation with the ODI was 0.684, and the correlation coefficients with each domain of the JOABPEQ ranged from −0.590 to −0.413, indicating moderate correlation. However, LROM and the LSDI-J were not correlated ($r=-0.055$, $P=0.734$).

Conclusions: The LSDI-J may not be suitable in Japan because there was no correlation with LROM, the most important factor for external validity. It may be necessary to investigate why the LSDI-J did not apply to the Japanese population in terms of lower limb function. Alternatively, a unique method may be needed to assess lumbar stiffness disability that is more suitable for actual clinical practice in Japan.

Keywords:

adult spinal deformity, lumbar stiffness, Lumbar Stiffness Disability Index, Oswestry Disability Index, Japanese Orthopaedic Association Back Pain Evaluation Questionnaire, lumbar range of motion, psychometric evaluation, external validity

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Introduction

In corrective fusion surgery for adult spinal deformity (ASD), long fusion from the thoracic spine to the pelvis is often performed[1]. Long fusion surgery has stable and excellent long-term outcomes[2,3]. However, due to difficulty in lumbar flexions, such as lumbar stiffness disability, long fusion may lead to challenges in activities of daily living (ADLs). Although instruments, such as the Oswestry Disability Index (ODI)[4], the Scoliosis Research Society-22r questionnaire (SRS-22r), and the MOS 36-item short-form health survey (SF-36)[5], are often used to evaluate treatment outcomes for adult spinal deformities, it is difficult to determine spinal stiffness using these scales. Some original methods of evaluating disability due to lumbar stiffness after long fusion surgery for patients with ASD have been described in

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Table 1. The Lumbar Stiffness Disability Index Developed by Hart et al. in 2013.

Choose the statement that best describes the effect of low back stiffness on your ability to:
1. Bend to your feet to put on your underwear and pants while dressing independently.
2. Bend through your waist to put on your socks and shoes.
3. Drive a motor vehicle.
4. Perform personal hygiene functions after toileting.
5. Bend forward to pick up a small object off the floor.
6. Get in and out of bed.
7. Get in and out of a chair.
8. Bathe the lower half of your body.
9. Get in and out of an automobile.
10. Engage in sexual intercourse.
Response options and score for each item
0 No effect at all
1 Minor effect
2 Significant effect
3 Require assistance
4 Cannot do at all

Japan, where they have not been generalized[6-8]. Therefore, using these methods is difficult to make international comparisons of lumbar stiffness disability. The Lumbar Stiffness Disability Index (LSDI), which was developed in the United States in 2013, is a self-report questionnaire in English consisting of 10 questions and rated on a 5-point scale to assess functional limitations related to lumbar stiffness in ADL (Table 1). The internal consistency, reliability, and external validity of this questionnaire have been demonstrated to be good[9,10]. In addition, the LSDI can help examine spinal fusion range and age[10-18]. The Korean version of the LSDI (K-LSDI)[19], the Chinese versions of the LSDI (C-LSDI)[20], and the Japanese version of the LSDI (LSDI-J)[21-23] have been validated linguistically. However, in Asian countries with different cultures and lifestyles from Western countries, it is necessary to conduct sufficient psychometric and external validity assessments when creating these Asian versions of the LSDI. In a previous study, Furuya et al.[23] described that the external validity between trunk range of motion (ROM) and LSDI score ($r=-0.66$); however, the external validity in comparison with lumbar ROM and LSDI scores has never been investigated in the C-LSDI and K-LSDI[19,20]. Therefore, the external validity of the LSDI has not been sufficiently confirmed in Asia. In patients who underwent lumbar fusion surgery, this study aimed to examine the internal consistency, reliability, and external validity of the LSDI-J.

Materials and Methods

The study design was approved by the Institutional Review Board before study initiation and complied with the principles of the Declaration of Helsinki. All patients provided written consent for the publication of case details.

Patient sample

Fifty consecutive patients (14 males and 36 females; mean age 70.6 years) who had undergone lumbar fusion surgery in our department a minimum of one year after surgery and visited our outpatient clinic between April and May 2019 were included in the study. They were surveyed using the LSDI-J questionnaire. The mean period of follow-up was 3.5 years, and the mean number of fusion levels was 4.4. The exclusion criteria were as follows: patients with other pathologies of scoliosis, including idiopathic scoliosis, ankylosing spondylitis, tuberculosis, and malignant spinal tumor; patients who underwent previous lumbar instrumented surgery; patients with severe postoperative complications; patients with severe hip and knee joint diseases or those who underwent total hip and/or knee replacement; and patients with severe psychiatric disorders.

