NORTHERN ILLINOIS UNIVERSITY

Literature Review of Lumbar Disc Lesions: from Onset to Return to Activity

A Thesis Submitted to the
University Honors Program
In Partial Fulfillment of the
Requirements of the Baccalaureate Degree
With Upper Division Honors

Department Of
Kinesiology and Physical Education

Grant Panzella
DeKalb, Illinois
May 12, 2018
The purpose of this thesis was to construct a literature review based upon an applicable topic to the field of athletic training/physical therapy. With non-descriptive low back pain being one of the most common conditions seen throughout the human lifespan, looking at a specific disorder in depth equips a clinician with more knowledge to successfully treat a larger patient population. The disorder is lumbar intervertebral disc lesions. There were no specific limitations for this review other than being restricted to lumbar intervertebral disc lesions. The most common patient demographics were looked at, as well as an athletic population experiencing lumbar disc lesions (for the purposes of being related to athletic training). The scope of research included spine anatomy and physiology, the anatomy and physiology of lumbar intervertebral disc lesions, intervertebral disc biomechanics, acute vs chronic mechanism of injury, how a patient will present during an evaluation, treatment options, the rehabilitation process, and returning to activity/play. After researching the literature, there are pros and cons to both conservative and non-conservative routes for treatment. With different levels of injury severity and the effects of injury differing with each patient, this is a decision that is patient specific.
Background

ANATOMY

The bones of the vertebral column, along with the bones of the skull, the sternum, and ribs, comprise the axial skeleton. The vertebral column is a foundational structure of the human body, as it provides axial support for the trunk and protection of the spinal cord. There are five regions of the vertebral column, all but one displaying a curved shape (Figure 1). The two most inferior regions are the sacral region, composed of five fused bones and having a convex curvature, and the coccyx, composed of four fused bones. There are 24 bones superior to these two bones in the spine, which are divided into the cervical, thoracic, and lumbar regions. The vertebrae in each region have key differences in their shape, facet joints, and intervertebral discs, allowing for different types of movement from each region.

The general structure of a vertebra includes a body, two superior and two inferior articular processes and facets, spinous process, and two transverse processes. In the middle of the vertebrae is the vertebral foramen, the hole in which the spinal cord lays. The spinous process and the transverse processes are attachment points for ligaments and muscles, providing stabilization and mobility respectively. The facet articular processes and facets, along with the body of the vertebrae, are the areas that form joints with consecutive vertebrae, the facets on the posterior aspect and the body on the anterior aspect. The facet joints are plane synovial joints.

The cervical region of the spine has a lordotic shape (curving inward) and is made up of seven vertebrae, named C1-C7. These vertebrae are the lightest and smallest of all of the vertebrae in the vertebral column. Unlike its two inferior regions, the cervical region of the vertebral column has two bones unique in shape compared to the rest (Figure 2). C1 is called the atlas and is the bone that forms the atlanto-occipital joint with the skull. This bone does not have
a body or a spinous process but contains larger-than-usual superior and inferior articular facets. The atlas allows flexion and extension of the head, but locks with the occipital bone. C2 is called the axis. This bone looks like a hybrid between the atlas and the rest of the cervical vertebrae, but the only difference between the axis and C3-C7 is the dens, a spine-like superior projection off of the body that acts as the missing body for the atlas. The dens projects into the body space of the atlas, allowing for rotational movement at the head. For C3-C7, the body is wider laterally than anteriorly to posteriorly, the spinous process is short and projects directly back, the vertebral foramen is large and resembles a triangular shape, and each transverse process contains foramen, through which arteries run to provide blood supply to the brain. The superior facets are pointed in a superior direction with the long side parallel with the coronal line of the body (Figure 3).

The thoracic region of the spine has a kyphotic shape (curving outward) and is made up of twelve bones that are larger and heavier than the cervical vertebrae, named T1-T12. The most superior vertebrae of the thoracic region look like the vertebrae of the cervical region and the most inferior vertebrae of the thoracic region look like the lumbar vertebrae. However, these vertebrae are distinguishable by the heart shape of their bodies and the first ten have six costal facets (two superior and two inferior costal facets for the head of the rib and two transverse costal facets for the tubercle of the rib) (Figure 3). The vertebral foramen are circularly shaped and the spinous processes are pointed inferiorly. The superior articular facets are pointed in a superior direction, but face slightly laterally, allowing for rotational movement in the thoracic region. Because they lie in the frontal plane, flexion and extension are limited in the thoracic region.

The lumbar region, like the cervical spine, has a lordotic curve, but is made up of five vertebrae, appropriately named L1-L5, the largest and heaviest of all the vertebrae. These
vertebrae and their intervertebral discs experience the most stress in the spine and their design reflects their ability to handle the increased load. The bodies are large and kidney shaped, their spinous processes are knoblike, allowing for easiest attachment by the largest back muscles, and the vertebral foramen are triangular in shape like the cervical vertebrae (Figure 3). The location and direction of projection of the articular processes differs from the rest of the vertebrae. They face significantly inward (compared to the other two regions) and superiorly. This restricts rotational movement in the lumbar region.

