

The Management of Low Back Pain: A Comprehensive Rehabilitation Program

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Introduction

Low back pain (LBP) is a ubiquitous condition with a 60% to 90% lifetime incidence and a 5% annual incidence. It is the most common cause of disability in the United States in people younger than 45 years of age and is second to the common cold as the most frequent reason for visiting the doctor. The annual cost of managing LBP is estimated to be a staggering \$56 billion. Although 90% of episodes resolve without medical attention in 6 to 12 weeks, 70% to 90% of patients with LBP have recurrent episodes. Despite a decrease in symptoms, these patients have anatomic and functional changes that increase their chance of reinjury. Therefore, it is essential that rehabilitation focuses not only on resolving the symptoms associated with injured and overloaded tissues but also on identifying and rehabilitating the unique associated biomechanical deficits and functional adaptations.

The benefits of exercise are profound and include improved cardiovascular fitness, muscle strength, flexibility, and endurance. Enhanced mood, increased pain tolerance, and better sleep also have been found to be related to exercise. There is also evidence that spine motion improves disk health through more efficient delivery of nutrients and removal of metabolic waste products. Exercise appears to be relatively safe in patients with LBP; there is no evidence that regular exercise increases the risk of additional back problems in patients with acute, subacute, or chronic LBP. Exercise appears to exert a neutral effect or may even slightly reduce the risk of future back injuries. On the other hand, bed rest has deleterious consequences in the setting of LBP, leading to decreased cardiovascular fitness, muscular strength, flexibility, bone density, and disk nutrition; increased spinal segment stiffness and depression are also associated with inactivity. There is no proven benefit of prolonged bed rest for patients with nonradicular pain. Therefore, no more than 2 days of absolute bed rest is

recommended for patients with nonspecific LBP. Relative rest, which allows for short periods of rest between activities and helps minimize the negative effects of bed rest, is actually preferred.

There are several reasons why the clinician should choose rehabilitation techniques for patients with LBP. Rehabilitation techniques help resolve the clinical symptoms and signs created by a primary lumbar spine injury so that active treatment encouraging independence can be initiated as soon as possible, and the untoward effects of inactivity can be minimized. By addressing both the primary site of injury and secondary sites of dysfunction, rehabilitation restores function, returns patients to activity, and theoretically lessens the chance of recurrence, thus optimizing outcome. Specifically, rehabilitation after a lumbar spine injury may help decrease days lost from work or sports activities and may increase productivity. Rehabilitation of lumbar injuries must continue beyond resolution of symptoms so that all other aspects of the injury complex, including flexibility, strength, power, and endurance, are fully rehabilitated. A plan for prevention of recurrent episodes of LBP is developed based on the comprehensive rehabilitation program so that optimal physiologic and biomechanical fitness is maintained; therefore, the risk of injury is potentially minimized.

Therapeutic Exercise and Cardiovascular Fitness, Flexibility, and Strength

In addition to reducing the intensity of back pain and the degree of disability related to back pain, the broad goals of a rehabilitation program are to improve cardiovascular fitness, flexibility, and strength, because deficits in all of these areas have been found in patients with LBP. Cardiovascular training can result in enhanced metabolism of free fatty acids, less body fat, increased insulin sensitivity, improved blood flow to muscles, higher

maximal cardiac output, greater $\text{VO}_{2\text{max}}$ (maximal oxygen consumption during exercise), lower heart rate for a given level of exertion, and reduced blood lactate accumulation and minute ventilation at a given submaximal level of exertion. In addition, studies suggest that individuals who are more physically fit may have LBP less often than individuals who do not exercise. On the other hand, aerobic conditioning is easily lost if a back injury results in more than 1 week of reduced activity. Specifically, $\text{VO}_{2\text{max}}$, the best indicator of aerobic fitness, decreases by 25% after 3 weeks of bed rest. In addition, patients with chronic LBP have reduced aerobic capacity in comparison with healthy control patients; however, it is unclear whether LBP reduces fitness or if reduced fitness leads to LBP. Therefore, aerobic training is an important aspect of a comprehensive rehabilitation program. According to the American Heart Association (www.americanheart.org), in order to attain a high level of cardiovascular fitness, exercise should be performed for 30 to 60 minutes on most days of the week at 50% to 80% of one's maximum capacity. Improvements in cardiovascular fitness, as measured by a 10% to 20% increases in $\text{VO}_{2\text{max}}$, usually can be noted within 8 to 12 weeks of training implementation. Many studies have found that patients with LBP are capable of improving their aerobic capabilities.

Rehabilitation for patients with LBP is also geared toward improving flexibility, which is defined as the ability to move a single joint or series of joints through an unrestricted pain-free range of motion. Flexibility is dependent on the extensibility of muscles and connective tissue that cross and surround a joint. General benefits of improved flexibility include increased available joint range of motion and reduced stress across one or more joints. Patients with LBP may report feeling "less stiff" and being able to perform activities of daily living (ADLs) and other work, sports, and/or leisure activities more comfortably. To produce normal lumbar motion, flexibility must be present in the hip flexors, hip extensors, hip rotators, adductors, abductors, hamstrings, quadriceps, and the gastrocnemius-soleus complex. A normal degree of flexibility of the hamstrings is required for appropriate lifting and bending postures; a flexibility deficit in the hamstrings appears to be a predisposing factor in the development of LBP. Particular muscles prone to tightness in patients with LBP include the erector spinae, tensor fascia latae, iliopsoas, quadratus lumborum, and hamstrings. Also, deficits in lead hip internal range of motion have been documented in golfers with LBP. Several methods of stretching exist, including static (steady force application over a period of 15 to 60 seconds); ballistic (use of rapid force in a repeated bouncing, throwing, or jerking maneuver); and proprioceptive neurofacilitation (techniques of hold-relax or contract-relax with or without agonist contraction). More recently, functional stretching, which in-

cludes activity and sport-specific stretches performed in a dynamic manner in multiple planes of movement, has come into favor. Despite the chosen stretching technique, rapid high-force stretches, which produce tissue recoil, should be avoided. Also, in patients with lumbar instability, end-range flexibility exercises should be avoided to prevent further dysfunction and pain. In general, stretching is effective in restoring normal trunk range of motion in patients with LBP. In patients with chronic LBP, flexibility training leads to a 20% average improvement in trunk flexibility.

