A Review Paper

Dynamic Muscular Stabilization in the Nonoperative Treatment of Lumbar Pain Syndromes

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ABSTRACT

The results of a three-year study of patients with herniated nucleus pulposus and radiculopathy are presented. Nonoperative treatment options for these lumbar disorders, ie, an aggressive physical rehabilitation program, pain control methods, exercise training designed to eliminate repetitive intervertebral disc or facet joint injury, and dynamic muscular lumbar stabilization techniques, were utilized.

Successful outcomes were achieved in 50 of the 52 (96%) nonoperatively treated patients. A subcategory of patients with extruded nuclear fragments had an 87% success rate. Ninety-two percent of the overall study population was able to return to work.

The rehabilitation of patients with low back pain is a comprehensive process, requiring both accurate diagnosis and early intervention. The primary rehabilitation goal should be functional optimization, not pain relief—although pain may be the patient's chief complaint. Patients' daily activities may be limited owing to pain, and their quality of life may have deteriorated. Pain may curtail their ability to work, maintain their household, or participate in recreational activities.

Thus, rehabilitation programs should improve patient function and quality of life—not just treat pain. They must teach patients how to control their lumbar dysfunction so that pain does not dictate their life-style.

NONOPERATIVE TREATMENT

We recently reported on the nonoperative treatment of patients with a herniated nucleus pulposus and radiculopathy who were followed for at least three years.[17] Criteria for the study included a computed tomographic (CT)

or magnetic resonance imaging (MRI) scan that displayed a herniated nucleus pulposus, a primary complaint of leg pain, straight leg raising that reproduced the leg pain at < 60°, and an electromyograph (EMG) that revealed electrophysiologic evidence of radiculopathy. All patients underwent an aggressive physical rehabilitation program.

The study group included a subset of patients who were seeking a second opinion regarding lumbar disc surgery. These patients had been advised by a surgeon to undergo disc excision. The results were analyzed for this group separately and the study population as a whole. A group of patients with extruded nuclear fragments were also analyzed separately.

The results are quite startling. Fifty of the 52 nonoperatively-treated patients (96%) achieved successful outcomes. A successful outcome was defined as a self-rating in the good or excellent category as determined by the study's outcome criteria. Eighty-three percent of the second-opinion cases (15/18) also had successful nonoperative outcomes. Patients with extruded nuclear fragments (13/15) had an 87% success rate. Ninety-two percent of the entire study population was able to return to work, as compared with only 75%[1] to 85%[3] in previously reported surgical studies. The median sick leave time required in our study was 3.9 months; this compares favorably with the surgi-

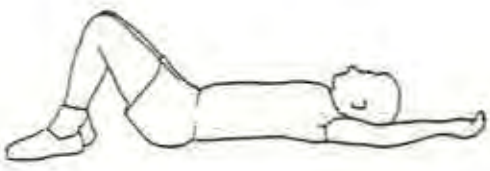

Figure 1. *Dynamic abdominal bracing exercise. The patient lies supine with the knees bent, one arm above the head and one at the side. The legs are then raised off the floor with bent knees and the arms and legs pumped alternately. The spine is maintained in a neutral position.*

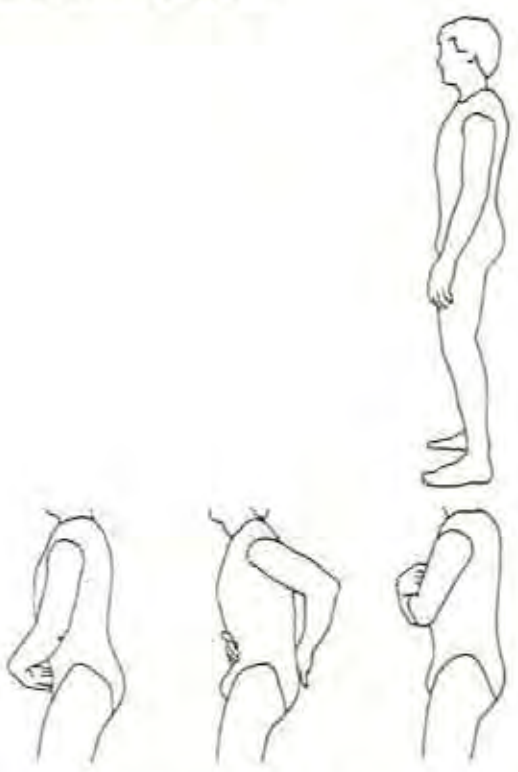

Figure 2. *The patient is instructed on how to find and maintain the neutral spine position. He or she is encouraged to rotate the pelvis forward and backward until a balanced, pain-free mid-range position is attained.*

