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Clinical Study

Walking performance in individuals with lumbar spinal stenosis—possible outcome measures and assessment of known-group validity

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Abstract

BACKGROUND CONTEXT: One of the primary goals of treatments received by individuals with lumbar spinal stenosis with neurogenic claudication is to improve walking ability. Thus, a thorough and valid assessment of walking ability in patients with lumbar spinal stenosis is needed. Duration of continuous walking and steps per day could be relevant when evaluating walking ability in daily living.

PURPOSE: To describe and evaluate a method for estimating continuous walking periods in daily living and to evaluate the known-group validity of steps per day in individuals with lumbar spinal stenosis.

STUDY DESIGN: This is a cross-sectional observational study.

PATIENT SAMPLE: The study contains three study groups: individuals with lumbar spinal stenosis, individuals with low back pain, and a background population from the Lolland-Falster Health Study (LOFUS).

OUTCOME MEASURES: Participants in all three study groups wore an accelerometer on the thigh for seven days.

METHODS: Accelerometer data were processed to summarize the continuous walking periods according to their length: the number of short (4−9 seconds), moderate (10−89 seconds), and extended (≥90 seconds) continuous walking periods per day, and the number of steps per day. Results from the three groups were compared using negative binomial regression with lumbar spinal stenosis as the reference level.

FDA device/drug status: Not applicable.

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RESULTS: Continuous walking periods of moderate length were observed 1.48 (95% CI 1.27, 1.72) times more often in individuals from the background population than in individuals with LSS. Continuous walking periods of extended length were observed 1.53 (95% CI 1.13, 2.06) times more often by individuals with low back pain and 1.60 (95% CI 1.29, 1.99) times more often by individuals from the background population. The number of steps per day was 1.22 (95% CI 1.03, 1.46) times larger in individuals with LBP and 1.35 (95% CI 1.20, 1.53) times larger in individuals from background population.

CONCLUSIONS: The impact of neurogenic claudication on walking ability in daily living seems possible to describe by continuous walking periods along with steps per day. The results support known-group validity of steps per day. This is the next step toward a clinically relevant and comprehensive assessment of walking in daily living in individuals with lumbar spinal stenosis.

Keywords: Accelerometer; Low back pain; LOFUS; Lumbar spinal stenosis; Neurogenic claudication; Validity; Walking performance; Wearable sensor

Introduction

Maintaining the ability to perform activities of daily living and to stay physically active are essential parts of healthy aging [1−3]. Lumbar Spinal Stenosis (LSS) primarily affects elderly individuals [4], leading to an increase in sedentary time while reducing physical activity [5]. The condition restricts the patient's walking ability, necessitating pauses during walks to alleviate symptoms of neurogenic claudication [4,6] and reducing their daily step count [7].

The development of treatments and management strategies for patients with clinically manifest LSS could benefit from an assessment of physical behavior, including movement behaviors like sitting, standing, biking, and walking performance. Walking performance is the walking an individual performs in daily life [8], and one way to quantify this in LSS patients could be to assess the interrupted walking pattern associated with neurogenic claudication along with steps per day. A thigh-worn accelerometer can detect movement behaviors [9−11], and the step count accuracy of such accelerometers has previously been demonstrated in LSS patients to be reasonable within a laboratory environment during continuous walking [12]. The accuracy during continuous walking appears to transfer to daily living conditions (data available upon request). It has also been suggested that accelerometer variables on continuous activity can differentiate between LSS, knee osteoarthritis, and healthy individuals [13]. Thus, including the measurement of continuous walking by a thigh-worn accelerometer could be a viable approach when seeking to describe symptom-specific walking in patients with LSS.

Comparing the assessment of continuous walking among individuals with LSS to individuals with LBP and individuals from a background population allows for evaluating whether these variables can be used to differentiate walking patterns characteristic of neurogenic claudication. Individuals with LSS often suffer from low back pain as well, and previous research [14] suggests that older adults with LBP also have reduced physical function. Still, individuals with LBP do not typically present with the characteristic interrupted walking pattern seen in neurogenic claudication.

Purpose

This study aims to explore a method for describing the walking performance of individuals with LSS and neurogenic claudication by investigating the method's ability to detect differences in continuous walking during daily life between individuals with LSS and individuals with LBP, and between individuals with LSS and participants from a background population. Furthermore, we will investigate the known-group validity [15] of steps per day from a thigh-worn accelerometer.

