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Walking speed as an alternative measure of functional status in lumbar spinal stenosis patients.

Michael Grelat (M.D)^{1,2}, Anaïs Gouteron³, Jean-Marie Casillas (M.D PhD)^{2,3}, Baptiste Orliac³, Jacques Beaurain (M.D)¹, Isabelle Fournel (MD PhD)⁴, Davy Laroche (PhD)^{2,3}

1. Neurosurgery department, University Hospital of Dijon, Dijon, France
2. INSERM UMR 1093, Cognition, Action and Sensorimotor plasticity University of Burgundy Franche-Comté, Dijon, France
3. CIC INSERM 1432, Technological Investigation Platform, University Hospital of Dijon, France
4. INSERM CIC 1432, Clinical Epidemiology Unit, Dijon University Hospital , France

Corresponding author:

Michael Grelat

michael.grelat@gmail.com

Phone number: +33 (0)380295200

Objectives: The main objective was to compare estimated walking perimeter (WP) and actual WP during a free walking test (the 6 minute walk test (6MWT)) in patients with lumbar spinal stenosis (LSS). The second objective was to describe the correlation between measured gait parameters and functional parameters.

Materials and methods: Single-center prospective study. 38 patients with symptomatic LSS (23 men, 15 women), mean age: 69.3 ± 7.9 years. Intervention: 6MWT. Main Outcome Measure: Patients were first asked to verbally estimate their WP. Then, WP was evaluated using a 6MWT at self-selected speed. In the absence of need to stop, and if a distance of 500m was not reached, the test was extended to this distance. Specific functional scores (Oswestry, Quebec) were recorded and a quality of life questionnaire was completed.

Results: WP was estimated to be lower than 500m in 21/38 patients, but only 7 patients actually stopped walking before reaching 500m. The median estimate error in these patients was 200m (IQR:65-250). The shorter the estimated distance was, the greater the estimation error ($r=-0.63$, $p=0.002$). The average walking speed was slow. Functional parameters (Oswestry, Quebec) were weakly and inversely correlated with real WP ($r=-0.44$ to -0.31 respectively), and moderately inversely correlated with measured walking speed ($r=-0.51$, $p \leq 0.001$ for both).

Conclusion: Direct measurement of free walking speed should be considered as valid functional assessment in current practice for patients with LSS instead of estimated WP. To assist therapeutic decision-making, the most relevant type of walking test (duration, distance, velocity) need to be determined.

Keywords

Lumbar spinal stenosis, 6 minute walk test, Walking perimeter, Walking speed

Introduction

Lumbar spinal stenosis (LSS) is a common disorder which is diagnosed in 13 to 14% of patients who consult a specialist for low back pain (1). Its prevalence increases with aging (2): LSS is the leading reason for lumbar spine surgery in people over 65 years old (3). Its most frequent semiology is defined by the North American Spine Society as a variable clinical syndrome with back and / or leg pain associated with radicular or multi-radicular claudication after a variable period of walking and quick relief with anteflexion (4,5). Paresthesia of the lower limbs and muscle weakness can also occur (6,7).

The functional impact of LSS can deteriorate the quality of life and autonomy of an elderly patient, especially when combined with other frequent comorbidities, and can lead to social and professional isolation in its most severe forms. Surgical management is considered when conservative treatments are not adequate and the patient experiences persistent pain and disability (5). The therapeutic decision is based on a combination of criteria: disease history, standard clinical examination, specific scores assessing pain and functional impact, and diagnostic imaging (7). However, the clinical and radiological diagnostic criteria of LSS vary considerably (8), and it is therefore recommended that functional outcome measures be validated in routine clinical practice as a complement to the aforementioned diagnostic criteria (9).

