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# Nonsurgical management of patients with lumbar spinal stenosis: a literature review and a case series of three patients managed with physical therapy

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Lumbar spinal stenosis (LSS) is a recognized source of significant disability among the elderly and a substantial expense to the health care system. Patients with LSS may actually suffer from greater physical burden than those with many other significant medical conditions, such as chronic obstructive pulmonary disease, systemic lupus erythematosus, and congestive heart failure [1]. LSS is a prevalent condition, with an estimated 13% to 14% of those patients who seek help from a specialty physician and 3% to 4% who see a general practitioner for low back pain (LBP) diagnosed with LSS [1–4]. From 1979 through 1992, data from the National Hospital Discharge Survey revealed an eightfold increase in surgery for spinal stenosis [2], and this disorder is noted as the most common diagnosis associated with spinal surgery in patients over 65 years of age [5–7]. Over thirty thousand

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surgical procedures for LSS are performed annually with an inpatient expense of almost one billion dollars [8,9]. Although the substantial societal impact of LSS is apparent, there is uncertainty about the natural history of the disorder and evidence for both nonsurgical and surgical management remains unclear [2,5,7,10,11]. As the population continues to age, it will become increasingly important to determine the appropriate strategies for management of patients suffering from this spinal disorder. The purpose of this article is to briefly review the clinical diagnosis and presentation of LSS, review the status of the literature on nonsurgical management of the condition, and to present three cases of patients managed with manual physical therapy.

LSS has been defined as a focal narrowing of the spinal canal, nerve root canals, or intervertebral foramina [12,13]. Classification of the disorder may be made based on the location of the narrowing, either in the central or lateral canal, or on the etiology of the stenosis, either primary or secondary [12,14]. Primary stenosis refers to various congenital etiologies whereas secondary or acquired stenosis is from degenerative, post surgical (iatrogenic), spondylolisthetic, posttraumatic, or combined etiologies [12,15,16]. The most frequently reported classification of LSS is that of degenerative etiology, especially among the elderly [15,17–20]. Although LSS is classified according to the structural findings from imaging studies, many researchers report significant radiographic LSS in asymptomatic individuals [21–24], and no consistent strong relationship has been identified between imaging findings and results of treatment [2,25–27]. Thus, the magnitude of symptoms cannot be directly attributed to the severity of degenerative changes. Researchers report that in addition to a fixed structural component, LSS has a dynamic or movement-associated component. Compressive forces (axial loading) and spinal extension have been demonstrated to decrease the cross-sectional area (CSA) of the central spinal canal and the neuroforamen, whereas spinal flexion and non-weight-bearing postures have been demonstrated to increase CSAs [28–34]. In addition, evidence suggests that the structural and dynamic elements of stenosis may lead to increased epidural pressures [35] or vascular congestion or insufficiency [36–39] in the spinal region, thus contributing to the symptoms associated with LSS [40]. This dynamic component helps to explain the typical clinical presentation of a patient with LSS. Symptoms are increased when standing and walking due to increased spinal extension and compressive loading, and are decreased when sitting. Ultimately, the patient's clinical presentation must corroborate the imaging findings before a diagnosis of lumbar spinal stenosis can be made [2,41].

### **Clinical presentation**

Factors from both the history and physical examinations are important in the diagnosis of LSS. Patients diagnosed with degenerative LSS are typ-

ically over 50 years of age with an insidious onset of chronic, progressive LBP, and more recent onset of lower extremity (LE) symptoms [7,15, 40–43]. Many patients with LSS suffer from neurogenic claudication, a combination of pain, tension, and weakness that occurs with walking and is relieved when sitting [7,40,42,44]. Neurological changes are reported in 20% to 50% of patients [7,41], but cauda equina syndrome is rare [7,16,26, 45–47]. Patients with LSS frequently demonstrate lumbar spine motion restrictions and experience pain with lumbar extension [15,35,41,48,49].

Activities requiring lumbar extension or weight bearing (such as walking, standing, or going down stairs) typically increase symptoms associated with LSS, whereas activities or positions involving decreased weight bearing or lumbar flexion (such as sitting, stooping or bending forward, lying down, or leaning forward on a shopping cart or walker) ease symptoms [35,40, 42,48]. Diminished walking tolerance is considered to be one of the most significant functional limitations associated with LSS with measures or reports of walking tolerance often used as a functional outcome measure for these patients with LSS [15,26,48,49].

Several researchers have quantified the value of examination findings for the diagnosis of LSS. Katz and colleagues [41] identified the absence of pain while seated as a highly specific finding for the diagnosis of LSS (Specificity [Sp] = 0.93). In other words, a patient report of no pain with sitting is helpful to rule in the diagnosis of LSS. These researchers also report the findings of pain below the buttocks, age over 65, and no pain with flexion as highly sensitive for the diagnosis of LSS (Sensitivity [Sn] = 0.88, Sn = 0.77, and Sn = 0.79, respectively) [41]. Fritz et al [50] identified a patient ranking of sitting as the best posture (Sn = 0.89) and standing or walking as the worst posture as highly sensitive (Sn = 0.89). The absence of ranking sitting as the best posture and standing or walking as the worst posture decreased the likelihood of the patient having LSS (Negative Likelihood Ratios = 0.28 and 0.33, respectively). Additionally, a two-stage treadmill test (TSTT) has been suggested as a diagnostic tool in determining the presence of LSS [50]. The TSTT is conducted by comparing the results of a patient's walking tolerance with a level and inclined (15%) bout of walking at a self-selected comfortable pace. The best classification of those with LSS, as determined by a radiological reference standard, occurred with the findings of an earlier onset of symptoms and prolonged recovery time with level treadmill walking (Sp = 0.947, Positive Likelihood Ratio [PLR] = 14.51) [50]. As a single finding, the presence of a longer total walking time during inclined walking is predictive of LSS (Sp = 0.923, PLR = 6.49) [50].