We hypothesize that (1) as the duration of continuous walking periods increases, individuals with LSS will engage in fewer periods of continuous walking compared to individuals with LBP and individuals from a background population and, (2) individuals with LSS will walk fewer steps per day than individuals from a background population.

Method and materials

This study, which is part of the Physical Activity in the Elderly Spine Patient study (PAESP study) [16], involves a cross-sectional design that includes one week of accelerometer monitoring in three different study populations with elderly participants: individuals with LSS, individuals with LBP, and a background population consisting of individuals from the Lolland-Falster Health Study (LOFUS).

Participants

LSS

Individuals with LSS were recruited from the Spine Centre of Southern Denmark, which attends to patients with spinal pain syndromes from the Region of Southern Denmark. General medical practitioners, chiropractors, and other hospital departments can refer patients to the Spine Center. The Spine Centre's attending clinicians invited patients diagnosed with LSS to meet with the study's principal investigator, who assessed eligibility, gave written and verbal information about the study, and collected informed consent from the patients willing to participate. Recruitment and data collection were completed between December 2019 and November 2022.

The inclusion criteria were:

- Age 60 or above.
- Degenerative LSS with the clinical presentation of neurogenic claudication corresponding to six or more items of a Delphi study on diagnosis [17] and radiologic diagnosis confirmed by magnetic resonance imaging.
- Fluent in Danish.

The age limit of 60 years was chosen as part of the PAESP study's focus on elderly spine patients, and to increase the likelihood of degenerative LSS. Individuals were excluded if they had signs of dementia or suffered from another disease or condition that limited their walking more than their LSS, for example, severe cardiovascular or pulmonary diseases, vascular claudication, or pronounced walking impairment from arthrosis or fracture of the lower limb. All LSS participants in the PAESP study performed a self-paced walking test and were excluded if they discontinued the test due to symptoms unrelated to LSS or did not show signs of neurogenic claudication before the time limit of 30 minutes.

LBP

Individuals with LBP were recruited from three chiropractic clinics in Southern Denmark, ie, two placed in Jutland and one on the island of Funen. Chiropractors in the clinics were instructed by the principal investigator on eligibility criteria and to include patients consecutively. The chiropractor assessed eligibility and invited patients to participate. Participants gave informed consent after written and verbal information from the chiropractor themselves or an assistant. Recruitment and data collection were completed between August 2022 and January 2023.

The inclusion criteria for individuals with LBP were:

- Age 60 or above.
- Low back pain, with or without radiating symptoms to the legs.
- Low back pain as the dominant complaint.
- Fluent in Danish.

The exclusion criteria were the same as for the LSS participants, except for the walking test.

LOFUS

The Lolland-Falster area is a rural provincial area where the mortality rate and the percentage of people receiving public support are higher compared to the rest of Denmark [16]. The LOFUS Health Study is a cohort study including individuals living in the Lolland-Falster area [16]. The study randomly invited individuals aged 18 and above, along with any present household members. Recruitment and data collection were completed between February 2016 and February 2020. A subsample of study participants was invited to wear an accelerometer on both the lower back and the thigh, with the only requirement that they could walk. This study included all LOFUS participants who were 60 years old or older with thigh-accelerometer monitoring.

Data collection and processing

Collection of descriptive variables

An online questionnaire, completed on the day of inclusion, was used to collect descriptive variables (pain intensity in back and legs, symptom duration, Swiss Spinal Stenosis Questionnaire (SSSQ) [18]) in LSS and LBP patients. Demographic variables (age, sex, level of education), height, and weight for the LSS individuals were drawn from the Spine Centre's clinical database which patients fill out electronically. For LBP patients, the demographic variables, height, and weight were part of the online questionnaire. The online questionnaires in LSS and LBP were collected and managed using REDCap (Research Electronic Data Capture) hosted by the Region of Southern Denmark [19,20]. REDCap is a secure, web-based software platform designed to support data capture for research studies.

Demographic and descriptive variables were collected with an electronic questionnaire in the LOFUS study, except for height and weight which were measured. For more details, please refer to the published study protocol [16].

Transformation of descriptive variables

The question on education answered by LSS and LBP participants asked about the length of the participant's education and had three options: (1) long, (2) medium, and (3) short. The question on education in the LOFUS study had six levels. To ensure comparability, the education data collected from the LOFUS participants was adjusted to align with the LSS and LBP questionnaire, resulting in the following categorizations: (1) long higher education, (2) medium or short higher education, and (3) No education, short courses, or vocational education.