In terms of functional status, impaired walking tolerance is the disability most often reported in patients with chronic low back pain (10). Consequently, assessing walking perimeter (WP) limited by neurogenic or spinal claudication is essential for the diagnosis of LSS and decisions regarding treatment (11). However, previously noted discrepancies between patient-reported WP and the actual covered distance (measured on a treadmill) is a significant limit to this practice, and can lead to under or over estimation of WP (12). WP should be assessed in chronic low back pain patients with physiologically appropriate walking tests (more so than on a treadmill) (13), but the modalities of these tests are not clearly established in terms of procedure (fixed distance or fixed duration) and recommended speed (self-selected or brisk) to evaluate functional impairment (14-16).

The main objective of this study was to compare estimated WP (perceived distance declared by the patient) and real WP measured in patients with LSS with the 6 minute walk test (6MWT) at a free velocity. Secondly, we tried to describe the correlation between measured gait parameters for assessing level of disability among those most easily accessible in the walk test(i.e. WP and walking speed) and functional features.

Material and methods

Participants

This study uses the preoperative data of patients included in the SPEED study (Quantitative evaluation of motor function before and after surgery for degenerative lumbar spinal stenosis). Patients with LSS referred to the neurosurgery department of a University Hospital (Dijon, France) for consultation between September 2016 and June 2018 were recruited. Diagnosis of LSS was confirmed on lumbar MRI with a minimum of Schizas grade C (17). The inclusion criteria were: age > 18 years, both sexes, acquired degenerative LSS, pain > 3 months, resistance to conventional medical treatment, ability to walk \geq 10 meters without help. We excluded patients with previous spine surgery, other locomotor disorders (osteo-articular, peripheral circulatory or neurological disorders for example) which could significantly alter gait, individuals under stewardship or legal guardianship as well as pregnant or breastfeeding women. All patients provided informed consent. This study was undertaken in accordance with Good Clinical Practice guidelines and was approved by the local hospital ethics committee. There was no change in care management for patients who participated in this study after inclusion. It was recorded, beforehand, on the clinical trial registry (NCT03194607).

Collected Data

For each patient, the following data were collected: sex, age, professional status (in activity or pensioner), body mass index, main stenosis level, spinal canal size, Schiza grading, and visual analogue scale assessment for back and radicular pain. Specific chronic low back pain functional scores to were completed: the Oswestry disability index (ODI) (18), and the Quebec score (19). These 2 scores range from 0 to 100, the highest value expressing the most severe impairment. Quality of life was assessed with the 12-Item Short-Form Health Survey functional score (SF12) (20).

WP measures

Locomotion was evaluated independently with two different procedures:

- 1) Estimated WP: WP was estimated in meters by the patient and collected during routine neurosurgical consultation. The surgeon clearly asked the patient in the usual manner: “How far can you walk at your usual pace on flat ground without stopping because of your typical back pain or pain radiating to your lower limbs?” If the patient reported a WP greater than

500m, the declared walking distance was truncated to 500m. Indeed, WP beyond 500 meters does not seem to be reliably related to LSS, and the diagnosis of neurogenic or spinal claudication may be not pertinent in such cases (21). Furthermore, in a 6-point score used to classify the degree of severity of patients with LSS analyzed before surgery, 500m corresponded to the lowest level of neurogenic claudication (22).

2) The measured WP applying the 6MWT at self-selected speed: This test was conducted on a flat 50-meter-long indoor walking track previously recognized by the patient. Following a 15-minute rest phase, patients were instructed to walk at their freely-chosen walking speed. Simple and standardized instructions were used to minimize the influence of extrinsic factors. No encouragement was given during the test, but patients were told the elapsed time every 2 minutes by the same trained operator who was following approximately one meter behind. No analgesic treatment was allowed during the test. The measured WP was defined as the distance traveled until the usual radicular or back pain caused the patient to stop and occurring before the end of the 6MWT (23,24) (patients were informed that they could stop walking if pain was not sustainable). If radicular or back pain did not stop the patient from walking, the test was stopped at 6 minutes if the patient had reached at least 500 meters. Any patient who did not reach 500 meters after 6 minutes was asked to continue walking until 500 meters (time to completion was recorded). The test result was expressed in meters and walking speed was calculated (m/s) both during 6MWT (6MWT walking speed) and 500 meters test (free walking velocity). The parameters monitored during the tests were continuous assessment of breath-by-breath gas exchange using a portable device (K4b2, Cosmed, Rome, Italy) and continuous heart rate monitoring (T31 coded TM-Polar, Kempele, Finland). VO₂ uptake and heart rate were directly computed and extracted from the devices with the incorporated software (K4b2 v10, Cosmed, Rome, Italy).

