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RESEARCH

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Impact of spinal surgery on locomotive syndrome in patients with lumbar spinal stenosis in clinical decision limit stage 3: a retrospective study

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Abstract

Background Locomotive syndrome (LS) is characterized by reduced mobility. Clinical decision limit (CDL) stage 3 in LS indicates physical frailty. Lumbar spinal canal stenosis (LSS) is one of the causes of LS, for which lumbar surgery is considered to improve the CDL stage. This study aimed to investigate the efficacy of lumbar surgery and independent factors for improving the CDL stage in patients with LSS.

Methods This retrospective study was conducted at the Department of Orthopaedic Surgery at our University Hospital. A total of 157 patients aged ≥ 65 years with LSS underwent lumbar surgery. The 25-Question Geriatric Locomotive Function scale (GLFS-25) was used to test for LS, and the Timed Up and Go test (TUG) was used to evaluate functional ability. Lower limb pain was evaluated using a visual analog scale. Patients with at least one improvement in the CDL stage following lumbar surgery were included in the improvement group. Differences in lower limb pain intensity between the groups were evaluated using the Wilcoxon rank-sum test. The Spearman's rank correlation coefficient was used to determine correlations between Δ lower limb pain and Δ GLFS-25. Logistic regression analysis was used to identify factors associated with improvement in LS.

Results The proportion of patients with improved CDL stage was 45.1% (improvement/non-improvement: 32/39). Δ Lower limb pain was significantly reduced in the improvement group compared with that in the non-improvement group (51.0 [36.3–71.0] vs 40.0 [4.0–53.5]; $p = 0.0107$). Δ GLFS-25 was significantly correlated with Δ lower limb pain ($r = 0.3774$, $p = 0.0031$). Multiple logistic regression analysis revealed that TUG and age were significantly associated with improvement in LS (odds ratio, 1.22; 95% confidence interval: 1.07–1.47).

Conclusions Lumbar surgery effectively improved the CDL stage in patients with LSS. In addition, TUG was an independent factor associated with improvement in the CDL.

Keywords Lumbar spinal canal stenosis, Locomotive syndrome, Low back pain, Visual analog scale

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Background

The number of older adults who require nursing care is increasing in Japan, along with aging of a large proportion of the population. Musculoskeletal disorders resulting from fractures and falls and joint diseases are the most common causes of nursing care and can result in mobility loss [1]. In 2007, the Japanese Orthopaedic Association (JOA) defined locomotive syndrome (LS) as a condition in which mobility is reduced due to musculoskeletal disorders [2]. Later, in 2015, they established a scale to assess the severity of LS called clinical decision limit (CDL), which included stages 1 and 2 [2]. CDL stage 1 is defined as a state in which a decline in mobility has begun but which may be improved through exercise habits and dietary correction. In contrast, patients in CDL stage 2 show a progressive decline in mobility. However, this classification was met with some uncertainty, as disease statuses encompassed by CDL stage 2 were broad, ranging from mild to severe. Therefore, the JOA defined the additional CDL stage 3 in 2020 for early detection and therapeutic intervention for severe LS [3]. Patients in CDL stage 3 experience limited social participation owing to a significant loss of mobility. As some patients experience additional complications from orthopedic diseases and require surgery, and with the establishment of CDL stage 3, it is necessary to evaluate the extent to which LS may be improved with surgery.

The relationship between lumbar spinal canal stenosis (LSS) and LS has recently attracted much attention in the field of spinal diseases [4]. LSS is a disease in which nerves are compressed due to intervertebral disc and joint degeneration and thickening of the ligamentous tissue. In a Japanese cohort study, the prevalence of LSS was reported to be very high, affecting approximately 10% of adults [5]. Patients with LSS have reduced lower extremity function due to pain, numbness, and intermittent claudication [6], which increases the risk of falling [7] and significantly impacts daily life. Lumbar spine surgeries such as decompression and spinal fusion can relieve symptoms and improve activities of daily living (ADL) in patients with LSS.