Table I. Pain Control of Lumbar Disc Disorder

- Back first aid
- Trial extension exercises
- Trial of traction
- Basic stabilization exercise training
- Nonsteroidal anti-inflammatory drugs
- Non-narcotic analgesics
- Corticosteroids
  - Oral
  - Epidural injection
  - Selective nerve root injection (ie, selective epidural)
  - Facet injection

cal series that have been presented. Neurologic weakness of the lower extremity musculature did not adversely affect the outcome. This success rate resulted from a program of dynamic muscular lumbar stabilization. This type of training program can begin on completion of the pain-control phase of the rehabilitation program.

PAIN CONTROL PROGRAM

Pain control methods (Table I) must be based on the patient's ability to function and comply with the prescribed exercise program. Patients should be enlisted in therapeutic exercise regimens as their pain and neurologic loss permit. The initial stage of back first aid involves ice application, rest, and instruction in body mechanics to facilitate pain-free movement; transcutaneous nerve stimulation or acupuncture may also be implemented. Medication use is minimized. A trial of traction (gravity inversion, pelvic traction, or autotraction) is used for patients with refractory radicular pain following extension exercises. Traction should be continued in those patients who have a marked reduction of radicular pain.

Non-narcotic analgesics (acetaminophen) and nonsteroidal anti-inflammatory drugs may be prescribed. Occasionally, a limited course (up to two weeks) of a class-III narcotic analgesic (eg, Tylenol with codeine) may be used. Schedule II medications, sedative hypnotics, or muscle relaxant medication are not prescribed for pain control.

Bed rest is not recommended. Patients are instructed to pursue a level of activity that does not exacerbate radicular pain or worsen a neurologic deficit. Epidural injection of a corticosteroid is the treatment of choice for persistent radicular pain, although a tapered course of oral corticosteroids may be prescribed. The caudal or translumbar route of injection can be used for disc herniation at the L4-5 and L5-S1 levels, and a translumbar approach is used for disc herniations at L3-4 and above.[19] Local anesthetization by instillation of nonionic contrast material under fluoroscopic guidance is used in all cases. Straight leg raising is assessed at the peak of local anesthesia (0.5% lidocaine final concentration in a 10-mL volume). If relief is not obtained during this phase, corticosteroid therapy is administered by selective nerve root injection at the root of greatest involvement (as determined by electromyographic study and imaging tests).

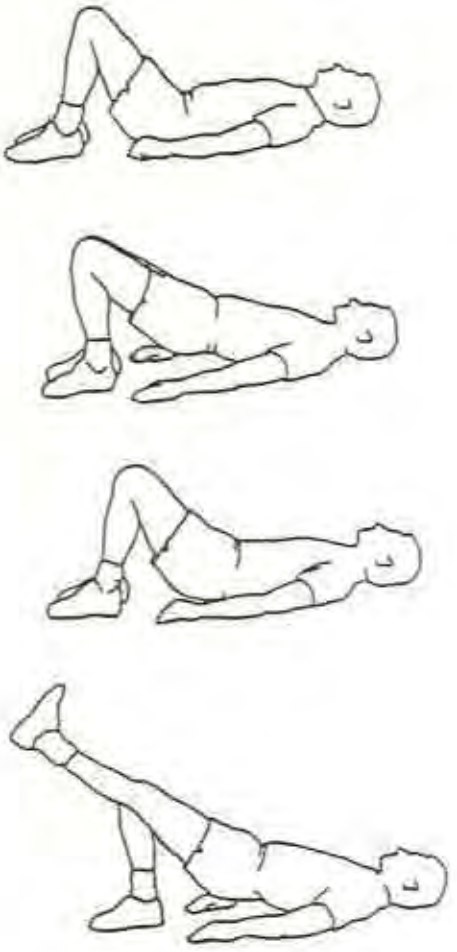

Figure 3. *The bridging exercise strengthens abdominal, buttocks, and low back muscles. The patient lies supine with knees bent, raises the hips and back from the floor, and holds the position. The exercise is repeated with the hips one inch off the floor, and then with alternate leg extensions. Throughout, the spine is maintained in a neutral position.*