The goal of a comprehensive rehabilitation program for LBP is to correct muscle weaknesses and imbalances with strengthening exercises. Strength training has been used as a successful strategy to reduce LBP and improve function. Other benefits include the potential for reduced risk of reinjury and an increased sense of well-being in patients with LBP. With complete bed rest, muscle has been shown to lose 1% to 3% of its strength per day and 10% to 15% per week during the first 2 weeks. Studies have shown that patients with chronic LBP have reduced strength and greater atrophy of the back muscles in comparison with healthy control patients. A 70% loss in trunk muscle strength was found in patients with lumbosacral pain persisting 6 months or longer. More globally, strength of the core muscles has been found to be preferentially affected in patients with LBP. Studies have reported that the multifidi muscles are atrophied in patients with LBP. A significant asymmetry in hip extensor strength was found in female athletes with LBP; there was an association between this strength imbalance and recurrence of LBP over the ensuing year. In addition to strength deficits, motor control abnormalities have been identified in the core musculature. Patients with LBP appear to have delayed activation of the transversus abdominis. One study reported, that compared with control patients, patients with LBP have delayed trunk muscle activation where the contraction of all trunk muscles precede that of the muscle responsible for lower limb movement; this delay was consistently and most significantly related to contraction of the transversus abdominis. Delayed firing and poor endurance of the gluteus maximus and medius have also been found in patients with LBP. In contrast to these findings that demonstrate the importance of individual core muscles, a more recent study reported that no muscle in isolation dominated in the enhancement of spine stability; each muscle's individual role was continuously changing across tasks. Therefore, it was proposed that global muscle activation by co-contraction of multiple agonist/antagonist muscles was preferable to training primarily "local" muscles. In addition to the core musculature, many other muscles are weak in patients with LBP, including the rectus femoris, vastus medialis and lateralis, tibialis anterior, and peroneus longus and brevis.

Strengthening exercises can be categorized into back extensor strengthening or core strengthening. Traditional strengthening of the back extensors is based on the progressive overload principle whereby increases in muscle strength are associated with muscular hypertrophy and enlargement of muscle cross-sectional area. Examples of this type of exercise include back extensor strengthening machines as well as roman chair exercises, which rely on one's own body weight to strengthen the back extensors. A typical strengthening routine is composed of three sets of 8 to 12 repetitions, performed once or twice a week; resistance should increase by no more than 10% per week. Studies have shown that such progressive resistance training results in improvements of 30% to 80% in volitional back muscle strength. It is unclear, however, whether these findings correlate with any functional benefits. In addition, although the human body functions in three cardinal planes (sagittal, frontal, and transverse), and back injury most commonly results from a combination of these motions, particularly flexion and torsion, these exercises are likely nonfunctional because they are performed solely in the sagittal plane.

Core strengthening is now favored among rehabilitation specialists and has come to supersede other therapeutic exercise regimens such as traditional back extensor strengthening. The core is the center of the functional kinetic chain and can be conceptualized as a “box” with the lumbar muscles (erector spinae and multifidi), abdominals, (transversus abdominis, internal oblique, external oblique, and rectus abdominis), hip girdle (iliopsoas, gluteus maximus and medius, hamstrings, and thoracodorsal fascia), and quadratus lumborum comprising the sides of the box. The diaphragm forms the top and the pelvic floor forms the bottom of the box. The core can be thought of as a muscular corset that works as a unit to stabilize the body and spine with and without limb movement. Core strengthening (also known as dynamic lumbar stabilization, motor control [neuromuscular] training, neutral spine control, and muscular fusion) describes the training of muscular control around the lumbar spine to maintain functional stability. This type of exercise is based on the belief that LBP is intimately linked with functional instability, defined as a significant decrease in the capacity of the stabilizing systems to maintain the neutral zone (the range in which internal resistance from active muscular control is minimal) within physiologic limits. Although intersegmental injury and intervertebral disk degeneration are associated with a larger neutral zone, muscular co-contraction of small intersegmental muscles and larger, more “global” muscles provide active stiffness or stability, thereby making the zone smaller. Rehabilitation of the core also allows the multisegmented spinal column to maintain its center of gravity through multi-

ple ranges of motion, counteracting gravity and applied forces to decrease torsion and shear on spinal structures.

In contrast to progressive resistance training of the back extensors, which form part of the core, core strengthening involves more than simply making muscles strong. In fact, motor relearning of inhibited muscles may be more important than actual strengthening in patients with LBP. According to one study, muscular endurance, not absolute strength, is the most important factor in maintaining a “margin of safety” for stability. This study specifically reported that only a very small increase in the activation of the multifidi and abdominal muscles was required to stiffen spinal segments, including 5% of a maximum voluntary contraction for ADLs and 10% for rigorous activity. Contrary to the commonly held notion, core strengthening is not equivalent to sit-ups and pelvic tilts. Traditional sit-ups are unsafe because they cause increased compression loads on the lumbar spine; pelvic tilts may also increase spinal loading by decreasing lordosis. Moreover, these two traditional exercises are nonfunctional. Instead, with core strengthening, the focus is on a motor control model whereby specific deficits are identified and muscles then trained to provide dynamic stability and segmental control to the spine. Faulty movement patterns are targeted with the components of the movement isolated and retrained into functional tasks specific to the patient's needs. It is imperative that exercises progress from training isolated muscles to training as an integrated unit to facilitate functional activity. Studies demonstrating the efficacy of core strengthening in patients with LBP, along with a core strengthening protocol in the context of a comprehensive rehabilitation program for LBP, will be discussed in subsequent sections.