The Timed Up and Go test (TUG) is an objective measure of functional disability that can be used to evaluate various activities such as standing, accelerating, walking, decelerating, and turning, which are often limited in patients with lumbar degenerative diseases [8]. TUG can be easily conducted with a chair and a 3-m walking space and does not require special equipment [9]. A previous study used TUG to measure motor impairment in patients with lumbar degenerative diseases, with < 11.5 s classified as no impairment, 11.5 to 13.4 s as mild impairment, 13.4 to 18.4 s as moderate impairment, and > 18.4 s as severe impairment [8]. TUG is not easily affected by the patient's mental state, lifestyle, or physique [10, 11] and is highly related to factors of daily life functions such as lower limb muscle strength, sense of balance, walking ability, and ease of falling. Furthermore, the TUG is used to evaluate motor function in a wide range of subjects, from healthy patients to those with lumbar degenerative diseases [11, 12]. Thus, the TUG is useful for evaluating preoperative physical function in patients with LS.

Previous studies have reported that surgical treatment of knee joint [13] and hip joint disease [3] can improve the condition of patients in CDL stage 3; however, only few studies have reported on lumbar degenerative diseases. Therefore, this study aimed to investigate the efficacy of lumbar spinal surgery for patients with LSS in CDL stage 3 and the preoperative factors associated with the improvement of the CDL stage.

Methods

Patient and public involvement

This retrospective study was conducted between May 2020 and April 2021 at the Department of Orthopaedic Surgery at University Hospital, and 157 patients aged ≥ 65 years with lumbar spinal stenosis who underwent lumbar spinal surgery without serious complications (such as ischemic heart disease or stroke) were enrolled. The inclusion and exclusion criteria are shown in Fig. 1. Among the 157 patients enrolled in this study, patients with CDL stages 0, 1, and 2 ($n = 56$) and patients with missing data ($n = 30$) were excluded. Finally, patients in CDL stage 3 were included in this study ($n = 71$).

This study was conducted following the Declaration of Helsinki and was approved by the Ethics Committee of the University. Consent to participate in the study was obtained using an opt-out approach.

Recorded data

A physical therapist performed physical function tests, and the patients completed the questionnaire. Age, sex, BMI, TUG, trunk and limb skeletal muscle mass, grip strength, life-space assessment (LSA), prognostic nutritional index (PNI), low back pain, lower limb pain, lower limb numbness, surgical method, and symptoms of lumbar spinal stenosis were adopted as survey items for preoperative factors related to the improvement in LS. Furthermore, the 25-Question Geriatric Locomotive Function scale (GLFS-25) and JOA Back Pain Evaluation Questionnaire (JOABPEQ) were used to examine patients before and after lumbar spinal surgery.

TUG

The TUG was conducted using a stopwatch to measure the time elapsed from when the subject's body moved to the time they turned at a cone 3 m away and returned to

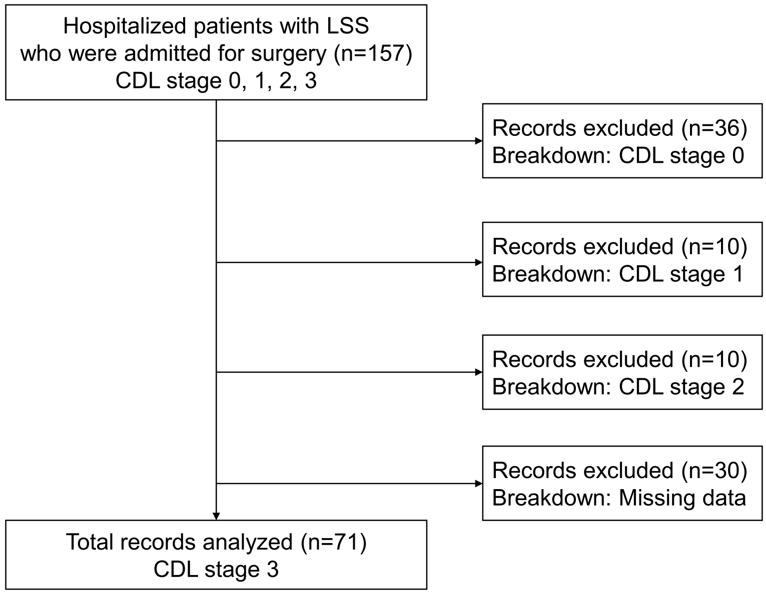

Fig. 1 Diagram of the inclusion and exclusion criteria in this study. Abbreviations: CDL, clinical decision limit; LSS, lumbar spinal canal stenosis

sitting on the chair. A chair with a height of 42.0 cm and elbow rests was used. The subject was given the following instruction: "Please get up from the chair, walk as fast as possible, turn at the cone 3 m ahead, and sit on the chair again. You may turn in either direction."