The results of injection therapy are assessed at two to three weeks. If disabling radicular pain persists, a second epidural corticosteriod injection is administered. If the persistent back pain is consistent with facet syndrome, facet joint corticosteroid injections are initiated. Injection therapy is used to facilitate

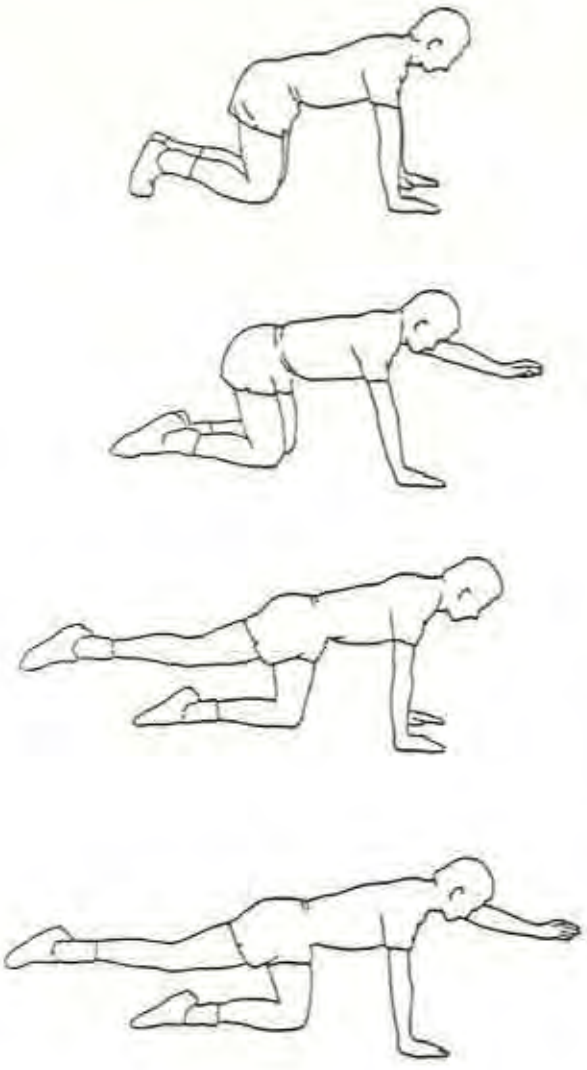

Figure 4. *Quadriped arm and leg exercises. The patient kneels on all fours and tightens the stomach and buttocks muscles. The arms and legs are raised alternately.*

functional progress. Decisions to inject or reinject are based on the patient's progression with the active exercise program.

The goal of the exercise training phase is the attainment of adequate musculoligamentous control of lumbar spine forces to prevent further injury to the intervertebral discs, facet joints, and related structures. Prior to progression beyond the pain control phase, patients are at risk of a repeat injury that may further limit their activity. The physician must identify why the injury occurred, and what the potential risk factors may be. Patients alerted to these risk factors will be encouraged to utilize appropriate preventive measures.

Once a lumbar motion segment is injured, the risk of repetitive injury is increased. The recidivism rate in low back pain patients is well documented[3] as are the benefits obtained from work-place prevention programs.[4] Studies also have demonstrated the effect of fatigue on the lumbar intervertebral disc and the progressive development of gradual disc prolapse.[5] These findings illustrate the biomechanical process of repetitive injuries to the intervertebral disc leading to progressive pathology. They explain how a "simple" anular tear, with subsequent anular injury, can develop into a full-blown disc protrusion or herniation. Therefore, early identification of an anular tear suggests that a back school program be instituted promptly to prevent future injury and disability. Spine care should not consist of simple "band-aid" treatment. Preventive measures should be a mainstay of spine practices; we cannot ignore prevention and merely treat pain.