Evidence-Based Approach to Specific Therapeutic Exercise Interventions for Specific LBP Diagnoses

Several advances have been made in the field of medicine to the understanding of identifying and managing pathology in the human body. For example, in the field of microbiology, hundreds of different disease-causing microorganisms have been discovered and specific antibiotics developed for treatment of each microorganism. As a result of this knowledge, no longer are all infections considered identical and managed simply with a course of penicillin. Similarly, musculoskeletal clinicians have also gained an appreciation of the various pain generators causing LBP, including muscles, ligaments, facet joints, intervertebral disks, and spinal nerves. Therefore, it makes no more sense to manage all causes of LBP with the same set of exercises as it does to treat all infections with penicillin.

Although specific therapeutic exercise interventions have been developed to address different diagnostic subsets of LBP, guidelines regarding the effectiveness of exercise for LBP, including the well-known Cochrane Database of Systematic Reviews, are sometimes confusing and controversial. According to the Cochrane Database, there is strong evidence that exercise therapy is no more effective than other active or even inactive treatments of acute LBP. In addition, there is conflicting evidence regarding the efficacy of exercise compared with inactive treatment for chronic LBP. Exercise therapy appears to be more effective than the usual care provided by the general practitioner and equally effective as conventional physiotherapy. The studies cited by such guidelines often contribute to misconceptions about the lack of efficacy of exercise for LBP because in many instances, a uniform exercise program was used irrespective of an ill-defined underlying condition. As a result, what is demonstrated is that nonspecific treatments of nonspecific diagnoses lead to nonspecific results. It is unreasonable to expect specific benefits from an exercise program if no specific diagnoses are made before initiation of the treatment arm of a study. Furthermore, a physical therapy program that is not individualized to each patient lessens the chance of successful rehabilitation of patients who have different causes of LBP. In summary, absence of proof because of methodologic flaws in the available literature is not equivalent to proof that exercise has no beneficial effect.

Better designed studies exist in which diagnostic subsets of patients with LBP are defined and treatments specific for these diagnoses are evaluated. For example, in the literature, back pain is not considered a nebulous entity but rather a presentation with many different etiologies including mechanical, flexion based (for example, disk herniation), extension based (for example, facet pathology, spinal stenosis), and instability mediated. In addition, as opposed to a blanket approach to physical therapy, specific therapeutic exercise protocols such as the McKenzie technique and core strengthening are evaluated in patients with LBP. In general, these studies show more promising results regarding the efficacy of therapeutic exercise for the management of LBP. For example, the effectiveness and medical costs of a classification approach to the rehabilitation of patients with acute, work-related LBP were compared with an approach based on the Agency for Health Care Policy Research guideline that advocates a more general approach for the first 4 weeks of rehabilitation. Joint mobilization or manipulation and spinal active range-of-motion exercises were assigned to those patients with unilateral symptoms who did not have signs of nerve root compression and positive findings for either sacroiliac joint dysfunction or asymmetric restriction of lumbar side-bending motion and lumbar segmental hypomobility. Patients with a flexion pattern (preference for

sitting and centralization with lumbar flexion) were given lumbar flexion exercises while those with an extension pattern (preference for standing and centralization with lumbar extension) were given lumbar extension exercises. Trunk strengthening and stabilization exercises were the treatment modalities for patients with frequent previous episodes, a positive response to prior manipulation or bracing as treatment, the presence of an “instability” catch, or lumbar segmental hypomobility. Finally, patients with radicular signs that did not centralize with movement who may have had a lateral shift deformity were given either mechanical traction or autotraction. The findings of this study show that classification-based treatment results in significantly better outcomes for disability (at up to 1 year of follow-up), return to work, and patient satisfaction at 4 weeks compared with the guideline-based group; there was also a trend toward less cost with the more specific treatment.

Several other studies have demonstrated the efficacy of two specific physical therapy regimens, movement therapy based on the results of directional preference testing and core strengthening, for diagnostic subsets of LBP. Directional preference testing is based on the McKenzie technique of repetitive end-range lumbar test movements, which have traditionally been shown to be helpful in evaluating the presence or absence of discogenic pain. With this mechanical assessment, a clinical phenomenon known as centralization commonly occurs where the most distal extent of referred or radicular pain rapidly recedes toward the lumbar midline by a single direction of repeated end-range movement. For example, with a discogenic etiology, the most common direction of lumbar testing that centralizes pain is extension, whereas a smaller group of patients will centralize only with laterally directed movements or even lumbar flexion. The recommended treatment then consists of that specific directional preference of end-range exercises and appropriate symptom-driven posture strategies.

There is strong evidence of good outcomes for centralizers with this directionally driven treatment modality. For example, patients with acute and subacute LBP with or without radicular symptoms who might benefit from an extension-mobilization program based on centralization with extension movements and positive findings from pelvic alignment tests were identified; these patients were then randomized to either an extension-based (with sacroiliac mobilization) or a flexion-based exercise program. The extension group improved more rapidly per the modified Oswestry Low Back Questionnaire, administered at days 3 and 5 of treatment. In addition, one study found that a unidirectional exercise program in extension with an additional focus on posture and ergonomics had superior outcomes at 3 weeks and 1 year compared with education in a “mini back

school” in patients with acute LBP with or without radiating pain. In a review of 87 patients with LBP and radiating leg pain, it was reported that centralization occurred in 87% of such patients; the occurrence of this phenomenon during initial mechanical evaluation was an accurate predictor of successful treatment outcome and a reliable determinant of the appropriate direction of treatment exercise. Nonoccurrence of centralization, however, accurately predicted poor treatment outcome. In a multicenter, randomized controlled trial of 312 patients with acute or chronic LBP or sciatica with or without neurologic findings, a standardized mechanical assessment was used to identify two groups of patients, based on the presence or absence of a directional preference. The 230 patients who exhibited a lasting beneficial pain response to one particular movement were then randomized to one of three exercise treatments including directional exercises “matching” the directional preference, exercises directionally “opposite” to the directional preference, and nondirectional exercise. Although all three exercise treatment groups showed improvement in all outcomes including pain intensity and medication usage, there were significantly greater improvements in every outcome in the group treated with matched directional exercises compared with the other treatment groups.

