Clinical Instability of the Lumbar Spine: Diagnosis and Intervention

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Lumbar stabilization or 'core' stabilization exercises are currently popular interventions for patients with mechanical low back pain (MLBP). Stabilization exercises have typically been prescribed for patients with '*spinal instability*.' But can we actually identify patients with spinal instability, and are these patients likely to benefit from stabilization exercises?

The incidence of spinal instability is difficult to determine partially because of the lack of an accepted operational definition. Estimates of the percentage of patients with low back pain arising because of spinal instability range from 13% to 30% of the total population of patients with MLBP.[1,2]

Specific classification systems may assist in identifying patients with MLBP attributed to spinal instability. Classification allows interventions to be designed for, and directed toward, specific subgroups as opposed to an entire population of patients. Delitto et al[3] introduced a classification system using patient symptoms and physical examination findings, now known as the Treatment-Based Classification (TBC). This system assists with clinical decision-making and provides information about specific interventions for each classification. One subgroup in the TBC system is the 'stabilization' category (previously known as the 'immobilization' category). Patients placed into this subgroup are hypothesized to have spinal instability and are treated with specific stabilization exercises. However, actually classifying a patient into this subgroup may not be a simple process. Givens et al[4] studied examiner agreement in assigning patients to different subgroups and found differences in the number of patients assigned to the stabilization subgroup by different examiners. Perhaps the characteristics of patients manifesting spinal instability are either poorly identified or poorly understood.

The purposes of this article are to suggest an operational definition of *clinical instability* and to examine the literature for the current best evidence for identifying those patients who would best respond to stabilization exercises as the primary intervention. In addition, exercises that have been reported effective in managing patients with clinical instability of the lumbar spine will be presented and discussed.

SEGMENTAL INSTABILITY VERSUS CLINICAL INSTABILITY

Early attempts to define *spinal instability* were based on spinal pathology associated with excessive movement at the intervertebral or *segmental* level.[5] *Segmental instability* was proposed to exist because of failure of the passive restraints (ie, the intervertebral disc, ligaments, and facet joint capsules) that function to limit segment motion. This original, narrow concept of spinal instability was broadened when Panjabi[6] hypothesized that the neuromuscular system might also play an important role in controlling segmental motion. He published a model of a spinal stabilization system represented by 3 major subsystems. These subsystems consist of the passive, or osteoligamentous subsystem, the active, or musculotendinous subsystem, and the neural control subsystem. Spinal stability within this model depends on the proper functioning and interaction of all 3 subsystems (see Figure 1). Within this model, Panjabi defined segmental instability "as a significant decrease in the capacity of the stabilizing system of the spine to maintain the intervertebral neutral zones within the physiological limits so that there is no neurological dysfunction, no major deformity, and no incapacitating pain."[7] The neutral zone to which he referred is defined as a portion of the total physiologic range of intervertebral motion. The total physiologic range consists of a neutral zone and an elastic zone (see Figure 2). Neutral zone motion, defined in biomechanical terms, is the zone of movement surrounding the neutral position of the segment, a zone in which movement occurs with little resistance. The elastic zone starts at the end of the neutral zone and stops at the end of physiologic range. Motion within the elastic zone occurs with considerable internal resistance. Panjabi's definition focused upon changes in the neutral zone. He considered *segmental instability* to be an abnormal movement of one vertebra on another secondary to an increase in the size of the neutral zone.[7]

Clinical instability, on the other hand, might be defined as the observable signs and the symptoms of patients hypothesized to have a disruption of the spinal stabilization system. Thus one interpretation of Panjabi's model might be that *clinical instability* is dysfunction in one or more of the stabilizing subsystems leading to an increase in the size of the neutral zone. The increase in the neutral zone causes, or contributes, to segmental instability and results in MLBP.