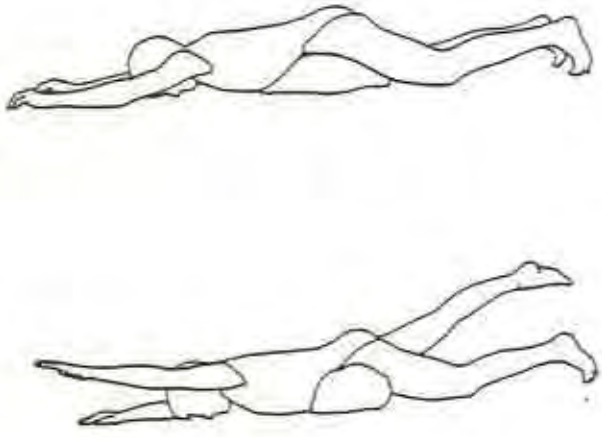

Figure 5. *The prone arm and leg lift exercise strengthens the arm, shoulder, and leg muscles. The patient lies prone, uses the abdominal muscles to stabilize the position, and lifts one arm and the opposite leg. The motion should be controlled; the trunk should not move.*

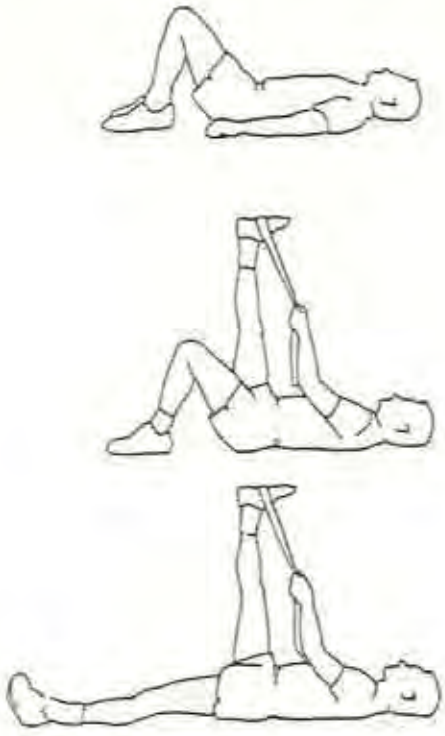

Figure 6. *In the hamstring stretch exercise, the patient lies on his or her back with the knees bent. A long strap is looped under the sole of the right foot and the leg is straightened. The exercise is then repeated with the left leg.*

STABILIZATION CONCEPTS

Repetitive flexion and torsional stress to the lumbar intervertebral discs and facet joints leads to advanced degenerative changes.[6,7] Knowledge of gradual disc prolapse secondary to fatigue of the anular fibers is important for understanding this phenomenon.[5] Stabilization eliminates repetitive microtrauma to the lumbar motion segments, thereby encouraging healing of the initial injury. It also may alter the progression of the degenerative processes.

Muscle fusion uses the musculature to brace the spine and protect the motion segments against repetitive microtrauma and excessively high single-occurrence loads. The abdominal mechanism, which couples the midline ligament and the dorsolumbar fascia combined with a slight reduction in lumbar lordosis, can eliminate shear stress to the lumbar intervertebral segments. The abdominal musculature may flex the lumbar spine through its action on the superficial portion of the dorsolumbar fascia. It also may extend the lumbar spine through its action on the deep portions of the fascia that form the alar interspinal ligaments. This coupled action enables the abdominal muscles to corset the lumbar region in concert with the latissimus dorsi, which also acts on the dorsolumbar fascia. The lowering of the center of gravity with slight knee flexion (facilitated by adequately strong quadriceps) is an important element of bracing the spine.

Due to the changes in axial rotation that are possible at the intervertebral segments at different degrees of lordosis, control of lordosis in flexion and extension is extremely important. These mechanisms explain how balanced muscular function and flexibility permit the control of stresses applied to the lumbar intervertebral segments. It should be pointed out that the anulus of the intervertebral disc is solely responsible for load transmission of the intervertebral segment.[6] Removal of the nucleus does not greatly affect the joint response. Therefore, repetitive

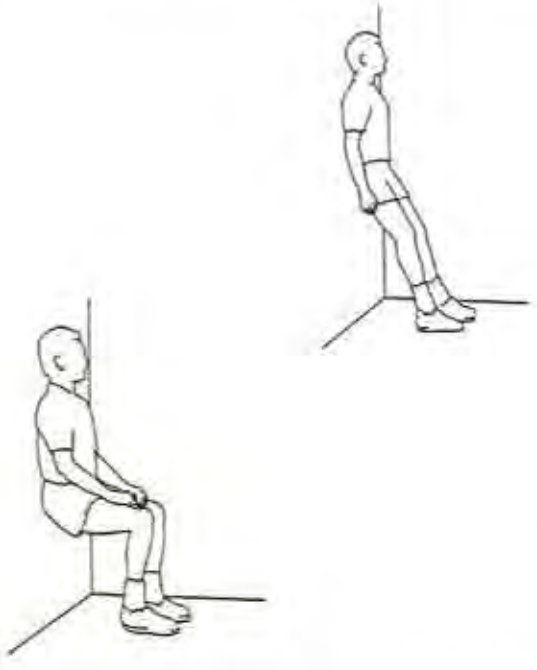

Figure 7. *The thigh muscles are strengthened with the wall slide quadriceps strengthening exercise. The patient leans against a wall and slides down; the knees are not bent more than 90°.*

loads applied to the lumbar intervertebral joint will fall on the outer anular fibers, leading to progressive tearing and fatigue and potentially progressive disc prolapse.