Demographics of participants

Sex, age, body mass index (BMI), postoperative follow-up period, and the number of fusion levels were recorded. Pelvic incidence (PI), pelvic tilt, sacral slope (SS), lumbar lordosis (LL), PI-LL, thoracic kyphosis, and sagittal vertical axis were measured from lateral view images of standing radiographs.

Japanese version of the LSDI

After obtaining approval from our university's Institutional Review Board and permission from the author of the original version to develop the Japanese version[10], the LSDI was translated into Japanese following the cross-cultural adaptation guidelines designed by Beaton et al. and Wild et al.[21,24,25]. Participants wrote a score for each ADL on a scale from 0 (no effect at all) to 4 (cannot do at all). The LSDI-J score was calculated by summing each item score, dividing by the total possible score, and multiplying by 100. The final scores ranged from 0 to 100, with higher scores indicating greater disability due to lumbar stiffness[10].

Internal consistency

Cronbach's alpha coefficients were obtained for all patients to assess internal consistency[26]. Distribution of responses to each item of the LSDI-J was examined separately to assess the proportion of missing data. The distribution of the total scores is summarized by means and standard deviations, with Cronbach's alpha values ranging from 0 to 1, with higher values indicating higher correlations among the items in the questionnaire. For clinical research, a Cronbach's alpha value of 0.9 or higher is ideal, and a value of 0.7 or higher is considered satisfactory.

Retest reliability

The intraclass correlation coefficient (ICC) was calculated to evaluate the retest reliability[27]. Among the 50 patients, 31 patients (9 males and 22 females; mean age 72.5 years) who could complete the questionnaire again in the outpatient clinic three weeks after the first questionnaire were included in the study. The ICC values ranged from 0 to 1, which were considered to be satisfactory at ≥0.70 (0.81-1.0, excellent; 0.61-0.80, very good; 0.41-0.60, good; 0.21-0.40, fair; and 0.00-0.20, poor).

External validity

Among the 50 patients, 41 (13 males and 28 females; mean age 70.5±10.6 years) who underwent fusion surgery at intervertebral levels 1 to 5 were investigated for external validity. The lumbar disorders causing the surgery were ASD in 33 patients (80.5%), spondylolisthesis in 6 (14.6%), and lumbar instability in 2 (4.9%). Six patients underwent level 1 fusion, two underwent 2 levels, nine underwent level 3, 15 underwent level 4, and nine underwent level 5. In these patients, the ODI[4], and the Japanese Orthopedic Association Back Pain Evaluation Questionnaire (JOABPEQ)[28] were assessed for external validity, and the correlation between these scores and the LSDI-J scores was investigated. The ODI was calculated by dividing the summed score by the total possible score, which was multiplied by 100 and expressed as a percentage.

Using the same method as Hart et al.[10], forward bending LL, backward bending LL, and lumbar ROM (LROM=backward bending LL - forward bending LL) were measured on standardized, voluntary flexion, and extension lateral view radiographs of the lumbar spine. We compared the LSDI-J scores with the measurements of lumbar parameters. LROM was computed as the difference in the Cobb angle measured from the lower endplate of T12 to the upper endplate of S1. These measurements were performed by an investigator who was independent of the patient care team on digital images using the Wakayama Medical University Integrated Information Network System 4 (NEC, Tokyo, Japan) image analysis system. In addition, we compared the LSDI-J with the number of fixed vertebrae. The correlation was considered to be "strong" (| r | ≥0.7), "moderate" (0.7< | r | ≤0.4), or "weak" (0.4< | r | ≤0.2).

Statistical analysis

To evaluate external validity, Pearson's correlation coefficient was used to determine the correlation between the ODI, forward bending LL, backward bending LL, LROM, and LSDI-J. We compared mean LSDI-J scores between the numbers of fixed vertebrae using the analysis of variance models with and without adjustment for age, sex, and BMI. The correlation coefficients between the JOABPEQ and LSDI-J were evaluated using Spearman's rank correlation coefficient. All statistical analyses were performed using JMP data analysis software version 14 (SAS Institute Inc., Cary, NC, USA). Statistical significance was set at *P*<0.05.

Results

Table 2 summarizes the characteristics of all 50 patients who participated in this study, the 31 patients who participated in the reliability research, and the 41 patients who participated in the external validity evaluation.