The joints made by the bodies of vertebrae are cartilaginous joints. Between the bodies of vertebrae are intervertebral discs, which serve as a cushion between the bones (Figure 4). There are 23 intervertebral discs in the body with ones missing between C0-C1 and C1-C2. The discs are named according to the vertebrae they lie between, as explained in the previous sentence. These structures are made up of three parts: the nucleus pulposus, annulus fibrosis, and cartilaginous endplates. The nucleus pulposus is located more central to the body of the vertebrae and it gives the disc its elasticity and compressibility. It is highly elastic as it is semigelatinous, highly hydrated, and rich in proteoglycans. The annulus fibrosus surrounds the nucleus pulposus and makes up the remainder of the disc. Made of collagen fibers, this structure keeps the nucleus pulposus within the disc. The cartilaginous endplates act as connective tissue as they anchor the disc to the successive vertebrae, preventing disc movement. The space provided by the intervertebral discs, along with their cushioning capabilities, allow for movement in the trunk, including flexion, extension, and lateral movement. These discs also act as shock absorbers for the spine in different types of physical activity.

The vertebral column has many more components than just the vertebrae and intervertebral discs. Although the annulus fibrosis of the intervertebral discs acts as connective
tissue between vertebrae, they cannot hold up the spine alone.\textsuperscript{1} Ligaments connect bone to bone and are the support system, responsible for holding together the vertebrae against stress.\textsuperscript{2} The two major support ligaments are the anterior and posterior longitudinal ligaments, whose primary function is to prevent translation of the vertebral bodies (Figure 5). The anterior longitudinal ligament is thick and runs along the most anterior aspect of the vertebrae. The posterior longitudinal ligament runs along the posterior aspect of the vertebral body and it limits flexion of the spine. On the opposite side of the vertebral column, the ligamentum flavum runs along the anterior aspect of the spinous processes. It connects the vertebrae at their laminae, the part between transverse and spinous processes. The interspinous ligaments connect the vertebrae by their spinous processes and prevent flexion and rotation. Along the posterior aspect of the spinous processes runs the supraspinous ligament, filling the space between spinous processes. From the occipital bone to C7, this becomes the ligamentum nuchae. Connecting successive transverse processes are intertransverse ligaments, which prevent lateral flexion. Off the transverse processes of L4 and L5 attaches the iliolumbar ligament. This ligament inserts into the iliac crest and is responsible for restricting movement between the lumbosacral and sacroiliac joints. The pelvic bones are held in place with the sacral bone by other ligaments, such as a sacrospinous, sacroiliac, and sacrotuberous ligaments.

Skeletal muscle allows movement in the body.\textsuperscript{1} In the spine, muscles are used for movement and stabilization. The various processes and projections on the vertebrae are optimal places for muscles to attach. Many of the muscles leading into the upper and lower extremities stem off the vertebral column at the cervical, thoracic, lumbar, and sacral regions. The primary mover muscles are extrinsic, meaning they are large, superficial, and responsible for larger movements because they cross other parts of the body. Other muscles are secondary movers and
are intrinsic, meaning they are smaller, deeper, and do not cross into other body parts. Figure 6 shows both deep and superficial muscles.

Cervical muscles allow the for cervical flexion, extension, lateral flexion, and rotation. Primary movers of the cervical spine include both intrinsic and extrinsic muscles. The extrinsic muscles are the upper one-third of the trapezius (extension, lateral flexion, rotation), levator scapulae (extension, scapular elevation and downward rotation), sternocleidomastoid (flexion, lateral flexion, rotation of the skull), and all three aspects of the scalene muscles (lateral flexion). Intrinsic muscles acting specifically on the head for extension include splenius cervicis, obliquus capitis superior, and rectus capitis posterior major and minor. Other intrinsic muscles acting on the head are splenius cervicis (same side rotation), longus capitis and colli (flexion), obliquus capitis inferior (ipsilateral rotation), and the rectus capitis anterior and lateralis (head flexion and stabilization).

There are four extrinsic muscles that are responsible for movements in the cervical spine and upper extremity whose origins attach to parts of the thoracic and lumbar spine. The rhomboid major and minor are extrinsic muscles that originate off of C7-T5 and insert on the medial border of the scapula, responsible for scapular stabilization. The latissimus dorsi is responsible for adduction in the upper extremity. It originates from lumbodorsal tissue from T7-L5, the lower three or four ribs, and the iliac crest of the pelvis and inserts into the floor of the intertubercular sulcus of the humerus. The trapezius muscle is the largest, most superficial muscle of the back. This muscle originates from the occipital bone of the skull, ligamentum nuchae, and spinous processes of C7-T12. Functionally, this muscle is divided into three sections. The upper third inserts on the lateral one third of the clavicle and acromion process. It is responsible for cervical extension, lateral flexion, and rotation as well as elevation and upward
rotation of the scapula. The middle third inserts on the acromion process and superior, lateral border of the scapula. It is responsible for retraction of the scapula. The lower third inserts on the medial portion of the scapula and is responsible for scapular depression, retraction, and upward rotation.

The primary movements at lumbar spine are flexion, extension, and lateral flexion, but rotation is possible as well. The primary movers acting on the lumbar spine are the rectus abdominus (flexion), external and internal obliques (flexion, opposite side rotation, lateral flexion), and latissimus dorsi (extension, stabilization).

