Takase *et al. BMC Musculoskeletal Disorders* (2025) 26:209
https://doi.org/10.1186/s12891-025-08456-8

BMC Musculoskeletal Disorders

RESEARCH Open Access

Age diversity among older surgically treated patients with lumbar spinal stenosis: a retrospective comparative study of early and late older adults

Ken Takase[1], Soya Kawabata[1], Takehiro Michikawa[3], Yuki Akaike[1,2], Takao Tobe[6], Risa Tobe[4], Sota Nagai[1], Takaya Imai[1], Hiroki Takeda[5], Shinjiro Kaneko[5], Shigeki Yamada[4,6] and Nobuyuki Fujita[1*]

Abstract

Background At present, the threshold defining older adults is 65 years, and this classification has been widely accepted globally. However, with the extension of both life expectancy and healthy life expectancy, there is a need to reconsider this age-based definition. This study compared the characteristics and surgical outcomes of older patients with lumbar spinal stenosis (LSS) between the early and late stages to clarify age diversity in this population.

Methods Data collected from consecutive patients aged ≥ 65 years who underwent LSS surgery were retrospectively reviewed. All participants completed the Zurich Claudication Questionnaire, Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ), and 25-Question Geriatric Locomotive Function Scale preoperatively as well as 6 and 12 months postoperatively. Frailty was evaluated using the 11-point modified frailty index. Polypharmacy was defined as the concomitant use of at least six drugs.

Results In total, 311 older patients with LSS were enrolled. Among them, 136 patients younger than 75 were categorized into the E group, and 175 patients aged 75 and older were categorized into the L group. Baseline characteristics, including frailty and polypharmacy, significantly differed between the groups. The frequency of effective case of surgical treatment on JOABPEQ was significantly lower for walking ability in the L group. At 1 year after surgery, the incidence of non-improvement in locomotive syndrome stages was higher in the L group than in the E group (relative risk = 1.38, 95% confidence interval [CI] = 1.08–1.78). In addition, when the L group was further divided into three subgroups based on age, the relative risk was 1.32 (95% CI = 0.99–1.76) for patients aged 75 to < 80, 1.42 (95% CI = 1.07–1.88) for those aged 80 to < 85 years, and 1.68 (95% CI = 1.16–2.45) for those aged ≥ 85.

Conclusions Significant differences were observed in baseline characteristics and postoperative improvement of walking ability and locomotive syndrome based on age among older patients with LSS. Our findings underscore the significant age diversity among older adults, highlighting the necessity of considering each patient in a more nuanced age-specific manner rather than adopting a one-size-fits-all approach.

*Correspondence:
Nobuyuki Fujita
nfujita2007@gmail.com

Full list of author information is available at the end of the article

Keywords Lumbar spinal stenosis, Age, Early older adults, Late older adults, Locomotive syndrome

Background

With the extension of life expectancy, the global population of older adults is steadily growing [1]. However, older adults are diverse regarding their individual health status, functional ability, labor capacity, and economic circumstances [2]. Against this backdrop, a flexible approach to defining older individuals is becoming increasingly crucial. The age threshold defining older adults is currently 65 years, a classification that has been widely accepted globally [3]. However, with the prolongation of both life expectancy and healthy life expectancy, there is a need to reconsider this age-based definition. A categorization of "early older adults" (aged 65–74) and "late older adults" (aged ≥ 75) was recently proposed, and the need for different medical interventions and preventive measures for each age group was suggested [4]. However, the differences between early and late older adults across various disease conditions have not been thoroughly clarified [5, 6].

Lumbar spinal stenosis (LSS), a common degenerative spinal disease, is clinically associated with symptoms such as numbness and pain in the lower limbs and buttocks and marked by intermittent claudication [7, 8]. In some cases, LSS can lead to muscle weakness and sensory deficits in the lower limbs and bladder and bowel dysfunction, significantly impairing activities of daily living [7, 8]. The number of patients affected by LSS is increasing with population aging [9, 10], resulting in more frequent surgeries for older patients with LSS. To date, several studies have examined surgical outcomes in older patients with LSS, focusing on health-related quality of life and surgical complications [11–16]. More recently, the characteristics of older patients with LSS have been analyzed from various aspects of aging, including frailty (reflecting a decline in overall health), sarcopenia (indicating a decline in strength and physical function because of the loss of muscle mass), locomotive syndrome (signifying a deterioration in mobility), and polypharmacy (indicating excessive medication use) [17–19]. However, the differences between early and late older patients with LSS from these perspectives remain unclear. Thus, this study categorized older patients with LSS into two groups, examined their characteristics and surgical outcomes, and ultimately clarified the age diversity in surgical outcomes among these patients.

