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Low Back Pain and Mechanical Diagnosis Treatment: A Case Report

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LOW BACK PAIN AND MECHANICAL DIAGNOSIS TREATMENT: A CASE REPORT

By

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This Scholarly Project, submitted by Alicia Bullinger in partial fulfillment of the requirements for the Degree of Doctor of Physical Therapy from the University of North Dakota, has been read by the Advisor and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

Shawnn Decker
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Permission

Title:	Low Back Pain Treated by Mechanical Diagnosis Treatment: A Case Report
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Signature Alicia Bullyn

Date 12/8/16

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Abstract:

Background and Purpose: Acute low back pain is one of the most common and expensive reasons for adults to see a family physician and is commonly treated by physical therapists. Although most patients recover quickly with minimal treatment, patient education and exercises directed by a physical therapist may decrease recurrent pain and need for health care services. The purpose of this case study is to determine if the McKenzie Method is effective treatment for acute low back pain in the medical workforce using evidence based practice.

Case Description: Patient was a 37-year-old Caucasian female who worked as a registered nurse in a rural hospital. She experienced acute low back pain injury when attempting to transfer a patient. Patient stated there was an audible "pop," in her back at time of injury. Patient was prescribed Flexeril and Percocet in the emergency department and was experiencing high levels of pain with radiating symptoms from her right low back into her right foot.

Outcomes: The patient responded well to initial treatment. Patient was able to meet her short term and long-term goals while using the McKenzie Method with only 4 treatment sessions.

Discussion: Overall, the patient responded well to the McKenzie treatment approach. It seems that further research needs to be completed on the efficacy of McKenzie treatment despite the positive outcomes in this case study. Limitations exist due to the lack of functional assessment application.

Chapter One: Background and Purpose

Acute low back pain (LBP) is one of the most common and expensive reasons for adults to see a family physician[1,2]. This condition is commonly and effectively treated by physical therapists. Research has shown little to no support for the efficacy of ultrasound, laser, traction, thermal modalities, electrical stimulation, and acupuncture or bed rest in the treatment of mechanical LBP [3,4,5,6]. However, evidence does show support for short-term benefits acquired through exercise, non-steroidal anti-inflammatory drugs, patient education, behavioral modification and joint manipulation[7,8,9,10].

The spine is made of a combination of bones, ligaments, tendons, muscles and highly sensitive nerves and nerve roots[11]. Its purpose is to protect these highly sensitive nerve roots while still providing a wide range of mobility in many different planes of movement[12]. Most people take this versatility for granted except for those who suffer from chronic or acute low back pain. These people are driven to seek treatment to relieve their pain and prevent a recurrence.

Many different structures in the spine can cause back pain including: irritation of the large nerve roots, irritation of the smaller nerves that innervate the spine and subsequent musculature, strain on the erector spinae muscles, and injury to the bones, ligaments, joints or the intervertebral disc[13]. The lower back has more motion than the rest of the spine and also carries all the weight of the torso. Increased motion and body weight make the low back the most frequently injured area of the spine[14].

The lumbar segment of the spine consists of the facets and the posterior and anterior longitudinal ligaments along with the lumbar disc. The facets are sagittal in orientation and promote flexion and extension of the lumber spine[15]. The posterior longitudinal ligament is narrow but provides some stability to the posterior wall of the disc and helps protect the anterior side of the spinal canal. The anterior longitudinal ligament is broad and thick. It primarily resists hyperextension of the lumbar spine but also provides good anterior disc wall stability.

The lumbar disc contains the nucleus pulposus and the annulus fibrosus. The nucleus pulposus is the shock absorber of the spine and allows the vertebral segments to pivot. It is non-innervated and non-vascular in nature[16]. The annulus fibrosus is composed of tough, fibrous connective tissue and provides structural integrity of the disc while containing the nucleus. It differs from the nucleus as it does have nociceptive and proprioceptive innervation[17].

According to the dynamic internal disc model lumbar flexion compresses the anterior portion of the disc causing the nucleus to move posteriorly while extension causes the posterior section to compress and the nucleus to move anteriorly. Lateral flexion and rotation result in contralateral movement of the nucleus[18].