Knowledge of repetitive extension maneuvers enhances understanding of the load transmission to the facet joints. It is well documented that narrowing of the intervertebral disc increases load transmission to the facet joints.[9] A degenerative segment concomitant with repetitive extension and rotation loads to the lumbar intervertebral joints may lead to joint failure. Therefore, the principle of neutral spine positioning also may be applied to this portion of the motion segment.

Muscle fusion involves co-contraction of the abdominal muscles to maintain a corset for the lumbar spine that consists of the midline ligament and thoracolumbar fascia, coupled with proper pelvic positioning. The spinal extensor muscles reduce translational stress to the intervertebral segments during activity, and balance shear stress to the intervertebral segments. The multifidus muscle appears to be the most active; however, owing to its short segmental nature it is the most difficult muscle to strengthen. The gluteus maximus may be the most important extensor muscle, controlling the lumbar-spine lifting power.[9]

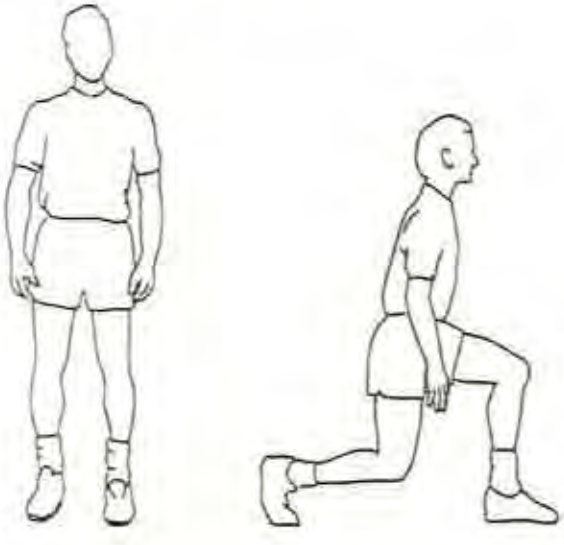

Figure 8. *The forward lunge exercise strengthens the thigh and buttocks muscles. It enhances proper spine stabilization. The patient stands with his or her feet apart, shoulder width, and the knees bent. The patient lunges forward until one knee almost touches the floor; the exercise is repeated with the opposite leg.*

The abdominal muscles clearly play a key role in dynamic muscular lumbar-spine stabilization. Exercises to strengthen the abdominal muscles abound, and a review of the literature on this subject is revealing. The iliacus is the major muscle involved in that stage of the sit-up exercise performed from 45° to vertical sitting.[10] The exercises that require the least effort of the abdominal muscles are full sit-ups and abdominal curl-ups after the initial 30% of motion.[11] The performance of the total concentric phase of the sit-up exercise is accompanied by greater abdominal-muscle activity than that found during the total eccentric phase.[12] The oblique muscles and the rectus abdominis are most active during the initial head and shoulder phases of abdominal sit-ups. The force of abdominal muscle contraction can be increased by additional resistance, ie, slantboard inversion, manual resistance, or cross-chest weight holding.[12]

The magnitude of muscle recruitment for the lower rectus is increased when the feet are supported in a hook-lying position.[12] Non-supported feet during this exercise favor greater contraction of the upper rectus. Positions such as the elevated chair position or hanging from a bar or rings induce more muscle recruitment than other exercises.[12] The trunk curl, with only the head and scapula raised and the knees flexed at 45° (with or without foot support), and accompanied by a body twist, requires greater recruitment of the rectus abdominis and oblique muscles than do symmetrical exercises.[12] This curl-up position, with only the scapula and head raised, also causes the least amount of lumbar spine movement.[13]