Trunk and limb skeletal muscle mass

Skeletal muscle mass was assessed using the bioelectrical impedance method (Inbody720, Inbody Co., Ltd., Seoul, Korea). All patients were assessed on the day of admission. The participants grasped the handle of the analyzer with embedded electrodes and stood on a platform with the soles of their feet in contact with the electrodes (two electrodes each were placed on the feet and hands).

Hand grip strength

Grip strength was measured using a Smedley-type grip strength meter (Takei model T.K.K. 5101, Takei Kiki Kogyo, Akiha-ku Niigata, Japan). The participants were instructed to grip the strength meter as firmly as possible after hearing the signal. They were instructed as follows: "Please hold the grip strength meter for 3 s." The right side was measured twice, and the maximum value was adopted.

Life-space assessment (LSA)

The LSA was originally developed as a simple questionnaire to assess physical activity in older adults. It is a clinically useful index that has been utilized in clinical practice and research [14]. The total score is 120, with higher scores indicating higher activity levels.

Prognostic nutritional index (PNI)

The PNI scale reflects a patient's inflammatory and nutritional status and is associated with postoperative complications in spinal diseases [15, 16].

Evaluation of pain

Low back pain, lower limb pain, and lower limb numbness were evaluated using a visual analog scale (VAS), with a score of 100 indicating extreme pain and 0 indicating no pain.

GLFS-25

The GLFS-25 test focuses on physical pain and ADL in the preceding month. For this study, each item was scored from "no disability" (0 points) to "severe disability" (4 points), and the total score was used to evaluate the CDL stage of the LS patient. Scores were classified as follows: stage 1, $\geq$ 7 points to < 16 points; stage 2, ≧16 points to < 24 points; and stage 3, ≧24 points [17].

JOABPEQ

The JOA developed the JOABPEQ, a quality-of-life assessment specific to lumbar spine disease that uses patient-oriented and self-reported functional status. The JOABPEQ is a disease-specific tool consisting of 25 items corresponding to five subscales: low back pain, lumbar spine function, walking ability, social function, and mental health. The score for each subscale ranges from 0–100, with higher scores indicating better conditions [18].

Statistical analysis

All statistical analyses were performed using JMP version 15.0 statistical software (SAS Institute Inc., Cary, NC, USA). The GLFS-25 was used to evaluate the CDL stage. Patients with preoperative CDL stage 3 were included in the study, and those with at least one improvement in the CDL stage after lumbar spinal surgery were included in the improvement group [19]. The patients were evaluated before the operation and three months after surgery.

The Wilcoxon rank-sum test was used to compare the improved and non-improved groups. Logistic regression and decision tree analyses were used to investigate the preoperative factors associated with improvements in LS. The Spearman rank correlation coefficient was used to determine correlations between Δ lower limb pain, Δ lower limb numbness, Δ low back pain, and Δ GLFS-25. In all cases, statistical significance was set at $p < 0.05$. All data are expressed as the median (interquartile range) and range.

Table 1 Characteristics of the patients

	Clinical Decision Limits stage 3 (*N* = 71)	
	Median	**Range (min-mx)**
Age (years)	77	65–91
Sex (Male/Female)	27/44	
BMI (kg/m^2)	23.6	15.4–32.1
Limb skeletal muscle mass (kg)	13.9	8.9–23.3
Trunk skeletal muscle mass (kg)	16.6	11.7–23.7
Hand grip strength (kg)	21.4	8.1–44
TUG (s)	11.5	5.4–38.4
LSA	48	0–120
PNI	51.9	36.2–64.9
Low back pain (VAS)	63	0–100
Lower limb pain (VAS)	68	0–100
Lower limb numbness (VAS)	60	0–100
GLFS-25	44	24–87
Surgery (decompression/fusion/decompression and fusion)	47/17/7	
Patient's symptoms (neuropathic/cauda equina/mixed symptoms)	34/24/13	

Abbreviations: *BMI* body mass index, *TUG* Timed Up and Go, *LSA* life-space assessment, *PNI* prognostic nutritional index, *VAS* visual analog scale, *GLFS-25* 25-Question Geriatric Locomotive Function Scale

Results

Characteristics of patients with LSS

Of the 157 participants who met the eligibility criteria for this study, 71 patients' data were analyzed after applying the exclusion criteria. Patient characteristics are shown in Table 1.

