HHS Public Access
Author manuscript
Spine J. Author manuscript; available in PMC 2019 January 01.

Published in final edited form as:
Spine J. 2018 January ; 18(1): 15–21. doi:10.1016/j.spinee.2017.08.262.

Objective Measurement of Function Following Lumbar Spinal Stenosis Decompression Reveals Improved Functional Capacity with Stagnant Real-Life Physical Activity

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Abstract

Background Context—Lumbar spinal stenosis (LSS) is a prevalent and costly condition associated with significant dysfunction. Alleviation of pain and improvement of function are the primary goals of surgical intervention. While prior studies have measured subjective improvements in function after surgery, few have examined objective markers of functional improvement.

Purpose—We aimed to objectively measure and quantify changes in physical capacity and physical performance following surgical decompression of LSS.

Study Design/Setting—Prospective cohort study.

Patient Sample—38 patients with LSS determined by the treating surgeon's clinical and imaging evaluation, and who were scheduled for surgical treatment were consecutively recruited at 2 academic medical facilities, with 28 providing valid data for analysis at baseline and 6 months after surgery.

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*Author MS receives support from The Mobilize Center at Stanford University (NIH grant U54EB020405)

Outcome Measures—Before surgery and at 6 months after surgery participants provided 7 days of real-life physical activity (performance) using Actigraph accelerometers; completed 2 objective functional capacity measures, the SPPB (Short Physical Performance Battery) and SPWT (Self Paced Walking Test); and completed 3 subjective functional outcome questionnaires, ODI (Oswestry Disability Index), SSSQ (Spinal Stenosis Symptom Questionnaire), and SF-36.

Methods—Physical activity, as measured by continuous activity monitoring, was analyzed as previously described according to the 2008 American Physical Activity Guidelines. Paired t-tests were performed to assess for post-surgical changes in all questionnaire outcomes and all objective functional capacity measures. Chi squared analysis was used to categorically assess whether patients were more likely to meet these physical activity recommendations after surgery.

Results—Participants were 70.1 years old (+/− 8.9) with 17 females (60.7%) and an average body mass index of 28.4 (+/− 6.2). All subjective measures (ODI, SSSQ, and SF-36) improved significantly at 6 months after surgery; as did objective functional measures of capacity including balance, gait speed and ambulation distance (SPPB, SPWT). However, objectively measured performance (real-life physical activity) did not change following surgery. While fewer participants qualified as inactive (54% vs 71%), and more (11% vs 4%) met the physical activity guideline recommendations at the 6-month follow-up, these differences were not statistically significant (p=0.22)

Conclusions—This is the first study of which we are aware to objectively evaluate changes in post-surgical performance (real-life physical activity) in people with LSS. We found that at 6 months after surgery for LSS, participants demonstrated significant improvements in self-reported function and objectively measured physical capacity, but not physical performance as measured by continuous activity monitoring. This lack of improvement in performance, despite improvements in self-reported function and objective capacity, suggests a role for post-operative rehabilitation focused specifically on increasing performance after surgery in the LSS population.

Keywords

Lumbar spinal stenosis; surgery; outcome; physical activity; performance; capacity; function

Introduction

Lumbar spinal stenosis (LSS) is a debilitating[1–6] and costly condition[7–9] responsible for more than 7000 quality-adjusted life-years of work loss.[10] It is also the most common reason for spine surgery in individuals older than age 65.[11] Alleviation of pain and improvement in function are the primary goals of surgical intervention for LSS. Various groups have investigated both the short and long-term functional outcomes of LSS surgical management.[1–3,12–15] However, these studies relied on a variety of different patient reported outcomes, which are subject to multiple potential inaccuracies[16,17] and are not reflective of objective functional measurements.[18]

When considering function, it is important to recognize the two distinct categories, defined by the International Classification of Functioning (ICF): capacity and performance.[19] Capacity represents the capability of a person to complete a given task in a controlled environment (e.g. a timed walking test), while performance represents what a person does in his or her current environment (real-life physical activity). The few studies that have objectively assessed functional changes after treatment for LSS have most often tested capacity with timed walking test or similar measures.[4,20,15] While many tools exist to capture capacity in research and in the clinical setting, the ability to measure performance remains limited in both settings. Continuous activity monitoring seems a logical means of assessing performance by measuring free-living physical activity; yet, to date only a handful of spine studies have employed activity monitors.[21]