The motion in the lumbar spine is divided between the L1-L5 vertebral segments. The lower segments (L3-L5) possess more motion than the upper segment (L1-L3). The lower two segments are the most likely to result in injury. The two lowest discs (L4-L5 and L5-S1) take the most strain and are the most

likely to herniate. This can cause low back pain and numbness that can radiate down the leg and into the foot.

Most patients recover quickly with minimal treatment, patient education and exercises directed by a physical therapist. The McKenzie Method, now known as Mechanical Diagnosis Treatment (MDT), may decrease recurrent pain and the need for health care services[19]. MDT is a reliable assessment process intended for all musculoskeletal problems including LBP using a well-researched, exercise-based approach of assessment, diagnosis and treatment to create a comprehensive evaluation of patients without the use of expensive diagnostic imaging[20].

The treatment principles of MDT promote the body's potential to repair itself and do not involve the use of medication, heat, cold, ultrasound, needles or surgery. This ultimately empowers patients to learn the principles and control their own symptom management that in turn reduces dependency on medical intervention.

MDT is comprised of four primary steps: assessment, classification, treatment and prevention. Most musculoskeletal pain is mechanical in origin. This means that a position, movement or activity caused the pain to start. The MDT system is designed to identify the mechanical problem and develop a plan to correct or improve the mechanics and thus decrease or eliminate the pain and functional problems[21].

Robin McKenzie identified three syndromes primarily associated with MDT. Those syndromes are Postural, Dysfunctions and Derangements. The

Postural Syndrome is the response of normal tissue to abnormal loading and pain results from mechanical deformation of soft tissues or vascular insufficiency from sustained positional or postural stresses. The Dysfunction Syndrome is pain that is caused by mechanical deformation of abnormally shortened soft tissue such as scar tissue, contractures, adherence or adaptive shortening. This pain is only felt when the abnormally shortened tissues are on stretch. Lastly, the Derangement Syndrome is an internal change in the normal resting position of affected joint surfaces. It is the displacement of articular tissue of any origin and that causes pain or obstructed movement until the tissue has been returned to its normal position[22].

Studies have looked at prognostic factors in the literature that may help predict those at risk of poor recovery from work related low back pain[23]. Those whose symptom duration was greater than 6 months had significantly less functional improvement than those whose symptom duration was less than 1 month[24].The functional improvement score is influenced by age, symptom duration, and inclusion of mobilization/manipulation, strengthening and flexibility exercises.

The treatment of low back pain (LBP) is also heavily influenced by cost and poses an enormous economic burden to society[25]. These costs are direct and indirect ranging from medical costs to loss of productivity. Mean direct and indirect costs for LBP care are about twice as high for patients with chronic LBP compared to acutely ill patients[26]. Indirect costs account for more than 52% to 54% of total costs and about 25% of direct costs refer to therapeutic procedures

and hospital or rehabilitation care. Patients with high disability and limitations in daily living show a 2- to 5-fold change for subsequent high healthcare costs. In a study with 1,843 participants, nearly 14% were receiving work disability compensation after 1 year[27].

Physical therapists familiar with the MDT use spinal stabilization exercises to identify a subgroup of patients with LBP. These patients have pain that is rapidly reversible allowing return to full function[28]. This method uses a single patient-specific direction of preference using simple end-range low back exercises and some posture modifications. Studies targeting MDT have focused on patients whose persisting pain had led to recommendations of disc surgery where 50% were then found to still have a rapidly reversible disc problem with high rates of nonsurgical rapid recovery. Using this form of evidence-based MDT can result in tremendous cost savings and greatly improved clinical outcomes. Based on logistic regression analysis there was a lower risk of subsequent medical service usage among patients who received physical therapy early after an episode of acute low back pain relative to those who received physical therapy at later times[29]. The purpose of this case study is to determine if the McKenzie Method is the appropriate treatment for acute low back pain in the medical workforce using evidence based practice.

Chapter Two: Case Description and Examination

The patient was a 37-year-old Caucasian female with a Body Mass Index (BMI) of 27. She worked midnight shifts as a registered nurse in a rural hospital and was a single mother of a 10 year old boy. She enjoyed participating in a recreational fitness program at home and reported no previous LBP incidences.