Table 3 summarizes the mean and standard deviation of the scores, number of responses, response rate, and Cronbach's alpha coefficient for each question on the LSDI-J. While all other questions were answered. the response rates for questions 3 and 10 were low (68.3% and 36.6%, respectively). For the 10-item questionnaire, Cronbach's alpha coefficient was 0.652. The alpha coefficient without Question 10, which had the lowest response rate, was 0.849, and that without questions 3 and 10 was 0.908, indicating that there was no problem with the reliability of the LSDI-J. To evaluate retest reliability, the ICC was 0.824 for the 10-item LSDI-J, 0.851 for the 9-item LSDI-J excluding Question 10, and 0.807 for the 8-item LSDI-J excluding questions 3 and 10. All ICCs showed excellent results. Thus, the LSDI-J was confirmed to be highly reliable.

Table 4 summarizes the results of the external validity in 41 patients. The correlation coefficient between the ODI and 10-item LSDI-J was moderate, with the highest correlation among the external validity evaluations (r=0.684, *P*<0.0001, 95% confidence interval [CI]: 0.465 to 0.823). The correlation with the scores obtained after excluding questions with poor response rates was moderately similar. The correlation coefficients between the JOABPEQ and 10-item LSDI-J ranged from −0.590 to −0.413, indicating a moderate correlation for all domains. The correlations between the 9- and 8-item LSDI-J were moderately similar. The correlation coefficient between forward bending LL and the 10-item LSDI-J was 0.110 (*P*=0.492, 95% CI: −0.204 to 0.404), indicating no correlation. Similarly, there was no correlation with backward bending LL (r=0.072, *P*=0.654, 95% CI: −0.241 to 0.372). The correlation coefficient between LROM and the 10-item LSDI-J was −0.055 (*P*=0.734, 95% CI: −0.357 to 0.257), indicating no correlation (Fig. 1). There was also no correlation between the 9- and 8-item LSDI-J, excluding the low response rate questions (r=−0.017, *P*=0.918, 95% CI: −0.323 to 0.293; r=0.005, *P*=

Table 2. Characteristics of All 50 Patients Enrolled in This Study and 41 Patients for Evaluation of External Validity.

	All patients enrolled in this study (N=50)	Patients for retest reliability (N=31)	Patients for evaluation of external validity (N=41)
Sex (male)	14 (28.0%)	9 (29.0%)	13 (31.7%)
Age (years)†	70.6±10.0	72.5±7.5	70.5±10.6
BMI (kg/m^2)†	23.1±2.9	22.9±3.1	23.2±3.1
Number of fusion levels†	4.4±2.3	3.9±0.9	3.5±1.3
Time since surgery (years)†	3.5±1.3	3.7±1.1	3.4±1.2
PI (deg.)†	51.7±13.4	51.4±14.4	51.0±14.0
PT (deg.)†	26.1±11.7	27.9±12.8	25.7±12.4
SS (deg.)†	25.6±9.4	23.5±9.6	25.2±10.1
LL (deg.)†	33.3±14.2	28.3±12.4	31.3±14.7
PI-LL (deg.)†	18.4±17.5	23.1±18.6	19.6±18.8
TK (deg.)†	29.8±14.5	28.8±15.2	29.0±14.0
SVA (mm)†	62.6±54.4	75.6±57.7	64.4±59.0
LSDI-J score†	22.0±17.5	24.7±17.8	23.1±17.6
ODI†	28.7±17.3	31.3±18.3	31.2±18.0
JOABPEQ for low back pain*	71.4 (11.4, 100)	71.4 (42.9, 100)	71.4 (42.9, 100)
JOABPEQ for lumbar function*	58.3 (25.0, 83.3)	50.0 (25.0, 83.3)	58.3 (25.0, 83.3)
JOABPEQ for walking ability*	57.1 (28.6, 78.6)	50.0 (21.4, 78.6)	50.0 (41.9, 78.6)
JOABPEQ for social life function*	51.4 (45.9, 86.5)	51.4 (37.8, 86.5)	51.4 (41.9, 86.5)
JOABPEQ for mental health*	62.1 (41.7, 68.9)	57.3 (38.8, 68.9)	62.1 (41.7, 68.9)

BMI, body mass index; PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; LL, lumbar lordosis; TK, thoracic kyphosis; SVA, sagittal vertical axis; ODI, Oswestry Disability Index; JOABPEQ, Japanese Orthopaedic Association Back Pain Evaluation Questionnaire; SF-36, The LSDI score is calculated as the raw score divided by the total possible score and multiplied by 100, †mean±standard deviation, *median value (the first quartile, the third quartile).