Decreased performance is a serious problem in patients with LSS given that physical inactivity is a risk factor for many chronic diseases including diabetes, obesity, and heart disease.[22] Conversely, it is recognized that increased physical activity can improve both pain and function in this population.[23,24] Accordingly, to achieve substantial health benefits the 2008 American Physical Activity Guidelines calls for participation in 150 minutes of moderate to vigorous physical activity per week, accumulated in bouts of 10 minutes or more.[25] We previously found that only 4% of patients with neurogenic claudication meet these physical activity guidelines, with 75% not achieving even 1 qualifying bout of moderate to vigorous physical activity within one week.[26]

Since surgical decompression of LSS is known to improve capacity,[4,20,15] we hypothesize that it will also improve performance (real-life physical activity). The goal of this study is to objectively measure and quantify changes in physical capacity and performance following surgical decompression of LSS. The Editor-in-Chief of *The Spine Journal* recently called for spine outcomes research to adopt objective measures to overcome the inherent limitations of a science built almost exclusively on self-report.[16] To our knowledge, this is the first study to objectively measure the functional impact of spine surgery on patients with spinal stenosis in both categories of human function: capacity and performance.

Material and methods

Study Design

This is a prospective observational study of patients scheduled to undergo surgical treatment of LSS. Participants were consecutively recruited at two academic medical centers in North America including (The US and Canadian institutional details are withheld here during peer review). Ethics approval for this study was provided from both institutions and the study conducted in a HIPAA compliant manner.

Inclusion and exclusion Criteria

Patients were considered for enrollment if they were at least 40 years of age, had received a diagnosis of LSS, and were scheduled for surgical treatment of LSS through a shared-decision process with the treating surgeon. The diagnosis of LSS was made by the treating spine surgeon and based on both the clinical evaluation and magnetic resonance imaging findings. Patients were excluded if they were unable to complete questionnaires or receive instructions in English, or if they had any significant comorbid condition that could limit walking, such as severe cardiopulmonary disease, stroke, or pregnancy. Recently, and international Delphi study developed a consensus on the clinical diagnosis of lumbar spinal stenosis.[27] These findings were not available when we designed and completed this study. Future investigations of patients with lumbar spinal stenosis should consider the criteria outlined in the Delphi study.

Outcomes

All participants were assessed at two time points: one week prior to the scheduled surgery and 6 months following surgery. At the pre-op assessment, age, gender and body mass index of each participant was recorded. At both assessments, participants completed commonly used and validated patient reported functional outcomes including the Oswestry Disability Index (ODI), Short-Form 36 (SF-36), and the Swiss Spinal Stenosis Questionnaire (SSSQ). For the latter two, the analysis here focuses on the physical function and bodily pain subscales, and the physical function and symptom subscales, respectively.

Objective measures of capacity were obtained by independent and trained examiners, including the self-paced walking test (SPWT) previously validated in the LSS population,[28] and the Short Physical Performance Battery (SPPB), which is validated in other adult populations.[29,30] The SPPB data was collected at one of the two centers and thus provided for approximately half of the participants. Performance was measured by accelerometry, described in greater detail below.

Physical Activity (Performance) Analysis

At each of the two assessments, participants were instructed to wear an ActiGraph GT3X accelerometer (ActiGraph, LLC; Ft. Walton Beach, FL) on the right hip for 7-consecutive days from waking up until returning to bed at night. The ActiGraph contains a tri-axial accelerometer that records inertia in 3 planes. These signals are first filtered to eliminate artifacts not caused by human movement and then summed into a 1-minute epoch score described as a “count-per-minute.” These so-called activity counts are a validated continuous measure of physical activity intensity commonly used in medical research.[21,31,32] Ranging from a score of 0 to >30,000 these activity counts allow stratification of physical activity into relevant categories based on energy expenditure, including sedentary activity, light activity, moderate activity and vigorous activity. Importantly, wear-time estimation is required to screen for valid data from the monitors, and we use the National Cancer Institute (NCI) protocol to achieve this.[21] Specifically, at least 4 days with valid data are needed to provide accurate estimates of real-life physical activity, and only days with 10 or more hours of valid wear-time qualify.[33] If a participant’s accelerometer data did not comply with these requirements at either of the 2 assessments, he or she was excluded from analysis in this study.