The patient was in a lot of pain from lifting and transferring a 350-pound patient at work. Patient stated that she heard her back "pop," at time of injury but thought that she was fine to continue working. After three days of continued work she finally sought medical attention at the emergency room due to intolerable pain. The patient was prescribed Flexeril and Percocet from the emergency department's physician and was referred to her primary care physician who subsequently referred her to physical therapy.

On her initial visit to physical therapy, patient described her pain using the visual analog scale (VAS) (with 0 being no pain and 10 being the worst pain possible) as a 7/10 with complaints of radiating pain from her right low back into her right foot continuously since the time of injury. She stated that her low back pain was daily and constant with brief alleviation by repositioning. However, her radiating symptoms into her foot were intermittent and described as numbing, tingling, shooting and burning sensations which worsened after prolonged periods of sitting (lumbar flexion) such as driving. Patient also reported loss of sleep due to pain and symptoms.

Patient's self-reported prior level of function was independent with activities of daily living (ADL) and transfers. Her ADL requirements included

working as a nurse, lifting, carrying or pulling objects greater than fifty pounds. Patient lived in a manufactured home with a five step entry and bilateral hand rails. Patient reported taking Topamax, Claritin, Albuterol and a multivitamin prior to injury onset. Patient denied a relevant past medical history other than migraines from neck pain and hip problems but no previous episodes of low back pain. There were no diagnostic tests performed or ordered from either the emergency department or the patient's primary care physician.

The patient displayed a guarded posture favoring the right low back and leg while seated and standing. This posture was typical of a relevant lateral component in MDT, a derangement that does not respond in the sagittal plane, but responds to application of force lateral. She also displayed an exaggerated lumbar lordosis and an antalgic gait favoring the right lower extremity.

Upon physical therapy evaluation and palpation, it appeared that the patient's pain and symptoms were radiating from level L4-L5 and L5-S1 of the spine. The patient had greatly increased point tenderness in this region making it difficult to fully assess her mechanical problems.

The patient's range of motion (ROM) was limited in forward flexion with patient's fingertips able to reach her knees using a ratcheting motion due to increased pain. Patient displayed the same ratcheting motion with lumbar extension, but was only limited by 25% of motion due to pain. Her pain decreased with lumbar extension when hips were laterally shifted to the right. During right side bending the patient was able to reach fingertips to mid thigh with a guarded

posture and complaints of pinching in her low back. She was able to reach to her knee during left side bending while displaying the same guarded posture.

Patient's hamstring, anterior tibialis, fibularis, and extensor hallicus strength were equal bilaterally while quadriceps strength was diminished on the right. Results of patient's manual muscle testing are listed in table 1.

Table 1

Right Lower Extremity Manual Muscle Testing	**Left Lower Extremity Manual Muscle Testing**
Hip Flexors: 3/5	Hip Flexors: 5/5
Quadriceps: 3/5	Quadriceps: 5/5
Anterior Tibialis: 4/5	Anterior Tibialis: 5/5
Extensor Hallucis: 4/5	Extensor Hallucis: 5/5
Fibularis Muscles: 4/5	Fibularis Muscles: 5/5
Hamstrings: 4/5	Hamstrings: 5/5

Table 1 depicts the results of manual muscle testing.

Patient's lower extremity sensation and tone was normal bilaterally. Patient was hypoflexive bilaterally for L3 and S1 reflex testing of the quadriceps and achilles tendons respectively. Patient was positive to the right and negative to the left for a supine straight leg raise (SLR) test. Patient displayed a positive jump sign (an involuntary reaction to stimulation of a tender area or trigger point) with palpation of the posterior superior iliac spine and L4-S1 regions. She was tender to palpation at right paraspinals and sacroiliac joint with muscle spasms noted. The physical therapist was unable to assess the patient's segmental mobility due to pain and point tenderness along with other commonly used special tests. These other tests, or concordant signs in MDT include, the Slump, Prone Knee Bend, and Segmental Instability.