Surgical results of patients with LSS

Lumbar spinal surgery improved the mean GFLS-25 score from 48.8 preoperatively to 30 postoperatively. At 3 months postoperatively, the rates of CDL stages 0, 1, 2, and 3 were 7%, 18.3%, 19.7%, and 55%, respectively. In total, the proportion of patients with improved CDL stage was 45.1% (32/71) (Table 2).

Comparison of preoperative status between the two groups

Patients in the improvement group were significantly younger than those in the non-improvement group. In addition, the LSA score was significantly higher in the improvement group than in the non-improvement group (Table 3). The TUG times in the improvement group were significantly shorter than that in the non-improvement group. The two groups had no significant differences in limb skeletal muscle, trunk skeletal muscle, PNI, VAS scores, surgical method, or symptoms.

With the exception of pain and lumbar function in the non-improvement group, lumbar spinal surgery improved the JOABPEQ scores in both the groups. Similarly, lumbar spinal surgery improved the VAS scores for low back pain, lower limb pain, and lower limb numbness in both groups (Additional file 1).

Cox regression analysis for factors related to improvement in LS

Multivariate regression analysis was performed with the following variables related to improvements in LS: age, sex, BMI, LSA, PNI, handgrip strength, and TUG time.

The TUG time and age were significantly associated with improvement in LS ($p = 0.0017$ and $p = 0.031$) (Table 4). LSA, BMI, PNI, and handgrip strength were not significantly associated with improvements in LS ($p = 0.38$, $p = 0.45$, $p = 0.61$, $p = 0.65$).

Table 2 The ratio of patients' CDL stage at 3 months postoperatively

Improvement group			Non-improvement group
CDL stages 0	**CDL stages 1**	**CDL stages 2**	**CDL stages 3**
N = 5 7.0%	*N* = 13 18.3%	*N* = 14 19.7%	*N* = 39 55.0%

Abbreviations: *CDL* clinical decision limit

Table 3 Comparison between the two groups

	Improvement group (*N* = 32)		Non-improvement group (*N* = 39)		*P*
	Median	Range (min–max)	Median	Range (min–max)	
Age (years)	75	65–81	78	67–91	0.008*
Sex (Male/Female)	14/18		13/26		0.4
BMI (kg/m^2)	22.8	15.4–32.1	24.2	17.7–31.2	0.3
Limb skeletal muscle mass (kg)	14.9	9.8–23.3	13.9	8.9–21.9	0.3
Trunk skeletal muscle mass (kg)	16.8	12.4–23.3	16.5	11.7–23.7	0.3
Hand grip strength (kg)	23.3	12.8–44	20.6	8.1–43	0.1
TUG (s)	9.6	5.4–21.5	14.5	6.4–38.4	0.0002*
LSA	54	4.5–120	37.5	0–110	0.02
PNI	52.4	36.9–64.9	51.2	36.2–60.5	0.2
Low back pain (VAS)	51	8–100	67	0–100	0.2
Lower limb pain (VAS)	65	18–100	69.5	0–100	0.8
Lower limb numbness (VAS)	51	0–100	65.5	0–100	0.4
GLFS-25	40	24–65	58	25–87	0.002*
Surgery (decompression/fusion/decompression and fusion)	19/10/3		28/7/4		0.4227
Patient's symptoms (neuropathic/cauda equina/mixed symptoms)	15/8/9		19/16/4		0.1101

Abbreviations: *BMI* body mass index, *TUG* Timed Up and Go test, *LSA* life-space assessment, *PNI* prognostic nutritional index, *VAS* visual analog scale, *GLFS-25* the 25-Question Geriatric Locomotive Function Scale

* Indicates statistical significance

Table 4 Multivariate analysis for the factors associated with the improvement of locomotive syndrome

Factors	Multivariate analysis for the improvement of locomotive syndrome (95% Confidence interval, *P*-value)
TUG	1.22 (1.07–1.47, 0.0017*)
Age	1.15 (1.01–1.32, 0.031*)
LSA	1.01 (0.99–1.04, 0.38)
BMI	1.07 (0.90–1.28, 0.45)
PNI	1.04 (0.90–1.21, 0.61)
Hand Grip strength	1.02 (0.94–1.12, 0.65)