Many studies have reported beneficial outcomes for a core program in the management of lumbar disk herniation, lumbar instability, and acute LBP. In one classic study, a dynamic lumbar stabilization or core strengthening program for patients with lumbar radiculopathy was described. Good or excellent self-reported outcomes were obtained in 50 of 52 patients (96%) with a stabilization and abdominal program, together with flexibility exercises, joint mobilization of the hip and the thoracolumbar spinal segments, gym training, and aerobic activity. Another study then compared a specific core strengthening “stability” protocol for treating patients with chronic LBP secondary to instability from spondylolysis and spondylolisthesis with a standard treatment directed by the treating physician involving supervised exercise programs and modalities. The specific exercise treatment program consisted of 10 weeks of training of the deep abdominal muscles, with co-activation of the lumbar multifidi proximal to the pars defect; this activation was then incorporated into previously aggravating static postures and functional tasks. The core strengthening group showed a statistically significant reduction in pain intensity and functional disability levels, maintained at 30-month follow-up, whereas the control group demonstrated no significant change. In a recent study, patients experiencing a first-time episode of acute LBP were randomly allocated to a control group receiving advice and medications or a specific exercise group performing exercises targeting the multifidus in co-contraction with the transversus ab-

dominis. The core strengthening group had fewer recurrences of LBP in comparison with the nonexercise group at 1 year (30% versus 84%) and at 2 to 3 years (35% versus 75%). It can be concluded from these studies on the McKenzie technique and core strengthening that therapeutic exercise leads to beneficial results for patients with LBP if performed in a specific manner and directed at a specific pain generator.

A Comprehensive Rehabilitation Program for Low Back Pain

The clinician must have an understanding of the unique biomechanical stresses placed on the lumbar spine and its kinetic chain. A thorough patient history, physical examination, and any appropriate radiologic studies will help facilitate a specific diagnosis including the potential pain generator and any associated musculoskeletal dysfunctions. A specific treatment approach, customized for each patient’s unique presentation, can then be used for the most optimum outcomes. A comprehensive rehabilitation program seeks to reduce pain and inflammation, correct soft-tissue inflexibilities, and improve muscle strength deficits and imbalances as well as endurance in the involved spinal segments and the entire kinetic chain. Another important function of LBP rehabilitation is education and training for posture, body mechanics, and proprioception with the goal of maintaining the spine in the most optimal biomechanical position during activity. No single component of the rehabilitation program should be used in isolation, but rather in concert with other appropriate components.

The Acute Phase of Rehabilitation

Rehabilitation can be conceptualized as occurring in three stages—acute, recovery, and maintenance; however, these phases are not time-dependent and tend to overlap. During the acute stage of rehabilitation, goals are oriented toward decreasing the signs and symptoms of the injury (pain, swelling, stiffness, and other clinical findings). Before initiating a specific physical therapy intervention, the clinician should educate the patient about the proposed etiology of their LBP and the recommended treatment plan. A period of relative rest may also be suggested. Modalities such as ice or low-level heat wrap therapy, as well as medications including acetaminophen, nonsteroidal anti-inflammatory drugs, narcotics, steroids (oral or epidural), or muscle relaxants are frequently prescribed in the acute phase. These agents decrease pain, inflammation, and/or muscle spasm and thereby permit early and more rapid progression of rehabilitation. Corsets are associated with a significant potential for dependence and their use should be gradually discontinued as soon as possible; however, patients with instability may benefit from control of available lumbar range of motion and proprio-

ceptive feedback. Corsets also provide warmth to underlying soft tissue and may decrease intradiskal pressure.

When formal rehabilitation begins, the physical therapist or other appropriate clinician should emphasize education and protection of injured tissues, because this is considered by many to be the most important component of a LBP program. Specific points should include positions of comfort, proper sitting and standing ergonomics, and proper body mechanics for movement including position change, performance of ADLs (dressing, bathing, toileting, driving), and lifting. The clinician also may recommend that the patient avoid early morning flexion, especially during the first hour after awakening, because of the increased fluid content and hydrostatic pressures in the disk during that time. It has been reported that in patients with chronic nonspecific LBP who controlled early morning flexion for 6 months, during the first 6 hours of the day, pain intensity, total days in pain, impairment and disability, and medication usage were decreased. Passive techniques such as manual therapy (see chapter 14) and modalities may also play an important role during the acute phase of rehabilitation. Although such passive treatments may facilitate a patient's progress, if used in a protracted manner they place the patient in a dependent role and become counterproductive to proceeding with participatory function-oriented and ultimately independent care.

Modalities

Modalities are physical agents used to produce a therapeutic tissue response and to control pain and/or inflammation while the injury is given a period of relative rest. They are most effective when applied in response to a specific diagnosis with close monitoring of the patient's response. Commonly used modalities in the management of LBP include cold, heat, and electricity. The physiologic effects of cryotherapy include vasoconstriction with reflexive vasodilatation and decreased local metabolism, enzymatic activity, and oxygen demand. Because it lessens muscle spindle activity and slows nerve conduction velocity, cryotherapy is often used to decrease muscle spasticity and guarding to improve flexibility and function. On the other hand, cold is associated with increased connective tissue stiffness and muscle viscosity. Indications for cryotherapy in LBP include acute trauma, edema, hemorrhage, pain, and muscle spasm. Cold is preferable to heat for acute spine injury (especially during the first 48 hours after injury) because it controls pain and spasm and also decreases inflammation. To minimize the risk of developing neurapraxia, cold application should not exceed 30 minutes, and efforts should be made to protect peripheral nerves in the region being treated. Contraindications to cryotherapy include ischemia, Raynaud's disease or phenomenon, cold intolerance, skin insensitivity, and inability to report pain.