Statistical analysis

The patients were classified into 2 groups: one with potentially limited WP due to LSS (WP lower than 500m (WP₅₀₀₋)), the other without significantly limited WP (WP higher than 500m (WP₅₀₀₊)). The difference between the WP estimated by the patient and the WP measured during the walk test was calculated for each patient of the WP₅₀₀₋ group. The difference between the two distances is the estimation error. The maximum walking distance measured by the walk test was 500 meters and the maximum walking distance declared by the patients was then truncated to 500 meters for the analyses. The correlation between the functional test results (i.e. ODI, Quebec) and estimated WP, estimation error, and functional scores was

estimated with a Spearman correlation coefficient including the 95% confidence interval. A T-test was used to compare the WP₅₀₀₋ and WP₅₀₀₊ groups and to compare the estimation error of WP₅₀₀₋ against 0 (unilateral test). Quantitative variables were presented as mean \pm standard deviation (SD) or as median [Inter Quartile Range (IQR)] as appropriate. Statistical analyses were done with SAS software, version 9.4 (SAS Institute, Inc.). An alpha value of 5% was chosen to determine the significance of the parameters.

Results

Thirty eight patients were included in this study (23 men and 15 women), mean age 69.3 ± 7.9 years. Seven patients were still working and 31 were retired. The flow diagram of the participants can be found in Figure 1 and Table 1 presents patient characteristics. L3-L4 and L4-L5 were the most affected parts of the spine. All patients had a minimum Schizas grade of C. The patients maintained their usual analgic medications (specified in Table 1), without modification for at least 3 months.

6MWT was feasible, without cardiorespiratory limitation, for all the patients. The average heart rate at the end of the walk test was 107 ± 15 bpm (heart rate at rest = 80 ± 15 bpm). The mean VO₂ at the end of the walk test was 14.6 ± 2.7 ml/min/kg (VO₂ at rest = 4.4 ± 0.8 ml/min/kg).

Twenty one of 38 patients estimated their WP to be lower than 500m, but only 7 patients stopped before reaching 500m during the walk tests. Table 2 shows the estimated WP with the corresponding estimation error, the measured free walking speed and the distance for all patients and the two subgroups (WP₅₀₀₋ and WP₅₀₀₊). The 21 patients of the WP₅₀₀₋ group significantly underestimated their WP (median estimation error = 300[IQR:200-335]; $p < 0.001$). Free walking velocity was also significantly lower ($p = 0.003$) in the WP₅₀₀₋ group compared to WP₅₀₀₊ group. As shown in Figure 2, the shorter the estimated distance was, the greater the error.

Demographics (sex, age, professional status), clinical characteristics (BMI, lumbar and radicular pain) and SF-12 questionnaire sub-scores (quality of physical and mental health) were not associated with the estimated WP or the measured WP, nor with the error estimation. Functional scores were weakly correlated with estimated WP (ODI questionnaires: $r = -0.27$ [95%CI:-0.54;+0.05], $p = 0.10$, Quebec scores: $r = -0.29$ [95%CI:-0.56;+0.03], $p = 0.07$) and with measured WP (ODI questionnaires: $r = -0.44$ [95%CI:-0.67;-0.14], $p = 0.005$); Quebec score: $r = -0.31$ [95%CI:-0.57;+0.01], $p = 0.06$).