Abbreviations: *TUG* Timed Up and Go test, *LSA* life-space assessment, *BMI* body mass index, *PNI* prognostic nutritional index

* Indicates statistical significance

Decision tree algorithm for factors related to improvements in LS

A decision tree algorithm was used for variables related to improvements in LS, including age, sex, BMI, LSA, PNI, handgrip strength, and TUG time. In the decision tree analysis, the TUG time was selected as the first divergence variable and LSA was selected as the second divergence variable. Among patients with TUG time < 12.4 s, CDL stage 3 was improved in 66.7%, and LSA was the second divergence variable in patients with TUG ≥ 12.4. Patients with a TUG time ≧12.4 s and LSA ≥ 40 showed improvement from CDL stage 3 by 46.2%. Among patients with reduced physical function, CDL stage 3 was improved in 46.2%, with an LSA score of 40 or higher (Fig. 2).

Relationship between the breakdown of CDL stage and preoperative TUG 3 months postoperatively

Figure 3 shows the relationship between the breakdown of the CDL stage and preoperative TUG time 3 months after lumbar spinal surgery. In patients with CDL stage 3 LS, the preoperative TUG time 3 months after the procedure was significantly longer than that for those in CDL stages 0 and 1 (Fig. 3). The results showed that patients who had low preoperative TUG times improved to either CDL stage 0 or 1 from stage 3 following the surgical procedure.

Relationship between Δ GFLS-25 and Δ pain scales

Δ GLFS-25 was significantly positively correlated with Δ lower limb pain, Δ lower limb numbness, and Δ low back pain (Table 5).

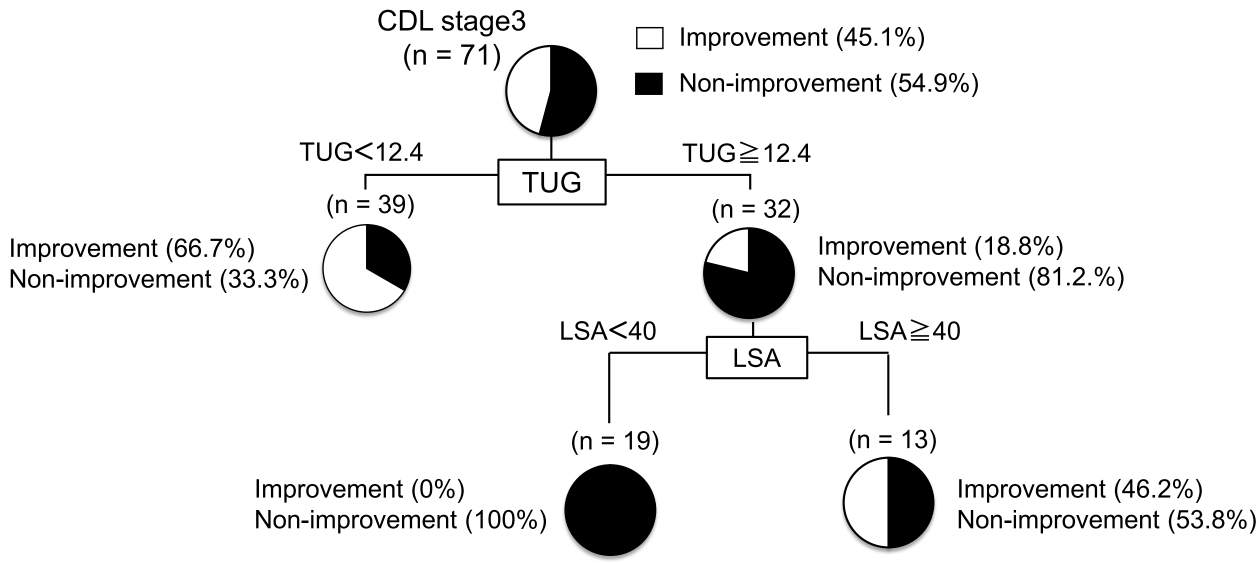

Fig. 2 Decision tree analysis for preoperative factors associated with the improvement in locomotive syndrome. Abbreviations: CDL, clinical decision limit; LSA, life-space assessment; TUG, Timed Up and Go test