The cervical, thoracic, and lumbar regions of the spinal column all have intrinsic muscles that either are responsible for movement at each joint or aid in movement. The main movements of the thoracic region include rotation and lateral flexion. Because of the type of movement occurring between thoracic vertebrae, intrinsic muscles here are the primary movers. These intrinsic muscles are also the secondary movers for the cervical and lumbar spine and they work to have an effect along the entire vertebral column. These muscles include the middle and lower thirds of the trapezius muscles (thoracic fixation), iliocostalis (extension, lateral flexion, posture), longissimus (extension, lateral flexion), spinalis (extension), semispinalis (extension), quadratus lumborum (flexion), intertransversarius (lateral flexion), interspinales (extension), multifidus (stabilization, rotation) and rotatores (stabilization, same side rotation).

Other than trunk support and places of attachment for muscles, the vertebrae are also responsible for protection of the spinal cord. Made up of nervous tissue and part of the central nervous system, the spinal cord is the two-way navigation system to and from the brain that runs through the vertebral foramen. The spinal cord is slightly thicker than normal at two points called the cervical and lumbar enlargements. Nerves come off the spinal cord and act as a
communication system between body tissues and the central nervous system (Figure 7). Nerve roots branch off from the spinal cord and exit the vertebral column through intervertebral foramen, which are holes between successive vertebrae. The spinal nerve roots are divided into four regions, appropriately named after the regions of vertebrae they run between (cervical, thoracic, lumbar, and sacral). The spinal cord eventually comes to a cone-shaped conus medullaris at L1, where it breaks up into the cauda equina: a set of nerve continuations that runs to the coccyx and are the nerves responsible for innervation of the lower extremity. There are three layers of connective tissue surrounding the spinal cord and all nervous tissue to protect it. Along the vertebral column lies epidural space, made up of adipose tissue for additional protection for some of the body’s most delicate tissues.

Tissue in the body cannot live and function without oxygen and other key nutrients. Blood supply to the vertebrae and the spinal cord comes the thoracic aorta, which eventually branches off into the artery of Adamkeiwicz (becoming the anterior vertebral artery) and a pair of posterior vertebral arteries (Figure 8). The lateral aspects of the vertebral column are provided blood supply in segments from the following radicular arteries: ascending cervical arteries, deep cervical arteries, posterior intercostal arteries, lumbar arteries, and lateral sacral arteries. These radicular arteries bridge the gap between the thoracic aorta and the vertebral arteries. Deoxygenated blood from the vertebral column, along with the rest of the abdomen and thorax, it brought back to the heart via the azygos and hemiazygos veins, which branch into the superior vena cava.

PHYSIOLOGY

Movement at individual intervertebral joints is minimal, but when added together provide the movement experienced every day. The cervical region has the greatest range of motion as it
allows for flexion, extension, lateral flexion, and rotation. The thoracic region’s main movement is rotation, but is limited in flexion, extension, and lateral flexion. The lumbar spine experiences most of its movement through flexion and extension. There is some lateral flexion, but rotation at the lumbar level is prevented by the nature of the articular facet joints.

To accommodate for the more significant ranges of motion, the intervertebral discs in the cervical and lumbar regions are thicker than those in the thoracic region. The lumbar spine, when displaying its natural lordotic curve, contains discs that are thicker anteriorly compared to posteriorly (Figure 9). The components of the intervertebral discs allow the movement seen between each vertebra. During flexion at the lumbar spine, there is an increase in pressure on the anterior portions of the annulus, which pushes the nucleus posteriorly and places pressure on the posterior annulus fibers. The opposite occurs with extension at the lumbar spine. With lateral flexion, the side where flexion occurs experiences increased pressure on those fibers and pushes the nucleus to the opposite side, placing pressure on the contralateral-side annulus fibers. The hydration aspect of the nucleus pulposus allows fluid motion by dispersion of compressive forces on the disc when stresses are placed upon it.

**Epidemiology**

The literature states that 39.9% of people will experience low back pain at some point throughout their lives (±24.3%). Different mechanisms of injury include chronic vs acute onset. Chronic onset is an overload injury that progressively worsens if not taken care of with symptoms increasing gradually. Acute injuries occur when forces are great enough to cause injury in one moment, not over time. Low back pain can have the following effects on someone: significant impairment of physical and psychological health and a decline in simple social responsibilities, such as work and family responsibilities. The most common age that one
experiences low back pain is during the middle-aged period of life (45-65 years of age), but the symptoms are more detrimental on the elderly population (65+). Low back pain has a higher prevalence in females compared to males. A survey conducted in 2002 showed the following breakdown of patients experiencing low back pain: 28% reported no chronic back pain, 49% reported grade I (low-intensity/low-disability), 12% reported grade II (high-intensity/low-disability), and 11% reported grades III and IV (high-intensity/high-disability). Risk factors for low back pain include job responsibilities, body demographics, psychological factors, and the aging process and degeneration at the intervertebral joints. There are different etiologies that can cause low back pain; treatment options depend on the diagnosis to find the specific cause.

Pathology

An intervertebral disc lesion results from increased pressure on the annulus fibrosis due to pushing of the nucleus pulposus on specific annulus fibers (Figure 10). The pushing of the nucleus pulposus in any direction is a result of the nucleus’s inability to disperse pressure evenly across the rest of the disc and endplates. This increase of pressure causes a loss of water from the incredibly hydrated nucleus, which reduces its mobility within the disc. As humans age, biochemical changes in the intervertebral disc naturally occur and promote the loss of water within the nucleus pulposus. Therefore, age is a risk factor for intervertebral disc lesions.