The SLR test is considered a routine test during the examination of the lumbar spine among patients who present with sciatica as it tests the lumbosacral plexus by stressing the sciatic nerve[30]. An ipsilateral SLR has 72-97% sensitivity but 11-66% specificity for a herniated intervertebral disc. A leg elevation of less than 60 degrees is abnormal and suggests compression or irritation of the nerve roots. A positive test reproduces the symptoms of sciatica with pain that radiates below the knee, not merely back or hamstring pain.

A myotome is defined as a muscle or group of muscles served by a single nerve root. Myotome testing confirmed patterned weakness for an L4-L5 and L5-S1 nerve root due to the right lower extremity weakness compared to the left lower extremity. The right lower extremity weakness was greater for the L4 nerve root affecting hip flexion, knee extension and hamstrings the greatest with mild deficits in the tibialis anterior, extensor hallicus longus, and fibularis longus and brevis.

Dynamic testing involves repeated movements in specific directions. Repeated movements can give the clinician some valuable insight into the patient's condition. Internal derangements tend to worsen with repeated motions while the symptoms of postural dysfunction remain unchanged. Repeated motions can indicate the irritability of the condition, as well as indicate to the clinician the direction of motion to be used as part of the intervention. If pain increases during repeated motion in a particular direction, exercising in that direction is not indicated. If pain only worsens in part of the range, repeated motion exercises can be used for that part of the range that is pain-free, or which does not worsen

symptoms. Pain that is increased after the repeated motions may indicate a re-triggering of the inflammatory response, and repeated motions in the opposite direction should be explored.

Forward flexion or the fingertip-to-floor test (FTF) was performed in conjunction with the SLR during examination. The FTF has good validity in patients with acute/subacute LBP, and even better validity in those with radicular pain as compared to the SLR at 1 month and 1 year post treatment[31,32].

Range of motion deficits and the positive SLR on the right were consistent with a right L4-L5, L5-S1 disc herniation. Following these findings the physical therapy diagnosis was documented as a disc herniation at the level of L4-L5. According to MDT, this patient would be diagnosed having a lumbar disc derangement with a significant lateral component.

Intervention

It was decided to use the McKenzie Extension Pattern for treatment. Treatment successes using the McKenzie method can be predicted using certain demographic and clinical factors including: age, gender, pain duration, pain location, spine region, McKenzie classification, therapeutic force, and centralization/abolition of symptoms[33]. Typically patients with pain duration less than 12 weeks had 7 times greater success rates than patients with longer pain duration and patients with back pain had odds of success about 3.5 times greater using the McKenzie method. Patients with centralization or abolition of pain had odds of success about 2.7 times greater than those without these symptom responses. Following the physical therapy examination it was evident that the patient favored an extension pattern for AROM which seemed to centralize her symptoms. Her treatment is described in table 2.

Table 2

Initial Treatment: VAS 7/10	**Second Treatment: VAS 6/10**
Extension in lying with hips placed laterally to the right: 3 sets x 5 reps x patient's tolerance Extension in lying with hips in neutral: 3 sets x 5 reps x patient's tolerance Extension in lying with hips placed laterally to the right PT overpressure at L4-S1: 3 sets x 5 reps x patient's tolerance Cold packs x 15 minutes to patient's low back to calm inflammation	Extension in lying with hips placed laterally to the right: 3 sets x 5 reps x patient's tolerance Extension in lying with hips in neutral: 3 sets x 5 reps x patient's tolerance PT overpressure in prone at L4-S1: 3 sets x 30 sec x grade 1-2 Prone hip extension: 1 set x 5 reps x patient tolerance Cold packs x 15 minutes to patient's low back with pillow placed under the hips to reduce right radicular symptoms and to calm inflammation
Third Treatment: VAS 4/10	**Final Treatment: VAS 0/10**
Extension in lying: 1 set x 10 reps x 5 sec Extension in lying with PT overpressure at L4: 3 sets x 10 reps x 5 sec Extension in lying with patient overpressure: 1 set x 10 reps x 5 sec Prone hip extension: 2 sets x 10 erps x 5 sec Bird dogs: 2 sets x 10 reps x 5 sec Prone plank: 1 set x 2 reps x 30 sec Hot pack with interferential current x 20 min to right lumbar paravertebrals	Forward flexion: 1 set x 1 rep x 3 sec Extension in standing: 1 set x 7 reps x 2 sec with last rep producing right radicular symptoms Extension in lying: 1 set x 15 reps x 3 sec Extension in lying with PT overpressure: 1 set x 15 reps x 3 sec Prone hip extension: 1 set x 15 reps x 3 sec Bird dog in quadruped: 1 set x 15 reps x 3 sec PA glides x 2 min to lumbar spine followed by extension in lying with PT overpressure: 1 set x 5 reps Hot pack with interferential current x 20 min to right lumbar paravertebrals