The 7 patients who stopped the walk test before reaching 500m walked from 115m to 400 m with a median distance of 350m [IQR:300-400] whereas the declared walking distance ranged from 50 to 400 with a median distance of 100m [IQR:50-300], which means that 50% of patients made an estimation error of 200m or more. In these 7 patients, ODI ranged from 40 to 56 with a median of 46[IQR:42-52] and Quebec score of 33 to 64 with a median at 55[IQR=41-59];

Moderate significant relationships were found between the functional scores (ODI: -0.51 [95%CI:-0.71;-0.22], $p=0.001$ and Quebec score -0.51 [95%CI:-0.71;-0.23], $p=0.0008$) and the measured free-walking speed in all the patients (Figure 3).

Discussion

This study confirms the significant discrepancy between perceived and actual walking limitations in patients with LSS. When the estimated WP is short, the risk of estimation error is more important. Therefore, estimated WP and measured WP seem to capture different dimensions of disease impact: the first may reveal an emotional state and provide insight to the patient's representation of disease; the second provides information about the actual functional capability of the patient (partially related to motivation). Furthermore, the use of a standardized test (the 6MWT) shows that stopping walking due to pain is actually uncommon and does not seem to be correlated with other functional characteristics. Direct assessment of free-walking speed is more relevant than WP because it is correlated to functional status and is easier to implement in practice.

By analogy with arterial limitations of walking, our results corroborate a study which compared estimated and actual vascular claudication in patients with peripheral arterial disease (25): the patients' estimated WP was approximately 66% of the actual distance covered. Conversely, 67% of 31 patients with locomotor limitations of various origins overestimated their WP in another study (26). Similar overestimation was found in patients assessed in a spinal outpatient setting, who estimated 245m when the actual distance was 111m (the reasons for stopping were unspecified) (27). A study specifically assessing neurogenic claudication in 63 patients with LSS revealed wide variations in estimated and measured WP: one third of the group were able to estimate WP within 50m, and the remaining two thirds were shared between over and underestimation (28). Unlike our protocol, WP was assessed on a treadmill, which is less realistic and tends to underestimate WP in patients with LSS when compared to a self-paced walk test (29). The difference

between a conventional walk test and the treadmill test has already been shown in heart patients (30). In this regard, the conditions for assessing locomotion seem of particular importance, especially concerning walking speed which should be as close to the usual velocity as possible. The self-paced walking speed is of particular interest for this purpose because it is the most efficient type of walking and maintains a steady state of aerobic metabolism (31). Walking speed correlates with age and sex (32), is associated with functional capacities and global health status (33), and is a predictive factor of mortality (34). In people with chronic low back pain, the decrease in free walking speed has long been known (35). It is mainly related to decreased step length in patients with LSS (36) and analyzed as a protective strategy against pain (37), where the person tries to avoid the rise in epidural pressure observed during neurogenic claudication (38). With a moderate aerobic effort demonstrated by heart rate and VO_2 , our patients were slower in comparison with healthy subjects of the same age (39).

Among current fixed-duration walk tests, the 6MWT is the most commonly used to assess the functional impact of various diseases (40). It is often the main means of assessing the impact of various therapeutic interventions in clinical practice. For LSS, 6MWT has been used to evaluate patients at 2 years after surgical treatment, where is showed no significant difference in covered distance for decompression surgery plus fusion surgery and decompression surgery alone (41). However, there is some ambiguity in the instructions for required walking speed in the 6MWT (42). For the reasons previously reported, we chose to recommend a free speed, similar to the initial instructions of the 6MWT, which was developed for chronic heart failure patients (43). A possible limitation of the 6MWT applied to LSS is that it misses late claudication which may occur after 6 minutes of walking. For this reason, our protocol planned to extend the 6MWT if necessary, until 500 meters was attained. The exact cut-off point for WP values to differentiate between severe and moderate forms of LSS have not yet been specified. The distance (assessed on a treadmill) is hypothetically around 400 to 500 meters (21,22), but it has not been formally established by large scale studies. A very different fixed-duration walk test (30 minutes) at free velocity, the self-paced walking test, was applied to assess WP on a level track in patients with LSS, showing an adequate reproducibility and a significant difference with a treadmill test which underestimated the WP (29). In other studies, the WP obtained with the self-paced walk test was correlated with estimated distance (44) and with the results of the treadmill test (45) for patients with an average WP around 1000m. In a recent study of patients 6 months after surgery for LSS, the self-paced walk test showed an improvement of physical capabilities