There are seven levels of severity of lumbar intervertebral disc lesions. Robin McKenzie, a physiotherapist from New Zealand, studied the effects of movement on low back pain and concluded that it can be derived into three progressive syndrome classifications. The first is postural syndromes, a non-severe case of pain occurring after being in certain positions for an extended period. The second class is dysfunction, characterized by reduced range of motion, stiffness, reduced soft tissue mobility, and a constant or intermittent pain. These are
early changes in the biomechanics of the disc and only continue to progress if not addressed. The third classification is derangement and there are seven types, increasing in severity. Derangement one is a mild disc bulge due to posterior pressure on the annulus fibrosus and resulting in central or unilateral pain in the low back stemming from the level of the disc. Derangement two is a continuation of the first: moderate disc bulge with pain extending to the buttocks. Derangement three is a further continuation, more prominent and extending into the upper thigh. The fourth derangement is a further continuation of the third, with pain extending to the knee. This derangement is paired with a shift of the lumbar spine to compensate the pain and try to open up the joint space to reduce the pressure on the annulus. The fifth derangement is a further continuation paired with pain below the knee, resulting from nerve irritation from the bulging annulus. The sixth derangement is when the nucleus has herniated through the annulus and results in pain down the lower leg, possibly into the foot. Derangement seven is its own kind: anterior movement of the pulposus and anterior bulge of the annulus fibers. The sixth derangement classifies extrusion. The most severe form of a lesion is called sequestration, which is the breaking off of the nuclear material from the pulposus and leaking out into the tissue outside of the disc.

The most common onset of lumbar intervertebral disc lesions is insidious. As can be seen by the many classifications of posterior and posterolateral lesions and the one classification of anterior lesions, the occurrence of posterior lesions is much higher. Chronic posterior lesions result from repetitive increased pressure on the anterior aspect of the disc through flexion of the lumbar spine. This flexion literally pushes the nucleus pulposus posteriorly within the disc so much that it starts to stay posteriorly placed, increasing the pressure on the posterior annulus fibers. Throughout the course of the day, humans flex at the lumbar spine 1000 times, whether
slumped in a chair due to bad posture and weak core or bending over to pick something up off the ground. Yet extension only occurs around 100 times a day, of which standing is included. This, paired with a thicker anterior portion, explains the high relevance of posterior lesions compared to anterior. A study was conducted researching the effect of axial overloading on lumbar intervertebral discs. It was concluded that overloading increased the pressure on the posterior fibers of the annulus fibrosus similarly to repetitive flexion. A chronic onset in patients with the seventh derangement is a result of lumbar lordotic fixation, where the lumbar spine displays a hyperlordotic curve.

Some patients experiencing lumbar intervertebral disc lesions have acute onset. In these cases, there is a load on the spine that it cannot handle for whatever reason. Usually, it is paired with a movement that opens the joint space. The high amount of pressure on the annulus causes a rupture of the fibers and results in one of the levels of derangement.

The population of people experiencing lumbar intervertebral disc lesions is diverse overall. In a nonathletic population, disc pathology is the most common back pathology in the lumbar spine. Most cases involve chronic onset and mechanisms of injury, including repetitive flexion and poor posture. The athletic population involves patients from a variety of sports. In a literature review published in 2016, articles were examined looking at different patient populations with lumbar intervertebral disc lesions, which included Olympic athletes, athletes in the National Football League, Major League Baseball, National Hockey League, National Basketball Association, and National Collegiate Athletic Association. Because of the movements of everyday life and the stresses placed on one’s body during sport, disc lesions can occur. Chronic onset patients can come from any of the previously listed sports but are higher in patients who repetitively flex and/or flex with loading at the lumbar spine due to their sport.
Acute onset patients are more likely to come from sports of which the opening of the joint space between intervertebral discs occurs or there is increased pressure on the anterior portion of the disc than the normal movement provides. The literature review found the highest occurrence of injury in athletes from the National Football League (linemen more often than not) and Olympians. Other athletes at higher risks include gymnasts and throwers.

**EVALUATION**

The first part of the evaluation gathers subjective information, or information the clinician gathers prior to putting hands on the patient. It is subjective information because the patient verbally gives it. Information in this part of the evaluation includes but is not limited to type, level, and location of pain, previous medical history, perceived onset of injury, description of what happened, any current medication, and any other details they might notice about the injury. The type of athlete and the common movement/load requirements for their sport, along with this other information, is key background information for the clinician to have a better understanding of what happened at the anatomic level. Whether the onset of injury is chronic or acute can factor into the patient’s perceived pain level. If the pain has been occurring for some time and only continues to worsen in the case of chronic onset, the perceived pain will be more accurate than a patient who has not experienced the pain of a lesion previously. The severe pain might bring on shock, so it is important to keep the patient calm and level headed throughout the entire evaluation to try to get accurate subjective information.

