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Masterclass

Lumbar spinal stenosis-diagnosis and management of the aging spine

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ABSTRACT

Low back pain and lumbar spinal stenosis (LSS) is an extensive problem in the elderly presenting with pain, disability, fall risk and depression. The incidence of LSS is projected to continue to grow as the population ages. In light of the risks, costs and lack of long-term results associated with surgery, and the positive outcomes in studies utilizing physical therapy interventions for the LSS patient, a non-invasive approach is recommended as a first line of intervention. This Masterclass presents an overview of LSS in terms of clinical examination, diagnosis, and intervention. A focused management approach to the patient with LSS is put forward that emphasizes a defined four-fold approach of patient education, manual physical therapy, mobility and strengthening exercises, and aerobic conditioning.

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1. Introduction

Population projections by the United Nations estimate that between the years 2010 and 2040, the number of people in the world who are 65 years or older will increase from 8 to 14 percent and in more developed regions the percentage will increase from 16 to 25 percent (Population Reference Bureau, 2010). Prevalence studies indicate that currently up to 50% of the population over 65 experiences low back pain (LBP) (Bressler et al., 1999). These demographic trends highlight the need for physical therapists to become proficient in the management of the aging spine. The impact of LBP in the older population is far reaching and includes functional limitations (Scudds and Robertson, 1998; Weiner et al., 2003; Tong et al., 2007), mental health issues in relation to depression in the elderly (Weiner et al., 2003; Meyer et al., 2006), and balance deficits with associated increased fall risk (Yagci et al., 2007).

The patient with Lumbar Spinal Stenosis (LSS) suffers from both LBP and lower extremity (LE) symptoms. The most common LE complaint is either unilateral or bilateral intermittent neurogenic claudication, or a combination of LE pain, tension, and weakness that occurs with walking and is relieved with sitting. These symptoms are hypothesized to come either from neural compression, a local vascular deficiency, or both (Porter, 1996; Akuthota et al., 2003). Furthermore, recent pain sciences literature suggests that given the long standing nature of the LBP, there are likely abnormal pain processing mechanisms further contributing to the patient's problem (Giesecke et al., 2004).

As the population ages, an increasing number of people will be seeking medical care for pain and limited activities associated with LSS. Physical therapy interventions that involve impairment-based manual therapy, therapeutic exercise, patient education, and a walking program in patients with LSS provides a promising, low risk, and effective first alternative to operative management (Whitman et al., 2006). The purpose of this Masterclass is to describe the current physical therapy management approach of the patient with LSS.

2. Diagnosis

2.1. Imaging

Degenerative LSS is frequently described from an anatomical perspective as a narrowing of the spinal canal. Central spinal canal cross-sectional area determines the extent of the stenosis with $<75 \text{ mm}^2$ classifying absolute spinal stenosis through x-ray, Magnetic Resonance Imaging (MRI)-single and triple sequence, Computerized Tomography (CT), Ultrasound (US), and myelography (Lohman et al., 2006; Sirvancie et al., 2008). To date, we are unaware of an identified association between patient report of symptoms, functional outcomes (Oswestry), Visual Analog Scale (VAS), and anatomical impairment in patients with LSS (Beattie et al., 2000; Lohman et al., 2006; Geisser et al., 2007; Sirvanci et al., 2008). In fact, examination of asymptomatic subjects showed that >30% had canal narrowing that would be classified as consistent with LSS (Weisel et al., 1984;

Boden et al., 1990). Imaging therefore cannot be considered a gold-standard in diagnosis of LSS, and must only be considered as an adjunct to a thorough physical examination.