Methods

Participants

Longitudinal data collected from consecutive patients aged ≥ 65 years who underwent LSS surgery at our institution between April 2020 and July 2023 were retrospectively reviewed. Board-certified spine surgeons decided the surgical indications and procedures for patients in consideration of their symptoms and imaging results, including magnetic resonance imaging, computed tomography, and myelography, as stipulated in the guidelines [7, 8]. The exclusion criteria applied to cases of adult spinal deformities where deformity correction and fixation involved screws placed at the upper level extending to the thoracic spine or at the lower level involving screws in the ilium or sacroiliac joint.

Ethics approval

The study was approved by the ethics committees of the institution (approval no. HM 23–354). All eligible patients were included, excluding those who withdrew via opt-out. This study was conducted in compliance with the guidelines of the Declaration of Helsinki.

Data collection

All participants completed patient-reported outcome measures (PROMs), including the Zurich Claudication Questionnaire (ZCQ) [20], Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ) [21], and 25-Question Geriatric Locomotive Function Scale (GLFS-25) [22], before surgery, 6 months after surgery, and 1 year after surgery. The following data were collected: age; sex; body mass index (BMI); medical history including diabetes mellitus, hypertension, dyslipidemia, cardiovascular disease, stroke, and cancer; polypharmacy; preoperative American Society of Anesthesiologists (ASA) physical status; frailty; serum albumin levels; spondylolisthesis; degenerative lumbar scoliosis; failed back surgery syndrome; radiographic parameters; and surgical procedures. Concerning the radiographic parameters, sagittal vertical axis (SVA), thoracic kyphosis (TK), pelvic tilt (PT), pelvic incidence (PI), and lumbar lordosis (LL) were evaluated via standing full-length plain radiography.

Frailty

Frailty was evaluated using the 11-point modified frailty index (mFI), which considers 11 factors extracted from the patients' medical records. Using this index, patients were categorized into three groups: robust (score = 0), prefrail (score < 0.21), and frail (score > 0.21) [23].

Locomotive syndrome

The locomotive syndrome stage was determined by the GLFS-25 total score as 0 (score ≤ 6), 1 (score ≥ 7), 2 (score ≥ 16), or 3 (score ≥ 24) [22]. Stage 0 does not correspond to locomotive syndrome, and as the stage number increases, it indicates worsening function, with stage 3 representing the most severe functional impairment [22].

Surgical outcome assessment

The surgical intervention was deemed "effective" if there was an improvement of ≥ 20 points in the JOABPEQ score postoperatively or if the score improved from < 90 preoperatively to ≥ 90 postoperatively [21].

Polypharmacy

Pharmacists primarily investigated the preoperative prescribed drugs as part of home therapy when the patients were admitted. Polypharmacy was defined as the use of at least six drugs [24].

Statistical analysis

Data were compared between the groups using Student's *t*-test, Fisher's exact test, or the Mann–Whitney U test, as appropriate. The McNemar–Bowker test was used to examine longitudinal changes in the locomotive syndrome stage. In this analysis, stages 0 and 1 were combined. Statistical analyses were performed using the Statistical Package for the Social Sciences (version 29.0; IBM Inc., Armonk, NY, USA). We defined postoperative non-improvement in locomotive syndrome as no change or an increase in the locomotive syndrome stages at 1 year after surgery. When we investigated the association between age and the incidence of postoperative non-improvement of locomotive syndrome, Poisson regression model was applied to estimate the relative risk (RR) and 95% confidence interval (CI). Poisson regression was performed using STATA16 software (Stata Corporation, College Station, TX, USA). $P < 0.05$ denoted statistical significance.

Results

A total of 519 consecutive older patients diagnosed with LSS met the above criteria and had complete preoperative data. Of these, 395 patients (76.1%) attended the outpatient clinic 6 months after surgery and responded to the PROMs. Among them, 311 patients (59.9%) responded to the PROMs at their 1-year postoperative visit. No patients opted out. Therefore, in the current study, the data of 311 older patients with LSS were analyzed. Among them, 136 patients younger than 75 were categorized into the E group, and the remaining 175 patients aged ≥ 75 were categorized into the L group. Initially, we compared the baseline characteristics of the groups (Table 1). Polypharmacy was significantly more frequent in the L group. In terms of medical history, the frequencies of hypertension and cardiovascular disease were significantly higher in the L group. Consistent with these findings, the ASA and frailty scores were significantly higher in the L group. Serum albumin levels were significantly lower in the L group. Regarding radiographic parameters, SVA, PT, and PI-LL were significantly higher in the L group.