Patients with intervertebral disc lesions can experience any type of the three major kinds of pain: sharp, dull, or neurologic. Because of the effect this injury can have on nerve roots, there is a high chance of some sort of neurologic or sciatic symptoms. This pain is characterized by tingling or burning sensations. Location of pain is important because it can shed light on
where the lesion is. In some patients, the experienced pain is local to the injury and this localized pain can reveal which disc is experiencing the lesion. Questions about a patient’s previous medical history are important as well because there are risk factors for lumbar intervertebral disc lesions, including smoking, diabetes, and protrusion and other previous lumbar spine trauma.\(^9\)

The second part of the evaluation is the objective part, from which information is gathered by what the clinician obtains through their observations.\(^2\) The first thing the clinician should be looking at is how the patient moves. The patient may appear to have a slow gait and may be slow to change positions out of fear of worsening the pain. The second thing the clinician should do is confirm the location of pain through palpation. For lumbar intervertebral disc lesions, some patients experience local pain while others experience pain down into the posterolateral aspects of the low back, buttocks, and radiating down the leg. For patients with localized pain, palpation of the superior and inferior spinous processes, superior and inferior transverse processes, and the joint space between the two vertebrae will confirm which disc has a lesion because the patient will experience an increase of symptoms. Muscular palpation might induce muscle spasm.

In any injury where there are neurologic symptoms, it is important to complete a neurologic screen to see how affected the nerve root is (related to the severity of the lesion) and to confirm which nerve root is affected (Figure 11).\(^2\) This is important in the cases of patients that experience pain radiating down the leg. Neurologic screening tests the sensory, motor, and reflex aspects of the nerve. The sensory areas affected by the L1 and L2 nerve roots start at the location of the nerve root in the spine but move laterally and wrap around the anterior aspect of the leg. Innervation of these areas is the femoral cutaneous nerve. When testing the motor function of the L1 and L2 nerve roots, the clinician performs a hip flexor manual muscle test
with the patient sitting with knees bent and hanging off the table. L3 sensory innervation is one level inferior to L2 and is also the femoral cutaneous nerve. The motor nerve test is a manual muscle test for the rectus femoris. The patient sits on the table and the clinician tells the patient to maintain knee extension against their load. L4 sensory innervation is the saphenous nerve and it covers from the location of the nerve root out of the spine, wrapping laterally and inferiorly around the hip, down the anterior aspect of the lower thigh and along the medial aspect of the lower leg. Its motor innervation is the deep peroneal nerve, which is tested with a manual muscle test for ankle dorsiflexion. L5 sensory innervation is from the superficial peroneal nerve, covering area from its nerve root origin around the mid-thigh, down the anterior aspect of the lower leg, and medial aspect of the foot. Its motor innervation is the same as L4 but can be tested specifically for L5 with a manual muscle test for extension of the hallux. There is no reflex testing for L1, but reflex testing for L2-L4 is the femoral nerve. The reflex test for L5 is the tibial nerve.

For range of motion, flexion, extension, lateral flexion, and rotation are assessed. Gross assessment is more common than physical measurements because the symptoms a patient experiences will generally present on one side, reflective of which side the lesion is on. Another reason that gross assessments are completed is because everyone has different amounts of flexibility and there is no standard measurement for all patients in the spine. The non-affected side is the “norm” that the clinician would compare to. Active range of motion is assessed for flexion by bending forward and touching their toes. The clinician can take a measurement of how far the distance is between the patient’s fingertips and the ground or two measures of the distance between the patient’s C7-S1 spinous processes: one in neutral and one bent over. The clinician could also measure flexion by using two inclinometers, placing one in line with the patient’s
posterior superior iliac spine and the other fifteen centimeters superior to the first subtracting the two values. This is also the way a clinician would measure extension. For lateral flexion, the clinician would measure from the patient’s fingertips to the ground and compare bilaterally. For rotation, the clinician would measure bilaterally from gross observation. In the case of lumbar intervertebral disc lesions, range of motion in all directions will be limited by pain.

For passive range of motion, the clinician completes flexion (supine) and extension (prone), observing for pain through movement not activated by the muscles.\textsuperscript{2} Lower trunk rotations are how a clinician assesses passive rotation for the lumbar spine, grossly comparing bilaterally. The additional range of motion tested by the clinician is passive lateral glide, in which the clinician stabilizes the patient’s shoulder laterally against the wall and pushes medially on the pelvis, gliding the vertebral column laterally towards the wall (Figure 12). This is important in patients that experience pain radiating down the leg. If pushing the vertebral column towards the side that pain is radiating down reduces symptoms, then that could be a positive test for an lumbar intervertebral disc lesion. In these patients, movement through these ranges of motion, despite not actively performing them, will show a limited range due to pain. For the benefit of the patient and consistent limitations in active and passive range of motion, it is safe to assume that they cannot perform resisted range of motion or manual muscle tests without an increase in pain.

Because referred pain can present in the patient and limit all types of range of motion, information regarding functional movement can be gathered by the completion of ten repetitions in any direction.\textsuperscript{6} Conclusions can be drawn about the quantity and location of pain by these findings in terms of where the intervertebral disc lesion is. If the nucleus pulposus is pushed posteriorly because of pressure applied through flexion, ten repetitions of prone extension can
reduce symptoms as it pushes the pulposus applying pressure on the annulus fibrosis off it, reducing the pressure of the bulge.\(^2\) If the bulge is posterior and lateral, offsetting the patient’s hips in the opposite direction of the pain and instructing ten repetitions of prone extension should help relieve radiating symptoms and start to localize the pain. If the nucleus pulposus is applying pressure to the anterior aspect of the annulus fibrosis and anterior structures, ten repetitions of flexion will push the pulposus posteriorly, relieving the pressure on the bulging structure. If ten repetitions of a movement increase symptoms, it is important for the patient to stop immediately. Increasing or decreasing of symptoms is indicative of the direction the disc is bulging and the location of the lesion.