2.2. Physical examination

The clinical diagnosis of LSS, and exclusion of other competing diagnoses, is determined through the patients' history, determination of symptom characteristics, movement examination, gait analysis, balance tests, sensory-motor testing, palpation of peripheral pulses, treadmill testing, and assessment of an ankle brachial index (ABI). Differential diagnosis is needed to rule out pathological conditions with similar symptoms to neurogenic claudication such as spinal tumors, peripheral neuropathies, diabetic neuropathies, iliacus arterial involvement and local musculoskeletal abnormalities. Given an absence of a gold-standard for the diagnosis of LSS, the diagnostic tools discussed are based on comparison with expert opinion. Sugioka et al have recently developed and validated a clinical prediction rule (CPR) for the diagnosis of LSS which is solely based on patient self-report, however the magnitude of the likelihood ratio is not large (Sugioka et al., 2008). This CPR and other studies which have examined clinical diagnostic criteria for LSS are listed in Table 1.

As reflected in the CPR by Konno et al. (2007), the integrity of the LE vascular system must be ruled out as a source of intermittent claudication symptoms. This can be achieved by consideration of the patient history, observation of the LE skin texture and color, palpation of peripheral pulses, comparison of a treadmill verses a cycling exercise test (Dyck and Doyle, 1977), and performance of an ABI test (Hatala et al., 1997). A lower ABI (less that 1.0) suggests increased likelihood of Peripheral Artery Disease (PAD). At times the results of these examinations are not definitive because the older adult may have a "mixed" clinical picture which includes LE pain secondary to neurogenic claudication from LSS as well as vascular claudication symptoms from LE small vessel disease.

Thorough examination of the lower quarter is also required, and impairments in these regions will serve to direct specific intervention strategies. Typical impairments in this patient population include mobility abnormalities, especially hypomobility, in the thoracic spine, lumbar spine and hips (Whitman et al., 2003). Additionally, these patients often present with weakness in core trunk musculature and muscle imbalance around the hips. Additionally, gastrocnemius, leg length discrepancies, and significant impairments or faulty mechanics at the knee, ankle, or foot should be identified and considered in the overall management of the patient(Fritz et al., 1997a; Whitman et al., 2003).

3. Physical therapy management

A consistent four-fold approach to the physical therapy management of the patient with LSS is recommended. This distinct approach includes; patient education, manual therapy, exercise and aerobic training.

3.1. Patient education

Patient education is inherent to physical therapy practice and valued by those with clinical experience in the treatment of

Table 1
Diagnosis.

Diagnostic tools			
Reference	Examination		+ Likelihood ratio
Sugioka et al., 2008	Validated CPR		
	Characteristic	Assigned risk score	1.90 (with risk score ≥7)
	60–70 years old	2	
	>70 years old	3	
	Onset over 6 months	1	
	Decreased symptoms with forward bending	2	
	Decreased symptoms during backward bending	−2	
	Increased symptoms standing	2	
	Intermittent claudication pain	1	
	Urinary incontinence	1	
Konno et al., 2007	CPR		
	Characteristic	Assigned risk score	3.31 (with risk score >7)
	60–70 years old	1	
	>70 years old	2	
	Absence of diabetes	1	
	Intermittent claudication pain	3	
	Increased symptoms standing	2	
	Decreased symptoms with forward bending	3	
	Increased symptoms during backward bending	1	
	Good peripheral circulation	3	
	Abnormal Achilles DTR	1	
	Increased symptoms with forward bending	−1	
	Positive Straight leg raise	−2	
Katz et al., 1995	■ >65years old		2.5
	■ Absence of pain while sitting		6.6
	■ Severe LE pain		2.0
	■ Wide based gait		14.3
	■ Balance deficits Rhomberg testing		4.3
	■ Sensory-motor deficits.		2.1–2.8
Fritz et al., 1997a	Sitting identified as least painful position		3.1
Fritz et al., 1997a	Two-stage treadmill test; inclined verses level walking		
	■ Less time to symptoms while level walking		4.07
	■ Longer recovery post level walking		2.59