Next, the ZCQ scores before surgery and 6 months and 1 year after surgery were calculated separately for each group (Table 2). Longitudinal observation revealed that both symptom severity and physical function scores were significantly improved in both groups at 6 months and 1 year postoperatively. Cross-sectional observation identified no significant difference in symptom severity between the two groups before and 6 months and 1 year after surgery. Regarding physical function, there was no significant difference in the score between the two groups preoperatively, but the L group had significantly worse scores at 6 months and 1 year postoperatively. Concerning satisfaction, the score did not differ between the groups at 6 months after surgery, but the score was significantly worse in the L group at 1 year postoperatively. We also conducted separate analyses based on the surgical procedure, dividing the cases into those without fusion and those with fusion. The results of these analyses are presented in supplementary Tables 1 and supplementary Table 2. Although there were differences in statistical significance, the trends were consistent with the results of the overall analysis. Table 3 presents the rate of surgical effectiveness 1 year postoperatively in the five domains of the JOABPEQ in the two groups. Among the five domains, there were no significant differences between the two groups regarding the rates of improvement in pain disorder, lumbar function, and psychological disorder. Meanwhile, the rate was significantly lower for walking ability in the L group.

Figure 1 presents the distribution of locomotive syndrome stages in the two groups both before and after surgery. In both groups, the distribution significantly improved at 6 months and 1 year postoperatively. Although no difference was detected between the groups preoperatively, the distribution was significantly worse in the L group at 6 months and 1 year postoperatively. Finally, the prevalence of non-improvement in locomotive syndrome stages 1 year after surgery was compared between two groups using a Poisson model (Table 4). In the multivariable analysis, we adjusted for some covariates (sex, BMI, serum albumin level, frailty, PI-LL, and polypharmacy) that showed significant differences in baseline characteristics between the two groups (Table 1). Using the E group as the reference, the RR for the L group was 1.38 (95% CI = 1.08–1.78), which reached statistical significance. Next, the L group was further divided into three subgroups by age: 75 to > 80 years, 80 to > 85 years, and ≥ 85 years (Table 4). The RRs for these subgroups were calculated as 1.32 (95% CI = 0.99–1.76), 1.42 (95% CI = 1.07–1.88), and 1.68 (95% CI = 1.16–2.45),

Table 1 Comparison of baseline characteristics between two groups

		E group (*n* = 136)		L group (*n* = 175)		*p* value
Sex		Men	77 (56.6%)	Men	80 (45.7%)	0.056
		Women	59 (43.4%)	Women	95 (54.3%)	
Age (years)		70.6 ± 2.9		80.5 ± 3.7		< 0.001
BMI (kg/m2)		23.9 ± 3.8		23.7 ± 3.8		0.329
Polypharmacy		77 (56.6%)		132 (75.4%)		< 0.001
Medical history	Diabetes mellitus	37 (27.2%)		47 (26.9%)		0.945
	Hypertension	82 (60.3%)		134 (76.6%)		0.002
	Dyslipidemia	57 (41.9%)		84 (48.0%)		0.285
	Cardiovascular disease	30 (22.1%)		62 (35.4%)		0.01
	Stroke	20 (14.7%)		18 (10.3%)		0.238
	Cancer	22 (16.2%)		30 (17.1%)		0.821
ASA	3	16 (11.8%)		25 (14.3%)		0.027
	2	100 (73.5%)		140 (80.0%)		
	1	20 (14.7%)		10 (5.7%)		
11point- Modified Frailty Index	Frailty	30 (22.1%)		48 (27.4%)		0.006
	Pre-frailty	83 (61.0%)		117 (66.9%)		
	Robust	23 (16.9%)		10 (5.7%)		
Laboratory data	Alb (g/dl)	4.1 ± 0.4		4.0 ± 0.4		0.042
Degenerative spondylolisthesis		50 (36.8%)		70 (40.0%)		0.561
Degenerative lumbar scoliosis		22 (16.2%)		35 (20.0%)		0.387
Failed back syndrome		17 (12.5%)		14 (8.0%)		0.189
Radiographic parameters	SVA (mm)	52.9 ± 45.9		61.9 ± 47.0		0.041
	LL (°)	34.7 ± 12.3		33.3 ± 14.4		0.448
	TK (°)	30.0 ± 10.0		32.5 ± 12.5		0.057
	PT (°)	21.7 ± 8.6		25.0 ± 8.7		0.001
	PI-LL (°)	12.5 ± 13.4		16.8 ± 14.0		0.003
Surgical procedure	without fusion	76 (55.9%)		97 (55.4%)		0.936
	with fusion	60 (44.1%)		78 (44.6%)		
Operative time (min)		153.7 ± 107.6		149.9 ± 97.4		0.999
Intraoperative blood loss (ml)		183.9 ± 173.3		180.1 ± 193.0		0.485