Special tests that the clinician would perform whose positive signs indicate lumbar intervertebral disc lesions are straight leg raise, well straight raising, Milgram test, and sciatic and femoral nerve tension tests.\(^2\)

**Rehabilitation**

Rehabilitation is the most important step in the evaluation process because can speed up the process of healing. There are seven principles of rehabilitation: avoid aggravation, timing, compliance, individualization, specific sequencing, intensity, and total patient.\(^5\) Using these principles as guidelines to follow when creating a rehabilitation program for the patient, one can reach the ultimate goal of returning to activity/play with no pain or limitations. There are short term goals based on the phase of rehabilitation a patient is in and one should progress through these phases in a timely, yet specific manner to the patient. Rehabilitation should be safe, effective, efficient, and will be specific to the patient as severity of injury, type of activity one returns to, and the body’s response to rehabilitation is different for each patient.
TREATMENT

When looking at routes of treatment, a patient can choose to treat conservatively, meaning without surgical intervention, or invasively, picking the surgical route. The clinician working with the patient often takes on a role in helping the patient weigh their options to decide what fits best in their present life and circumstances. A primary rule in the role of the clinician, whether they be a doctor, physical therapist, or athletic trainer, is to try the conservative route first because of the cost and risks of surgical intervention. There usually is nothing to lose by choosing the conservative route other than time, which could be a determining factor depending on the patient’s life events. Regardless of the limited range of motion, exercises can be done to reduce symptoms. The severity of the lesion is the most determining factor to jump directly to the surgical route as any broken off material (sequestration) needs to be removed from the vertebral column. Also, if the lesion is large enough and protruding out of the disc space, physical therapy reducing pressure on the annulus fibers might improve mobility but might not decrease pressure on the involved nerve root as the lesion remains extruded. In this case, there is no reduction in symptoms similar to sciatica and surgery is the option.

It is important to remember that the decision of having surgery comes with complications and risks. Obviously, there is a risk of failure of the surgery to accomplish its goal. Other complications include deep vein thrombophlebitis, reaction to anesthesia, dizziness, wound infection, and shock. All of these are more likely to occur closer to surgery than further into the rehabilitation process, but it is important to take note of because they can affect therapeutic intervention and can be life-threatening to the patient. This is one of the reasons that the surgeon has a time- and symptom-based protocol to follow for progression through the rehabilitation process.
The main purpose of surgery is to reduce pressure on the nerve root but may also be/include repairing or removal of annulus fibers. The most common surgical intervention is a microdiscectomy, which is partial removal of the intervertebral disc that is protruding and affecting a nerve root. Other options for reducing pressure, listed from least to most severe are a discectomy, the complete removal of the intervertebral disc, laminectomy, which is the trimming of the lamina of the vertebrae to open space in the vertebral column, disc replacement, which is replacement of the entire disc with an artificial one made of plastic and metal, and spinal fusion, which involved the fixation of two vertebrae via plates and screws. Although there are different types of surgical interventions, for this literature review, postsurgical rehabilitation will be based on microdiscectomy as it is the most common (Figure 13). The microdiscectomy will alleviate symptoms stemming from increased pressure on the nerve root, but the original cause of injury has yet to be fixed. This is where preoperative physical therapy comes into play.

A study was published in 2015 comparing long-term outcomes of microdiscectomy and nonsurgical patients with intervertebral disc lesions. This study was a randomized control trial that took patients experiencing persistent symptoms for at least six weeks. The primary outcomes were Oswestry Disability Index and SF-36 bodily pain and physical function scores. The secondary outcomes were Sciatica Bothersomeness Index, leg and back pain bothersomeness, patient satisfaction with care and with symptoms, patient global perceived improvement, and work status. Outcomes were measured at six weeks, three, six, and twelve months, and annually after for eight years. Overall, there was no significant difference in the primary outcomes, but the secondary outcomes that showed small, yet significant improvements were sciatica bothersomeness, satisfaction with symptoms, and self-rated improvement in patients a part of the surgical group. Long-term (after eight years) the patients that saw the greatest improvement
originally reported higher pain levels, radiating symptoms, sequestrated discs, and longer presence of symptoms, confirming that surgery is more successful in patients with increased severity. For low pain-intensity patients, there was no significant difference between conservative and invasive treatments.

PHASES

Throughout all four phases of rehabilitation, therapeutic modalities can be used to benefit symptoms of the patient. Surgical patients will be on prescription medication for pain for at least the first week post-operation, if not longer. Ice is suggested to numb the pain and reduce swelling; the patient should be icing for twenty minutes every hour they are awake for the first week. For conservative patients, icing will help with pain but will tighten up muscles in a patient with an already limited range of motion, so it is not the best modality. Heating prior to the start of a therapy session can warm up those muscles and help increase range of motion. Heating and icing are more likely to be seen during the first and second phases in the rehabilitation program and should be continued until the patient feels as though they no longer are beneficial. Electrical stimulation can be used to control sciatica symptoms and pain. Soft-tissue release can be used for muscle tightness.