patients with LSS. The definition of LSS, the intent of the manual therapy and exercise interventions, the course of physical therapy, the purpose of the home exercise program (HEP), self-management strategies, pain sciences information, and prognosis comprise the patient education package. Concepts of foraminal cross-sectional area related to positioning should be used judiciously as an over-emphasis on anatomical explanations for the patients symptoms may contribute to a fear avoidance of activity and an over medi-calization of the problem (Breslau and Seidenwurm, 2000). The patient should be encouraged to identify activities and situations that cause discomfort and problem solve with the therapist to determine appropriate movement strategies and easing positions. Helpful advice may include items such as temporary avoidance of prolonged overhead activities, temporary avoidance of prolonged axial loading (standing, use of backpacks, prolonged overhead working postures), and methods of self lumbo-pelvic flexion and/or rotational stretching techniques for pain control in standing, sitting, and lying. Basic body mechanics are taught to the patient with LSS, and they should be advised to change positions frequently, know and respect their current limits, and to pace activities such as housework and yard work (Rademeyer, 2003; Vo et al., 2005). In addition, an explanation of the current concepts of pain as an "output and not an input" can help reframe the patient's relationship with the problem and motivate them to increase their functional status. Finally, patients should be aware of the natural course of this condition. Despite the frequent recommendations patients receive from the uninformed (including friends, relatives, and medical providers), patients should know that the majority of those with LSS do quite well over time, their condition either remaining the same or improving over time with no intervention at all (Johnsson et al., 1991) and that long term results are often no different when comparing those who received surgery for LSS and those who were treated non-surgically (Atlas et al., 1996, 2000, 2005).

3.2. Manual therapy

A recent systematic review by Reiman et al. (2009) concluded that the use of manual therapy in conjunction with exercise is of potential benefit for the LSS population. In a randomized controlled trial (RCT) by Whitman et al. (2006), as well as in all of the lower level studies identified by Reiman et al. (2009) (prospective cohorts, case series and case report studies), utiliza-tion of manual therapy in a management program is associated with improvements in pain and disability. It is interesting to note that the manual therapy used in these studies was not of uniform technique nor applied only to one region. The techniques used in these studies were varied, and included both thrust and non-thrust manipulation/mobilization. Successful results were repor-ted with techniques described as follows: flexion–distraction manipulations, sidelying lumbar rotation thrust, posterior-to-anterior mobilizations, sidelying translatoric side bending manipulations, thoracic thrusts, neural mobilizations (DuPriest, 1993; Atlas et al., 1996, 2000, 2005; Simotas et al., 2000; Snow, 2001; Whitman et al., 2003; Creighton et al., 2006; Murphy et al., 2006).

In the single RCT utilizing manual therapy for patients with LSS identified by Whitman et al. (2006); Reiman et al. (2009) demon-strated that in 58 patients diagnosed with LSS treatment through the use of manual therapy, flexion and impairment-based exercises, and body weight supported treadmill walking was superior to flexion exercises, treadmill walking and sub-therapeutic ultra-sound. The patients in the group receiving manual therapy were treated by 8 experienced manual therapists. These therapists used a variety of thrust and non-thrust manipulative techniques,

depending on the patient's presentation and the therapist's clinical judgment. This eclectic, impairment-based treatment approach was applied to the thoracic and lumbar spine, pelvis, and lower extremities. See Fig. 1 for more details regarding the regions treated and types of interventions performed in this trial. After six weeks of biweekly treatment, perceived recovery as defined as +3 ("some-what better") or greater on the Global Rating of Change scale, was significantly higher in the group receiving manual therapy, body weight supported treadmill walking and impairment-based exer-cise. Although not significant, this trend continued at the one year follow-up. Secondary outcome measures of the Modified Oswestry Disability Index, a treadmill walking test, Numeric Pain Rating scale and the satisfaction subscale of the Swiss Spinal Stenosis scale also favored the group receiving manual therapy at 6 weeks and one year.

From the limited research available, the combined use of manual therapy and exercise in the patient population with LSS appears to be an effective intervention. Typical techniques are illustrated in Appendix A. Manual therapy appropriately used with this population involves not only the lumbar region but also the thoracic region, pelvis, hips and lower extremities. In essence, the concept is to treat all elements of the "musculoskeletal system" involved in upright ambulation. The recommended manual therapy approach is impairment-based and most commonly involves thrust and non-thrust mobilization/manipulations to the lumbar and pelvic regions. These interventions frequently emphasize rotation, flexion and distraction, but may involve other techniques dependent upon the individual patient presentation. Additionally, identified hypomobilities in adjacent areas are addressed. Generally, techniques aimed at improving thoracic spine extension are employed.