BMI, body mass index; ASA, American society of anesthesiologists physical status; SVA, sagittal vertical axis; PI, pelvic incidence; PT, pelvic tilt; LL, lumbar lordosis

FBSS, Failed back surgery syndrome

Pearson's chi-square test or Mann-Whitney U test was used

Table 2 Pre- and postoperative scores of ZCQ in two groups

			E group (*n* = 136)	L group (*n* = 175)	*p* value
ZCQ (Mean ± SD)	Symptom severity	Preoperation	3.30 ± 0.76	3.38 ± 0.69	0.593
		6POM	2.38 ± 0.82	2.46 ± 0.76	0.263
		1POY	2.33 ± 0.82	2.49 ± 0.74	0.051
		p value (preoperation vs. 6POM)	< 0.001	< 0.001	
		p value (preoperation vs. 1POY)	< 0.001	< 0.001	
	Physical function	Preoperation	2.56 ± 0.62	2.60 ± 0.65	0.775
		6POM	1.75 ± 0.68	1.93 ± 0.70	0.013
		1POY	1.69 ± 0.67	1.90 ± 0.66	0.001
		p value (preoperation vs. 6POM)	< 0.001	< 0.001	
		p value (preoperation vs. 1POY)	< 0.001	< 0.001	
	Satisfaction	6POM	2.01 ± 0.72	2.07 ± 0.70	0.452
		1POY	1.94 ± 0.74	2.15 ± 0.74	0.009

6POM, 6 months after surgery;1POY, 1 year after surgery; ZCQ, Zurich Claudication Questionnaire

Wilcoxon signed-rank sum test or Mann-Whitney U test was used

Table 3 Comparison of frequency of effective case of surgical treatment on JOABPEQ (E group vs. L group)

		E group ($n=136$)	L group ($n=175$)	*p* value
The number of effective case of surgical treatment on JOABPEQ	Pain disorder	83 (61.0%)	106 (60.6%)	0.935
	Lumbar function	64 (47.1%)	83 (47.4%)	0.948
	Walking ability	100 (73.5%)	101 (57.7%)	0.004
	Social life	69 (50.7%)	70 (40.0%)	0.059
	Psychological disorder	51 (37.5%)	58 (33.1%)	0.424