The goal of the first phase of rehabilitation is to increase flexibility and range of motion. As stated during the evaluation section, the patient will most likely present limited range of motion in all planes, depending on the severity of the injury. Postural syndromes will not show a limited range of motion due to pain from being in a certain position for an extended period of time, but the next step of progression (before any bulging of the disc) of dysfunction is named to explain that the pain is limiting range of motion. The further progressive disorder is derangements, of which all seven present limited range of motion.
For any anterior translated disc issues, the goal is to decrease pain by pushing the nucleus pulposus posteriorly via flexion. This comes into play with the seventh derangement. In 1955, Paul Williams, an orthopedic surgeon, believed that the cause of low back pain was the lordotic curve of the lumbar spine. He created a series of lumbar flexion exercises to fight against the natural curve of the lumbar spine (Figure 14). These exercises place pressure on the anterior part of the lumbar intervertebral disc, reducing anterior bulges. They are flexed-knee sit-ups, posterior pelvis tilt, knee-to-chest hold/stretch, seated toe touch hold/stretch, deep lunge with back hip/knee extended, and full squats. Not all of these exercises can be performed the first day in a rehabilitation program, and if they can, the amount of movement in exercises like toe touches and squats will be limited.

It was not until 1981 that McKenzie published work on his conclusions for extension, not flexion, being the key to limiting back pain. He created a sequence of six exercises for the first phase of rehabilitation in order to relieve the posterior pressure on the disc, decrease symptoms, and increase range of motion. These exercises are listed in a progressive order and the clinician should instruct progression based off of the patient’s ability to perform them: prone lying, prone lying on elbows, prone lying on hands with elbows extended, trunk extension in a standing position, cat-cow exercise while seated, and knees to chest in supine (Figures 15-18). How the injury affects the body is different for all patients, regardless of the level of dysfunction or derangement they experience. Most will be able to perform a prone press-up, even if it is partial. The important part as a clinician is to explain to go as far as they can before they start to feel pain. This exercise, although second or third in order, is the best place to start unless they cannot perform it. At that point, start with prone lying and let gravity start to alleviate the pressure. The alleviation of pressure and the beginning of migration of the nucleus allows the first step of the
healing process of occur: inflammation. As one continues through the first phase of rehabilitation, they experience the second step of the healing process at the tissue perspective: proliferation.

As described in the evaluation section, ten repetitions of prone press ups can centralize pain. The pain may become more severe at the disc but radiating pain could reduce. With this being a confirmed diagnosis of a posterior intervertebral disc lesion and the major movement causing alleviation of pain, this is the one exercise given to the patient at the original evaluation to be done at home. The frequency is 30 repetitions every hour they are awake. Other at-home instructions are to avoid bending over and to do 30 repetitions of extension every time they bend forward. Progression occurs at the next therapy session as long as pain has continued to centralize or even diminish, involving the other exercises in McKenzie’s program that promote extension. The at-home exercise program can start to include some of these exercises if the patient feels comfortable doing them outside of therapy. Moving onto phase two is not dependent on increased range of motion, although that will occur. Rather, it is dependent on a period of time related to pain. The patient should continue the 30 prone press-ups at home on the hour until pain is gone. At that point, they can reduce the amount of sets per day to three plus every time they bend forward. Once the patient is pain-free for seven days, the scar tissue has been laid down in the annulus fibrosis, preventing posterior translation of the nucleus pulposus and preventing any bulging at the point they have previously experienced. This is the point at which conservative patients are ready to move on to phase two of rehabilitation: muscular strengthening and endurance.

For preoperative patients, this is the point one wants to reach before surgery. If the nucleus pulposus has migrated back to its central position in the disc and scar tissue has been laid
down, then the microdiscectomy will cut the annulus fibers protruding and relieve nerve root symptoms. Phase one of rehabilitation starts before surgery in surgical patients (as long as it is tolerated) and will restart approximately one-week post operation, with the rehabilitation program following progressively just like conservatively treated patients. The limitation with surgical intervention is a pain-free range of motion throughout phase one, so this phase is typically longer for the surgical patient than for a patient taking a conservative route.

The focus of phase two of the rehabilitation process is muscular strength and endurance. Phase two is marked by laid down scar tissue, which begins the third step of healing: remodeling. For patients with disc lesions, the key to these exercises is correct form. This involves teaching the body to maintain pelvis neutral in all exercises. The primary focuses are abdominal, oblique, gluteal, and back extensor muscle groups. Some exercises include bridging, abdominal and oblique curls, straight leg raises, latissimus dorsi pull downs, pushups, side stepping, and monster walks (Figures 19-24). As the patient gets stronger, they can progress (as long as they are pain-free) to prone leg lifts, dead bugs, bird dogs, supermans, bridging with kicks, mini-squats, and increased resistance with any of the early phase exercises (Figures 25-27). For any exercise in phases two through four, the standard duration is 30 repetitions, either broken up into three sets of ten, two sets of fifteen, or one set, whether the exercise is completed at the therapy session or at home. For the at-home exercise program, frequency is reduced to twice a day. Exercises for the at-home program should be focused on range of motion as the resisted “heavy” lifting should be done at therapy. As the patient is progressed to the next steps of therapy, the exercises at home focus on increasing functionality.