To harmonize with the LOFUS questionnaire, the duration of symptoms in LBP and LSS individuals was dichotomized into shorter or longer than six months. This derived variable was then combined with questions three and four of the SSSQ symptom severity scale to dichotomize individuals by "pain in back or buttocks≥six months" and "pain in legs or feet≥6 months”, respectively. The questions on pain in the LOFUS questionnaire asked about pain above six months in specific body areas including back, buttocks, and legs, and had a binary response of yes or no for each body area. To facilitate comparison with question three of the SSSQ symptom severity scale, the LOFUS questions addressing pain in the back and buttocks were aggregated into a single variable.

Body mass index was calculated from the collected height and weight.

Accelerometer monitoring

The three study groups all wore an Axivity AX3 (Axivity Ltd, The Core Bath Lane, Newcastle Helix, Newcastle upon Tyne, NE4 5TF, United Kingdom), and some participants in the LSS group wore a comparable Axivity AX6. The AX3 and AX6 are lightweight sensors with battery life sufficient for one week of monitoring or more. Participants in all groups had the accelerometer attached with medical tape anteriorly on their right thigh midway between the hip and the patella. Details on how it was attached to the LOFUS participants can be seen in a specific attachment study [16]. The attachment in LBP and LSS participants followed protocol four of the attachment study.

The individuals with LBP had the accelerometer attached by either an assistant or a chiropractor on the day of inclusion. The principal investigator instructed relevant personnel in the chiropractic clinics on how to attach the accelerometer. For individuals with LSS, the principal investigator personally attached the accelerometer on the day of inclusion.

Processing of accelerometer data

Accelerometer data from all three groups were handled and analyzed in the same way. These algorithms were used to calculate steps per day and time spent walking. The algorithms in question were the step detection algorithm developed earlier in the PAESP study [12] and an algorithm for detecting time in different movement behaviors [9].

Wear time was established by processing the accelerometer’s measurements of accelerations and temperature with a previously described wear time algorithm [16]. The data from a participant was included if there was a minimum of 22 hours of wear time on three weekdays and one day of the weekend.

Variables on daily walking. We identified periods of continuous walking and summarized the mean number of periods per day that lasted for specific durations: 4−9 seconds, 10−19 seconds, up to 89 seconds with 10-second intervals, and ≥90 seconds. This summary of walking periods was visualized in a barplot (Fig. 1). Trends visual in the barplot were used to further summarize the number of continuous walking periods into three variables for the final investigation of differences in continuous walking periods between the study populations.