### **Conservative management**

Many researchers and reviewers suggest that patients with LSS undergo a period of conservative therapy before considering surgical intervention [2,16,51–54]. Despite this frequent recommendation, however, the recent

report by the Agency for Healthcare Research and Quality [2] stated that only 15 of the 147 surgical management trials they reviewed reported that the patients received, and showed no improvement after, a course of conservative treatment. The actual amount of prior conservative treatment reported in these 15 studies was as little as 2 weeks in duration [2]. These facts may reflect the paucity of evidence available on the natural history of LSS and the clinical course of patients managed conservatively, and the limitations in drawing conclusions from the studies currently available. Conservative management strategies for LSS frequently include combinations of varied types of interventions such as bed rest, medications, epidural steroid injections, acupuncture, physical agents, postural or ergonomic advice, corsets, and flexion-based exercise programs. Outcome measures used for both surgical and nonsurgical studies are often not assessed by blinded individuals, are not objective in nature, or are poorly defined. No studies exist that investigate the efficacy of a focused, noninvasive intervention program compared with a control group using a large sample size, well-established outcome measures, testers blinded to group assignment, and evaluation of long-term outcomes.

Available evidence does demonstrate that the natural history of LSS does not appear to be one of inevitable deterioration, and some patients with LSS may improve over time. In a study on the natural history of patients with LSS followed over a 4-year period, Johnsson et al [43] reported that 85% of subjects demonstrated either improvement or no change in symptoms and 70% reported either increases or no change in walking tolerance with no treatment administered.

Several studies have documented the outcomes of conservative treatment regimens or compared surgical with nonsurgical approaches [15,26,51,55–61]. Only one study randomly assigned patients to either surgical or nonsurgical treatment groups. Amundsen and colleagues [26] reported long-term outcomes for 18 subjects with moderate symptoms who were randomized into the nonsurgical group and 50 subjects with mild to moderate symptomatic LSS who were nonrandomly assigned to nonsurgical treatment. Nonsurgical intervention included admission to an inpatient ward for 1 month, use of a hyperextension back brace, back school education, and encouragement to walk and move as normally as possible. Subjects were advised to wear the brace for 2 to 3 more months after discharge, start general physical training and ambulation, and keep their backs slightly kyphotic. Stabilizing exercises were employed, but according to the authors, no attempt was made to improve mobility of the spine. Outcomes were established from a combination of the opinion of the nonblinded examining physician and the patients' self-rating. The researchers reported "good" results for 47% to 57% of all nonsurgically treated patients at 4 years. Although the operational definitions for categorization of level of symptoms at baseline and the exact method of classification into the overall treatment result groups of "excellent," "fair," "unchanged," or "worse" at the follow-up

assessments were unclear, the results of this study demonstrate that approximately one half of patients with mild to moderate symptoms of LSS are able to improve with a nonoperative course of treatment [26].

Researchers from the Maine Lumbar Spine Study provided outcome information on 148 patients with LSS either confirmed by imaging or based on a strong clinical suspicion of stenosis [51,55]. Subjects in this study were not randomized into treatment groups and the patients selecting surgery were worse both clinically and radiographically at baseline than those selecting conservative management. A total of 67 patients underwent combinations of assorted nonsurgical treatments, including medications (narcotic analgesics); epidural steroid injections; bed rest; bracing; and various forms of exercise, manual medicine intervention, or physical modalities [51,55,56]. Well-established outcome measures were used, including pain ratings, quality of life assessment, functional status assessment (Roland Scale), and questions regarding patient satisfaction. At the 1-year follow-up, over 80% of the nonsurgically treated patients' pain did not worsen, and half of these patients reported improvement. This status remained almost the same at 4 years, with over 70% of the nonsurgical group reporting that they were not worse and one half of these patients reporting improvement. Additionally, 49% of the nonsurgical patients were satisfied to live the rest of their lives at their current status. At the 4-year follow-up, 85.7% of the subjects with moderate symptoms at baseline who were treated nonsurgically were the same or better. Although this study indicates that many patients may respond positively or at least remain stable over time, it is difficult to conclude which particular types of nonsurgical interventions were most efficacious.

Several other studies with both surgical and nonsurgical arms also support the premise that many patients with LSS may do well without surgery. Hurri et al [57] provided 12-year data for 18 nonsurgically treated patients, one third of whom had severe LSS. Improvement was demonstrated in 44% of the nonsurgical group and only 11% worsened. Additionally, both Johnsson et al [58] and Mariconda et al [59] reported improvements in small cohorts of patients who either refused surgery or had severe comorbidities that were contraindications for surgery. The nonsurgical interventions were not well defined in these studies.