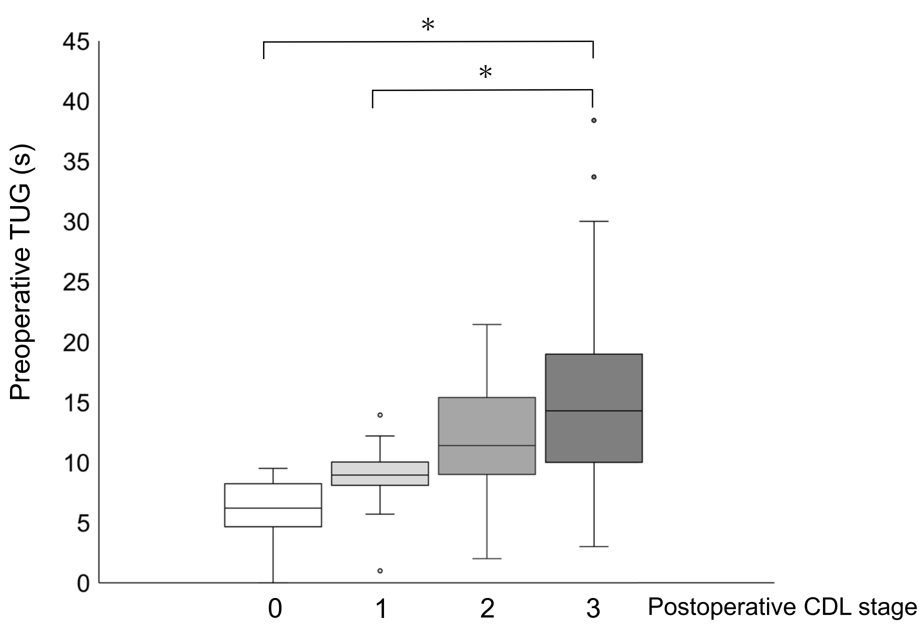

Fig. 3 Relationship between the breakdown of the CDL stage and preoperative TUG 3 months after lumbar spinal surgery. Abbreviations: CDL, clinical decision limit; TUG, Timed Up and Go test. * indicates statistical significance

Table 5 Relationship between the Δ GLFS-25S and other Δ VAS scores

	Δ Lower limb pain	Δ Lower limb numbness	Δ Low back pain	Δ GLFS-25
Δ Lower limb pain	1.0000			
Δ Lower limb numbness	0.5684*	1.0000		
Δ Low back pain	0.4479*	0.3315*	1.0000	
Δ GLFS-25	0.3615*	0.3723*	0.4103*	1.0000

Abbreviations: *GLFS-25* the 25-Question Geriatric Locomotive Function Scale, *VAS* visual analog scale

The numbers in the table indicate correlation coeffect. *Indicates statistical significance

Comparison of Δ GLFS-25 and Δ pain scales between groups

Lower limb pain and GFLS-25 scores were significantly better in the improvement group than in the non-improvement group ($p = 0.0107$, $p = 0.002$). Low back pain and lower limb numbness in the improvement group were not significantly higher than those in the non-improvement group ($p = 0.0953$, $p = 0{,}1041$) (Fig. 4).

Discussion

In this study, the rate of CDL stage improvement achieved by lumbar spinal surgery was 45.1% (32/71) in patients with CDL stage 3. The VAS score for lower extremity pain was significantly improved in the group with an improvement in the CDL stage. Moreover, the Δ GLFS-25 was significantly correlated with the Δ VAS of all pain scales. Thus, the improvements in LS might have been associated with a reduction in pain. The reduction in pain achieved by lumbar spinal surgery improved the ADL and CDL stages. Furthermore, the preoperative TUG time was the most relevant factor for the postoperative results. The patients with good physical function can expect to improve their stage of locomotive syndrome in CDL 3.