The U.S. Department of Health and Human Services provided guidance to help adults maintain or improve their health through regular physical activity via the 2008 American Physical Activity Guidelines. Here, participation in 150 minutes of moderate to vigorous physical activity per week is recommended.[25] The National Cancer Institute (NCI) defines the accelerometry intensity intervals as follows: sedentary (0–99 counts), light (100–2,019), moderate (2,020 to 5,998) and vigorous (above 5,999 counts).[34] We use these NCI intensity intervals to determine if an individual meets the recommendations of the physical activity guidelines both before and after surgery. As proposed by NCI, only activities occurring in bouts of 10 minutes or more are considered for the calculation of the total time spent in the moderate to vigorous range. The participants not meeting the guideline recommendations are further divided into inactive (0 minutes of moderate to vigorous activity) or low active (between 1–149 minutes) groups.[26]

Statistics

The self-reported outcomes and capacity measures were collected at least 7 days prior to surgery and compared to the same measures repeated 6 months after surgery using paired t-tests to test for significant differences. Physical activity collected at the same times before and after surgery was analyzed categorically using chi-square analysis to compare those meeting to those not meeting physical activity guidelines. Other secondary measures of real-life physical activity are also compared using paired t-tests and reported.

Results

Thirty-eight (38) patients were recruited from the two centers using the same inclusion criteria. Of these, 10 did not provide valid accelerometry data at one or both assessments and were excluded from the analysis. Thus a total of 28 participants provided valid data for pre- and post-surgical analysis. Of these, the average age was 70.1 (standard deviation 8.9) with 17 being female (60.7%) and an average body mass index of 28.4 (standard deviation 6.2) (Table 1).

Subjectively, participants reported significant improvements in disability, according to all of the measured patient-reported outcomes (Table 2). Objectively, physical capacity measures showed similar statistically significant improvements in gait speed, balance and ambulation distance at 6 month follow-up (Table 3). However, objectively measured real-life physical activity (performance) did not change following surgery (Table 4). Still, interesting trends are observed. Before surgery 71% (20/28) of participants qualified as inactive (defined as 0 qualifying bouts of moderate to vigorous physical activity per week), another 25% (7/28) qualified as low active (defined as 1–149 qualifying minutes of moderate-vigorous physical activity per week), and only 4% (1/28) met the 2008 American Physical Activity Guidelines which calls for participation in at least 150 minutes of moderate to vigorous physical activity per week, accumulated in bouts of 10 minutes or more.[25] After surgery, fewer qualified as inactive (54%, or 15/28), and more (11%, or 3/28) met the physical activity guideline recommendations. Yet, these differences were not statistically significant (p=0.22) (Table 4). Additional physical performance details derived from the activity monitors are displayed in Table 5.

Discussion

To our knowledge, this is the first study to objectively quantify changes in functional performance following surgery for LSS. We found that at 6 months after surgery patients self-reported significant improvements in all symptoms and functional outcomes as assessed by ODI, SSSQ (both symptom and physical functioning scales), and as SF-36 (physical function and bodily pain scales). They also improved significantly in objectively measured capacity including walking speed, balance, and ambulation distance. Despite these improvements, this cohort did not show a statistically significant improvement in real-life physical performance.[25] Thus, we have disproven our hypothesis that improvements in capacity following surgical treatment of LSS will also result in improved performance.