Table 3. Raw Scores, Number of Responses, Response Rate, and Cronbach's Alpha Coefficient for Each Question of LSDI-J.

	Raw score (Mean±SD)	Number of responses (response rate)	Cronbach's alpha coefficient (10-items)	Cronbach's alpha coefficient (without Q10)	Cronbach's alpha coefficient (without Q3 and 10)
Q1	1.1±0.9	50 (100.0%)	0.612	0.827	0.894
Q2	1.2±0.9	50 (100.0%)	0.632	0.826	0.893
Q3	1.5±1.7	33 (66.0%)	0.605	0.908	-
Q4	0.5±0.7	50 (100.0%)	0.624	0.828	0.898
Q5	0.9±1.0	50 (100.0%)	0.598	0.804	0.878
Q6	0.6±0.7	50 (100.0%)	0.606	0.820	0.892
Q7	0.6±0.7	50 (100.0%)	0.640	0.804	0.905
Q8	0.8±1.0	50 (100.0%)	0.610	0.808	0.884
Q9	1.0±1.1	50 (100.0%)	0.567	0.834	0.925
Q10	1.8±1.8	17 (34.0%)	0.844	-	-
Total		450 (90.0%)	0.652	0.849	0.908

LSDI-J, Japanese version of lumbar stiffness disability index; SD, standard deviation

0.976, 95% CI: −0.303 to 0.312, respectively). There were no significant differences between the numbers of fixed vertebrae with or without adjustment for age, sex, and BMI (Table 5), and there was no particular trend when examined between groups individually (Fig. 2).

Discussion

In this study, the LSDI-J had a high internal consistency and reliability. Upon evaluating the external validity, LSDI-J showed a moderate correlation with the ODI and all domains of the JOABPEQ. However, it showed no correlation with the LL and LROM of the radiological assessment.

The English version of the LSDI developed in the US was evaluated for external validity by correlating LROM with lateral radiographic images of the lumbar spine flexed back and forth, with a correlation coefficient of −0.71, indicating a strong correlation[10]. However, in the present study, which used the same evaluation method as Hart et al.[10], we did not observe any correlations. Hart et al. stated that, in a retrospective study, there was a significant difference in LSDI between 1- and 5-intervertebral fusion[9]. However, the present study showed no significant difference among all categories in numbers of fixed vertebrae. Although this study included cases with one or two intervertebral fusions, it is possible that a study focusing on cases with more ex-

Table 4. The Correlation Coefficients of LSDI-J Score Compared with ODI, JOABPEQ, LL, and LROM for External Validity.

Variables	10-items scores of LSDI-J			9-items scores of LSDI-J (without Q10)	8-items scores of LSDI-J (without Q3 and 10)
	Correlation coefficients	*P* value	95% CI	Correlation coefficients	Correlation coefficients
ODI†	0.684	<.0001	0.465, 0.823	0.647	0.682
JOABPEQ for low back pain*	−0.566	0.0001	N/A	−0.515	−0.601
JOABPEQ for lumbar function*	−0.590	<.0001	N/A	−0.523	−0.560
JOABPEQ for walking ability*	−0.463	0.002	N/A	−0.411	−0.472
JOABPEQ for social life function*	−0.413	0.007	N/A	−0.413	−0.448
JOABPEQ for mental health*	−0.415	0.007	N/A	−0.346	−0.454
LL (flexion position) (deg.)†	0.110	0.492	−0.204, 0.404	0.128	0.103
LL (extension position) (deg.)†	0.072	0.654	−0.241, 0.372	0.110	0.099
LROM (deg.)†	−0.055	0.734	−0.357, 0.257	−0.017	0.005

LSDI-J, Japanese version of lumbar stiffness disability index; ODI, Oswestry Disability Index; JOABPEQ, Japanese Orthopaedic Association back pain evaluation questionnaire; LL, lumbar lordosis; LROM, lumbar range of motion (extension LL minus flexion LL); 95% CI; 95% confidence interval, †Pearson product-moment correlation coefficient, *Spearman's rank correlation coefficient.