JOABPEQ, JOA Back Pain Evaluation Questionnaire

*Pearson's chi-square test

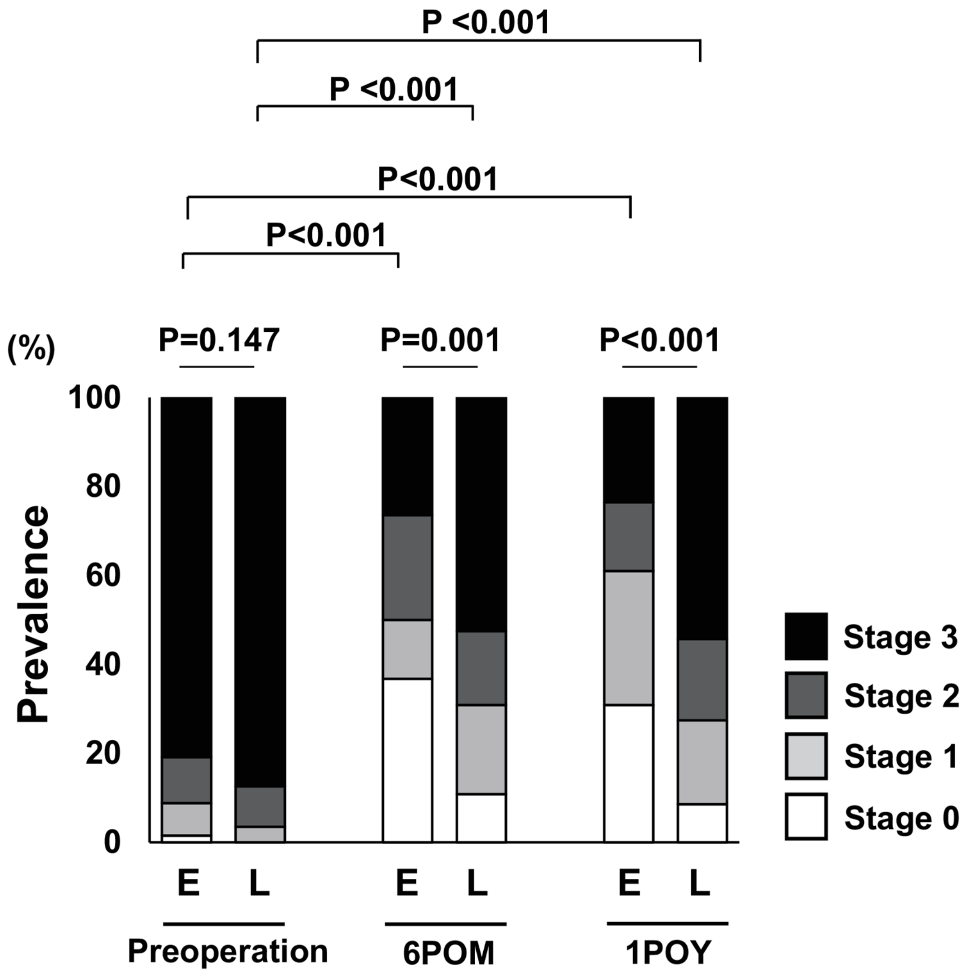

Fig. 1 Pre- and postoperative distribution of locomotive syndrome stages in the early (**E**) and later older patient groups (**L**). 6POM, 6 months after surgery; 1POY, 1 year after surgery. In the statistical analysis, stages 0 and 1 were grouped together

Table 4 Association between age groups and postoperative non-improvement of locomotive syndrome

		Number of patients	Number of incidents	Incidence (%)	Uni-variable model		Multi-variable model*	
					Relative risk (95% confidence interval)	p-value	Relative risk (95% confidence interval)	p-value
Age (years)	65–74	136	49	36.0	Reference		Reference	
	75-	175	102	58.3	1.62 (1.25–2.09)	< 0.01	1.38 (1.08–1.78)	0.01
Age (years)	65–74	136	49	36.0	Reference		Reference	
	75–79	86	45	52.3	1.45 (1.07–1.96)	0.02	1.32 (0.99–1.76)	0.06
	80–84	67	43	64.2	1.78 (1.34–2.37)	< 0.01	1.42 (1.07–1.88)	0.02
	85-	22	14	63.6	1.77 (1.20–2.60)	< 0.01	1.68 (1.16–2.45)	< 0.01

*We applied a Poisson regression model and adjusted for sex, body mass index, albumin, 11point-Modified Frailty Index, PI-LL, and polypharmacy respectively, indicating that the rate of non-improvement significantly increased with advancing age.

Discussion

This study is the first to compare the characteristics and surgical outcomes of older patients with LSS by dividing them into early and late older groups. In summary, our findings indicate significant differences in baseline characteristics between these two groups. Moreover, we observed that the improvement in locomotive syndrome following surgery diminished with increasing age.

In terms of baseline characteristics, notable differences in frailty and polypharmacy rates between the early and late older groups were consistent with prior studies [25, 26]. In addition, radiographic parameters including SVA, LL, PT, and PI-LL, also varied significantly between the groups. These findings align with the established trend that the sagittal balance of the spine worsens with age [27]. Interestingly, despite the retrospective nature of this study, surgical procedures differed minimally between the groups. This suggests that patients aged 75 and older did not avoid fusion surgery when necessary.

In this study, postoperative outcomes showed significant differences in the JOABPEQ scores only for treatment effectiveness in walking ability. This suggests that while surgery alleviates the disability caused by LSS, other age-related factors, such as knee or hip osteoarthritis and peripheral arterial disease, may increasingly hinder walking ability as patients age [28, 29].

Locomotive syndrome, caused by musculoskeletal impairments, is a critical factor that elevates the risk of falls and fractures in older adults [30]. Early diagnosis and intervention are essential to prevent the transition to long-term care dependency [30]. Although locomotive syndrome staging in this study was based solely on the GLFS-25, prior research indicates that staging determined using all three tests including the GLFS-25, two-step test, and stand-up test, does not significantly differ from staging based only on the GLFS-25 [31, 32]. Therefore, the methodology used here is considered valid.