Heat therapy is also commonly used in the setting of LBP and includes both superficial heat and deep heat or diathermy. In general, heat creates higher metabolic demand, which promotes increased capillary permeability as well as increased blood flow, bringing leukocytes and oxygen to tissue. Deep heat has also been shown to decrease spasm and pain and increase collagen distensibility, thereby improving flexibility. Indications for heat in the treatment of LBP include pain, muscle spasm, and decreased collagen extensibility. Contraindications to heat include inflammation, hemorrhage/bleeding disorder, decreased sensation, poor thermal regulation, malignancy, edema, ischemia, atrophic/scarred skin, and inability to respond to pain. Hydrocollator or heat packs, heating pads, and low-level heat wraps are typically used to provide superficial heat by warming tissue structures via conduction, the transfer of heat directly from one surface to another. Superficial heat typically penetrates greatest at a 0.5- to 2.0-cm depth from the skin surface, depending on the amount of adipose tissue present. Heat packs are heated in stainless steel containers filled with 65° to 90°C water and then applied with towels (to minimize skin trauma and maintain heat insulation) in treatment sessions lasting 20 to 30 minutes. One recent study found that continuous use of low-level heat wrap therapy during sleep by patients with acute nonspecific LBP decreased pain throughout the next day, reduced muscle stiffness and disability, and improved trunk flexibility; these effects were sustained more than 48 hours after treatment was completed.

Ultrasound is the most commonly used form of deep heat therapy and warms tissue via conversion, the transfer of heat via a change in energy. Such heat can penetrate to depths of 5 cm below the skin surface, thereby providing a therapeutic benefit to tendon, ligament, joint capsule, and even bone. Selective heating is greatest when the acoustic impedance is high, such as at the bone-muscle interface. Ultrasound is more typically used for subacute and chronic injuries; other indications for its use in the treatment of LBP include associated tendinopathy and degenerative arthritis. Ultrasound is typically used for periods of 5 to 10 minutes at intensities of 1.0 to 4.0 W/cm². In addition to general heat precautions, specific contraindications for ultrasound include malignancy, open physal growth plates, pacemakers, laminectomy sites, regions of acute disk herniation with radiculopathy, fluid-containing cavities (for example, the uterus in a pregnant or menstruating woman, the testicle, or eye), unhealed fractures, joint arthroplasties containing methylmethacrylate or high-density polyethylene, and use near the brain.

Electricity is the third modality used in the treatment of LBP. Although transcutaneous electrical nerve stimulation is the most commonly used form of therapeutic electricity, other types include high-voltage pulsed galvanic stimulation, interferential electrical

stimulation, and minimal electrical noninvasive stimulation. Electricity acts physiologically to increase circulation and therefore aids in the removal of inflammatory by-products; it has also been reported to decrease edema, pain, spasm, inflammation, and muscle atrophy. Although typically indicated for chronic pain, transcutaneous electrical nerve stimulation appears to have a role in managing acute pain. Contraindications to electricity to treat LBP include active bleeding sites, cardiac pacemakers and defibrillators, areas with metal close to the skin, anesthetic areas, incompletely healed wounds, and use near the eyes, carotid sinus, or mucous membranes. Cryotherapy, heat therapy, and therapeutic electricity have all been shown to be helpful in relieving the pain and/or inflammation associated with LBP; however, there is little proven benefit when these modalities are used in isolation. Therefore, modalities should be considered an adjunctive treatment and included only as part of a comprehensive rehabilitation program.

During the acute phase of rehabilitation, the clinician should also introduce the concept of neutral spine and determine the patient's initial movement pattern. Neutral spine is an initial training posture, a loose-packed position that decreases tension on the ligaments and joints and allows a more balanced segmental force distribution between the disk and facet joints. It is considered to be the least painful and most biomechanically sound position of power and balance. Because the neutral spine is close to the center of reaction, it provides greater functional stability with axial loading and allows for quick movement into extension or flexion. The clinician should then instruct the patient in performing the first lumbar exercises, either in an extension or flexion bias based on the presumed lumbar pathology and response to repeated end-range movements. An extension bias is most commonly used with discogenic pain where symptoms tend to decrease (or centralize) with repetitive extension on motion pattern testing. In this patient population, extension exercises may reduce intradiskal pressure, allow anterior migration of the nucleus pulposus, and increase mechanoreceptor input, thus activating the pain gate mechanism. Notably, this movement pattern may increase symptoms in patients with large central disk herniations, foraminal herniations, or foraminal stenosis. On the other hand, in the setting of facet joint pathology or spinal stenosis, a flexion bias is typically indicated because symptoms tend to decrease with repetitive flexion movements. Flexion exercises may reduce facet joint compressive forces and provide stretch to the lumbar muscles, ligaments, and myofascial structures; these exercises, however, may also increase intradiskal pressure and thus exacerbate discogenic pain.