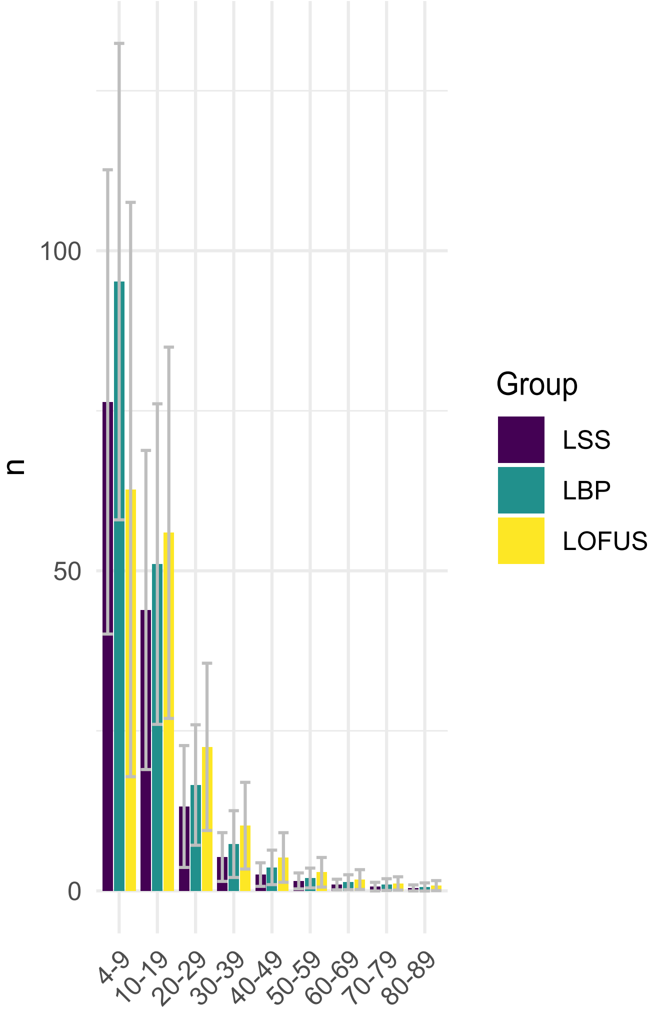

Fig. 1. Distribution of continuous walking periods during everyday life in individuals with lumbar spinal stenosis (LSS, n=84), low back pain (LBP, n=74), and a background population from the Lolland-Falster Health Study (LOFUS, n=1,481). The y-axis represents the mean and standard deviation of the number of continuous walking periods per day (n). The x-axis represents the duration of episodes in seconds.

The detected steps were summarized across all included monitoring days for each individual.

Study size

The size of the study population was determined with respect to other objectives in the PAESP study. Nonetheless, a sample size estimation was performed a-priori based on previously published information on steps per day in elderly individuals with LSS [21], LBP [22], and elderly individuals from a background population [23]. To detect a statistically significant difference in daily step count between elderly individuals with LSS and LBP (two-sided t-test, alpha 0.05, beta=0.2) a sample size of 15 participants in each group was required. To detect a statistically significant difference in daily step count between elderly individuals with LSS and a background population, a sample size of 11 participants was required in each group. No relevant studies on continuous walking were identified at the time of the preparation of the study.

Statistical methods

The study populations were compared regarding their descriptive variables using nonparametric statistical tests. Continuous and ordered variables were assessed using the Wilcoxon rank sum test, while dichotomous variables were evaluated using the chi-squared test.

Negative binomial regressions with LSS as a reference level were performed to investigate differences in the number of continuous walking periods and steps between LSS and LBP participants and between LSS and LOFUS participants. The number of continuous walking periods and steps were counted and analyzed as rate data, relative to the number of days monitored. Apriori, it was decided to adjust analyses for differences in three major demographic variables (age, sex, and education) if any statistically significant differences between LSS and the other groups were observed in these variables. It was decided to adjust for BMI upon discovering the significant differences between study groups in BMI. The appropriateness of the models was investigated through the distribution of deviance residuals. The choice of using negative binomial regression was driven by the presence of overdispersion when fitting a Poisson regression, as indicated by the Z-score test [24]. To estimate the dispersion parameter for the negative binomial regression, the residual deviance was divided by the degrees of freedom.

The dependent variables regarding continuous walking are a result of exploring the data, whereas steps per day were a predetermined dependent variable.

Missing data in education and BMI was imputed to enable the inclusion of all accelerometer data in the adjusted regression analyses. Imputation was made with multivariate imputation with chained equations using predictive mean matching. A total of 20 iterations were performed and the predictor matrix consisted of age, sex, and group.

The analyses were made using R [25] version 4.2.3 and RStudio [26] version 2023.3.1.466, along with the tidyverse [27], mice [28], gtsummary [29], and MASS [30] package.

The regional science ethics committee [31] reviewed the project in 2018 (20182000-128, documentation available upon request) and has underwritten the project in accordance with Section 2, no. 1 of the Danish Act on Research Ethics Review of Health Research Projects.

Results

A total of 112 individuals with LSS were invited to participate. Of these, 23 declined to participate, three accelerometers were lost in the mail, and two individuals had a monitoring period that was too short. The remaining 84 had complete accelerometer data, which were included in the analyses.

For individuals with LBP, out of a total of 130 invited, 39 declined to participate. Moreover, six individuals had a monitoring period that was too short and eleven had inaccessible accelerometer data due to faulty accelerometer settings or download complications. In the end, 74 had full accelerometer data available for analysis.

A total of 5,675 individuals in the LOFUS study agreed to wear accelerometers, of which 57 did not return their accelerometers. Accelerometer data from 1,498 individuals were missing at random from the data available for this specific study due to unfortunate circumstances. Thus, thigh-accelerometer data from 4,120 individuals were available, of which 1,640 individuals were aged 60 or older. Of these 1,640 participants, 160 had an insufficient amount of monitoring days, leaving 1,480 with complete accelerometer data for analysis. Further details on the inclusion of LOFUS participants can be seen in a previously published paper [16].

The mean days worn (SD) were 6.7 (0.59), 6.6 (0.58), and 5.9 (0.46), among LSS, LBP, and LOFUS participants, respectively.