Normalization of hip motion appears to be a key element for the successful treatment of patients with LSS. Distraction manipulation of the hip is a valuable intervention technique for restoration of hip motion and function (Hoeksma et al., 2004). The majority of patients should benefit from an anterior glide mobilization of the hip, along with manual stretching of the iliopsoas and rectus femoris. Inferior, posterio-lateral and caudal glides may also be useful. Furthermore, impairments at the knee, foot and ankle should be addressed as indicated. Generally, techniques aimed at improving hip and knee extension and ankle dorsiflexion are employed.

The choice of a particular procedure appears less important than the introduction of movement in these areas through manual techniques. The only reported adverse events in studies using
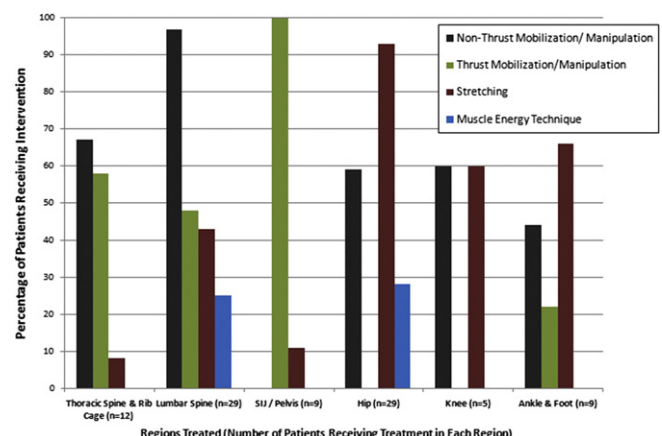

Fig. 1. Manual therapy interventions provided in RCT by Whitman et al.

thrust or non-thrust mobilization/manipulation techniques in this population are minor, transient soreness in a small percentage of patients (Murphy et al., 2006).

3.3. Aerobic training and exercise intervention

Overall exercise is a very important part of the plan of care for these patients. An evidenced based guideline from the North American Spine Society concluded through work group consensus that treatment by a physical therapist and exercise may be beneficial for those with LSS and neurogenic claudication (Watters et al., 2008). Although commonly utilized in the LSS population, higher level evidence supporting the utilization of exercise specifically in patients with LSS is sparse. Exercise prescription based on expert consensus is done with the purposes of providing improved overall fitness and function, an adjunct to manual therapy techniques, increased available cross-sectional area of the spinal canal, vascular changes, and self-management. The hemodynamic changes that occur with movement provide a theoretical basis for the positive, symptom-reducing effects of exercise (Watanabe and Parke, 1986; Baker et al., 1995; Jespersen et al., 1995; Takahashi et al., 1995; Iwamoto et al., 1997; Akuthota et al., 2003). Individualized exercises specific to patients with LSS often include components of unweighted walking or cycling, spinal mobility and lumbar flexion exercises, hip mobility exercises, hip strengthening, and core strengthening.

Unweighted treadmill walking has been part of a physical therapy plan of care in several studies for patients with LSS (Fritz et al., 1997a; Whitman et al., 2003, 2006). Patients are unweighted to the extent that pain is relieved in order that they can ambulate with good quality movement and pain-free for 30 min (Fritz et al., 1997a). The amount of unweighting is lessened over time as per the patient's response. Fig. 2 shows a patient on the unweighted treadmill. For those who do have unweighting systems available in their clinics, our experience is that patients will have a fairly dramatic response to the unweighting within the first couple of sessions of using the equipment for their aerobic exercise. If a patient does not have a substantial positive response within the first couple of sessions, we recommend cycling, walking on an inclined treadmill, or other forms of "unloading" such as pool walking. Pua et al. (2007) in an RCT demonstrated that cycling was just as effective as unweighted treadmill walking; therefore cycling is a viable alternative for use as an in-clinic exercise for those without unweighting equipment. Patients are advised to include an aerobic exercise/walking program at home, especially as soon as they are able to either control their lumbo-pelvic position to walk without pain or know how to quickly resolve symptoms to rest and return to walking. In our opinion, this approach of specifically encouraging a walking program is theoretically helpful for: (1) improving cardiovascular fitness (potentially improving oxygenation of small vessels impacted by the stenosis), as well as helping in treatment of any concomitant peripheral arterial disease, (2) allowing the patient to immediately use any gains in mobility and strength, (3) decreasing fear avoidance issues related to walking, (4) improved pain modulation through stimulation of large motor pathways. Appendix B is a clinical flow sheet for aerobic training.