Several studies have explored the relationship between LSS and locomotive syndrome in older adults [33, 34]. It has also been reported that patients with LSS who were diagnosed with frailty before surgery exhibited significantly less improvement in locomotive syndrome [17], in line with our findings in late older patients with LSS. Additionally, analyzing late older adults in 5-year increments revealed that the likelihood of non-improvement in locomotive syndrome stage increases significantly with advancing age. This underscores a strong age-related relationship within the older population.

These results highlight the need to distinguish between early and late older patients when considering LSS surgery. Preoperative counseling should emphasize these differences to help patients make informed decisions. As this study demonstrates the significant impact of age on surgical outcomes in locomotive syndrome among patients aged 65 and older, it is clear that the older population should not be treated as a homogeneous group. Instead, individualized evaluations and tailored management strategies are essential for optimizing outcomes in this growing demographic.

The current study had several limitations. First, this was a single-center study. The background of the institution can introduce bias regarding the types and number of comorbidities among older patients, making it preferable to conduct future research in a multicenter setting. The second limitation was that the follow-up period was limited to 1 year. Although postoperative data were also collected at 6 months, allowing us to observe temporal changes after LSS surgery, a follow-up period of at least 2 years would be preferable. The third limitation was that this study did not include data from younger adults. Frailty, locomotive syndrome, and polypharmacy are typically assessed only in older adults, making it challenging to include data from such individuals. The fourth limitation was that sarcopenia, another key indicator of aging, was not examined in this study. Further research is needed to independently address this aspect. Lastly, this study is retrospective in nature, and we were only able to evaluate approximately 60% of older patients who underwent surgery for LSS at our institution during the specified period. However, to the best of our knowledge, this is the first study to elucidate the differences between early and late older patients with LSS. The findings of the current study are expected to represent a valuable reference for the surgical treatment of older patients with LSS in the future.

Conclusions

In conclusion, this study identified differences in baseline characteristics and surgical improvement of walking ability between early and late older adults with LSS. Furthermore, advancing age appeared to negatively influence the improvement of locomotive syndrome following surgery in this population. However, as this study was conducted in a Japanese cohort and included a relatively small sample size, the generalizability of these findings to other populations remains uncertain. These results suggest the importance of accounting for age-related diversity among older adults when planning surgical interventions for LSS, but further studies are needed to confirm these findings in larger and more diverse populations. Advanced age or frailty alone should not preclude surgical intervention for LSS in older adults. However, it is advisable to thoroughly inform patients of the findings from this study during preoperative counseling before proceeding with surgery.

Abbreviations

LSS	Lumbar spinal stenosis
ZCQ	Zurich Claudication Questionnaire
JOABPEQ	Japanese Orthopaedic Association Back Pain Evaluation Questionnaire
GLFS-25	25-Question Geriatric Locomotive Function Scale
BMI	Body mass index
ASA	American Society of Anesthesiologists
SVA	Sagittal vertical axis
TK	Thoracic kyphosis
PT	Pelvic tilt
PI	Pelvic incidence
LL	Lumbar lordosis
mFI	Modified frailty index
RR	Relative risk
CI	Confidence interval

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12891-025-08456-8.

Supplementary Material 1

Supplementary Material 2

Acknowledgements
The authors would like to thank Ms. Satoko Okada and Ms. Yukari Kuno for their technical support.

Author contributions
N.F. and S.Y. designed the study. K.T., S.K. (Soya Kawabata), T.M., Y.A., T.T., R.T., S.N., T.I., H.T., and S.K. (Shinjiro Kaneko) contributed to the analysis and interpretation of the data. K.T., S.K. (Soya Kawabata), and T.M. performed statistical analysis. K.T., T.M., and N.F. wrote the initial draft of the manuscript. S.K. (Soya Kawabata), Y.A., T.T., R.T., S.N., T.I., H.T., and S.K. (Shinjiro Kaneko), and S.Y. critically reviewed the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding
This study received no external funding.