There was a statistically significant difference between the patients with LSS and individuals from LOFUS in age, education, and BMI, between LSS and LBP only in age and BMI. Please see Table 1 for the descriptive variables.

Distribution of the continuous walking periods

The number of continuous walking periods per day in nine fixed intervals up to <90 seconds is presented in Fig. 1. The mean (SD) number of continuous walking periods of 90 seconds duration or more per day was 2.3 (3.0), 4.1 (3.7), and 4.1 (3.7) in LSS, LBP, and LOFUS individuals, respectively. In summary, 97% of the continuous walking periods lasted less than 90 seconds.

Based on the distribution of continuous walking periods, three intervals were selected to describe the number of short (4−9 seconds), moderate (10−89 seconds), and extended (≥90 seconds) continuous walking periods per day in each participant.

Regression results on periods of continuous walking

The number of extended continuous walking periods was statistically higher in the LBP individuals and the LOFUS background population than in individuals with LSS, before and after adjustment for age, education, and BMI. Moderate continuous walking periods were statistically significantly more frequent in the LOFUS background population than in individuals with LSS, while short continuous walking periods were less frequent in the LOFUS background population. No significant differences were observed in short and moderate continuous walking periods between LBP and LSS. Please see Table 2 for the IRR and the confidence

Table 1
Descriptive statistics

Characteristic	LSS, n=84	LBP, n=74	LSS - LBP p-value[*]	LOFUS, n=1,481	LSS - LOFUS p-value[*]
Age, median (IQR), y	74 (69, 78)	70 (65, 76)	.02	70 (65, 74)	<.001
Sex, % female	39 (46%)	39 (53%)	.4	751 (51%)	.4
Length of education			.4		<.001
Long	5 (7.7%)[†]	4 (6.1%)[‡]		59 (4.4%)	
Medium	33 (51%)[†]	41 (62%)[‡]		412 (31%)	
Short	27 (42%)[†]	21 (32%)[‡]		870 (65%)	
BMI, mean (SD), kg/m^2	28.9 (4.9)	26.5 (3.9)	.004	27.5 (4.9)	.016
Pain ≥6 months					
Back and/or buttock, % yes	70 (90%)	30 (50%)[†]	<.001	269 (19%)	<.001
Leg and/or feet, % yes	68 (87%)	22 (34%)[‡]	<.001	280 (19%)	<.001
Back pain, median (IQR), range 0−10	6.35 (4.90, 7.50)	5.00 (3.00, 6.00)	<.001		
Leg pain, median (IQR), range 0−10	6.80 (5.73, 8.00)	2.00 (0.00, 5.00)	<.001		
Swiss Spinal Stenosis Questionnaire					
Symptom severity scale, median (IQR), range 1−5	3.29 (2.86, 3.61)	2.43 (1.71, 2.71)	<.001		
Physical function scale, median (IQR), range 1−4	2.40 (2.00, 2.80)	1.60 (1.00, 2.00)	<.001		

[*] Wilcoxon rank sum test; Pearson's Chi-squared test.

[†] 19%−22% missing.

[‡] 11%−14% missing.Variables not indexed have <10% missing.LSS = Lumbar Spinal Spinal Stenosis, LBP = Low Back Pain, LOFUS = Background population from Lolland-Falster Health Study, SD = Standard Deviation, IQR = Inter Quartile Range, BMI = Body Mass Index.

intervals of the Poisson regression analysis and Fig. 2 for the predicted number of extended continuous walking periods per day.

Differences in steps per day

The mean number of steps per day (SD) was 3,810 (2,324) in participants with LSS, 5,363 (2,737) in participants with LBP, and 5,872 (3,096) in participants from the LOFUS background population. The negative binomial regression showed a significantly higher number of steps per day in both LBP and LOFUS than in LSS, before and after adjustment for age, education, and BMI. See Fig. 3 for predictions of steps per day from the negative binomial regression.