Pelvic tilt activities involve the internal oblique muscles. Trunk rotation is performed largely by the internal oblique muscles coupled with the dorsolumbar fascia and latissimus dorsi. The rectus abdominis does not really function as a trunk flexor; it contracts maximally only during flexion when full spinal flexion has occurred as a result of gravity.[12,14]

The curl-up exercise (with or without foot support), performed by raising only the head and scapula off the ground and using a symmetrical contraction pattern as well as a rotated diagonal pattern, is the appropriate beginning exercise for abdominal strengthening. Complete sit-ups are unnecessary—abdominal muscles do not work in the second 45°of the motion; the iliacus and rectus femoris muscles are instead responsible. The complete sit-up places greater stress on the lumbar spine, and should always be contraindicated. Lumbar spine injuries are frequently caused by improper abdominal strengthening techniques.

A combination of fast repetitions and isometric-type repetitions will utilize all muscle fibers and will promote endurance as well as absolute isometric strength of the abdominal muscles. It is prudent to use the foot-supported position for sit-ups, with the knees bent at 45°, to allow for maximal contraction of the lower rectus and oblique muscles. However, the performance of some unsupported repetitions facilitates the development of isolated upper rectus strength. Advanced abdominal exercises can be executed with bilateral straight leg lifts while supported in an elevated chair or supine. Slow, controlled leg lifts will ensure lower abdominal isolation and eliminate nonproductive leg-swinging movements. An advanced program should include curl-ups performed on an incline board in symmetric and diagonal patterns. Adding the manual resistance of a partner or holding a weight plate on the chest promotes additional abdominal strength. To build abdominal strength, a progressive resistance program should be followed. The musculature should be challenged continuously for maximal benefit. Once a patient can perform three sets of 10 to 15 repetitions of an abdominal exercise with ease, advanced exercises should be undertaken.

To apply muscle fusion, adequate flexibility and spinal range of motion (ROM) must be attained. In an interesting study regarding diurnal variations and stresses on the lumbar spine, Adams et al described a daily pattern of changes in lumbar disc and ligament extensibility.[15] These changes, based on the creep of soft-tissue structures, lead to an increasd ROM. They noted that bending and lifting activities performed early in the morning, when ligamentous and anular fibers are less extensible, are more likely to cause fatigue damage to the disc than similar activities performed later in the day. Thus, flexibility of the structures eliminates this repetitive fatigue stress to the intervertebral joint. Muscles that attach to the pelvis as "guy wires" can effectively change the pelvic position and symmetry.

Pelvic positioning is key to postural control of the lumbar spine. Therefore, adequate flexibility of the hamstring, quadriceps, iliopsoas, gastrocsoleus, hip rotator, and iliotibial band muscles is important, as are flexible neural elements.

STABILIZATION TRAINING ROUTINES

Stabilization training routines (Table II) can be divided into basic and advanced programs. The basic program has been occasionally classified as a neurodevelopmental stage of postural control. It commences with exercises performed in the supine or prone position, then advances to exercises performed while kneeling, then standing, and, finally, to movements of position transition (ie, standing to sitting, sitting to standing, and supine to sitting). Meticulous technique is imperative while performing these exercises; therefore, an experienced physical therapist or exercise trainer should be employed. The basic level exercises are first taught with one-on-one instruction and then in a group. Each exercise is designed to develop isolated and co-contraction muscle patterns to stabilize the lumbar spine in its neutral position. A neutral spine position is not necessarily 0° of lordosis, but rather the most comfortable position for the individual based on the biomechanical principles discussed earlier.

Each patient should be monitored during the exercise program to define the optimal spine position. Care should be taken to ensure proper form and slow exercise-repetition speed. The neurophysiologic principle of central pathway irradiation secondary to in-

Table II. Exercise Training for Lumbar Disc Disorder

Soft Tissue Flexibility
- Hamstring musculotendinous unit
- Quadriceps musculotendinous unit
- Iliopsoas musculotendinous unit
- Gastrocsoleus musculotendinous unit
- External and internal hip rotators

Joint Mobility
- Lumbar spine segmental mobility
- Hip ROM
- Thoracic segmental mobility

Stabilization Program
- Finding neutral position
  (standing, sitting,
  jumping, prone)
- Prone gluteal squeezes with
  arm raises
  alternate arm raises
  leg raises
  alternate leg raises
  arm and leg raises
  alternate arm and leg raises
- Supine pelvic bracing
- Bridging progression
  basic position
  one leg raised with ankle weights
  stepping
  balancing on gym ball
- Quadruped (with alternating arm and leg movements with ankle and wrist weights)
- Kneeling stabilization (double knee, single knee, lunges with and without weight)
- Wall slide quadriceps strengthening
- Position transition with postural control