The improvements in self-reported function observed at 6 months following surgery are similar to those documented in other studies of LSS surgery. For instance, the SPORT trial demonstrated similar improvement in the SF-36 Bodily Pain and Physical Function scales as well as ODI 6 months after surgery.[14] The Maine Lumbar Spine Study reported improvements in function at 1-year using the Roland Morris disability score.[1] In this study, we also included the SSSQ, a functional measure specifically designed to track outcome in LSS that is known to improve after LSS surgery, with improvements similar to those reported in this study.[35,36]

To our knowledge, this is one of very few studies examining post-surgical capacity, and the first study to utilize two previously validated outcomes, the SPWT and SPPB. Frosth reported that results of the 6-minute walk test did not differ between surgically and non-surgically treated individuals at 2 years.[15] However, the 6-minute walk test suffers from a potential ceiling effect due to its inherent time limit. Alternatively, the SPWT that was used in this study does not have this same limitation, and the SPWT was validated in the LSS population while the 6-minute walk test is not.[37] The degree of improvement in the SPWT features (walking time, distance and speed) reported in this study are similar to those from a previous study.[4] In this study we also used the SPPB which is closely correlated with mobility, disability and even mortality in the elderly.[29,30] Both SPWT and SPPB improved significantly following surgery, indicating objective proof of significant improvement in functional capacity in our cohort.

Compared to the objective functional capacity outcomes, the functional performance outcomes tell a different story. The poor level of functional performance (real-life physical activity), as determined by continuous real-time activity monitoring, in patients with LSS was recently documented.[26] Thus, the low level of physical activity observed in this cohort prior to surgery is not surprising. What is surprising is the lack of a statistically significant improvement in this measurement 6 months after surgery, especially in the setting of robust and statistically significant improvements in self-reported symptoms and objectively measured capacity. While disappointing at first glance, this finding reveals at least three unique insights and opportunities.

First, some logical trends are observed in this data, with fewer patients qualifying as inactive (75% to 54%) and more patients actually meeting the activity guidelines (4% to 11%) from baseline to 6 months after surgery. Studies of larger cohorts may be required to fully measure this effect. This study, the first of its kind, provides the data required to properly power such a study.

Second, it may be unrealistic to expect patients with LSS to achieve physical activity guidelines targeted to the general US population. Recent research into the low levels of physical activity recorded in people with LSS prompted the study's authors to call for the development of disease-specific physical activity recommendations targeting the LSS population, focusing on light intensity activity as well as personalized and more realistic goals.[25] In order to accomplish this, emerging alternative and disease-specific analytic methods for assessing physical performance in pain and musculoskeletal populations may prove more useful.[36]

Third, symptoms of LSS lead to prolonged inactivity and establish unhealthy physical activity patterns. Thus, despite improvements in symptoms and physical capacity following surgery, habitual behaviors are not likely to change without targeted intervention focused on improving physical activity behaviors (performance). This creates opportunity for rehabilitation following recovery from LSS surgery. To this end, a recent study showed that patients with LSS are responsive to instructions to increase physical activity, and that even small increases in physical activity result in meaningful health benefits.[24] Combining information from these studies, it appears feasible for researchers to develop a disease-specific approach to physical activity prescription after surgery in this population. Ultimately, we interpret the lack of improvement in performance, despite improvements in self-reported function and objective capacity, as a call for patient-centered post-surgical rehabilitation of habitual physical activity in this population.

Strengths of this study include strict inclusion criteria and data collection procedures applied at two academic centers with busy spine surgery practices. The two centers are in different countries with different health systems and population characteristics, improving the generalizability of our findings. Also, objective measurement of functional outcomes in both domains, capacity and performance, prior to surgery and 6-months after has never been completed in an LSS cohort, resulting in new insights into recovery from surgery. In addition, participants completed common validated self-reported measures of symptoms and function, and the robust and statistically significant improvements recorded in this group mirror those reported by others, further supporting the generalizability of these findings. Finally, the activity monitor used in this study has been previously validated and proven reliable, with well-established algorithms to confirm adequate wear time and physical activity stratification. Limitations included the exclusion of 10 enrollees due to inadequate wear time, however this is in line with the anticipated proportion of failed activity monitor data collection when compared to studies using these monitors for other elderly populations. We did not track the number of levels treated or types of surgery performed, and this may impact the observed findings. We recommend future studies examine this information with sufficient subjects to examine these different subgroups. Our sample size was small, and perhaps underpowered to display significant changes in measured physical activity. Thus, we recommend replicating this study in a larger group, powered based on these results. We also recommend similar studies assessing a longer duration of follow-up, and examining the impact of different forms of rehabilitation on improvements in post-operative physical activity and performance.