Discussion

Key results

An accelerometer-based method to characterize daily continuous walking in individuals with LSS with symptoms of neurogenic claudication was developed. The method condenses the daily continuous walking periods into three categories according to duration: the number of short, moderate, and extended continuous walking periods per day. Individuals with LSS exhibited significantly fewer extended

Table 2
The results from the negative binomial regressions on differences in the number of short, moderate, and extended continuous walking periods and the number of steps between individuals with LSS, LBP, and participants from a background population (LOFUS). IRR above one indicates more frequent walking periods and steps than in individuals with LSS

		Short		Moderate		Extended		Steps per day	
	Group	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI
Unadjusted analysis	LSS, n=84	—	—	—	—	—	—	—	—
	LBP, n=74	1.26	0.98, 1.63	1.23	1.00, 1.52	1.71[†]	1.26, 2.31	1.40[‡]	1.17, 1.69
	LOFUS, n=1480	0.87	0.73, 1.04	1.55[‡]	1.33, 1.79	1.73[‡]	1.39, 2.13	1.54[‡]	1.35, 1.75
Adjusted analysis[§]	LSS, n=84	—	—	—	—	—	—	—	—
	LBP, n=74	1.03	0.83, 1.29	1.19	0.96, 1.47	1.53[†]	1.13, 2.06	1.22[*]	1.03, 1.46
	LOFUS, n=1480	0.60[‡]	0.51, 0.70	1.48[‡]	1.27, 1.72	1.60[‡]	1.29, 1.99	1.35[‡]	1.20, 1.53

[*] p<.05.

[†] p<.01.

[‡] p<.001.

[§] Adjusted for age, education, and body mass index.IRR = Incidence Rate Ratio, CI = Confidence Interval, LSS = Lumbar Spinal Stenosis, LBP = Low Back Pain, LOFUS = background population from the Lolland-Falster Health Study.

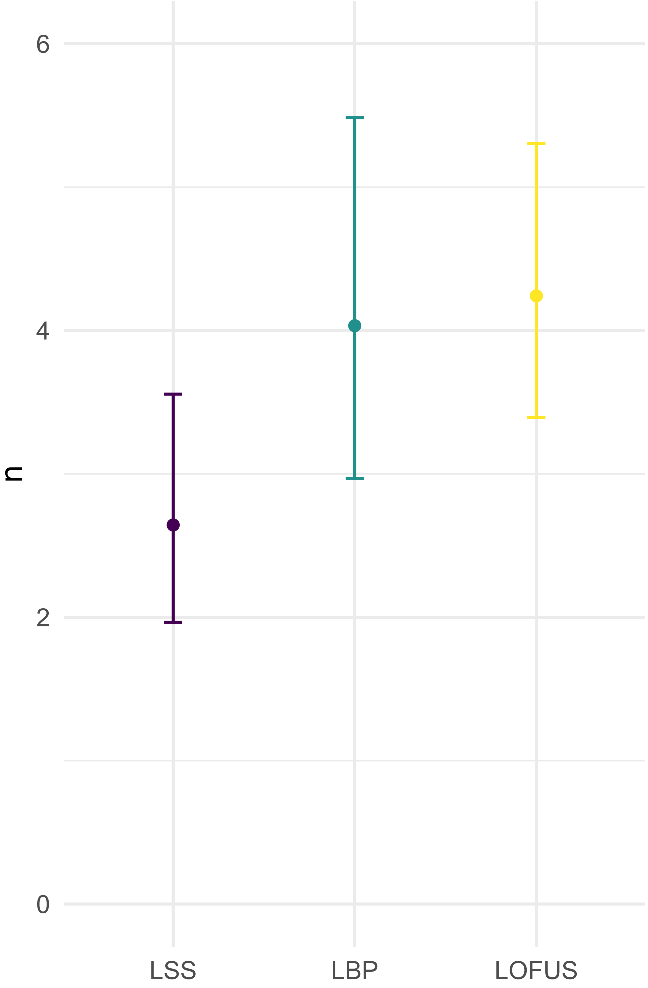

Fig. 2. Predicted number of extended continuous walking periods per day (n) after adjusting for age=74 years, education=long, and body mass index=28 kg/m2, in individuals with lumbar spinal stenosis (LSS), low back pain (LBP), and individuals from a background population participating in the Lolland-Falster Health Study (LOFUS).