Improved flexibility is frequently a key to intervention, as the presentation of the patient with LSS is often one of overall stiffness. Individually identified flexibility impairments can be addressed through manual therapy and self-stretching taught as a home exercise program. Lumbar flexion exercises have long been a foundation of treatment for those with degenerative spinal conditions and are thought to improve spinal flexibility, increase the foraminal cross-sectional area and improve hemodynamics. Several case studies and one RCT have used flexion exercises

Fig. 2. Unweighted treadmill walking.

successfully in the treatment of LSS (Fritz et al., 1997b; Whitman et al., 2003, 2006; Creighton et al., 2006; Murphy et al., 2006). Other spinal flexibility exercises typically given to the patient include thoracic extension self-mobilization or stretching exercises and lumbar rotation exercises. Patients often experience immediate relief of lower extremity symptoms with the sidelying lumbar rotation exercise (see Appendix C). This is frequently one of the first exercises taught to patients. Interventions targeted at maximizing thoracic extension are important because, at least theoretically, more flexibility in this region should lessen the extension range of motion required of the lumbar spine during standing and with walking.

The ability to move the hip, especially into extension, without concomitant lumbar extension is frequently necessary for pain free ambulation in the patient with LSS. In addition to manual therapy at the hip, the patient can perform hip flexor stretching while maintaining a Posterior Pelvic Tilt (PPT) (Fritz et al., 1997a; Rademeyer, 2003; Rittenberg and Ross, 2003; Whitman et al., 2003; Yuan and Albert, 2004; Vo et al., 2005). Other muscles around the hip, such as the hamstrings, rectus femoris, piriformis and tensor fascia latae can become shortened and the patient may respond positively to manual and self-stretching of these muscles. Weakness in the hip extensors and abductors complete the picture of typical muscle imbalances in the hip region of the patient with LSS, and should be addressed through a progressive resistive exercise program that is vigorous

enough to affect strength change (Fritz et al., 1997a; Rittenberg and Ross, 2003).

Core strengthening/stabilization is a mainstay of most treatment programs for LBP. Therefore, most patients with LSS are appropriate for some level of core strengthening, especially those with impaired strength or motor control of the abdominal and lumbar musculature. It is expected that most core strengthening will be done with a flexion bias and will attempt to allow the patient to control pelvic position and motion to minimize symptoms while standing and walking (Fritz et al., 1997a; Simotas et al., 2000; Rademeyer, 2003; Rittenberg and Ross, 2003; Whitman et al., 2003; Yuan and Albert, 2004; Vo et al., 2005). Specifically, patients can be taught to temporarily use a PPT to relieve symptoms, or even to maintain a slight PPT to lessen or avoid symptoms entirely while standing and/or walking.

Specific evidence directing dosage of exercise prescription is lacking in the patient population with LSS. A resulting problem of under-treating exists in which the clinician, likely due to a bias toward the patient's age, does not require an overload of the muscles or enough of a cardiovascular load with aerobic exercise during the prescribed exercise program. Co-morbities must be taken into account, but not applying the same strengthening and aerobic conditioning principles to these patients as is done for younger patients is a disservice and may keep the patient from reaching their maximum potential.

Exercise is essential to the treatment of the patient with LSS. Therapists must have a wide range of exercises available as patients with LSS present with a wide range of functional levels and frailty. LSS affects the senior athlete as well as the homebound. Appendix C is a package of commonly prescribed exercises that are often used in a home exercise program for patients with LSS.