Data availability
The datasets generated and/or analyzed during the current study are not publicly available due to the limitations of ethical approval involving patient data and anonymity; however, they are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This research was approved by the Fujita Health University Ethics Committee (approval no. HM 23–354). Informed consent was waived by the Fujita Health University Ethics Committee. The Fujita Health University Ethics Committee also approved our use of the opt-out method for obtaining consent, indicating that all eligible patients were included in the present study unless they contacted us to opt-out.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Orthopaedic Surgery, School of Medicine, Fujita Health University, 1-98 Dengakugakubo, Kutsukake-cho, Toyoake 470-1192, Aichi, Japan
[2]Department of Orthopaedic Surgery, Keio University School of Medicine, Tokyo, Japan
[3]Department of Environmental and Occupational Health, School of Medicine, Toho University, Tokyo, Japan
[4]Department of Clinical Pharmacy, Fujita Health University Hospital, Aichi, Japan
[5]Department of Spine and Spinal Cord Surgery, School of Medicine, Fujita Health University, Aichi, Japan
[6]Department of Pharmacotherapeutics and Informatics School of Medicine, Fujita Health University, Aichi, Japan

Received: 17 August 2024 / Accepted: 19 February 2025
Published online: 28 February 2025

References

1. World Health Organization. Ageing and health. https://www.who.int/news-room/fact-sheets/detail/ageing-and-health. Accessed 1 Oct 2022.
2. Beard JR, Bloom DE. Towards a comprehensive public health response to population ageing. Lancet. 2015;385:658–61.
3. Christensen K, Doblhammer G, Rau R, Vaupel JW. Ageing populations: the challenges ahead. Lancet. 2009;374:1196–208.
4. Cabinet Office. White Papers. Annual report on the ageing society. Annual Report. 2021. https://www8.cao.go.jp/kourei/english/annualreport/2021/pdf/2021.pdf
5. Ishii S, Ogawa S, Akishita M. The state of health in older adults in Japan: trends in disability, chronic medical conditions and mortality. PLoS ONE. 2015;10:e0139639.
6. Haeri NS, Perera S, Nadkarni NK, Greenspan SL. Association of inflammatory markers with muscle and cognitive function in early and late-aging older adults. J Nutr Health Aging. 2024;28:100207.
7. Kreiner DS, Shaffer WO, Baisden JL, Gilbert TJ, Summers JT, Toton JF, et al. An evidence-based clinical guideline for the diagnosis and treatment of degenerative lumbar spinal stenosis (update). Spine J. 2013;13:734–43.
8. Kawakami M, Takeshita K, Inoue G, Sekiguchi M, Fujiwara Y, Hoshino M, et al. Japanese orthopaedic association (JOA) clinical practice guidelines on the management of lumbar spinal stenosis, 2021– Secondary publication. J Orthop Sci. 2023;28:46–91.
9. Kalichman L, Cole R, Kim DH, Li L, Suri P, Guermazi A, et al. Spinal stenosis prevalence and association with symptoms: the Framingham study. Spine J. 2009;9:545–50.
10. Yabuki S, Fukumori N, Takegami M, Onishi Y, Otani K, Sekiguchi M, et al. Prevalence of lumbar spinal stenosis, using the diagnostic support tool, and correlated factors in Japan: a population-based study. J Orthop Sci. 2013;18:893–900.
11. Glassman SD, Carreon LY, Dimar JR, Campbell MJ, Puno RM, Johnson JR. Clinical outcomes in older patients after posterolateral lumbar fusion. Spine J. 2007;7:547–51.
12. Cassinelli EH, Eubanks J, Vogt M, Furey C, Yoo J, Bohlman HH. Risk factors for the development of perioperative complications in elderly patients undergoing lumbar decompression and arthrodesis for spinal stenosis: an analysis of 166 patients. Spine (Phila Pa 1976). 2007;32:230–5.
13. Pérez-Prieto D, Lozano-Álvarez C, Saló G, Molina A, Lladó A, Puig-Verdié L, et al. Should age be a contraindication for degenerative lumbar surgery? Eur Spine J. 2014;23:1007–12.
14. Saleh A, Thirukumaran C, Mesfin A, Molinari RW. Complications and readmission after lumbar spine surgery in elderly patients: an analysis of 2,320 patients. Spine J. 2017;17:1106–12.
15. Wang SK, Wang QJ, Wang P, Li XY, Cui P, Wang DF, et al. The impact of frailty on clinical outcomes of older patients undergoing enhanced recovery after lumbar fusion surgery: a prospective cohort study. Int J Surg. 2024;110:4785–95.
16. Wang SK, Li YJ, Wang P, Li XY, Kong C, Ma J, et al. Safety and benefit of ambulation within 24 hours in elderly patients undergoing lumbar fusion: propensity score matching study of 882 patients. Spine J. 2024;24:812–9.
17. Nagai S, Kawabata S, Michikawa T, Ito K, Takeda H, Ikeda D, et al. Association between frailty and locomotive syndrome in elderly patients with lumbar spinal stenosis: A retrospective longitudinal analysis. Geriatr Gerontol Int. 2024;24:116–22.
18. Park S, Kim HJ, Ko BG, Chung JW, Kim SH, Park SH, et al. The prevalence and impact of sarcopenia on degenerative lumbar spinal stenosis. Bone Joint J. 2016;98–B:1093–8.