Cardiovascular fitness should be initiated in reference to the initial movement pattern. For example, if the disk is the pain generator, aerobic activity that places the spine in a neutral to extension bias such as the

treadmill (0° incline) and the cross-country ski machine is typically indicated. Conversely, the stationary bicycle and inclined treadmill, machines that place the spine in a neutral to flexion bias, are usually recommended if LBP originates from the facet joint or spinal stenosis. Although there is a limited amount of literature on the subject, aquatic-based rehabilitation appears to be useful in the acute phase of rehabilitation because it allows early intervention of aerobic conditioning. Advantages of aquatic rehabilitation include eliminating gravitational forces in a graded manner to allow training with comfortable and adjustable axial loads; challenging vertical posture secondary to depth-dependent refractive alterations of proprioceptive cues; controlling velocity through water resistance, viscosity, buoyancy, and training devices; increasing the range of training positions as the result of buoyancy; and improving the margin of error. Aquatic therapy has also been shown to attenuate pain because of hydrostatic pressure, temperature, and turbulence as well as enhance psychological outlook. Criteria for advancement to the next stage of rehabilitation include adequate pain control and tissue healing that allows for normal or near-normal painless range of motion and initial strengthening of the injured tissues.

The Recovery Phase of Rehabilitation

The recovery phase is the second and typically most lengthy phase of a comprehensive rehabilitation program for LBP. During this stage, treatment emphasis shifts from resolution of clinical signs and symptoms to restoration of function. The goals of this stage are to regain local flexibility, proprioception, and strength at the injured and adjacent motion segments of the lumbar spine. In addition, this focus should be applied to the entire kinetic chain because secondary biomechanical deficits exist at distant sites from the original injury as a result of chronic overload before or as the result of injury. To achieve these objectives, the treatment emphasis in this stage of rehabilitation moves away from passive modalities and manipulation and toward more focused and aggressive active interventions. The focus is on core strengthening. In general, the goals of this type of therapeutic exercise are to improve core muscle activity and endurance; establish neuromuscular control of the core muscles; restore coordination and position sense; increase lumbar mobility; train motor and postural control and balance; and to make exercises functional.

Specifically, the clinician leads the patient through a set of stabilization exercises. The reeducation of the core musculature classically begins with exercises such as the cat and camel (flexing and extending the back in a quadruped position) and the pelvic clock (rotating the pelvis along an imaginary 'clock' in a supine position with the feet on the floor). These movements "turn on" pelvic and hip muscles and help achieve spinal segment and pelvic

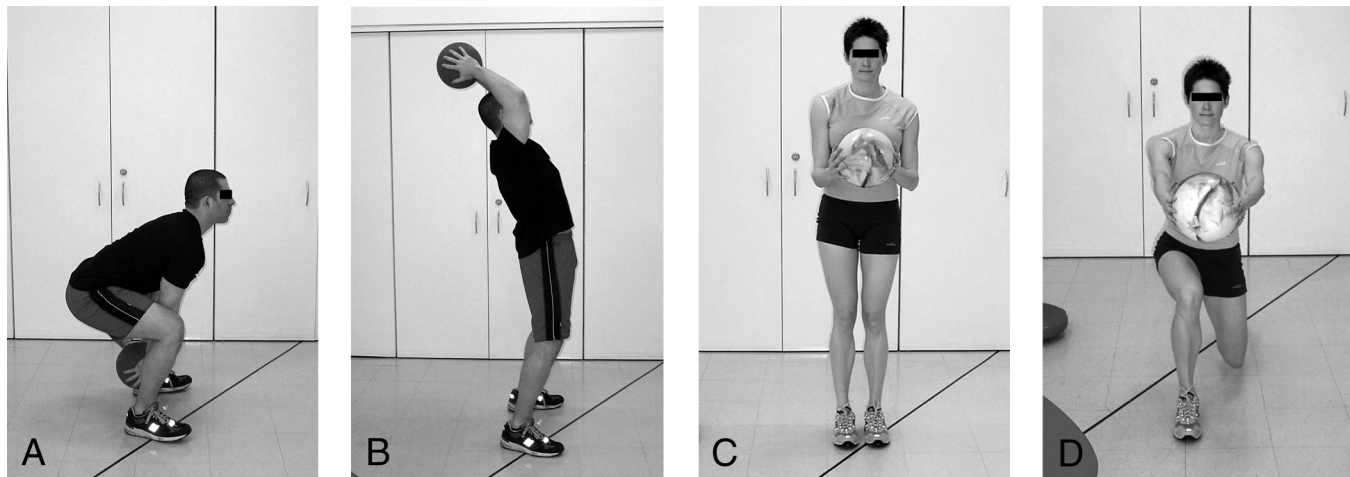


Figure 1 A through D, Core strengthening exercise in the sagittal plane.

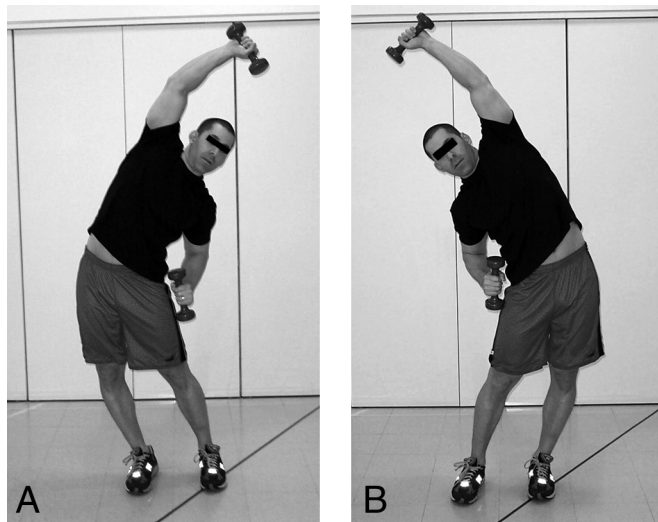


Figure 2 A and B, Core strengthening exercise in the frontal plane.

accessory motion before more aggressive exercises are attempted. Improving hip range of motion also has been shown to aid in dissipating forces from the lumbar spine. The patient then learns how to maintain the neutral spine in a static position, either supine or prone, which helps initiate awareness of motor patterns. Here, with verbal cues such as “bring the belly button back to the spine” or “squeeze the pelvic floor” and biofeedback, if necessary, the clinician facilitates activation of the core muscles. Once these muscles are “awakened,” the exercises progress to functional positions such as sitting and standing and then dynamic activities such as walking, running, and even jumping. In addition, because functional activities move through the neutral position, the exercises are advanced to nonneutral positions. Finally, graded challenges to the neutral spine are created, first

by gravity, and then by the therapist or an assistive device such as the physioball; these challenges should progress from the predictable to the unpredictable.