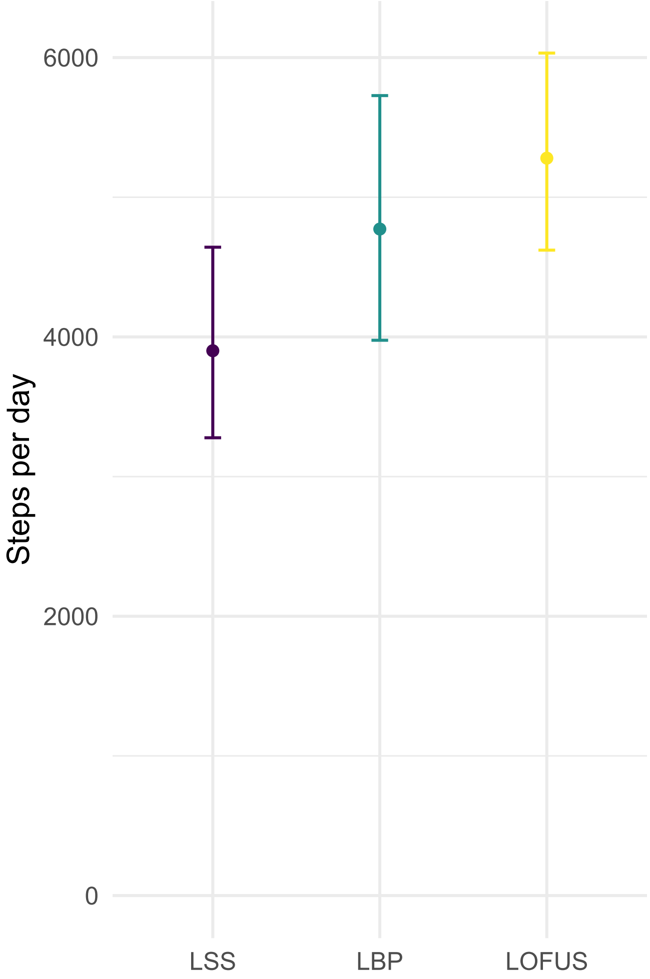

Fig. 3. Predicted steps per day with 95% confidence intervals after adjusting for age=74, education=long, and body mass index=28, in individuals with lumbar spinal stenosis, low back pain, and individuals from a background population participating in the Lolland-Falster Health Study (LOFUS).

periods of continuous walking per day than individuals with LBP and individuals from the LOFUS background population. The accelerometer detected fewer steps per day in participants with LSS than in participants with LBP and in participants from the LOFUS background population, which supports the known-group validity of a thigh-worn accelerometer when evaluating steps per day in patients with lumbar spinal stenosis.

Interestingly, the extended episodes of continuous walking were similar for individuals with LBP and individuals from the background population, with individuals with LSS being significantly disparate. By contrast, the number of steps per day appeared evenly staggered between groups, with individuals with LBP placed between individuals with LSS and individuals from the background population. This supports the notion that episodes of continuous walking measure an aspect of walking performance of particular relevance for LSS.

Strengths and limitations

The internal validity of our data was increased by ensuring that all groups included only participants 60 years old or older. The three groups were comparable in gender distribution, and the analyses were adjusted for the difference in age, education, and BMI. The probability that it was neurogenic claudication that produced the difference in walking was enhanced by using consensus-based criteria for establishing the clinical diagnosis of LSS along with MRI confirmation, and a self-paced walking test that ascertained that walking capacity was restricted by neurogenic claudication. Furthermore, the study used comparable accelerometers in all three groups, worn on the same wear-site with a high amount of wear time and identical accelerometer data processing.

The results should be interpreted in light of the included LSS individuals. These were heterogeneous in terms of surgical and nonsurgical candidates. All individuals with LSS were from a secondary care sector, thus a group filtered out from the general LSS population. The greater part of individuals with LSS might not seek care at all, or they may be managed adequately in primary care and not be referred for hospital care. Arguably, this could for example reflect differences in symptom presentation and severity, or patient preferences and communication. Furthermore, it is likely that the invitation to participate in the study did not reach all individuals with LSS who visited the Spine Centre, but the clinic personnel might have extended the invitation predominantly to those who seemed open and able to manage the task of participating in a study.

We cannot exclude that some of the included individuals with LBP might suffer from symptoms of neurogenic claudication, and the background population likely also has participants with LSS and neurogenic claudication, albeit probably at a lower rate. Despite this, the method was able to distinguish differences in walking between groups. The difference in periods of continuous walking and steps between LSS and LBP participants might have been less if the LBP participants had the same level of chronicity as LSS participants or were from the secondary sector. The difference between LSS participants and the LOFUS background population might have been greater if the LOFUS background population had been representative of Denmark’s general population in terms of health status, or if the comparison had been made to healthy controls.