Table 2 describes the treatments provided to patient in treatment sessions 1-4.

The patient was informed that treatment frequency and duration would work best at two times per week by three weeks for a total of 6 treatment sessions. Patient stated understanding and agreed to this treatment schedule. The patient was also instructed in a home exercise program consisting of extension in lying and extension in standing to help alleviate pain at work and at home. Patient stated she understood the home exercise program and was able to demonstrate the exercises prior to leaving the initial appointment.

Outcomes

The patient responded well to initial treatment. She was able to stand more comfortably and walk more easily following the initial treatment. The subsequent treatments had good outcomes with her pain centralizing each visit. The patient stated that she was satisfied with the results of her treatment and impressed with how quickly they took effect.

Despite the good results from the initial treatment, the patient failed to adhere to the treatment frequency and duration. Four treatment sessions were held over the course of 4 weeks at which point the patient self-discharged. It is difficult to understand what led to the failed adherence and abrupt discharge.

It is difficult to fully discuss the patient's outcomes due to the self-discharge. A functional outcome measure such as the ODI should have been distributed at the initial evaluation in order to document progress and satisfaction in quality of life. Due to the documented reduction in pain and addition of more difficult exercises it would appear that the patient had self-discharged due to the lack of severe symptoms.

Patient was able to meet her short term goals including: return to work with 4/10 or less, log roll mobility, ambulate 250 feet with 4/10 or less, lifting 50 lbs, return to her preferred fitness routine and increase in ROM by 50%. She was also able to meet most of her long term goals including: return to work with 1/10 pain or less and return to her preferred fitness routine. Long terms goals of ROM

and bed mobility within normal limits, ambulation of 500 feet with 1/10 pain or less, and elimination of lifting restrictions were not yet met at the time of self-discharge.

Chapter Three: Discussion

Overall, the patient responded well the McKenzie treatment approach. This patient presented similar to patients in other McKenzie research with acute LBP and seemed to respond quickly to this approach. The treatment premise and method was easy to explain to the patient. She was more able to complete her exercises at home and at work because she understood the course of treatment. This also made patient education easier.

The AROM measurements were useful in narrowing in on the patient's problem. Pain or restrictions with forward flexion and side bending are often indicative of a disc problem in patients who present with low back pain. The ratcheting motion exhibited by this particular patient is also a good indicator of a disc problem as the return to standing places more pressure on the disc and causes pain. The patient was able to feel relief when in extension position which also follows a typical pattern and presentation of a lumbar disc protrusion or herniation.

An Oswestry Disability Questionaire (ODQ) was not performed. Research suggests that in comparison with nonspecific LBP, the visual analogue scale (VAS) and ODQ scores were significantly higher and the pain duration was significantly longer than specific LBP ($P < 0.05$)[34]. Others have researched the responsiveness of a Patient Specific Outcome Measure (PSAQ) compared with the Oswestry Disability Index v2.1 (OCI) and Roland and Morris Disability

Questionnaire (RMDQ) for patients with subacute and chronic LBP[35]. They found the PSAQ was highly sensitive to improvement but not to deterioration and it was less specific to change than the ODI or RMDQ. Overall, the ODI was the most responsive measure for patients with mild to moderate low back pain disability. In contrast with previous research we recommend the ODI v2.1 rather than the RDMQ for patients with mild disability. This information concludes that an Oswestry assessment should have been administered to more properly track clinical change and quality of life.

It is apparent how useful a functional assessment would be in this case to properly document and discuss the patient's progress and clinical outcomes. A quality of life measure would also have been useful to determine how satisfied the patient was with her outcomes even if she was yet not back to her pre-injury abilities.