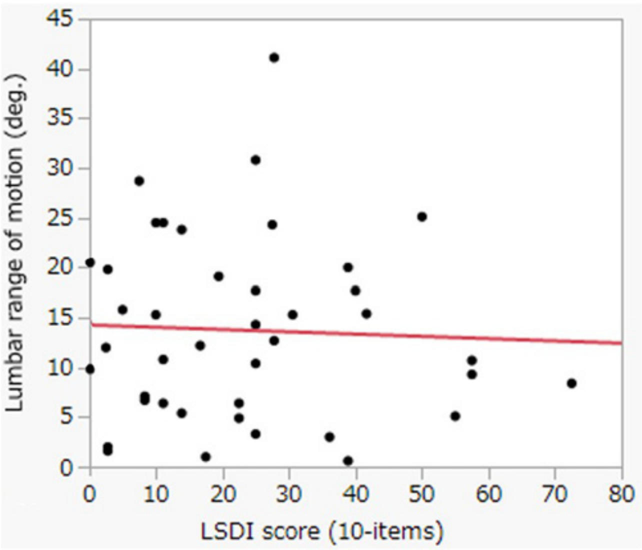

Figure 1. 10-item LSDI score vs. radiographic lumbar range of motion among 41 patients after lumbar fusion surgery.
LSDI, Lumbar Stiffness Disability Index

tensive fusions may have correlated with LROM. Therefore, we conducted a study in 42 cases, excluding cases with 1-2 intervertebral fusions from the original 50 cases included in this study. The results showed no correlation between LROM and LSDI-J (r=0.097, P=0.540, 95% CI: −0.213 to 0.390). This may be attributed to differences in culture and lifestyle between Western and Asian countries. Due to cultural and lifestyle differences, Asians have more hip flexion and external rotation movements than Westerners[29,30]. Asians may perform lumbar flexion movements more easily with greater hip flexion and external rotation than Westerners in ADLs after lumbar fusion surgery, as the lower extremity joints play a vital role in a sitting or squatting posture, especially hip joint motion[31,32]. Even if LROM is smaller in Asians, the greater compensatory effect of the hip joint may suppress lumbar stiffness disability[8]. There was no difference in patients' follow-up periods between the study by Hart et al. and the present study, although stiffness disability after lumbar fusion surgery may improve with longer postoperative follow-up.

In a previous study using the LSDI-J, possibly due to some influence of the proportion of lumbar spine disorders included in the study population, Furuya et al.[23] showed better results after evaluating external validity (Table 6). Our research included 80.5% with ASD, whereas theirs included only 32.1%. In addition, even though the studies were conducted in the same Japanese population[23], they employed a method of measuring trunk ROM from the body surface, unlike assessment of LROM radiologically, as in the study by Hart et al. In their procedure, trunk ROM was measured passively, which may not be compatible with the purpose of the LSDI, which is to measure voluntary movements.

We believe that it is necessary to develop a unique LSDI suitable for the clinical practice conditions in Japan. The LSDI does not include assessing lower extremity functions, such as the hip joint. To develop a more rigorous LSDI that can predict postoperative ADL disability in patients with ASD who require long fusion surgery, it may be necessary to include hip and lumbar motion.

This study had some limitations. First, since this was a retrospective study, recall bias is inevitable. We believe, in order to confirm its usefulness in the future, that it is necessary to conduct a prospective study to create a new LSDI-J. Second, because this was a cross-sectional study, we could not discuss responsiveness, which is often included in psychometric analysis. When a new LSDI-J is developed in the future, there is a need to conduct further research on responsiveness in longitudinal surveys. Third, since the present sample was composed of a higher percentage of females than males, the questionnaire results may have been influenced by differences in population and sex. Finally, in order

Table 5. The Analysis of Variance Test for the Equivalence of Mean LSDI-J Scores between the Numbers of Fixed Vertebrae.

Variable	Category	Unadjusted				Unadjusted			
		Mean difference	Standard error	*P*	Overall *P*	Mean difference	Standard error	*P*	Overall *P*
No. fixed vertebrae	1	Reference			0.31	Reference			0.60
	2	18.3	14.4	0.21		12.42	17.07	0.47	
	3	0.4	9.3	0.96		1.30	11.86	0.91	
	4	4.0	8.5	0.64		3.27	10.01	0.75	
	5	14.7	9.3	0.12		13.55	11.41	0.24	
Age (year)	-					0.14	0.34	0.68	0.68
Sex	Male					6.85	6.93	0.33	0.33
BMI (kg/m^2)	-					−0.19	0.96	0.85	0.85

LSDI-J, Japanese version of lumber stiffness disability index; BMI, body mass index