Fukusaki et al [60] provided the only well-designed, randomized, controlled trial that compared a conservative treatment with a placebo treatment for patients with LSS. In this study, 53 patients were randomized to one of three treatment groups (epidural saline, epidural anesthetics, or epidural anesthetics and steroids). A blinded examiner measured walking tolerance on a treadmill at 1 week, 1 month, and 3 months. All treatment groups received relief of symptoms at the 1-week and 1-month testing sessions, but no symptomatic relief remained at the 3-month follow-up session. This study [60] demonstrated that a local anesthetic block could provide temporary improvements in neurogenic claudication for patients with LSS. Epidural steroids, however, did not offer any additional benefit in the

short-term outcomes measured. Further discussion of injections or other forms of invasive nonsurgical interventions are outside of the scope of the present article.

Two large case series have reported the results of specific nonsurgical treatment regimens for LSS. Onel and colleagues [15] prospectively evaluated the efficacy of an inpatient treatment program for 145 subjects suffering from either central or lateral stenosis. Treatment included heating modalities, daily flexion and extension exercises, and administration of salmon calcitonin. The 1-month outcome data demonstrated improvements in lumbar flexibility and reported walking tolerance. Ninety-five percent of the group demonstrated improvement in global clinical improvement scores, which included measures of pain, spinal functional capacity, neurogenic findings, and neurogenic claudication distances; only two subjects were referred for surgical intervention due to neurological deterioration. No long-term outcomes were reported [15]. Simotas et al [61] retrospectively evaluated the outcomes of a cohort of 49 patients with central LSS. In the 3 years evaluated, conservative interventions included combinations of bed rest, oral corticosteroids, corsets, acupuncture, manipulation, transcutaneous electrical nerve stimulation, epidural steroid injections, and nonsteroidal anti-inflammatory (NSAID) medications. Additionally, almost all of the subjects received postural instruction, gentle lumbopelvic mobilization, and flexion-biased lumbar stabilization exercises. After 3 years, one quarter of the subjects were significantly better, almost one half noted at least some degree of overall improvement, and approximately one third reported improved walking tolerance. Nine patients (18%) ultimately opted for surgery. Although the interventions evaluated by Simotas et al [61] were too varied to establish the efficacy of any specific treatment, this study demonstrated that many patients undergoing nonsurgical intervention do not face inevitable deterioration, but often remain the same or experience positive long-term outcomes.

A few small case reports or studies on nonsurgical intervention for LSS are available in the literature. Kirkaldy-Willis [62] reported on the use of spinal manipulation for 11 patients with central stenosis. Subjects admitted to the study had not responded to previous conservative measures and were disabled by pain at the initiation of treatment. Although these patients had an 11.5-year mean duration of symptoms, improvement was noted in six of these patients and two were symptom free with no restrictions in work or other activities after a course of manipulative intervention. Fritz et al [63] reported on two subjects with LSS who received physical therapy intervention for 6 weeks. The therapy included impairment-specific stretching and strengthening and body weight supported ambulation. Both patients demonstrated 70% to 100% improvements in pain and disability by discharge that were maintained 1 month later [63]. DuPriest [64] demonstrated positive changes in pain and physical examination findings for one patient with LSS after 12 sessions of impairment-specific treatment. This patient sought

treatment after a previously unsuccessful 3-month course of other non-surgical interventions (intramuscular corticosteroids injection, NSAIDs, physical modalities, massage, and traction treatments). After undergoing treatment including manipulation, specific stretching and strengthening exercises, aerobic exercise (cycling and walking), ultrasound, and a heel lift, the patient was able to return to daily 4-mile walks and no longer had pain. These gains remained through the 3-month follow-up period. Rendeiro [65] also described positive outcomes for a patient with LSS after implementation of a manual physical therapy program. Although definitive conclusions on efficacy cannot be drawn from these reports due to small sample sizes, short-term follow-up, and lack of control groups for comparison, they provide insight into possible outcomes after participation in noninvasive and nonmedically oriented intervention programs.

In general, studies investigating the efficacy of nonsurgical intervention for LSS or comparing nonsurgical versus surgical management for LSS suffer from methodological drawbacks similar to those experienced in studies investigating surgical management for this disorder. The studies are often observational in nature without randomization or comparison group, utilize poorly defined management strategies and poor outcome measures, or include small sample sizes. Therefore, aside from demonstrating that many patients suffering from LSS may improve or at least remain status quo over time, a clinician can only derive limited conclusions from the literature to assist with designing a specific nonsurgical management strategy for individual patients. In the absence of strong literature-based evidence, providers must focus on signs and symptoms from the historical and physical examination to develop a plan of care. Further, the lack of evidence available serves as an indication that clinical trials designed to determine the efficacy of different types of nonsurgical intervention for patients suffering from LSS are indicated [2].