(46). However, because of the extended duration (30 minutes), this test may expose to issues not directly related to LSS (for example fatigue, dyspnea, or gait disorders of other origins). The psychometric qualities of other walking tests, especially those with “fixed distance” (i.e. 400 or 500m walk test), should be studied in future in order to assess both WP and free walking speed in patients with possible neurogenic or back claudication.

Study limitations

The main limitations of this study are the small sample size and the fact that we were not able to evaluate the reproducibility of the walking test and its responsiveness to change (though not included in our objectives for this study). In addition, we imposed the walking distance of 500m, but reliable data defining the precise severity of neurogenic or back claudication in patients with LSS is lacking, this distance is not necessarily the most appropriate. In our protocol, we did not evaluate pain at the end of the walk test. Such an assessment needs to be done in further studies in order to better understand the precise reason the patient stops walking. Finally, only the free-speed test was used, so the sensitivity of brisk walking should also be prospectively evaluated.

Conclusion

Direct measurement of WP, especially walking speed, during a standardized walking test is a simple and inexpensive tool for assessing the functional impact of LSS in addition to conventional clinical criteria and imaging. Additional studies are needed to pinpoint the respective contributions of self reported walking distance, free and brisk walking speed as well as the most relevant type of walking test (self reported, fixed-duration, fixed-distance,) in order to optimize reliability and responsiveness to change, and, in the future, to be able to use walking speed to assist therapeutic decision-making.

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Figures captions:

Figure 1: CONSORT Flow diagram.

Figure 2. Relationship between estimated walking perimeters recorded during medical consultation and the error value with the measured walking test. Only patients who estimated their walking perimeter as lower than 500m during consultation are shown (n=21). Spearman correlation coefficient and related p-value are shown.

Figure 3. A. Relationship between the Oswestry disability index (higher value indicates higher functional impairment) and the free walking speed of all patients (n=38). B. Relationship between the Quebec back pain disability scale (higher value indicates higher functional impairment) and the free walking speed of all patients (n=38). Spearman correlation coefficients and related p-value are shown.

HIGHLIGHTS:

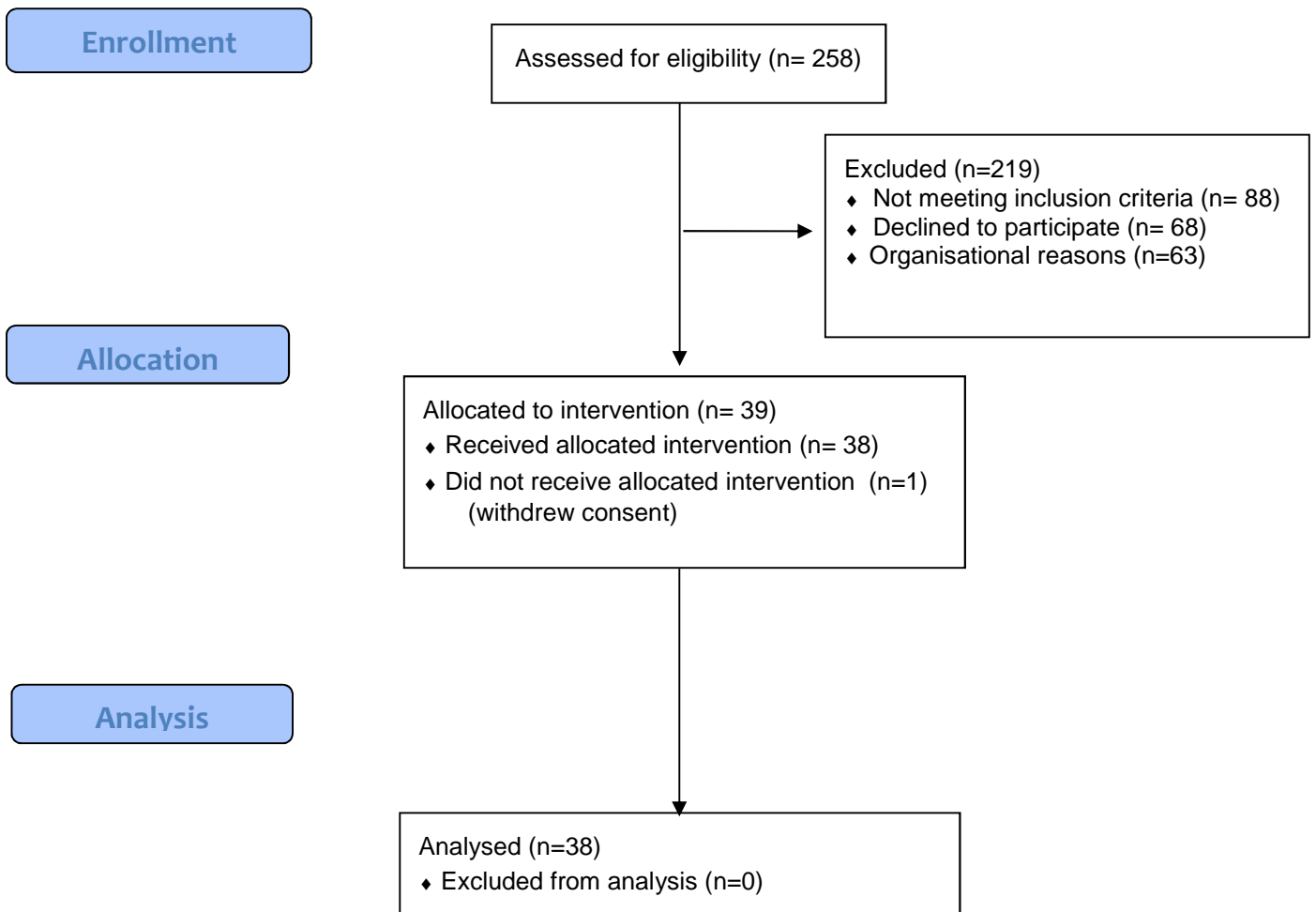
- Estimated walking perimeter should not be considered as valid functional assessment in current practice for patients with lumbar spinal stenosis.
- Direct measurement of WP during a standardized walking test is a simple and inexpensive tool for assessing the severity of LSS
- Direct measurement of free walking speed should be considered as valid functional assessment in current practice.