Activity-specific retraining is then directed based on ADLs and the patient’s unique functional activities. Each required motion is broken down into its individual components with the neutral spine trained for each; the parts are then reassembled so that the entire motion uses dynamic stabilization techniques. Finally, if the patient participates regularly in any sports activities, specific training should be included in this set of exercises. Because sports movement occurs in all three cardinal planes, the core should be trained in each of these directions (Figures 1 through 4). Additionally, because proprioception and balance are vital to the performance of sports, exercises should progress to labile surfaces. At the conclusion of this core strengthening program, the patient should have learned how to recruit spinal muscle stabilizers quickly and automatically, thereby controlling pain, optimizing soft-tissue repair and degeneration, gaining dynamic control of the segmental spine and kinetic chain forces, eliminating repetitive motion segment injury, and minimizing the chance of acute dynamic overload.

Other components of the recovery phase of rehabilitation include flexibility and strength programs and cardiovascular training. Flexibility exercises aim to correct muscle tightness, and allow the patient to assume a neutral position so that strength can be developed to help maintain correct neutral positioning during both static and dynamic conditions. Muscular weaknesses and imbalances, total body strength, endurance, and power, specific to the demands of the patient’s specific actions, are addressed in the strength program. Cardiovascular training helps provide the necessary aerobic and anaerobic fitness required for activities; when performed in a neutral spine position, such training helps maintain fit-

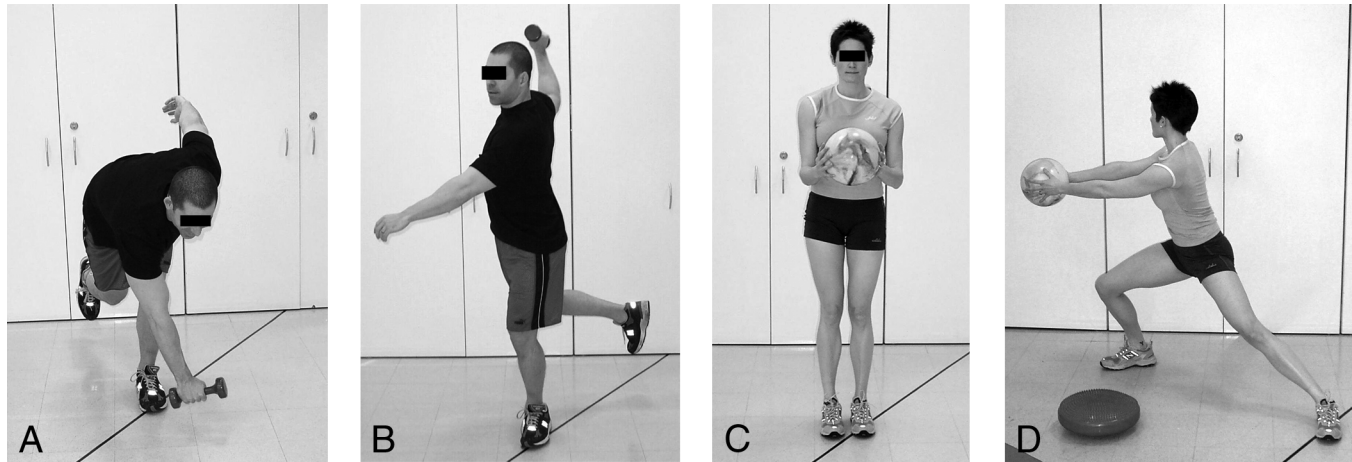


Figure 3 A through D, Core strengthening exercise in the transverse plane.

ness while protecting the lumbar spine. Criteria for advancement to the third stage of rehabilitation include complete pain control and tissue healing with essentially full painless range of motion and good flexibility. The athlete should be able to demonstrate strength of approximately 75% to 80% or greater compared with the uninjured side; there should also be good strength balance.

The Maintenance Phase of Rehabilitation

The final stage of a comprehensive rehabilitation program for LBP is the maintenance phase, which forms the basis for the prevention program. The goals of this stage of rehabilitation are to resolve the patient's residual biomechanical deficits and any subclinical adaptations (the substitute motions and/or activities used to compensate for an injury and its associated mechanical problems). This phase is devised as the patient returns to work or sport-specific activity to promote continued cardiovascular fitness and moreover, prevent reinjury. Specific components of the maintenance phase include education about ergonomics, equipment, and assistive devices; eccentric muscular strengthening with work and sport-specific training if applicable; power and endurance exercise; and progression to an independent home exercise program. The patient should also be equipped with the appropriate knowledge to solve problems that occur after discharge from physical therapy. Completion of a rehabilitation program for LBP is indicated by absence of signs and symptoms of the original injury, full pain-free range of motion, normal flexibility, normal strength and strength balance, good general fitness, normal mechanics for work or sport, and the ability to perform job and sport-specific skills. Rehabilitation must progress beyond the absence of symptoms. Because statistics show that 70% to 90% of patients with LBP have recurrent episodes, the absence of symptoms does not