### **Case series**

The purpose of this small case series is to describe a manual physical therapy program and long-term outcomes for three patients with LSS. The treating therapist utilized information from the historical and physical examination to establish an individualized plan of care for the patients. The treatment program addressed the impairments the treating therapist felt most contributed to the patients' low back and LE symptoms. Previous studies have been criticized for not including data on different dimensions of outcomes [7]. Therefore, we used a variety of measures to assess outcomes from multiple dimensions of the Nagi disability model, including the impairment level, the functional limitation level, and disability [63,66]. In addition to reporting changes in historical and physical examination findings and functional limitations, patient reports of global rating of change (GRC), and overall functional improvement, we included both region-specific and a

condition-specific self-report questionnaires and a patient report of walking tolerance.

### *Instrumentation*

The region-specific and condition-specific measures of disability used in this case series were the Oswestry Disability Index (OSW) and a modified Spinal Stenosis Scale (SSS), respectively. The OSW is a frequently used region-specific disability scale for patients with LBP [67]. The OSW used in this case series was the version studied by Fritz and Irrgang, with specific questions modified to improve compliance [68]. In a study including 67 patients with acute work-related LBP, Fritz and Irrgang [68] found the modified OSW to be reliable and responsive with a minimum clinically important difference (MCID) of 6 points over a 4-week period of time. The SSS is a condition-specific self-report questionnaire for patients with LSS [69,70]. This questionnaire consists of three scales addressing physical function status, patient satisfaction, and symptom severity. Each scale includes five to seven items scored on a Likert response scale, and each scale score is calculated as the unweighted mean of all answered items. The range of scores is from 1 to 5, 6, or 7, depending on the subscale, with lower scores corresponding with less disability, greater satisfaction, or less pain. Our only modification was to replace the word “surgery” with the word “treatment” on the satisfaction scale of the SSS. In a large prospective observational study of patients undergoing decompressive surgery for LSS, the difference in physical function and symptom severity scale scores between the unsatisfied and somewhat satisfied patients was 0.52 and 0.48, respectively. These scores represent the MCID for each scale. Although the SSS questionnaire has been found to be reliable, internally consistent, and more responsive than was a region-specific measure in studies evaluating surgical outcomes for patients with LSS [69], the psychometric properties of this modified SSS for patients undergoing nonsurgical management are unknown.

We used a retrospective GRC as an additional outcome measure, because no condition-specific measures have been validated for nonsurgically managed patients with LSS. The retrospective GRC as an outcome gold standard represents a credible option in the absence of an external gold standard and is a common, feasible, and useful method for assessing outcomes [71]. Jaeschke [71] has described a 15-point global self-rating scale whereby patients may rate their own perception of improvement. The scale ranges from  $-7$  (“a very great deal worse”) to  $0$  (“about the same”) to  $+7$  (“a very great deal better”). Intermittent descriptors of worsening are assigned values from  $-1$  to  $-6$ , and intermittent descriptors of improvement are assigned values from  $+1$  to  $+6$ .

Many researchers recommend or use a treadmill test to objectively assess walking tolerance after surgical and nonsurgical treatment [15,27,60,72–76]. Because the TSTT, as described by Fritz et al [50], was found to have good

discriminative ability for patients with LSS, the test was used as a diagnostic tool only in this case series. Unfortunately, we did not use any form of treadmill testing to assess maximal walking time or distance either preintervention or postintervention, and thus were only able to provide patient reports of walking tolerance for these three patients.

Each patient's overall functional status change was determined by comparing the individual's baseline with 18-month functional limitations. After reviewing the baseline limitations (Table 1), the patient was asked to "Estimate the overall percentage difference, if any, in your average ability to do these activities and any other necessary daily activities today versus your status when you first came to physical therapy."

#### *Patient description and historical examination findings*

The three subjects were retired military members who were treated in the Physical Therapy Clinic at Brooke Army Medical Center, San Antonio, Texas, and followed over an 18-month period. All patients reported LBP and LE symptoms that were aggravated by standing upright and walking. In all individuals, lower extremity pain was worse than the LBP and all symptoms resolved with bending forward or sitting. Table 1 includes more detailed historical examination findings.

#### *Patient 1*

This 81-year-old male suffered from worsening LBP and right LE symptoms extending to the posterior calf and plantar surface of the foot. The initial onset of symptoms started with a fall on to his back and buttocks 5 years prior. The LBP was an intermittent, deep ache with intermittent, deep, sharp pain in the right buttock. The right lower calf symptoms were intermittent with a tired, achy quality. This patient had not exercised regularly since the fall due to his LBP and LE symptoms and reported a "very sedentary" lifestyle with at least 6 to 8 hours of sitting per day. Standard radiographs demonstrated the following: multilevel degenerative disc disease with moderate disc space narrowing in L4-5 and L5-S1; pars defect of the left L4 vertebral body, Grade I anterior listhesis of L4 on L5; and transitional vertebra at the lumbosacral junction. General health issues included aortic valve replacement 1 year prior, hypertension, coronary artery disease, angina (only when mowing the lawn), shortness of breath with activity, 3-year history of vertigo, skin cancer removed in 1950s (unsure what type, not recorded in medical records), and positive smoking history (stopped in 1962).

#### *Patient 2*

This 63-year-old male had episodic, worsening LBP since a "blow to the back" in high school football 45 years prior. The LBP was described as an intermittent, deep, sharp pain. His intermittent LE numbness, tingling, and pain extended along the lateral thigh, leg, and foot. LE symptoms began 8 to 10 years prior and had progressively increased in frequency and intensity.