Current literature is on the fence in regards to the efficacy of the McKenzie Method. Some research states that a pure McKenzie approach is best for treating all types of back pain, both acute and chronic, while other research states it is best for acute cases only. Despite the positive outcomes in this case study, the overwhelming concensus in the literature is that MDT does not yield appreciable short term results[36,37,38]. Research focused on the nursing population may prove promising as there is a higher incidence of low back pain in this population relative to patient transfer methods. There is potential for LBP

prevention in the medical and nursing communities with patient education combining proper body mechanics and lifting techniques with the premise of the McKenzie extension treatments.

Limitations exist due to the lack of functional assessment application. It is difficult to discuss the patient's outcomes without an objective measure having been distributed. Other limitations are due to the patient's abrupt self-discharge and difficulty adhering to a treatment schedule. These limitations made it increasingly difficult to reassess and document patient's progress in a meaningful manner.

Chapter Four: Reflection

I picked this patient for my case study primarily because she was the only patient I saw in clinic for more than one or two visits before discharge or in this case self-discharge. In the rural setting when I performed my clinical it was very common for patients to only come for one or two visits in order to meet their PT threshold for pain medication prescriptions. This particular patient wanted no part in pain medications but wanted to return to work as quickly as possible in order to support her son.

This patient primarily worked midnights or an overnight shift at the hospital, which also played a huge role in her adherence to PT. It was difficult for her to comply with treatments that were both immediately after work or just before the clinic closed due to fatigue or lack of sleep. This is an important consideration in future patient management so that I can encourage patients to come at times that are most feasible for them and times when they will get the most out of their treatment versus simply being physically present.

Overall, this patient had a very typical presentation regarding low back pain and disc protrusion or herniation. The patient's mechanism of injury included a loaded position and twisting motion, which seems very relevant in the general population. This position and motion seems even more prevalent in nursing and healthcare related work because a large portion of those jobs revolves around

transferring patients and aiding them while standing, walking, or sitting often putting those workers in a loaded and rotated position.

Team communication could have helped to prevent this particular injury as the patient was unaware of the size or dependency of the person she was trying to help. As in most jobs, training in proper body mechanics and work place ergonomics could help to prevent similar injuries in the future. It is a physical therapist's job to help implement these programs in the community to help teach safety and health promotion in the work place.

As far as MDT goes, it showed fast results with this patient and is seemingly well supported by literature but I would like to treat patients with more body awareness and strength related exercises in the future. I think MDT does a great job at handling pain upfront but very little for preventing pain in the future. I did try to mix in some stabilization exercises with this patient as seen in Table 2 but my knowledge at the time was very limited in hindsight. Now, I would prefer to treat a patient with MDT maybe 1-2 visits to help them move more freely and then zero in on pelvis position, core/abdominal/hip stabilization and lifting mechanics to provide a patient with a well rounded treatment plan.

References

1. Kosloff TM, Elton D, Shulman SA, Clarke JL, Skoufalos A, Solis A. Conservative Spine Care: Opportunities to Improve the Quality and Value of Care. *Population Health Management*. 2013;16(6):390-396. doi:10.1089/pop.2012.0096.

2. United States Bone and Joint Initiative: The Burden of Musculoskeletal Diseases in the United States (BMUS), Third Edition, 2014. Rosemont, IL. Available at http://www.boneandjointburden.org. Accessed on (December 8, 2016).

3. Bekkering GE, Hendriks HJM, Koes BW, Oostendorp RAB, Ostelo RWJG, Thomassen JMC, van Tulder MW. Dutch Physiotherapy Guidelines for Low Back Pain. *Physiotherapy*. 2003;89(2):82–96. doi: 10.1016/S0031-9406(05)60579-2.

4. Airaksinen O, Brox JI, Cedraschi C, Hildebrandt J, Klaber-Moffett J, Kovacs F, Mannion AF, Reis S, Staal JB, Ursin H, Zanoli G. Chapter 4: European guidelines for the management of chronic nonspecific low back pain. *European Spine*. 2004;15(Suppl. 2):S192–S300.