19. Nagai S, Inagaki R, Michikawa T, Kawabata S, Ito K, Hachiya K, et al. Efficacy of surgical treatment on polypharmacy of elderly patients with lumbar spinal Canal stenosis: retrospective exploratory research. BMC Geriatr. 2023;23:169.
20. Stucki G, Daltroy L, Liang MH, Lipson SJ, Fossel AH, Katz JN. Measurement properties of a self-administered outcome measure in lumbar spinal stenosis. Spine (Phila Pa 1976). 1996;21:796–803.
21. Fukui M, Chiba K, Kawakami M, Kikuchi S, Konno S, Miyamoto M, et al. Japanese orthopaedic association back pain evaluation questionnaire. Part 3. Validity study and establishment of the measurement scale: subcommittee on low back pain and cervical myelopathy evaluation of the clinical outcome committee of the Japanese orthopaedic association, Japan. J Orthop Sci. 2008;13:173–9.
22. Corporation JOA. Locomotive syndrome in locomotive challenge Council. Locomotive Syndrome Pamphlet 2020. https://locomo-joa.jp/
23. Obeid NM, Azuh O, Reddy S, Webb S, Reickert C, Velanovich V, et al. Predictors of critical care-related complications in colectomy patients using the National surgical quality improvement program: exploring frailty and aggressive laparoscopic approaches. J Trauma Acute Care Surg. 2012;72:878–83.
24. Sato K, Inagaki R, Michikawa T, Kawabata S, Ito K, Morita M, et al. Prescription drug survey of elderly patients with degenerative musculoskeletal disorders. Geriatr Gerontol Int. 2022;22:121–6.
25. Fried LP, Tangen CM, Walston J, Newman AB, Hirsch C, Gottdiener J, et al. Frailty in older adults: evidence for a phenotype. J Gerontol Biol Sci Med Sci. 2001;56:M146–56.
26. Jyrkkä J, Enlund H, Korhonen MJ, Sulkava R, Hartikainen S. Patterns of drug use and factors associated with polypharmacy and excessive polypharmacy in elderly persons: results of the Kuopio 75 + study: a cross-sectional analysis. Drugs Aging. 2009;26:493–503.
27. Kobayashi T, Atsuta Y, Matsuno T, Takeda N. A longitudinal study of congruent sagittal spinal alignment in an adult cohort. Spine (Phila Pa 1976). 2004;29:671–6.
28. Ozaki M, Fujita N, Miyamoto A, Suzuki S, Tsuji O, Nagoshi N, et al. Impact of knee osteoarthritis on surgical outcomes of lumbar spinal Canal stenosis. J Neurosurg Spine. 2020;32:710–5.
29. Imagama S, Matsuyama Y, Sakai Y, Ito Z, Wakao N, Deguchi M, et al. An arterial pulse examination is not sufficient for diagnosis of peripheral arterial disease in lumbar spinal Canal stenosis: a prospective multicenter study. Spine (Phila Pa 1976). 2011;36:1204–10.
30. Nakamura K, Ogata T. Locomotive syndrome: definition and management. Clin Rev Bone Min Metab. 2016;14:56–67.
31. Yoshimura N, Muraki S, Iidaka T, Oka H, Horii C, Kawaguchi H, et al. Prevalence and co-existence of locomotive syndrome, sarcopenia, and frailty: the third survey of research on osteoarthritis/osteoporosis against disability (ROAD) study. J Bone Min Metab. 2019;37:1058–66.
32. Imagama S, Ando K, Kobayashi K, Machino M, Tanaka S, Morozumi M, et al. Differences of locomotive syndrome and frailty in community-dwelling middle-aged and elderly people: pain, osteoarthritis, spinal alignment, body balance, and quality of life. Mod Rheumatol. 2020;30:921–9.
33. Fujita N. Lumbar spinal Canal stenosis from the perspective of locomotive syndrome and metabolic syndrome: a narrative review. Spine Surg Relat Res. 2021;5:61–7.
34. Kato S, Demura S, Kabata T, Matsubara H, Kurokawa Y, Kajino Y, et al. Evaluation of locomotive syndrome in patients receiving surgical treatment for degenerative musculoskeletal diseases: a multicentre prospective study using the new criteria. Mod Rheumatol. 2022;32:822–9.

Publisher's note