Table 1  
Historical examination findings

Functional limitations	Patient 1		Patient 2		Patient 3	
	Baseline	18 months	Baseline	18 months	Baseline	18 months
Standing upright: LBP and right LE symptoms immediately; must lean forward		Pain free	Standing upright—immediate LBP and left LE symptoms; must lean forward	Pain free	Stands 2–3 min—LBP and left LE symptoms	Stand 45 min—right LBP
Go down stairs—LBP and right LE symptoms immediately		Pain free	Up or down stairs—immediate LBP and left LE symptoms	Pain free	Walks 4 min—LBP and left LE symptoms	Pain free
Transitions into/out of car, to/from supine/sitting/standing—LBP		Pain free	Lying on right side—immediate LBP and left LE symptoms; must roll to left side	Pain free	Lying prone—immediate LBP and left LE symptoms	Pain free
Vacuum one room—LBP and right LE symptoms; must sit		Pain free	Standing stationary 5–10 min—LBP and left LE symptoms; must lean forward or sit	Stands 10–15 min LBP, left LE symptoms to leg/foot	Lying supine—immediate LBP and left LE symptoms	Pain free
Mow lawn > 10 min—LBP and right LE symptoms; must sit or bend forward		Pain free for 10 min, can mow whole lawn	Water lawn with hose—LBP and left LE symptoms; must stop immediately	Pain free (last time he could do this was 3 years prior to initial visit)		

Walk >5 min—LBP and right LE symptoms; must sit or bend forward	Over 1 mile before stops due to fatigue	Walking three blocks—LBP and left LE symptoms; must bend forward or sit	“Almost unlimited,” walks over 8 blocks (approx 30 min) before LBP, left LE symptoms
Does ½ dishes—LBP and right LE symptoms; must sit	Pain free, unlimited		
24 hour pattern	Sleeps well	Wakes 2–3 times per night, eases immediately with position change	Sleeps well
Exercise routine	Not doing exercises “due to laziness”	None for 7–8 years due to LE symptoms	Stiff back and left LE symptoms first 5–10 min in the morning Walked 3 miles daily until onset of LBP and left LE symptoms. Stopped exercising due to pain “Very active” until onset of symptoms, now “very sedentary”
General activity	Sits minimum 6–8 hrs per day, “very sedentary”	“Not active,” “sedentary”	“Very active” “Very active” “Very active”
			Stiff back for 10 min in the morning Walks TIW, 2 miles per session

*Abbreviations:* LBP, low back pain; LE, lower extremity.

This patient's pain and disability from LSS caused him to retire from work 4 years prior and lumbar decompressive surgery was scheduled 1 year prior to the initial physical therapy (PT) examination. The back surgery was cancelled secondary to the patient needing a prostatectomy and the patient was referred to PT for nonsurgical management of his LSS. The MRI report from 1 year prior reported a congenitally small spinal canal with central canal stenosis at L3-4 and L4-5; canal flattening at L4-5; collapsed degenerative discs at L4-5, L5-S1; and mild right foraminal narrowing at L5-S1. General health issues included a history of prostate cancer (removed 1 year prior), hypertension, and allergies.

### *Patient 3*

This 71-year-old male reported a history of worsening intermittent dull ache in the left buttock and intermittent dull achy symptoms extending along the lateral left thigh to the proximal one third of the lateral tibia. These symptoms, of insidious onset 6 weeks prior, had caused this patient to cease his daily walking program. This patient's recent MRI report included mild spinal canal stenosis at L2-3 and L5-S1 and severe spinal canal stenosis from L3 through L5. General health issues included diabetes mellitus type II, hypertension, and glaucoma.

### *Initial physical examination findings*

All three patients presented with the following impairments: (1) a flexed standing posture and decreased passive extension of the hips, (2) stiffness of the lower lumbar spine and the hips upon manual mobility testing, (3) tightness in the iliopsoas and rectus femoris bilaterally, and (4) active range of motion limitations with reproduction of lumbar and lower extremity symptoms (limited into extension, side bending to the side of LE symptoms, and quadrant testing to the side of LE symptoms). Patients 2 and 3 tested positively on the TSTT. Patient 1 underwent a bicycle test to further differentiate between neurogenic and vascular claudication. Based on the patient's rate of perceived exertion, this individual worked harder on the bicycle test and exercised twice as long on the bicycle than he had during the TSTT, yet he complained of no LBP or LE pain while cycling. Lastly, all three patients demonstrated reflex and strength changes in the S1 distribution. Table 2 provides a detailed description of the physical examination findings for each patient at baseline and 18 months.

### *Physical therapy intervention*

Each patient received five sessions of impairment-specific manual physical therapy intervention. Treatment to the lumbar and lower thoracic spine regions included both rotational and posterior to anterior mobilization or manipulation techniques. Posterior to anterior accessory motion mobilization techniques were used to address hip stiffness and to try to increase hip

extension mobility. The therapist manually stretched the tight rectus femoris and iliopsoas muscles (see Fig. 1 [A–F] for pictures of selected manual physical therapy techniques used to treat these three patients). After improvement in spinal and hip mobility, gluteal muscle and lower abdominal muscle strengthening was initiated. With each visit, the patient was instructed in specific exercises designed to reinforce the physical therapy interventions that were found to be efficacious in that patient's care. The exercises were continually adjusted until the individual patient felt stretch or muscle activation in the targeted tissue region. Further sessions with the therapist (ranging from one to four additional appointments) were used for reinforcement of the home program. Lastly, all three patients were asked to go on a daily intentional walk. The patients were instructed to stop walking when symptoms reached the level that would normally make them stop.