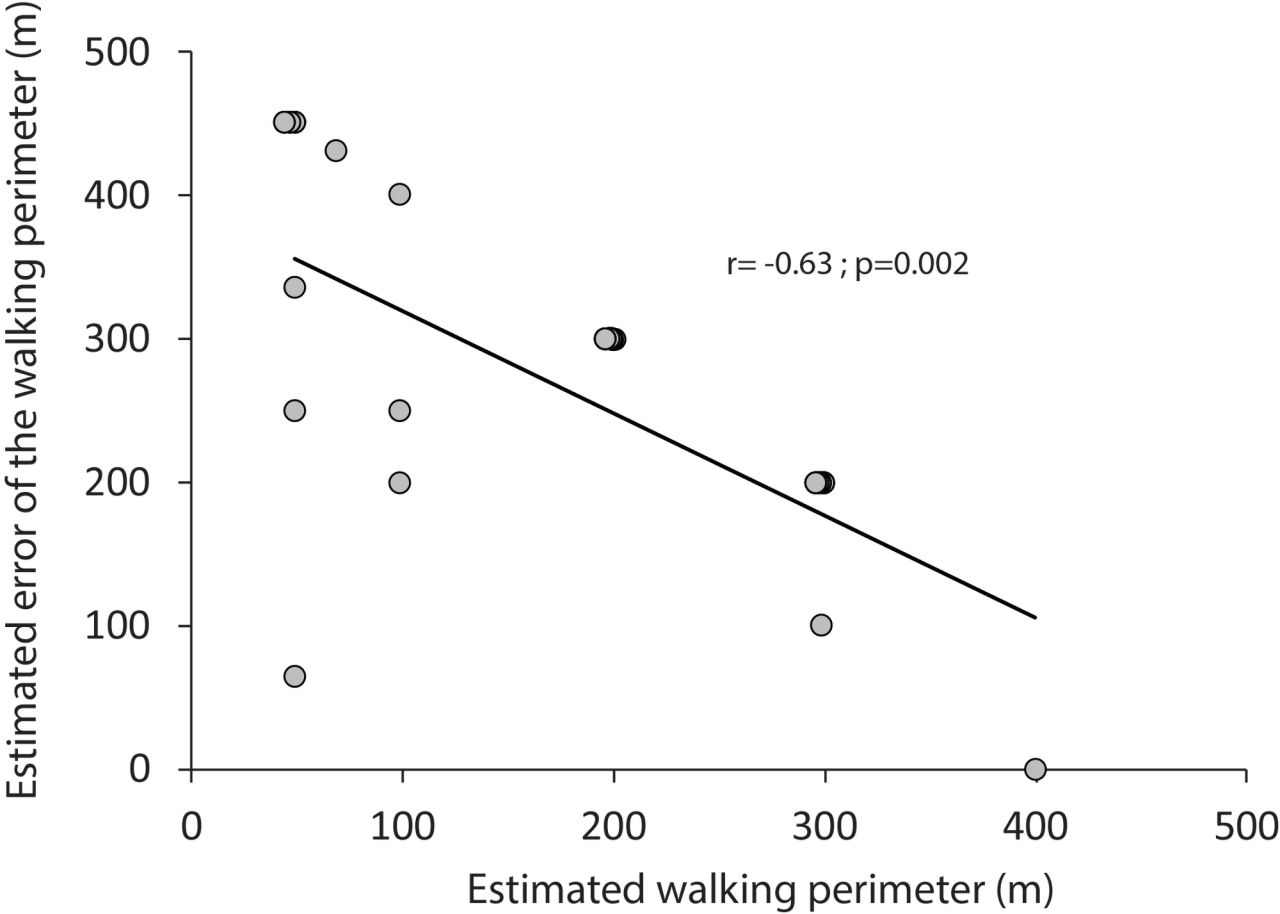


CONSORT

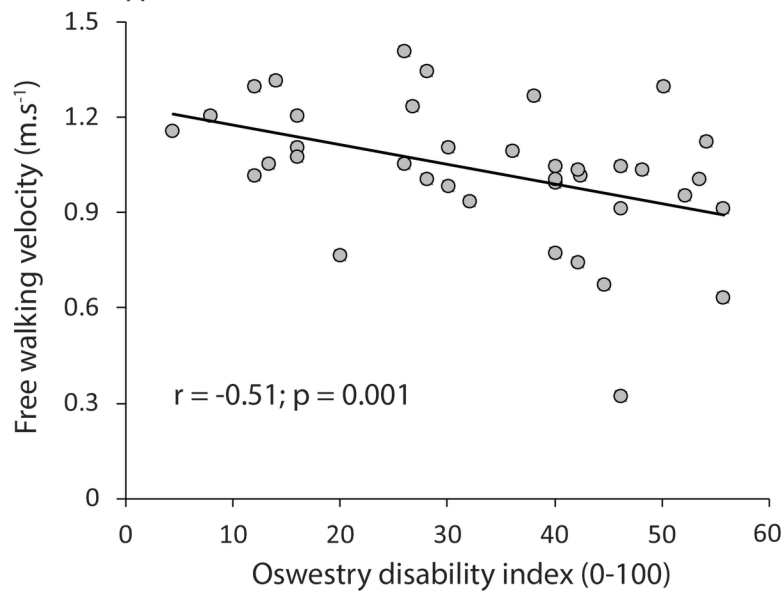
TRANSPARENT REPORTING of TRIALS

CONSORT 2010 Flow Diagram





A



B

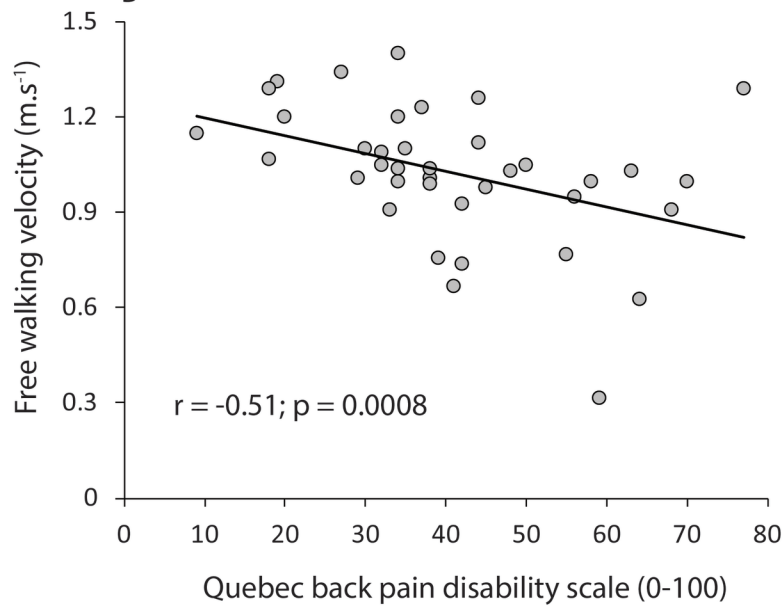


Table 1. Characteristics of patients.

	Mean \pm SD	N(%)
Demographic data		
Mean age (years)	69.3 \pm 7.9	
Sex		
Woman		15(39.5%)
Man		23(60.5%)
Professional status		
Active		7(18.4%)
Retired		31(81.6%)
Clinical features		
BMI (kg/m ²)	28.1 \pm 3.3	
Lumbar VAS	49.0 \pm 26.4	
Radicular VAS	53.5 \pm 27.2	
Pain treatments *		
		25 (65.8%)
Muscle relaxant		1 (2.6%)
Grade 1/2 analgesic		21 (55.3%)
Opioids		2 (5.3%)
Corticosteroids		1 (2.6%)
Antiepileptic drug		1 (2.6%)
NSAID		6 (15.8%)
Lumbar level* *		
L1-L2		25(65.8%)
L2-L3		28(73. 7%)
L3-L4		31(81.6%)
L4-L5		31(81.6%)
L5-S1		28(73. 7%)
Schizas grade (n=32)		
C		13(40.6%)
D		19(59.4%)
SF-12 Scores		
Quality of physical health	35.7 \pm 4.2	
Quality of mental health	54.4 \pm 5. 0	
Functional scores		
ODI	33.4 \pm 14.9	

Quebec

40.9±15.6

* One patient could take several medications

**Total > 100%, several levels might have been reached

VAS: Visual analogue scale

NSAID: Nonsteroidal anti-inflammatory drug

ODI: Oswestry disability index

SF12: 12-Item Short Form Survey

SD: Standard Deviation

BMI: Body Mass Index

Table 2. Distribution of free walking velocity, estimated walking perimeter and error of estimation. Mean, standard deviation (SD), median and Inter-Quartile Range (IQR) are provided.

Estimated Walking perimeter	n	Free walking velocity ($\text{m}\cdot\text{s}^{-1}$) Mean (SD)	Estimated Walking perimeter (m) Median [IQR]	Measured	Estimation
				walking perimeter (m) Median [IQR]	error (m) Median [IQR]
All	38	1.02 \pm 0.21	300[100-500]	500[500-500]	82.5[0-300]
Under 500m	21	0.94 \pm 0.23	200[50-300]	500[400-500]	300[200-335]
Over 500m	17	1.13 \pm 0.14	>500	500	0