4. Medical management

Management of spinal stenosis ranges from non-invasive measures including referral to a physical therapist, prescription medications such as nonsteroidal anti-inflammatories and opioids, to more invasive techniques such as epidural steroid injections and decompressive surgery (Delport et al., 2004; Campbell et al., 2007).

Epidural steroid injections (ESI) are increasingly used to relieve patients' symptoms. Several studies of low level evidence have reported some benefit from ESI in patients with spinal stenosis, however a systematic review concluded that the evidence is lacking and recommend more strenuous studies be performed (Nelemans et al., 2005; Buenaventura et al., 2009). Complications have been reported and include minor complications such as transient non-positional headaches, increase in low back pain, and an increase in leg pain. Rare major complications include cardiac and respiratory arrest.

Examination of Medicare records over 2002–2007 reveals that the trend in surgery has risen dramatically toward the use of increasingly complex fusion procedures with a corresponding rise in life-threatening adverse events, length of stay, re-hospitalization, costs, and mortality (Deyo et al., 2010). For the population with stable lumbar spinal stenosis, taking on this risk rather than pursuing a course of non-operative care has not been proven to be the best course of action (Weinstein et al., 2009). In fact, long term observational studies report that the long term results of surgery do not differ from the results of a conservative course of care (Atlas et al., 1996, 2000, 2005; Park et al., 2010). Decompressive surgery may be of benefit when the symptoms are intractable, functionally limiting and unresponsive to conservative treatment régimes. Converse to the trend of using complex, instrumented fusion techniques, select surgeons are employing a minimally invasive technique, using outpatient surgery and an interspinous process spacer to decompress the neural structures.

Cochrane reviews concluded that the efficacy of surgical verses non-surgical approaches cannot be determined by the current research (Gibson et al., 1999; Gibson and Waddell, 2005). Studies of surgery verses conservative treatment that conclude surgery as a superior treatment option often do not specify the details of the conservative treatment, which can range from completely undescribed (Mariconda et al., 2002) to patient education and hyperextension bracing (Amundsen et al., 2000) to non-descript physical therapy and a variety of alternative non-invasive treatments (Chang et al., 2005; Weinstein et al., 2008). The number of physical therapy sessions is often absent or is limited to as low as 4 visits, questioning the therapeutic value of such a limited time frame (Malmivaara et al., 2007). Therefore, without a standard for conservative care, it is difficult to conclude that the positive results genuinely support surgery over a course of well defined, impairment-based physical therapy. Patient selection for surgery is also ill-defined, lacking guidelines indicating who is most likely to benefit from surgery over a course of conservative treatment and there is evidence that the decision to perform back surgery may be geographically driven (Birkmeyer and Weinstein, 1999; Atlas and Delitto, 2006). Further studies determining the sub-groups that are most responsive to either surgical or non-surgical interventions are needed.

The appropriateness of surgery may be linked to whether or not the patient has concomitant spondylolisthesis. In the Spine Patient Outcome Study (SPORT), patients with lumbar degenerative spondylolisthesis were randomized into either a surgical group or into a non-surgical group consisting of "usual non-operative care". Those surgical LSS patients who also presented with spondylolisthesis had improved outcomes in terms of pain relief, function and overall satisfaction over those who had non-operative treatment at two and four years (Weinstein et al., 2009).