Patients 2 and 3 participated in a progressive body-weight supported treadmill ambulation training program. For this training, a cable and trunk harness system is used to lift, or unload, a specified amount of body weight from the patient while the patient walks on the treadmill. Body-weight support systems have been shown to decrease the downward excursion of the body's center of gravity [77] and predictably reduce the vertical component of the ground reaction force with walking and with running [78]. Theoretically, this same body weight support system will decrease compression forces usually placed on the lumbar spine with weight bearing, thus increasing the cross-sectional area of the spinal canal and neuroforamen. Clinically, it is our experience that many patients with LSS often tolerate walking with a body-weight supported system for longer periods of time and with less pain than without the support. Body-weight supported ambulation training has been advocated for patients with LSS [63], other spinal conditions [79], and various lower extremity disorders [80–82]. For our patients with LSS, enough body-weight support was used to alleviate LE symptoms and to allow the patients to walk as normally as possible and as long as possible. Naturally, the amount of support required fluctuated from session to session, but the overall goal was to gradually decrease the amount of unloading used and gradually increase the walking pace and distance.

Orthotics were prescribed for patient 3 after the efficacy of the manual intervention had been established. These were used to compensate for biomechanical deficiencies of the feet that the therapist determined adversely affected lumbar spine and pelvic mechanics with gait. The foot and ankle findings included marked bilateral pes planus (right > left), bilateral navicular drop of approximately 10 mm, no evidence of calcaneal inversion bilaterally throughout gait, short stride length bilaterally, and an apulsive gait. "Off-the-shelf" orthotics were customized for this patient with 2 degrees medial posting on the left forefoot, left rearfoot, and right rearfoot; and 4 degrees medial posting to the right forefoot. To determine whether the orthotics would be beneficial for this patient, the time to onset of neurogenic claudication was measured during three successive trials of walking first

Table 2  
Physical examination findings

	Patient 1		Patient 2		Patient 3	
	Baseline	18 months	Baseline	18 months	Baseline	18 months
Posture	Markedly flexed at hips, Lx spine, and Tx spine	Upright	Markedly flexed hips, Lx spine; extended TL junction	Extended at the TL junction	Slightly flexed at hips and Lx spine; slight right lat shift	Normal
Limited standing ROM	Lx ext, right SB, right quadrant marked—all with LBP and LE symptoms	Lx ext, right Lx quadrant min—LBP only	Bilat SB marked—LBP; Lx ext and left quadrant marked—LBP and LE symptoms	Lx ext and left quadrant min—LBP	Lx ext, left SB, and left Lx quadrant marked—LBP and LE symptoms	Ext with overpressure—bilat buttocks “tight”
Stiffness with segmental mobility testing	Marked St right L4, L5; mod L1–L3 St; mod lower Tx spine	Mod right L5	Marked St L4, L5; mod L1–L3 St; mod lower Tx spine	Mod St L4, L5	Marked St right and central L5; min St L4	Min St right L5
Stiffness with PA hip joint accessory mobility testing	Bilat—marked	Bilat—mod	Bilat—marked	Right—min	Bilat—marked	Left—mod
Iliopsoas tightness	Bilat—marked	Right—min	Bilat—marked	Bilat (right > left)—mod	Bilat—marked	Normal
Rectus femoris tightness	Bilat—marked	Bilat—mod	Bilat—min	Normal	Bilat—marked	Bilat—mod
Difficulty activating lower abdominals	Difficult sustaining contraction	Increased consistency, but still difficult	Difficulty sustaining contraction	Difficulty sustaining contraction	Difficulty sustaining contraction	Normal

Muscle weakness	Bilat gluteus medius and maximus	Normal	Bilat gluteus medius and maximus	Normal
Straight leg raise	Right—70°, LBP and LE symptoms, increases with dorsiflexion	Normal	Right—75°, HS pull only, no change with dorsiflexion	Normal
Neurological findings	Right AJI+, Right PF weakness	No change	Left—60°, LBP, ankle DF increases LBP; right—70°, post thigh tightness, no change with dorsiflexion	Bilat—75°, both with prox post ipsilat thigh symptoms, both increase with dorsiflexion
			Normal except bilat absent AJ, bilat PF weakness, ↓ sensation to the left lateral foot	No change except further ↓ strength with left ankle PF
			No change	Normal except: left ankle eversion 4/5, both PF weakness ( $l > r$ ), bilat absent AJ, absent left KJ, right KJI+

Only positive or remarkable findings noted here.