Conclusions

This is the first study, to our knowledge, to objectively evaluate post-surgical performance (real-life physical activity) in people with LSS. We found that at 6 months after surgery for

LSS, patients reported significant improvements in self-reported function and objectively measured physical capacity but not physical performance as measured by real-life physical activity monitoring. This lack of improvement in performance, despite significant improvements in self-reported function and objective capacity, suggests a role for post-operative rehabilitation focused specifically on increasing performance after surgery in the LSS population.

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Table 1

Demographics of study patients

# patients recruited	38
# patients with valid pre/post data	28
# female	17 (60.7%)
Average age	70.1±8.9
BMI	28.4±6.2

Values are mean ± standard deviation unless otherwise indicated.

Table 2

Subjective functional outcomes (n=28)

	Oswestry Disability Index % (ODI)	Swiss spinal stenosis questionnaire (SSSQ)		Short form-36 (SF-36)	
		Symptom Severity	**Physical Function**	**Physical Function**	**Bodily Pain**
Pre-surgery	48.21±18.39	2.79±0.60	2.45±0.70	41.18±23.55	35.88±19.74
Post-surgery	31.87±22.58	1.72±0.82	1.57±0.66	66.38±25.21	59.82±25.40
p-value	0.00	0.00	0.00	0.00	0.00

Values are mean ± standard deviation unless otherwise indicated.

Table 3

Objective functional outcomes

	Short Physical Performance Battery (SPPB) (n=13)				Self Paced Walk Test (SPWT) (n=28)			
	Total Balance	**Gait Speed**	**Chair Stand**	**Total Score**	**Time when symptoms appear (minutes)**	**Completed time (minutes)**	**Complete distance (meters)**	**Speed (kilometer/hour)**
Pre-surgery	3.55±0.69	2.64±0.92	1.18±0.87	7.36±1.91	2.24±2.70	11.24±10.82	643.10±736.82	2.77±1.13
Post-surgery	4.00±0.00	3.46±0.93	2.27±1.42	9.73±2.10	11.82±11.68	21.86±10.84	1370.29±831.30	3.47±0.99
p-value	0.05	0.00	0.01	0.00	0.00	0.00	0.00	0.00

Values are mean ± standard deviation unless otherwise indicated.

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Table 4

Real-life physical activity based on the activity monitor (n=28)

	Not meeting guidelines		**Meeting guidelines**	
	0 Bouts (Inactive)	**1–149 Minutes (Low active)**	**150+ Minutes (meeting guidelines)**	**P–value chi square**
Pre-surgery	20	7	1	0.22
Post-surgery	15	10	3	

Bouted activity indicates moderate-vigorous activity minutes counted only when they occur within a minimum 10-minute sustained activity bout.
Values indicate number of patients meeting various cut-points unless otherwise indicated.

Table 5

Secondary physical performance outcomes as measured by the activity monitor

	Sedentary range (0–99 counts)		Light range (100–2,019 counts)		Moderate range (2,020–5,998 counts)		Vigorous range (>5,999 counts)	
	Total counts	**%**	**Total counts**	**%**	**Total counts**	**%**	**Total counts**	**%**
Pre-surgery	1174.32±79.37	82.99±5.40	231.74±74.94	16.37±5.29	8.84±12.39	0.63±0.89	0.13±0.66	0.01±0.05
Post-surgery	1167.12±95.03	82.70±5.43	231.41±67.73	16.48±5.11	11.14±16.04	0.79±1.13	0.39±1.84	0.03±0.13
p-value	0.34	0.38	0.49	0.45	0.16	0.16	0.23	0.24

Values are average daily mean ± standard deviation unless otherwise indicated.