Case Report

Three-step treadmill test and McKenzie mechanical diagnosis and therapy to establish directional preference in a patient with lumbar spinal stenosis: a case report

G Padmanabhan¹, A Sambasivan², M J Desai³

¹The GW Spine & Pain Center, The George Washington University Hospital, Washington DC, ²The George Washington University Medical Center, Washington DC, ³Pain Medicine & Non-operative Spine Services, The GW Spine & Pain Center, Department of Anesthesiology and Critical Care Medicine and of Neurosurgery, The George Washington University Hospital, Washington, DC, USA

Background: Lumbar spinal stenosis (LSS) is defined as narrowing of the spinal canal. LSS is commonly treated conservatively, primarily with flexion-based exercises. We present a patient diagnosed with LSS, refractory to a flexion-based protocol who ultimately responded to an extension-based protocol following establishment of directional preference with three-step treadmill testing.

Description: A 64-year-old male was diagnosed with LSS with a 2-year history of bilateral neurogenic claudication unresponsive to flexion-based exercises. Initially, distinct directional preference or centralization was not demonstrated on repetitive movement testing. Ultimately, preference towards extension was established through a three-step treadmill test. An extension-based treatment plan was recommended, which provided significant relief despite focusing on exercises that are commonly avoided during traditional treatment for LSS.

Outcomes: He began to centralize pain to his lower back after 2 weeks and denied neurogenic claudication on repeat three-step treadmill test at 3 weeks. His drastic improvements in pain levels and functional status continued throughout four sessions.

Discussion: Although the patient's initial diagnostic label may bias towards a spinal flexion protocol, further mechanical testing revealed an extension directional preference. The three-step treadmill test was crucial in establishing his directional preference and guiding his treatment. Treadmill testing may be useful in a subset of patients who do not demonstrate distinct directional preferences on mechanical testing.

Keywords: Lumbar spinal stenosis, Three-step treadmill test, McKenzie MDT, Extension-based exercises

Introduction

Low back pain affects a reported 5.6% of US adults each day, and 60–70% of Americans at some point in their lifetime.^{1–3} Studies suggest that 18% of Americans experienced back pain in the previous month, and 3% of low back pain cases are attributed to spinal stenosis.^{4,5}

Lumbar spinal stenosis (LSS) was first described by Verbiest in 1954. At the time, he published a case review of seven patients who experienced radicular symptoms, muscular weakness, and neurogenic claudication in their lower limbs.⁶ Verbiest noted a narrowed lumbar spinal canal in each patient and provided the foundation for our current understanding of LSS.⁶ LSS is commonly defined as a narrowing

of the spinal canal, neural canal, and vertebral foramina; this can be caused by primary or secondary etiologies.^{6,7} The former occurs when congenital malformations cause narrowing of a newborn's spinal canal. The latter occurs when patients develop spinal stenosis through degenerative spondylolisthesis, post-surgical scarring, lumbar intervertebral disc herniation, hypertrophy of ligamentum flavum, facet arthropathy or a combination of conditions.^{8–10}

Patients with LSS struggle with postural-dependent lower extremity pain. They often report symptoms of neurogenic claudication: pain while standing upright or walking and relief of pain while sitting or standing in spinal flexion.^{2–5} Their pain is caused by the combination of spinal nerve impingement at a narrowed segment of the spinal canal and postural-dependent changes to the dimensions of the spinal

Correspondence to: M J Desai, The GW Spine & Pain Center, 2131 K St, NW, Washington, DC 20037, USA. Email: mdesai@mfa.gwu.edu

canal. The cross-sectional area of the spinal canal has been shown to decrease with extension and increase with flexion.^{11,12} A normal spinal cross-sectional area is reduced by 9% during extension but a stenotic spinal cross-sectional area has been shown to be reduced by up to 67% during extension.¹² Penning refers to this phenomenon as the 'rule of progressive narrowing', suggesting that the more a spinal canal is narrowed by stenosis, the more susceptible it will be to narrowing by extension.¹³