Spinal surgery for LSS carries significant risks and is a high cost procedure with diminishing returns. Patients stay for an average of 2.7–4.6 days in the hospital, dependent upon the type of surgical procedure and 20% of those undergoing complex procedures have slow recoveries requiring discharge to skilled nursing facilities (Deyo et al., 2010). Adverse events, such as dural tears, infection, wound complications, thromboembolic complications, epidural hematomas, nerve root injuries, instability, non-union, hardware failure and degeneration in adjacent segments and recurrent symptoms are reported (Malter et al., 1998; Carreon et al., 2003; Ragab et al., 2003; Yuan and Albert, 2004; Deyo et al., 2010). Life threatening complications occurring in 3.1% of patients undergoing surgery include; cardiopulmonary resuscitation, repeat endotracheal intubation and mechanical ventilation, cardiorespiratory arrest, acute myocardial infarction, pneumonias, pulmonary embolism, and stroke (Deyo et al., 2010). This rate increases to 5.2% for those undergoing more invasive, complex, and increasingly frequent procedures (Deyo et al., 2010). Death related to the surgery is possible but rare (Benz et al., 2001). Early mortality rates are 0.4% (Deyo et al., 2010). Re-operation rates range from 5% to 23% (Chang et al., 2005; Jansson et al., 2005). Along with the consideration of surgical risk, the long term benefit of surgery must be considered. The Maine Lumbar Spine Study followed two groups of LSS patients over time; one group underwent surgery and the second group was a non-operative group. Although the surgical group fared better in the short term, there was no significant difference between the surgery and non-operative groups of patients over the long term (Atlas et al., 1996, 2000, 2005). Similar to the Maine Study, in a subanalysis of the SPORT study, the researchers concluded that early trends favored

surgical outcomes for all LSS patients, but the positive effects declined over time. The authors recommended that those patients without scoliosis or degenerative spondylolisthesis can be managed adequately non-operatively regardless of the number of spinal levels that appeared stenotic (Park et al., 2010). The patient who makes the decision to undergo surgery should be adequately informed in order to weigh the risks of surgery, and the long term outcomes against his/her disability.

5. Conclusion

Demographic trends in the aging population and in the incidence of low back pain indicate that lumbar spinal stenosis is a condition that will be seen with increased frequency by manual physical therapists. It is currently diagnosed by a cluster of clinical examination findings augmented by imaging techniques. Patients with LSS are complex patients, often with chronic symptoms and significant comorbid conditions. Given the prevalence of LSS, the costs and mortality/morbidity of invasive treatment options, and similar efficacy results for low back pain relief over an 8–10 year period between those treated surgically and non-surgically, we recommend that patients receive a trial of an intensive, defined program of manual physical therapy and exercise before pursuing more invasive intervention options(Atlas et al., 2005; Deyo et al., 2010).

Growing evidence supports the use of manual physical therapy combined with exercise and aerobic training for safe, effective intervention with these patients. A four pronged approach including patient education, manual therapy, mobility and strengthening exercises, and aerobic training is recommended as the standard of conservative care. The manual physical therapy is directed not only to the lumbar spine, but to the thoracic spine, pelvis and lower extremities, and particularly the hips. It appears that effective manual intervention is not dependent upon a specific technique or manual therapy system, as long as appropriate movement is introduced to these areas and muscle balance impairments are addressed. Therapeutic exercise used with the LSS patient should be impairment based, supplement manual therapy, and initially biased toward lumbar flexion motions and lower quarter strengthening. Aerobic training may be achieved in many ways, but may be best addressed with progressive body-supported ambulation, ambulation on an inclined treadmill, or stationary cycling.

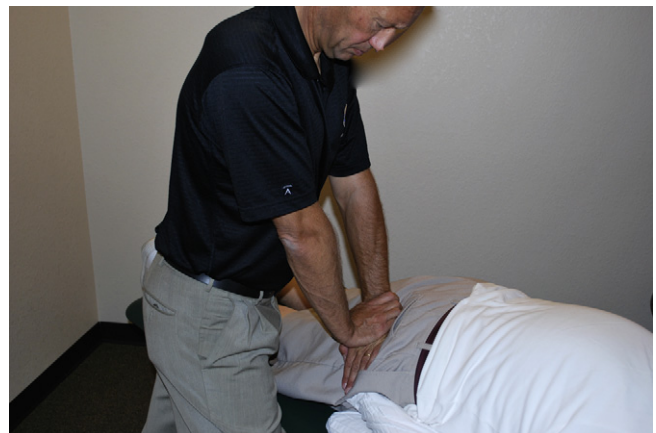**Appendix A2. Sidelying translatory lumbar manipulation**
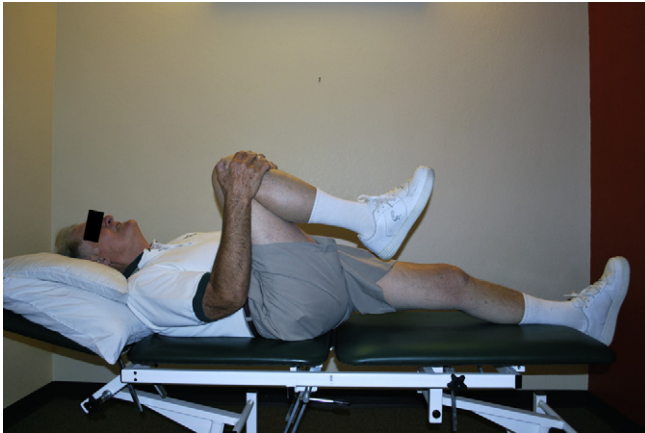