LS is caused by various orthopedic diseases, resulting in reduced quality of life and shortened expectancy of healthy life [2]. Fujita et al. reported that LSS is a potential risk factor for LS [4] and that lumbar spinal surgery effectively reduces the LS risk [20]. To the best of our knowledge, no studies have focused solely on CLD stage 3 patients with LSS, and this study has focused only on CDL 3 stage patients. We evaluated the extent to which surgery would improve LS. The change in the GLFS25 score in this study was comparable with that reported in previous studies [19, 20]. In this study, lumbar spinal surgery significantly improved not only the GLFS25 score but also the VAS score for low back pain and lower limb pain (Additional file 1). Moreover, the improvement rate of the CDL stage following lumbar spinal surgery was 45.1% (32/71) in this study. Notably, seven percent of patients who received the surgery overcame LS by undertaking the operation. Surgery is an effective treatment for patients with CDL stage 3.

Moderate physical activity is important for maintaining and improving life functions and preventing disease progression, disability, and frailty in older adults [21–23]. In addition, previous studies have reported that LSA is significantly correlated with ADL in community-dwelling

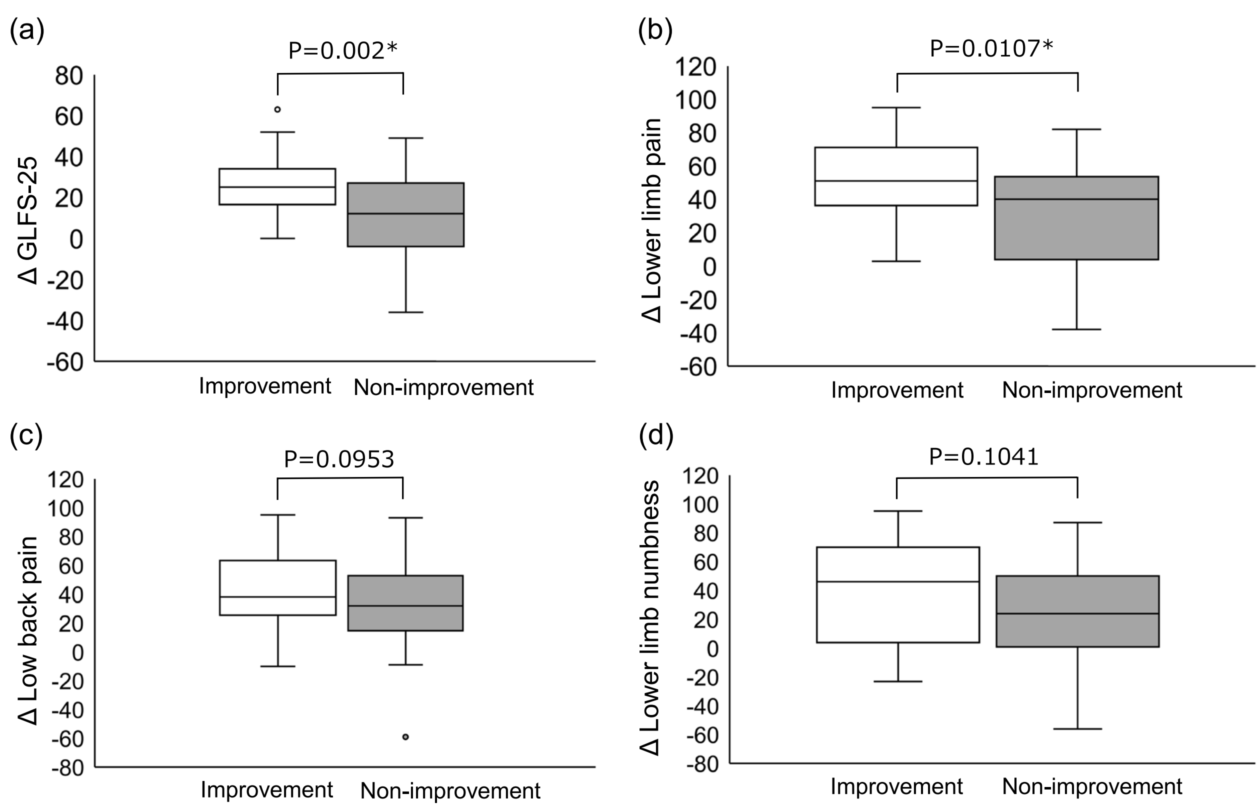

Fig. 4 Comparison between the two groups regarding (**a**) Δ GLFS-25, (**b**) Δ Lower limbs pain, (**c**) Δ Low back pain, and (**d**) Δ Lower limb numbness. Abbreviations: GLFS-25; 25-Question Geriatric Locomotive Function Scale. * indicates statistical significance