*Abbreviations:* AJ, ankle jerk reflex; AROM, active range of motion; Bilat, bilateral; deg, degrees; DF, dorsiflexion; ↓, limited or decreased; ext, extension; flex, flexion; glut, gluteus; HS, hamstrings; Lx, lumbar; Lx quadrant, combined motion including extension and ipsilateral side-bending and rotation; max, maximum; med, medius; min, minimal; mod, moderate; PA, post to anterior; PF, plantarflexion/plantar flexor; post, posterior; prox, proximal; RF, rectus femoris; SB, side bending; SLR, straight leg raise; St, stiff/stiffness; TL, thoraco-lumbar; Tx, thoracic; tight, tightness.



Fig. 1. Selected physical therapy interventions. (A) Supine iliopsoas muscle stretch. (B) Prone hip posterior to anterior mobilization. (C) Prone rectus femoris muscle stretch. (D) Lumbar rotation mobilization/manipulation in neutral. (E) Caudal glide to the hip joint in flexion. (F) Unilateral posterior to anterior lumbar spine mobilization.

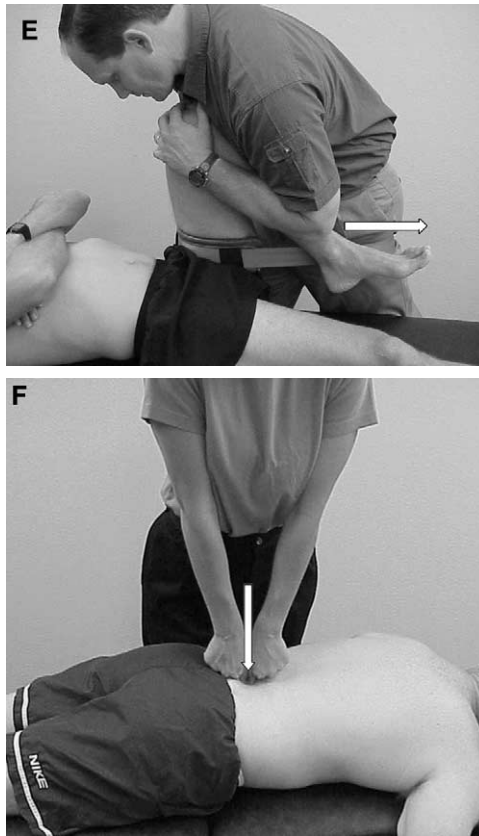


Fig. 1 (continued)

without the orthotics, then immediately with the orthotics, then again immediately without the orthotics. The time to onset of LE symptoms was equal with both trials of walking without the orthotics, and neurogenic claudication was appreciably delayed with the orthotics (40% longer before neurogenic claudication with orthotics). Table 3 provides a summary of the physical therapy interventions used with each patient.

### Outcomes

All three patients demonstrated substantial positive changes that were sustained up to 18 months. Tables 1 and 2 include the outcome information for the historical examination findings, functional limitations for each patient, and physical examination findings. The results of each patient's region-specific and condition-specific outcome questionnaires are included in Table 4. As a group, the patients' OSW score improvement ranged from

Table 3  
Summary of physical therapy interventions

	Patient 1	Patient 2	Patient 3
Total no. visits with therapist	9	10	9
Manual therapy sessions included:	5	5	6
	Spinal manipulation (rotational, PA graded)	Spinal manipulation (rotational, PA graded)	Spinal manipulation (rotational, PA graded)
	Hip joint mobilization (PA)	Hip joint mobilization (PA)	Hip joint mobilization (PA)
	Hip flexor stretching	Hip flexor stretching	Hip flexor stretching
	Body weight supported ambulation	Body weight supported ambulation	Body weight supported ambulation
	Gluteal muscle retraining		Gluteal and lower abdominal retraining
Visits focused on correct performance of home exercise program:			
Spinal mobility exercises	Flexion and rotational spinal mobilization exercises	Flexion and rotational spinal mobilization exercises	Flexion and rotational spinal mobilization exercises
Muscle stretching	Hip flexor muscle stretching	Hip flexor muscle stretching	Hip flexor muscle stretching
Muscle retraining	Gluteal and calf muscle retraining	Gluteal and calf muscle retraining	Gluteal and lower abdominal muscle retraining
Aerobic exercise	Daily walking	Daily: alternate walk and cycle	Daily walking

*Abbreviation:* PA, posterior to anterior.

66% to 95% of their baseline scores by discharge and 33% to 82% at 18 months. On the Physical Function Scale of the modified SSS, improvement ranged from 1.0 to 2.6 points from baseline to discharge and 0.9 to 2.6 at 18 months. On the Symptom Severity Scale, improvement ranged from 0.76 to 1.85 by discharge and 0.14 to 1.29 at 18 months. Except for patient 2's 18-month Symptom Severity Scale score, the magnitude of all of the improvements in outcomes noted by our patients surpassed the MCIDs previously established by Stucki et al [69] for the Spinal Stenosis Scale and by Fritz and Irrgang [68] for the modified OSW. Further, all three patients reported improvements in overall functional status. These results, in addition to the patients' responses on the GRC scale, are reported in Table 4. Finally,