The adjustment for education is imprecise due to missing data and different assessment methods in the groups. The results presented on continuous walking are from exploratory analyses and thus lack the firm conclusions on validity that clear-cut preestablished hypotheses would grant. Furthermore, it has not been studied whether the method used in this study correctly registers the number of periods of continuous walking in daily life among LSS patients, older individuals, or individuals with walking impairment in general.

Comparison to previous findings

Previous research indicates that the periods of continuous walking are accurate. The specificity and sensitivity for detecting time spent walking using a thigh-worn accelerometer are above 90% in an uncontrolled environment in healthy middle-aged adults [10] and previous validation of the method used in this study has indicated that extended periods of continuous walking are accurately detected (data available upon request). A study built on the same accelerometer and algorithm principles with healthy middle-aged individuals suggests that extended periods of walking may be more readily detected and the number of short periods might be overestimated [32]. However, the overall correlation between the number of accelerometer-detected and video-recorded periods of continuous walking was still at 0.94 [32]. Studies using slightly different accelerometer methodologies have also detected considerably more short than extended periods of continuous walking, with only three percent being above 199 seconds in middle-aged adults [33], and three percent above 60 seconds in an elderly population with intact walking ability [34], the latter detected by an ankle-worn StepWatch.

The difference found in step count between the LSS participants and the background population is in line with previous studies demonstrating a difference in step count when comparing to controls [7,35] and a difference in physical activity when comparing to a background population [5,13]. A comparison of individuals with LSS to individuals with LBP found no significant difference in daily step count using a hip-worn pedometer [35]. However, the participants were recruited from the same setting, few had severe symptoms, and there was a more similar pain score between the LBP and LSS participants than between the LBP and LSS participants in the PAESP study.

It could be speculated that the decreased physical activity from LSS could eventually result in increased BMI, but a higher BMI has also been seen to increase the risk of LSS [36]. The higher BMI of LSS participants found in this study and previous studies [7,35] highlights the need for further consideration of the overall health effect of LSS, and the need for a comprehensive assessment of physical behavior in research, clinical, and rehabilitation settings.

Clinical relevance

To our knowledge, no existing definitions exist of when a change in periods of continuous walking or steps per day is clinically relevant. However, extended periods of walking have been related to outdoor walking activity [32], and from our data, it seems the decreased number of extended walking periods is associated with hospital management. The results indicate that individuals with LSS might reach their capacity for walking during everyday life and that it is below the demands of the daily life of an average senior individual. Individuals with LSS perhaps compensate for their shortened walking capacity by increasing the amount of short and medium walking periods. Still, the fewer total steps per day indicate that this compensation cannot make up for the diminished walking capacity.

Walking ability and physical activity in everyday life are linked and should be evaluated according to the aim of the intervention, and physical activity in the light of the LSS individual’s walking performance. As previously stated [13], there is a need for disease-specific measures of function in daily life, instead of the more general evaluation of the amount of physical activity traditionally validated against energy expenditure [37]. Incorporating walking capacity, walking performance, and self-report measures would allow for a thorough assessment of interventions seeking to increase walking ability, directly evaluating outcomes relevant to the aim. This paper proposes the next step in directing the accelerometer technology toward direct measurement of the impact of LSS on physical behavior in everyday life, with clinically relevant variables on walking performance readily interpreted by clinicians and patients.

Conclusion

Utilizing a thigh-worn accelerometer for a summary of continuous walking periods and steps per day could be a relevant and valid way to evaluate walking in daily living in patients with LSS and neurogenic claudication, where steps per day have shown known-group validity in the secondary care setting of this study.

Declaration of competing interest

One or more of the authors declare financial or professional relationships on ICMJE-TSJ disclosure forms.

CRediT authorship contribution statement

Malin Eleonora av Kák Gustafsson: Writing − review & editing, Writing − original draft, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Berit Schiøttz-Christensen:** Writing − review & editing, Supervision, Conceptualization. **Therese Lockenwitz Petersen:** Writing − review & editing, Resources, Data curation. **Randi Jepsen:** Writing − review & editing, Resources, Data curation. **Niels Wedderkopp:** Writing − review & editing, Supervision, Methodology, Formal analysis, Conceptualization. **Jan Christian Brønd:** Writing − review & editing, Supervision, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Søren Francis Dyhrberg O'Neill:** Writing − review & editing, Supervision, Formal analysis, Conceptualization.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used Grammarly for grammar and spellchecking. After using this tool/service, the authors reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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