Although LSS is the most common indication for spinal surgery in patients above 65 years old, there continues to be two broad approaches to its treatment.¹⁰ In fact, arriving at the diagnosis of LSS is challenging in of itself. LSS likely represents a label rather than a true diagnosis. Controversy continues to surround LSS as some feel that claudicating symptoms must accompany the clinical picture whereas others consider it a radiographic diagnosis. The complexities of diagnosing such a broad clinical spectrum, with very little agreement among practitioners, and relying on either subjective complaints or radiographic interpretation can increase the potential for mis-management. As such, those that argue that LSS is essentially a structural abnormality, which is only amenable to surgical interventions, suggest that decompression surgery or spinal fusion offers the most appropriate remedy for its progressive course and poor prognosis.^{14–16}

Others consider LSS to follow a more favorable course and have reported cases of LSS that have responded favorably to conservative treatments.¹⁷ Nevertheless, physicians traditionally recommend a trial of patient education, exercises, pain medication, and flexion-based physical therapy before invasive surgical techniques are attempted.^{17,18} Atlas and Delitto note the lack of well-controlled reports in the literature comparing specific non-surgical treatments to surgical treatments for patients with spinal stenosis.¹⁹

A recent article noted that a combination of lumbar flexion exercises, body weight supported treadmill walking, aggressive walking to the point of claudication, muscle coordination training, lumbar semi-rigid orthosis, braces and corsets, pain-relieving modalities, manual medicine treatments, and postural instruction has been advocated as physical therapy modalities for LSS.²¹ Moreover, a flexion bias program is often emphasized during these therapies to increase neuroforaminal and spinal canal cross-sectional areas.¹⁹

The McKenzie mechanical diagnosis and therapy (MDT) method is a physical therapy approach that is considered effective at treating non-specific spinal pain.^{22–24} The approach focuses on defining and correcting the relationship between a patient's pain

symptoms and their postural movements. This method begins with a careful assessment of how a patient's posture, range of motion, and repetitive movements aggravate or alleviate their pain. The goal of this initial assessment is to categorize the patient into one of three clinical syndromes: a derangement syndrome, a postural syndrome, or a dysfunction syndrome.²⁵ A patient's directional preference, centralization, and peripheralization of pain are particularly noted to guide treatment decisions. Once a patient has been categorized, they are educated about their syndrome and taught to perform stretches and exercises that focus on correcting their directional preferences, centralizing their pain and alleviating their symptoms.²⁶

The purpose of this case report is to describe how the MDT approach is used during treatment of a patient with LSS. The goal of the paper is to further contribute to the literature describing conservative approaches to the care of this patient population.

Case Report

History and interview

A 64-year-old male reported a 2-year history of worsening intermittent bilateral pain in the buttock radiating to his ankles associated with numbness and tingling in his calves and the plantar aspects of his feet. The symptoms were provoked by walking approximately one block or standing for more than 2 minutes, and relieved by sitting or lying down. The patient was otherwise healthy with no past medical problems, recent weight loss, or night pain. His pain developed without any obvious traumatic events. During the initial examination, he reported a pain level of 7–9/10 on a numerical rating scale (NRS) and had an Oswestry disability index (ODI) score of 54%.

His symptoms worsened over the two previous years despite performing flexion-based physical therapy exercises, and core stabilization exercises. He also denied significant relief following two epidural injections that he received at an outside facility, approximately 6–8 weeks prior to his initial visit to our office. His exercise regimen at the initial visit consisted of daily flexion-based stretches, upper and lower body weight training, and 20–30 minutes of cardiovascular exercise 4–5 times per week.