5. Chou R, Qaseem A, Snow V, Casey D, Cross JT, Shekelle P, Owens DK. Diagnosis and Treatment of Low Back Pain: A Joint Clinical Practice Guideline from the American College of Physicians and the American Pain Society. *Annals of Internal Medicine*. 2007;147(7):478–491. doi: 10.7326/0003-4819-147-7-200710020-00006.

6. Delitto A, Georgr SZ, Van Dillen L, Whitman JM, Sowa G, Shekelle P, Denninger TR, Godges JJ. Low Back Pain. Clinical Practice Guidelines Linked to the International Classification of Functioning, Disability, and Health from the Orthopaedic Section of the American Physical Therapy Association. *Journal of Orthopaedic & Sports Physical Therapy*. 2012;42(4):A1–A57. doi: 10.2519/jospt.2012.42.4.A1.

7. The human movement system: our professional identity. Sahrmann SA *Physical Therapy.* 2014 Jul; 94(7):1034-42.

8. Effect of active limb movements on symptoms in patients with low back pain. Van Dillen LR, Sahrmann SA, Norton BJ, Caldwell CA, Fleming D, McDonnell MK, Bloom NJ *Journal of Orthopedic Sports Physical Therapy.* 2001 Aug; 31(8):402-13; 414-8.

9. Further examination of modifying patient-preferred movement and alignment strategies in patients with low back pain during symptomatic tests. Van Dillen LR, Maluf KS, Sahrmann SA *Manual Therapy.* 2009 Feb; 14(1):52-60.

10. Lehtola V, Luomajoki H, Leinonen V, Gibbons S, Airaksinen O. Sub-classification based specific movement control exercises are superior to general exercise in sub-acute low back pain when both are combined with manual therapy: A randomized controlled trial. *Bio Med Central Musculoskeletal Disorders*. 2016;17:135. doi:10.1186/s12891-016-0986-y.

11. Chan WC, Sze KL, Samartzis D, Leung VY, Chan D: Structure and biology of the intervertebral disk in health and disease, *Orthopedic Clinics of North America.* 42:447, 2011.

12. An HS, Jenis LG, Vaccaro AR: This node is not processed by any templates: chapter-titleAdult spine trauma. In Beaty JH, Rosemont IL: Orthopaedic knowledge update six. *American Academy of Orthopaedic Surgeons*, 1999:653.

13. Chaudhry H, Ji Z, Shenoy N, Findley T: Viscoelastic stresses on anisotropicannulus fibrosus of lumbar disk under compression, rotation and flexionin manual treatment, *Journal of Bodywork and Movement Therapy.* 13:182, 2009.

14. Bible JE, Biswas D, Miller CP, Whang PG, Grauer JN: Normal functional range of motion of the lumbar spine during 15 activities of daily living, *Journal of Spinal Disorders.* 23:106, 2010.

15. Jaumard NV, Welch WC, Winkelstein BA: Spinal facet joint biomechanics and mechanotransduction in normal, injury and degenerative conditions, *Journal of Biomechanical Engineering.* 133:071010, 2011.

16. Nixon J: Intervertebral disc mechanics: A review, *Journal of the Royal Society of Medicine.* 79:100,1986.

17. Cheung J T-M, Zhang M, Chow D H-K: Biomechanical responses of the intervertebral joints to static and vibrational loading: A finite element study, *Clinical Biomechanics.* 18:790, 2003.

18. Iencean SM: Lumbar intervertebral disc herniation following experimental intradiscal pressure increase, *Acta Neurochirurgica.* 142:669, 2000.

19. Casazza, B. (2012). *American Family Physician.* Feb. 15; 85(4):343-50.

20. The McKenzie Method. Available at: http://www.mckenzieinstituteusa.org/method-patients.cfm. Accessed October 12, 2016.

21. The McKenzie Method. Available at: http://www.mckenzieinstituteusa.org/method-patients.cfm. Accessed October 12, 2016.

22. The McKenzie Method. Available at: http://www.mckenzieinstituteusa.org/method-patients.cfm. Accessed October 12, 2016.