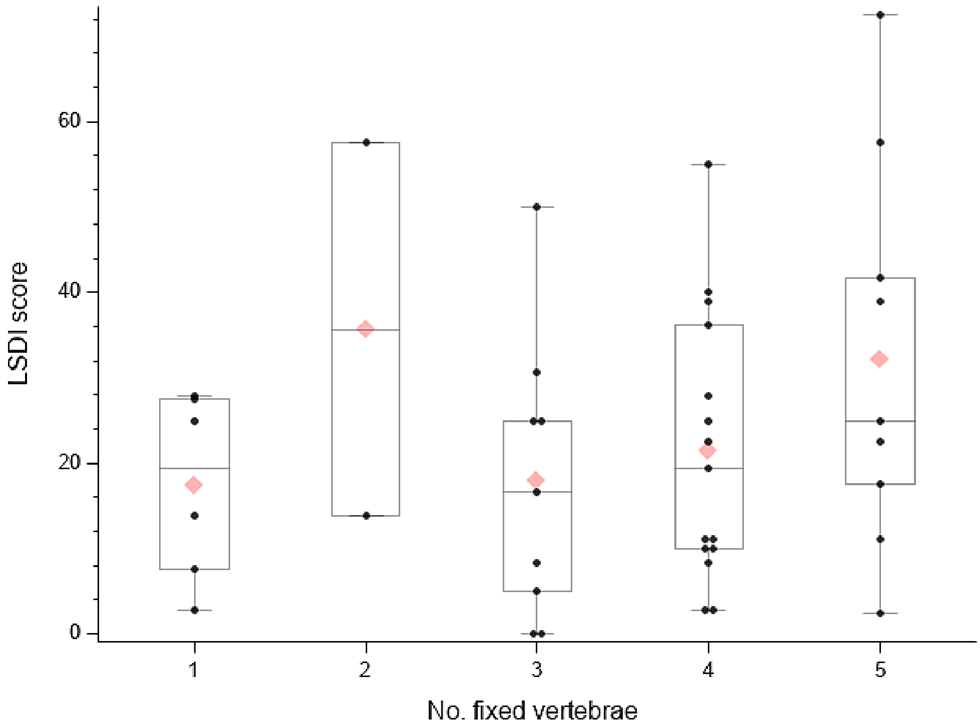

Figure 2. Distributions with box plots of 10-item LSDI scores by the numbers of fixed vertebrae.
LSDI, Lumbar Stiffness Disability Index

Table 6. Comparison of Internal Consistency, Retest Reliability, and External Validity in LSDI by Hart et al., K-LSDI, C-LSDI, J-LSDI by Furuya et al. and the Current Study.

	LSDI[10]	K-LSDI[19]	C-LSDI[20]	J-LSDI by Furuya[23]	Current study
Sex (male:female)	10:22	8:36	26:103	17:34	13:28
Mean age (years) (Mean±SD)	63.0±9.8	69.8	62.8 (range: 40–79)	71.7±9.3	70.5±10.6
Mean time since surgery (years)	2.2	3.1	Not mentioned	2.5	3.5
Internal consistency (Cronbach's alpha coefficients)	0.89	0.84	0.90	Shown using Bland–Altman analysis	0.65
Retest reliability	0.87	Not implemented	0.90	0.89	0.82
Correlation coefficient with lumbar range of motion	−0.71	Not implemented	Not implemented	−0.66*	−0.06

LSDI, lumbar stiffness disability index by Hart et al.; K-LSDI, Korean version lumbar stiffness disability index; C-LSDI, Chinese version lumbar stiffness disability index; J-LSDI; SD, standard deviation, Japanese version lumbar stiffness disability index, *by the method advocated by the Japanese Association of Rehabilitation Medicine[23].

to contrast it with the original study by Hart et al.[10], in this study we did not include patients who underwent thoracic-to-pelvic long fusion. We believe that more detailed studies are needed in postoperative patients of long fusion surgery in the future.

In conclusion, the LSDI-J was used to evaluate patients' condition after lumbar fusion surgery, and the results showed a high internal consistency and good reliability. The correlation between the ODI and JOAPBEQ was moderate. However, there was no correlation with LROM, the most important factor for external validity. It may be necessary to investigate why LSDI-J was not suitable for the Japanese population in terms of lower limb function, as the current LSDI-J may not be suitable for the Japanese population. Alternatively, it may be necessary to develop a unique method for assessing lumbar stiffness disability that is more suitable for actual clinical practice in Japan.

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Ethical Approval: This study was conducted with the approval of the Research Ethics Committee of Wakayama Medical University (No. 2488).

Informed Consent: Informed consent for publication was obtained by all participants in this study.

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