As the patient continues to show increases in strength, they may move on to phase three. The jump between phases two and three is not as apparent as jumps between other consecutive
phases. Strengthening exercises become more aggressive, adding more challenging exercises, or including variation on existing exercises. Some of the exercises add more body weight, such as side-lying sit up, prone trunk extension, and prone leg lifts off the table, meaning the patient is using the core, back, and gluteal muscles to lift the top half of their body off the table through a full range of motion (Figures 28-30). Other strength exercises that could be started during this phase include leg press, lunges, and resisted bridging (Figures 31 and 32). The third phase also adds plyometric and agility exercises, such as full squats, one legged balance exercises, cardiovascular intervention, medicine-ball trunk rotations, resisted leg lifts, and cable walking in a squat position (Figures 33 and 34). For the athletic population, an additional goal of the third phase is cardiovascular conditioning to prepare to return to sport (Figure 35).

Phase four of the rehabilitation is marked by the start of return to play/activity-based exercise. Because of the variability in the activity the patient is returning to, phase four is the most dynamic and patient-based phase of rehabilitation. Regardless of the patient population they are part of, return to play/activity of the surgical patient is dependent on the surgeon’s release based off their benchmark protocol, which has been followed through the entire rehabilitation process. In the middle-aged, working class population, these are resisted exercises that are similar to what they do on a daily basis for their job. For a profession like a meter reader, these exercises include kneeling and the goal is to get down and up off the floor quickly and without help. For jobs that include carrying a toolbox up a ladder and using tools while on it, this involves starting by going up and down the ladder and slowly adding weight to progress. A patient will be discharged and allowed to return to work when they can perform these activities without limitations or pain and have progressed to the approximate weight that they would be lifting upon returning to work. In the athletic population, the goal is to complete sport specific
exercises and drills without and pain or symptoms in anticipation of full participation, similar to the working population. For all athletes, this is the point at which they get to go back onto the field and start doing the easiest team drills. In the rehabilitation sessions, the focus at the beginning of this phase is to mimic exercises that apply similar forces to what they experience in their sport with no resistance. For all athletes, this looks like conditioning and stretching with the team. As the phase progresses for the gymnast, simple tumbling stunts are added, followed by more complex ones. For the football lineman, progression is seen with lining up like in game, but without an opposing lineman, and exploding out of the line, eventually leading to high-level pad drills, then low-level pad drills (Figure 36). Placing a football dummy in front of them while in line-form is another progressive step (Figure 37). For the thrower, resisted trunk rotation and weightless practice are next steps. One can progress with weight as tolerated until they are practicing with full weight and no restrictions. In the case with any athlete, it is important to correct any poor posture or form with any exercise as it can prevent reinjury.

When discharged, the patient is informed to continue the at-home exercise program to maintain good posture and continue strengthening their core and back, which is key to avoid reinjury. Precautions of all phases of rehabilitation include increasing of pain and/or symptoms with any exercise. If this happens, then the patient should stop the exercise immediately and regress to the point where the exercise does not cause an increase in symptoms. If progression to the fourth phase causes an increase in symptoms, then they are not ready to start return-to-activity exercises.

Conclusion

When facing a decision to go the non-conservative route of treatment for lumbar intervertebral disc lesions vs the conservative route, many factors must be taken into
consideration and because every patient is different, they must decide based off their circumstances. Typically, a clinician will always first suggest the conservative route because of the risk of surgery. Regardless of which route is chosen, the exercises and progression through phases of rehabilitation line up for both treatment options. As long there is some lower extremity and trunk mobility, exercises can be performed to promote the healing process and start gaining range of motion back. If during the conservative route progression is not occurring at a fast-enough rate or the severity of the injury is too significant, surgical intervention is the next step and can fix the damage that therapy alone could not. At that point, the goals of therapy also line up with conservative treatment, starting with increasing range of motion while controlling pain and inflammation. As a clinician, it is important to be knowledgeable of all options for treatment to help the patient make the decision that is best for them.
Appendix

Figure 1

Figure 2
Figure 11

Autonomic sensory zones
Figure 14
Figure 15 – Prone Lying with Elbows Extended

Figure 16 – Trunk Extension

Figure 17 – Cat-Cow
Figure 18 – Knees to Chest

Figure 19 – Bridges

Figure 20 – Abdominal Curls
Figure 21 – Oblique Curls

Figure 22 – Straight Leg Raises

Figure 23 – Lat. Pulldowns
Figure 24 – Side Stepping and Monster Walks

Figure 25 – Dead Bugs
Figure 26 – Bird Dogs

Figure 27 – Supermans

Figure 28 – Side-Lying Sit Ups
Figure 29 – Trunk Extensions

Figure 30 – Prone Leg Lifts

Figure 31 – Leg Press
Figure 32 – Resisted Bridges

Figure 33 – Medicine Ball Trunk Rotations

Figure 34 – Walking with Cable
References

6. McKenzie method of mechanical diagnosis and therapy. McKenzie Institute USA; New Zealand. 5-7,26,32.