During the initial visit, he demonstrated decreased lumbar lordosis, mild upper thoracic kyphosis, and a moderate head forward posture. His neurological screening did not reveal any focal deficits and he ambulated with a mild forward trunk lean. Active range of motion of his lumbar spine was measured by using a double inclinometry technique, which has been shown to have good reliability²⁷ and is displayed in Table 1. His passive straight leg raise test was limited bilaterally at 70% by hamstring tightness and

he demonstrated moderate limitation of bilateral rotation and mild restriction of bilateral side glides. Passive straight leg test has been shown to have poor sensitivity but good specificity in diagnosing lumbar radiculitis.²⁸ His repetitive movement testing showed lack of a directional preference and lack of centralization and he demonstrated a change in walking tolerance pre- and post-testing. The results of this test are displayed in Table 2. A three-step treadmill test was also performed; this consisted of the patient walking in spinal flexion, spinal extension, and a neutral posture at 1 mile/hour on a treadmill with a 15° gradient until the onset of buttock pain. The time duration to onset of pain is recorded in Table 3. This test revealed a previously unrecognized directional preference towards spinal extension. The patient also provided us with his previous imaging studies that confirm his LSS diagnosis and suggest that he also has a stable spondylolisthesis at the L4–L5 vertebral space. These studies are displayed in Figs. 1–4.

Provisional Classification/Diagnosis

Upon completion of our initial assessment, the patient was given the provisional classification of central symmetrical derangement below the knee with possible directional preference for extension suggested treadmill testing. The pertinent qualities of his back pain were:

1. extensive trial of flexion exercises failed to improve or exacerbate his symptoms;
2. flexion and extension stretches failed to elicit pain and mechanical responses;
3. there was a dramatic functional response to mechanical testing;
4. the three-step treadmill test revealed a directional preference towards spinal extension.

These qualities were unique because he lacked a directional preference towards spinal flexion, which was expected considering his severe LSS. Moreover, his treadmill test revealed the opposite directional preference towards spinal extension. These factors persuaded us to focus his therapies towards his functional impairment and directional preference rather than his LSS diagnosis and radiographic findings.

We recommended a trial of extension-based stretches and exercises along with education on the significance of his forward trunk lean posture and the use of a lumbar roll while sitting. He was advised to perform hourly extension exercises in the standing or supine posture and advised to stand from his chair

every 30–45 minutes. He was also provided with information describing the relationship between his exercises, improved walking tolerance, centralization, and peripheralization phenomenon. He was scheduled to return for a 24-hour follow-up reassessment.

Treatment day 2: 24-hour follow-up

During the 24-hour follow-up, the patient noted a significant reduction in his pain; this was partially attributed to the resolution of his right buttock and leg symptoms. His pain was now rated at a 2–3/10 on NRS and localized primarily to his left buttock and posterior thigh. He continued to endorse tingling in his left lateral calf and foot but denied numbness in either area. His resting posture and range of movement remained unchanged from his initial assessment but his gait pattern significantly improved, as he avoided forward trunk lean. He also began to centralize his left buttock pain to his left lower back region during mechanical testing.

Overall, his 24-hour follow-up exam revealed therapeutic progress with centralization of pain, improved posture, and decreased pain symptoms. He was reminded of the detrimental aspects associated with frequent standing, the importance of use of his lumbar roll, and was advised to continue with his hourly stretches. He was asked to follow-up in 1 week unless his symptoms returned or worsened.

Treatment day 3: 1-week post-assessment follow-up

Although the patient continued to endorse intermittent buttock and lower back pain, he reported resolution of his bilateral leg pain. He rated the intermittent pain at 1–2/10 on NRS and managed to control it with regular stretching. He also experienced intermittent left posterior thigh paresthesias, which did not extend beyond his mid-thigh. His mechanical testing revealed no significant changes in his range of movement from his previous visit. We repeated the repetitive movement testing and the results are displayed in Table 4. He was now able to walk 23 minutes on the treadmill until the onset of mild paresthesias in his left thigh and his ODI score was now 8. The patient was instructed to continue with his extension stretches 4–5 times a day and was scheduled to return to clinic in 2 weeks. His diagnosis of central symmetrical derangement syndrome below the knee was confirmed.