Appendix A3. Supine hip distraction manipulation

Appendix A1. Sidelying rotational lumbar manipulation

Appendix A4. Prone hip posterior–anterior mobilization

Appendix A5. Supine hip lateral glide mobilization

Appendix A6. Supine hip inferior glide mobilization

Appendix A7. Supine manual hip flexor stretch

Appendix A8. Prone thoracic manipulation

Appendix. B1: Aerobic training flow sheet

Appendix B: Aerobic Exercise Flowsheet

AEROBIC TRAINING		Patient Name:									
DATE	BP		HR		RR		RPE	TIME	SPEED	% GRADE/ RESISTANCE	%UNWEIGHTED
	pre	post	pre	post	pre	post	end of session				

Appendix. C1: Single knee to chest exercise

Appendix. C4: Thoracic extension self-mobilization
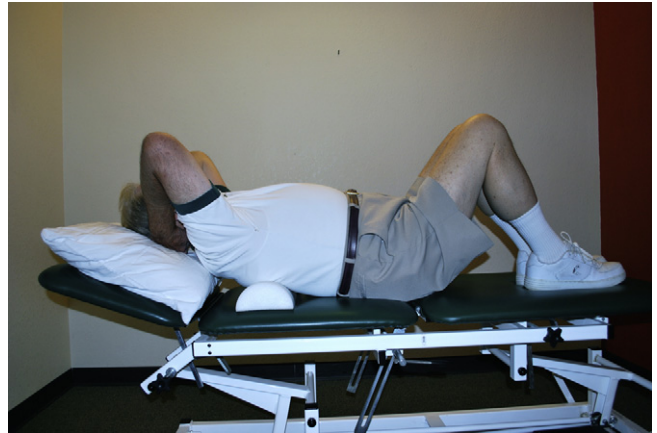
Appendix. C2: Double knee to chest exercise
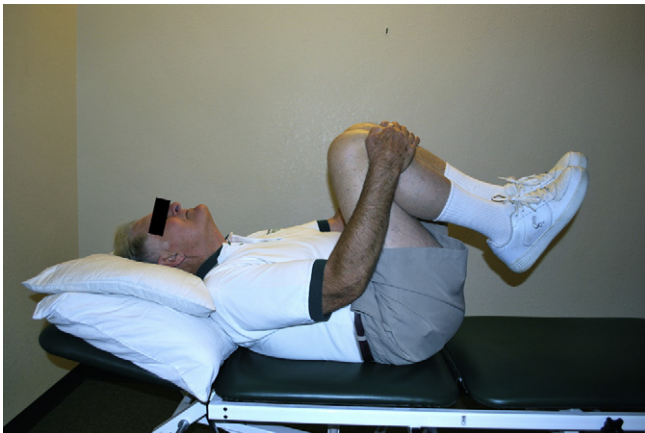
Appendix. C5: Lower abdominal strengthening exercise

Appendix. C3: Lumbar rotation stretch

Appendix. C6: Hip abduction strengthening exercise

Appendix. C7: Rectus femoris self-stretch

Appendix. C8: Iliopsoas self-stretch

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