older individuals [14, 24]. Cohort studies of relatively healthy community-dwelling older people reported LSA scores of 62.9 ± 24.7 [14] and 64.1 ± 24.7 [24]. Therefore, it can be inferred that patients with LSS in this study were more physically inactive as they had lower LSA scores (median score of 48) than those in previous studies. In the decision tree analysis, even in patients with reduced physical function (TUG ≥ 12.4 s), CDL stage 3 was improved with a 50% probability if the LSA was 40 or higher. Therefore, increasing preoperative physical activity may have affected the postoperative outcomes.

This study aimed to identify preoperative factors associated with the improvement of CDL stage 3 in patients with LSS. In the decision tree analysis, the preoperative factor most associated with LS improvement was the TUG time. In this study, five of 71 patients (7%) got cured of their LS 3 months after lumbar spinal surgery (Table 2). The median TUG time of these patients was 6.2 s, and their preoperative physical function was higher than that before the procedure (Fig. 3). In this study, the Δ VAS score for low back pain in the improvement group tended to be higher than that in the non-improvement group. Moreover, the Δ VAS score for lower limb pain in the improvement group was significantly higher than that in the non-improvement group. The Δ VAS scores for low back and lower limb pain were correlated with the Δ GLFS-25 score (Table 5), and the total GLFS-25 score was associated with pain in the patients with LSS [25]. Thus, improving low back and lower limb pain through lumbar spinal surgery might improve GLFS-25 scores. These patients may have been identified as being in CDL stage 3 because their ADL was severely limited due to pain, although their physical function was not impaired. Improved low back and lower limb pain due to lumbar spinal surgery may have dramatically improved ADL and allowed patients to break free from LS. In summary, older patients with CDL stage 3 LSS without any preoperative decline in physical function may have a good postoperative course in which they no longer have LS; such patients should be encouraged to undergo lumbar spinal surgery earlier. It has been suggested that preoperative physical function assessment is important in determining the indication for lumbar spinal surgery and that TUG time is an important factor among them.

This study has some limitations. First, it was a single-center study. Second, owing to the small sample size. I excluded thirty patient's data in this study because of missing data. There is a possible source of bias. Third, we assessed LS using only the GLFS-25; however, this is difficult to assess by two-step and stand-up tests in patients with the severe LS. Kato et al. showed that the use of GLFS-25 assessment was appropriate for patients with several LS and musculoskeletal diseases requiring surgery [26].

Conclusions

This study showed that improvement in the low back and lower limb pain through lumbar spinal surgery might be beneficial for improving CDL stage 3. TUG time was an independent factor associated with the improvement of CDL stage 3 in patients with LSS.

Abbreviations

LS	Locomotive syndrome
LSS	Lumbar spinal canal stenosis
CDL	Clinical decision limit
GLFS-25	25-Question Geriatric Locomotive Function Scale
VAS	Visual analog scale
TUG	Timed Up and Go test
BMI	Body mass index
LSA	Life-space assessment
PNI	Prognostic nutritional index
JOA	Japanese Orthopaedic Association
ADL	Activities of daily living
JOABPEQ	JOA Back Pain Evaluation Questionnaire

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12891-023-06966-x.

Additional file 1: Supplementary Table 1. Comparison between the two groups before and after surgery.

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Not applicable.

Authors' contributions

IN and RH participated in the study conception and design, interpretation of data, and drafting of the manuscript. SI, RO, TF, and SM performed data acquisition. KY, TY, TS, KY, KH, KS, HM, and NS participated in the interpretation of data and critical revision. All authors read and approved the final manuscript.

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Availability of data and materials

Hashida, Ryuki, 2022, "The impact of spinal surgery on the locomotive syndrome in patients with lumbar spinal stenosis," "https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/QPA7XO", Harvard Dataverse, DRAFT VERSION.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Kurume University Ethics Committee of University (Approval ID:22025). Consent to participate in the study was obtained using an opt-out approach. The opt-out information was informed at our university homepage following the URL (chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.hosp.kurume-u.ac.jp/uploads/ck/files/crc/upload/15398.pdf). Informed consent was obtained from all subjects and/or their legal guardian. No identifying information of the patients has been shared.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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