Table 1 Progression of active range of motion measured by dual inclinometer

	Lumbar flexion	Lumbar extension	Right-sided flexion	Left-sided flexion
Initial assessment	0–45°	0–10°	0–15°	0–10°
3-week follow-up	0–50°	0–15°	0–20°	0–20°

Note: This table illustrates active range of motion during initial assessment and 3-week follow-up.

Table 2 Initial repeated end range movement testing during initial assessment

Direction of movement	Number of repetitions	Pre-test symptoms	Test symptoms	Post-test symptoms	Mechanical response	Functional response pre-test (walking tolerance)	Functional response post-test (walking tolerance)
Flexion in standing (RFIS)	30	0/10	Produced buttock and leg pain radiating to the calf rated at 4/10	Not worse rated at 0/10	No change in AROM*	4 minutes	2 minutes
Extension in standing (REIS)	30	0/10	Produced buttock and back pain rated at 4/10	Not worse	No change in AROM*	30 seconds	15 seconds
Flexion in lying (RFIL)	30	0/10	No effect	No effect	No change in AROM*	45 seconds	7 minutes
Extension in lying (REIL)	30	0/10	No effect	No effect	No change in AROM*	5 minutes	10 seconds
						23 seconds	1 minute
						3 minutes	47 seconds
						38 seconds	8 minutes
							35 seconds

Note: This table demonstrates functional and mechanical responses to repeated end range movement testing during initial assessment.

*AROM: active range of movement.

Figure 1 Sagittal T2-weighted MRI-Demonstrating multilevel degenerative disc disease with disc protrusions at L3-L4 and L4-L5. Ligamentum flavum hypertrophy at L3-L4 with degenerative spondylolisthesis at L3-L4 is also noted.

Treatment day 4: 3-week post-assessment follow-up

During his final visit, the patient reported that his low back and buttock symptoms had essentially resolved with only sporadic mild lower back stiffness. He reported intermittent left thigh paresthesias. Mechanical testing demonstrated no change in his range of movement. Repetitive movement testing of repeated flexion in lying (RFIL), repeated flexion in standing (RFIS), repeated extension in standing (REIS), and repeated extension in lying (REIL) failed to reproduce any symptoms or mechanical response. Active range of motion testing of the lumbar spine was repeated and is displayed in Table 1. The three-step treadmill test was also repeated and was stopped after 10 minutes in the neutral, flexion, and extension postures because it

Figure 2 Axial T2-Weighted MRI-Tricompartamental spinal stenosis, L3-L4

Figure 3 Flexion Radiograph-Multilevel Degenerative disc disease with facet arthrosis and stable L3-L4 spondylolisthesis

Figure 4 Extension Radiograph-Multilevel Degenerative disc disease with facet arthrosis and stable L3-L4 spondylolisthesis

failed to reproduce his symptoms. His ODI was now scored at 0. He had moderate limitation of bilateral rotation and mild bilateral restriction of side glides.

The patient was advised to perform daily repetitive flexion movements in the supine posture and to continue with the extension stretches. The rationale for adding flexion stretches was to improve his mobility. He was discharged and requested to contact our office if his symptoms recurred.

Discussion

This case study describes a patient with a primary diagnosis of LSS, who benefited from a McKenzie MDT method treatment plan focused on improving his functional impairments and addressing his directional preference. The McKenzie MDT method is a unique approach to back pain because it classifies patients based on their subjective and objective findings rather than radiographic imaging.^{22,23} Moreover, it encourages patients to self-monitor and self-manage their symptoms. This approach begins with a thorough assessment of the patient's pain syndrome, including movements that aggravate or alleviate their symptoms, centralization and peripheralization phenomenon, and

a patient's directional preference. These factors typically guide treatment with the goals of centralization of symptoms and improved symptomatic and mechanical response.