Table 4  
Outcomes

	Patient 1			Patient 2			Patient 3		
	Baseline	Interim	18 months	Baseline	Discharge	18 months	Baseline	Discharge	18 months
Modified Oswestry	34	4 weeks 10 <sup>a</sup>	6 <sup>a</sup>	60	20 <sup>a</sup>	40 <sup>a</sup>	48	2 <sup>a</sup>	18 <sup>a</sup>
Modified SSS: physical function scale	2.6 <sup>b</sup>	3 months 1.6 <sup>a</sup>	1.2 <sup>a</sup>	2.4	1.4 <sup>a</sup>	1.5 <sup>a</sup>	3.6	1 <sup>a</sup>	1 <sup>a</sup>
Modified SSS: symptom severity scale	2.71 <sup>b</sup>	3 months 1.86 <sup>d</sup>	1.57 <sup>a</sup>	3.14	1.86 <sup>a</sup>	3	2.86	2.1 <sup>a</sup>	1.57 <sup>a</sup>
Modified SSS: satisfaction scale	N/A	3 months 1	1	N/A	1	1.67	N/A	1	1
Patient global rating of change	N/A	N/A	A great deal better	N/A	N/A	A very great deal better	N/A	N/A	A great deal better
Patient assessment of overall functional status versus baseline examination	N/A	N/A	“Approximately 95%”	N/A	N/A	“Almost 100% improvement”	N/A	N/A	“Almost 100% improvement”

No discharge Oswestry Disability Index (OSWI) or modified Spinal Stenosis Scale (SSS) data were collected for patient 1, thus the available interim scores are reported above.

<sup>a</sup> Denotes a change score  $\geq$  the minimal clinically important difference (previously established by Stucki et al [69] for postsurgical patients for the SSS, and by Fritz and Irrgang [68] for the Modified Oswestry Disability Index).

<sup>b</sup> Denotes that data were collected retrospectively.

although all three patients were taking pain medications for their lower back and leg pain at the baseline evaluation, the patients reported only occasional use of pain medication at the 18-month follow-up appointment.

## **Discussion**

This case series is the first to use a well-defined, impairment-based, non-invasive outpatient treatment program for patients with LSS and to provide patient-centered long-term outcome information. Most studies investigating the efficacy of conservative interventions or comparing surgical with non-surgical outcomes for patients with LSS combine invasive treatments, pharmacological management, physical modalities, and nonspecific exercises [15,51,55,61,83]. As previously discussed, the use of such unfocused management strategies prevents further differentiation of what aspect of care was the most beneficial for patients with LSS. Additionally, some researchers have reported on outcomes after prolonged inpatient treatment programs [15,26]. Although this situation allows for improved experimental control with human subjects, it is our opinion that a prolonged period of nonsurgical inpatient care for patients with LSS is not practical in the United States at this time. The outpatient treatment program we implemented focuses on the patients' individualized, prioritized impairments identified at the initial examination. The treatments emphasized manual physical therapy techniques targeting each patients' prioritized impairments, specific exercises to either reinforce the manual physical therapy treatment or strengthen specific muscles, and a walking program. Under this physical therapy program, the patients experienced significant improvements, and the potential adverse effects of invasive therapies or pharmacological management strategies often included in other "nonsurgical" treatment programs were avoided.

The use of long-term patient-centered outcome measures that focused on different levels of the disablement model was an asset of this case series. Many previous reports on nonsurgical management of patients with LSS only assessed short-term outcomes [15,63–65], used combinations of clinician opinion and patient-centered outcomes assessment [26], or did not establish the patient's baseline status before initiating intervention [84]. We examined changes over time at the impairment, functional limitation, and disability levels of the disability model at baseline and up to 18 months after initiation of physical therapy. Some areas for improvement in the outcome assessment tools that were utilized have been identified, however. Although the condition-specific SSS is a promising health outcome measurement tool for those with LSS, the psychometric properties of the modified SSS for those receiving nonsurgical intervention needs to be established. Additionally, even though the SSS asks questions specifically addressing the patient's walking tolerance, a more quantitative measure of this prevalent functional limitation would be beneficial. We suggest that future research studies incorporate assessment of walking tolerance with a treadmill test

at baseline, at discharge, and at scheduled follow-up sessions. Lastly, our method of quantifying the patient's overall functional improvement could possibly be improved by using the Patient Specific Functional Scale (PSFS) [85–87]. This is a patient-specific questionnaire that requires patients to identify up to five important activities that they are having difficulty with as a result of their condition. The patient rates difficulty on an 11-point numerical scale (0 = unable to perform the activity; 10 = able to perform activity at the same level as before the injury or problem) and the average score for up to five activities is established as the PSFS score. This scale has been established as reliable, valid, and responsive in other populations [85–87], but use with the LSS population has not been established.

This small case series demonstrates that patients with LSS can make significant gains in disability, symptoms, and function in relatively short periods of time; and that these gains can be maintained up to 18 months. Although the outcomes attained in this series seem promising, no cause and effect relationship can be established from case reports. Additionally, the treating therapist administered all questionnaires and assessments. Failure to perform outcome assessments in a blinded fashion is a threat to the validity of our findings. Our intention, however, is for this small case series to serve as a demonstration of the positive outcomes that are possible through the use of a focused, impairment-specific manual physical therapy management program. Additionally, it can provide insight into the types of outcomes that may be beneficial for assessing the progress of patients with LSS. The authors are currently involved in a randomized clinical trial comparing two conservative management strategies and a randomized clinical trial comparing conservative management and surgical management of LSS.

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