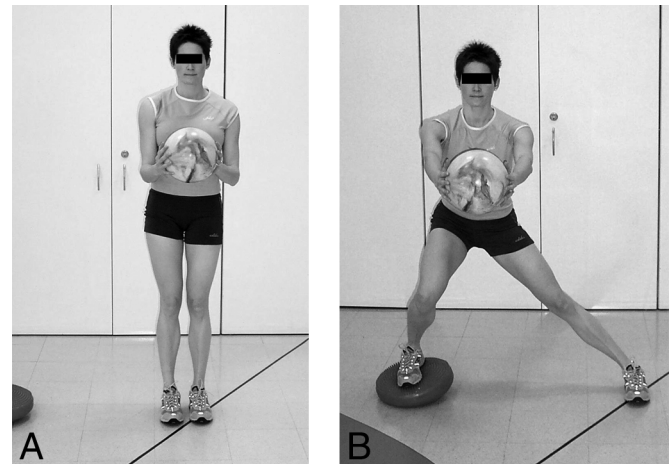


Figure 4 Core strengthening exercise in the frontal plane with labile surface.

necessarily imply normal function. By seeking to resolve the anatomic and functional changes associated with LBP, a comprehensive rehabilitation program may help reduce the incidence of LBP and its related impairments, disabilities, and high treatment costs.

Annotated Bibliography

Akuthota V, Nadler SF: Core strengthening. *Arch Phys Med Rehabil* 2004;85(suppl 1):S86-S92.

This review article uses a theoretic framework to describe the available literature on core strengthening in the rehabilitation of patients with LBP.

Fritz JM, Delitto A, Erhard RE: Comparison of classification-based physical therapy with therapy based on clinical practice guidelines for patients with acute low back pain: A randomized clinical trial. *Spine* 2003; 28:1363-1371.

In this study, the effectiveness and medical costs of a classification-based approach to the rehabilitation of patients with acute LBP was compared with an approach based on the Agency for Health Care Policy Research guideline, which indicates a more general approach for the first 4 weeks of rehabilitation. The findings of this study demonstrate that classification-based treatment results in significantly better outcomes for disability (up to 1 year), return to work, and patient satisfaction at 4 weeks compared with the results achieved in the guideline-based group; there was also a trend toward less cost with the more specific treatment regimen.

Hides JA, Jull GA, Richardson CA: Long-term effects of specific stabilizing exercises for first-episode low back pain. *Spine* 2001;26:E243-E248.

LBP patients were randomly allocated to a control group receiving advice and medications or a specific exercise group performing core strengthening exercises targeting the multifidus in co-contraction with the transversus abdominis. The core strengthening group had fewer recurrences of LBP compared with the nonexercise group at 1 year (30% versus 84%) and at 2- to 3-year follow-up (35% versus 75%).

Kavicic N, Grenier S, McGill SM: Determining the stabilizing role of individual torso muscles during rehabilitation exercises. *Spine* 2004;29:1254-1265.

The potential stabilizing role of individual lumbar muscles was evaluated through a systematic biomechanical analysis involving an artificial perturbation. Findings suggested that no single muscle dominated in the enhancement of spine stability, and the muscles' individual roles were continuously changing across tasks. Therefore, it was proposed that global muscle activation by co-contraction of multiple agonist/antagonist muscles was preferable to training primarily "local" muscles.

Long A, Donelson R, Fung T: Does it matter which exercise?: A randomized control trial of exercise for low back pain. *Spine* 2004;29:2593-2602.

In a multicenter, randomized controlled trial of 312 patients with acute or chronic LBP or sciatica with or without neurologic findings, the authors used a standardized mechanical assessment to identify two groups based on the presence or absence of a directional preference. The 230 patients that exhibited a lasting beneficial pain response to one particular movement were then randomized to one of three exercise treatments including directional exercises "matching" the directional preference, exercises directionally "opposite" to the directional preference, and nondirectional exercise. Although all three exercise treatment groups showed improvement in all outcomes including pain intensity and medication usage, there were significantly greater improvements in every outcome in the exercise-matched group compared with the other treatment groups.

Nadler SF, Malanga GA, DePrince M, et al: The relationship between lower extremity injury, low back pain,

and hip muscle strength in male and female collegiate athletes. *Clin J Sport Med* 2000;10:89-97.

In this cohort study of college athletes, a significant difference in side-to-side symmetry of maximum hip extension strength was observed in female athletes who reported lower extremity injury or LBP as compared with those who did not. Side-to-side difference in hip strength, however, did not differ between male athletes, regardless of reported lower extremity injury or LBP status. Female athletes appear to have a differing response of the proximal hip musculature to lower extremity injury or LBP, compared with their male counterparts.

Nadler SF, Steiner DJ, Petty SR, et al: Overnight use of continuous low-level heatwrap therapy for relief of low back pain. *Arch Phys Med Rehabil* 2003;84:335-342.

This study found that 8 hours of continuous low-level heat wrap therapy used during sleep by patients with acute nonspecific LBP decreased pain throughout the next day, reduced muscle stiffness and disability, and improved trunk flexibility. These effects were sustained more than 48 hours after treatment was completed. Adverse events were mild and infrequent.

Panjabi MM: Clinical spinal instability and low back pain. *J Electromyogr Kinesiol* 2003;13:371-379.

This article describes the stabilizing system of the spine which includes the spinal column, spinal muscles, and neural control unit. A hypothesis relating the neutral zone to pain is explained and in vitro experiments and mathematical models showing spinal muscles providing significant stability to the spine are presented. Increased body sway was found in patients with LBP, indicating a less efficient neuromuscular control system with decreased ability to provide the needed spinal stability.

Vad VB, Bhat AL, Basrai D, et al: Low back pain in professional golfers: The role of associated hip and low back range-of-motion deficits. *Am J Sports Med* 2004;32:494-497.

In this study, 42 professional golfers were categorized into group 1 (history of low back pain for more than 2 weeks that affected quality of play) and group 2 (no previous history of pain). A statistically significant correlation ($P < .05$) was observed between the group with a history of low back pain with decreased lead hip internal rotation, Fabere's distance, and lumbar extension.

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