Studies have shown that establishing a directional preference through the McKenzie method can be important in directing treatment for back pain.²⁹ Long *et al.* noted significant reductions in pain, disability levels, and pain medication usage after exercises were prescribed according to patient's directional preference.²⁹ She also found that patient's symptoms were aggravated by exercises that opposed their directional preference.²⁹

This case was unique because the patient lacked a directional preference on mechanical and repetitive movement testing but demonstrated a preference towards spinal extension upon treadmill testing. This contradicts the directional preference towards spinal flexion that is expected with LSS and suggests that he had an atypical presentation of LSS. Moreover, this provides a possible reason for his symptom persistence following traditional LSS therapies such as flexion-based exercises, and epidural injections. Potentially, this atypical presentation may be attributable to the L4–L5 spondylolisthesis or a discogenic component at

Table 3 Treadmill test comparison

	Time to initiation of pain in flexion posture	Time to initiation of pain in neutral posture	Time to initiation of pain in extension posture
Initial assessment	1 minute 12 seconds	3 minutes 15 seconds	8 minutes 53 seconds
2-week follow-up	No pain after 10 minutes	No pain after 10 minutes	No pain after 10 minutes

Note: This table demonstrates responses to three-step treadmill test during initial assessment and 2-week follow-up.

Table 4 Repeated end range movement testing progression

	Flexion in standing (RFIS)	Extension in standing (REIS)	Flexion in lying (RFIL)	Extension in lying (REIL)
Initial assessment	Produced buttock and leg pain radiating to the calf, not worse	Produced buttock and back pain, not worse	No effect	No effect
2-week follow-up	Produced bilateral buttock and leg pain to the knee, remain worse	Centralized pain to lower back	Produced bilateral buttock and leg pain to the knee, remain	Centralized pain to lower back
3-week follow-up	No effect	No effect	No effect	No effect

Note: This table demonstrates response to repeated end range movement testing throughout the treatment program.

this level. These alternative etiologies may have affected his functional response to repetitive movements and mechanical testing.

Our decision to focus on his functional impairment and treadmill directional preference rather than adopting traditional LSS therapies ultimately provided him with relief. The extension-based exercise program began to centralize pain to his lower back within a week; this is thought to be a crucial factor in successful recovery using the McKenzie method.^{30–32} Moreover, his symptoms had essentially resolved after 4 weeks of our therapy program. This supports the McKenzie method approach of treating a patient based on their assessments rather than their radiographic findings or prior diagnoses.

This case study illustrates the importance of determining a patient's directional preference before recommending a treatment plan. In clinical practice, a subgroup of patients may exist who fail to demonstrate a clear directional preference. The three-step treadmill test may be a useful tool to determine the directional preference for patients with LSS, as evidenced by this case. It is important to note that the three-step treadmill test is not traditionally performed during the initial assessment but that two-step treadmill testing has good test–retest reproducibility and was validated by Deen *et al.* in patients with LSS and neurogenic claudication.³³ A need for further studies to determine the reliability and validity of the three-step treadmill test exists. Further studies comparing extension-based treatment plans in patients with co-existing LSS and degenerative spondylolisthesis may be useful.²⁰

Conclusion

Here we present an example of a patient with LSS and concomitant degenerative spondylolisthesis who was successfully treated despite his lack of objective and subjective findings that typically guide McKenzie treatment plans.¹⁵ Although he was diagnosed with LSS through radiographic imaging, he did not demonstrate the centralization phenomenon or a directional preference towards spinal flexion that would be expected in LSS. He did however express significant functional changes post-repetitive movement testing and directional preferences during a three-step treadmill test. Together, these guided our

successful treatment plan. This case study is an example of functional response to mechanical testing and the use of a three-step treadmill test to determine directional preference in the setting of a patient without an obvious directional preference or centralization phenomenon. His response to extension-based exercises calls into question his original diagnosis and whether his condition may in fact be attributable to discogenic pain.

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