Abdominal Program
- Curl-ups
- Dead bugs (supported, nonsupported)
- Diagonal curl-ups
- Diagonal curl-ups on incline board
- Straight leg lowering

Gym Program
- Latissimus pull downs
- Angled leg press
- Lunges
- Hyperextension bench
- General upper-body weight exercises
- Pulley exercises to stress postural control

Aerobic Program
- Progressive walking
- Swimming
- Stationary bicycling
- Cross-country ski machine
- Running (initially supervised on a treadmill)

creased amplitude of effort must be kept in mind.[16] Engram motor programming is the goal of the exercise program; therefore, careful repetition of the exercises with precise movements is required. Once engram motor programming has occurred, the exercise routine is patterned in the motor cortex—available without conscious effort.

Once proper exercise form and technique have been achieved, the program can be advanced. Balancing upon a large gym ball will make the floor exercise more challenging. The addition of wrist and ankle weights or theraband resistance also intensifies the effort required. Therefore, this will require a greater degree of dynamic stabilization. These principles also can be applied to the weight training portion of the program. The patient is taught how to mount and dismount weight training equipment while maintaining stabilization principles. Patients should be educated as to the safe methods of changing the weight stack resistance pin on the machines and lifting and racking free weights as well as how to use free weights, pulleys, and single-station weight machines. This resistance equipment requires contraction of the lower abdominal musculature to maintain optimal anteverted pelvic po-

sitioning, with the lower back flattened against a back support while maintaining a stabilized neutral spine. Therefore, all gym routines become functional stabilization exercises.

Strengthening programs should be tailored to the individual's needs. Physical capacity for occupational and recreational activity is used to structure the program. The weight training program is geared not only for truncal musculature, but for total fitness. Aerobic and anaerobic training is incorporated in this program. Learning to stabilize the spine while riding a stationary bicycle, running on the treadmill, or swimming are integral stages of the program. Instruction that demonstrates proper spinal positioning while performing these activities is required. Patients progress from treadmill walking, to treadmill running, and finally to supervised track running.

Injured athletes with lumbar pain require highly specialized programs.[17] The training program for football linemen incorporates the previously discussed principles. However, the tasks of the lineman are broken down into individual components, including stance positioning, back pedaling while pass blocking, and pulling and dive positions for run-play blocking. Stress is placed on adequate knee flexion and strong abdominal muscles that cocontract with the gluteus maximus to attain the forward pelvic tilt, thereby eliminating excessive lordosis of the lumbar spine during axial loading. The player is taught how to take a blow while contracting his abdominal muscles to stabilize the spine. He is also taught how to fall and roll with an abdominal contraction. The motivated football player finds this type of positioning comfortable, efficient, and powerful. One-on-one drills reinforce stabilization principles while the player is being pushed and pulled.

During sports-specific training programs, the athlete starts with a basic level of exercise, and progresses to advanced training and then to sports-specific training. The sports-specific training begins with hands-on, one-on-one mat work that advances from isolated to compound movements. Video-taped exercise sessions and performance of specific athletic techniques are valuable coaching and training aids. The principles of athletic spine training can be applied to virtually all sports. It is important to work carefully with individual coaches before designing any training programs.

Torque to the lumbar spine is intrinsic to many sports; it is impossible to totally eliminate rotational stress. Minimization and control of this stress is warranted when possible. Most athletic lumbar spine injuries occur in the weight room secondary to repetitive microtrauma, not on the playing field or gymnasium floor.

Nonoperative treatment must meet reasonable time and cost criteria. Early goal setting that is based on the patient's occupation, recreational activities, and functional level is important. Once patients reach a plateau and their functional improvement is not affected by alterations in their exercise program, an independent program can be substituted for the supervised program. The overall goals of treatment are independence from medications, physical therapy, and/or manipulative treatment. Active exercise programs rather than passive modalities and manual treatment should be encouraged, as the latter are costly and ineffective.[17,18]

Functional progress, rather than the patient's pain level, is the criterion for determining advancement to the more challenging exercises. The program's endpoint is determined by maximal functional capacity that cannot be improved with additional exercise training or pain control.

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