23. Agnello A, Brown T, Desroches S, Welling U, Walton D. Can we identify people at risk of non-recovery after acute occupational low back pain? Results of a review and higher-order analysis. *Physiotherapy Canada*. 2010;62(1):9-16 8p. doi: 10.3138/physio.62.1.9.

24. Badke MB, Boissonnault WG. Changes in disability following physical therapy intervention for patients with low back pain: Dependence on symptom duration. *Archives of Physical Medicine and Rehabilitation*. 2006;87(6):749-756 8p.

25. Bakker EWP, Verhagen AP, van Trijffel E, Lucas C, Koning HJC, Koes BW. Individual advice in addition to standard guideline care in patients with acute non-specific low back pain: A survey on feasibility among physiotherapists and patients. *Manual Therapy*. 2009;14(1):68-74 7p. doi: 10.1016/j.math.2007.10.002.

26. Becker A, Held H, Redaelli M, et al. Low back pain in primary care: Costs of care and prediction of future health care utilization. *Spine*. 2010;35(18):1714-1720 7p.

27. Graves JM, Fulton-Kehoe D, Jarvik JG, Franklin GM. Early imaging for acute low back pain: One-year health and disability outcomes among washington state workers. *Spine*. 2012;37(18):1617-1627 11p.

28. Donelson R. Is your client's back pain 'rapidly reversible'? improving low back care at its foundation. *Professional Case Management*. 2008;13(2):87-96 10p.

29. Chan, T.F., Chou, F.H., Lin, Y.H., Lin, Y.L., & Tsai, E.M. (2009 November-December). Health promoting lifestyles and related factors in pregnant women. *Chang Gung Medical Journal*. 32(6):650-61.

30. Dutton, M. (2011). Dutton's orthopedic survival guide: managing common conditions. McGraw Hill, Inc.127, 139, 171, 959-960p.

31. Ekedahl H, Jönsson B, Frobell RB. Fingertip-to-floor test and straight leg raising test: Validity, responsiveness, and predictive value in patients with Acute/Subacute low back pain. *Archives of Physical Medicine and Rehabilitation*. 2012;93(12):2210-2215 6p. doi: 10.1016/j.apmr.2012.04.020.

32. Ekedahl KH, Jönsson B, Frobell RB. Validity of the fingertip-to-floor test and straight leg raising test in patients with acute and subacute low back pain: A comparison by sex and radicular pain. *Archives of Physical Medicine and Rehabilitation*. 2010;91(8):1243-1247 5p. doi: 10.1016/j.apmr.2010.05.002.

33. May S, Gardiner E, Young S, Klaber-Moffett J. Predictor variables for a positive long-term functional outcome in patients with acute and chronic neck and back pain treated with a McKenzie approach: A secondary analysis. *Journal of Manual Manipulative Therapy*. 2008;16(3):155-160 6p.

34. Kim G, Yi C, Cynn H. Factors influencing disability due to low back pain using the oswestry disability questionnaire and the quebec back pain disability scale. *Physiotherapy Research International*. 2015;20(1):16-21 6p.

35. Frost H, Lamb SE, Stewart-Brown S. Responsiveness of a patient specific outcome measure compared with the oswestry disability index v2.1 and roland and morris disability questionnaire for patients with subacute and chronic low back pain. *Spine*. 2008;33(22):2450-2458 9p.

36. Machado LA, Maher CG, Herbert RD, Clare H, McAuley JH. The effectiveness of the McKenzie method in addition to first-line care for acute low back pain: a randomized controlled trial. *Bio Med Center Medicine*. 2010;8:10. doi:10.1186/1741-7015-8-10.

37. Sheets C, Machado LAC, Hancock M, Maher C. Can we predict response to the McKenzie method in patients with acute low back pain? A secondary analysis of a randomized controlled trial. *European Spine Journal*. 2012;21(7):1250-1256. doi:10.1007/s00586-011-2082-1.

38. Petersen T, Christensen R, Juhl C. Predicting a clinically important outcome in patients with low back pain following McKenzie therapy or spinal manipulation: a stratified analysis in a randomized controlled trial. *Bio Med Center Musculoskeletal Disorders*. 2015;16:74. doi:10.1186/s12891-015-0526-1.