POTENTIAL CAUSES OR CONTRIBUTIONS TO CLINICAL INSTABILITY

Despite the general clinical acceptance of Panjabi's theory and definitions, other operational definitions of spinal instability remain in the current literature. Often, these definitions are based upon dysfunction in one particular stabilizing subsystem.

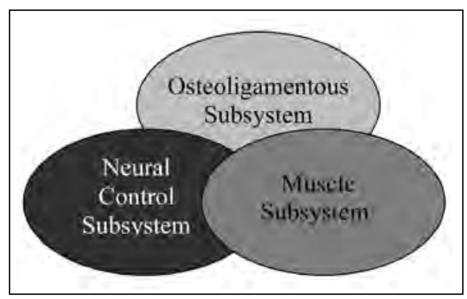

Figure 1. The 3 subsystems of the stabilizing system of the lumbar spine.

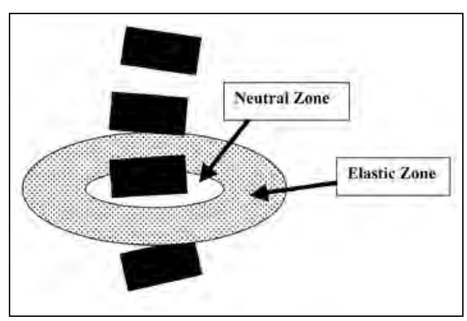

Figure 2. Intervertebral movement: neutral zone and elastic zone.

Passive subsystem

Injury to the passive subsystem, which comprises the osseous and ligamentous structures that support the spine, still remains the most commonly associated underlying pathology. Indicators of dysfunction in the passive subsystem include excessive translation or angulation on flexion-extension radiographs,[5] the presence of spondylolisthesis[8] or traction spurs[9] on radiographs, the presence of high intensity zones in magnetic resonance (MR) images of intervertebral discs,[10] gapping of greater than 1 mm in facet joints during twist CT scans,[1] and positive low pressure discography corresponding to levels of moderate to severe disc degeneration determined by MR images.[11,12] Along with the use of medical imaging to detect segmental hypermobility or instability, passive intervertebral or accessory movement testing has also been widely used.[13] Limitations to these traditional medical tests, in part secondary to the wide variability of segmental motion in asymptomatic individuals[14] and measurement errors associated with both static imaging[15] and manual assessment[16] techniques, have hindered this approach to identifying the stabilization subgroup of the MLBP population.

Active subsystem

Researchers have demonstrated that activation of specific trunk muscles significantly reduces the size of the neutral zone and segmental range of motion in all directions.[17,18] These findings support the crucial role of the active subsystem in providing stabilizing forces to the spine. Without the trunk musculature, the lumbar spine is unstable even at low loads.[18] Indicators of dysfunction in the active subsystem among patients with MLBP include decreased cross sectional area of the lumbar multifidus[19] or the transverse abdominus[20] determined by ultrasound scanning, reduced contraction of the lumbar multifidus determined by palpation,[21] reduced contraction of the transverse abdominus determined by a pressure feedback device,[21] and increased muscle fatigue measured by electromyography (EMG).[22]

Neural control subsystem

A current focus of low back pain research has been the role of dysfunction in the neural control subsystem in patients with recurrent and chronic MLBP. Indicators of dysfunction in this subsystem include changes in muscle onset timing[23] and changes in patterns of muscle recruitment[11,24] determined by EMG, changes in muscle activation and spinal stiffness determined by biomechanical modeling,[24,25] and changes in kinematic patterns of spinal movement determined by visual observation or instrumented motion analysis.[26,27]

Despite the many potential contributors to clinical instability, the most commonly associated pathology is altered intervertebral disc and ligamentous support of the spinal segment. However, not all patients with this passive subsystem damage demonstrate the signs and report the symptoms associated with clinical instability. In particular, segmental instability, when defined solely by passive subsystem failure and excessive segmental movement, has been criticized as an inadequate indicator of clinical instability.[13] In our opinion, clinical instability exists when changes within subsystems result in alteration of segmental motion or erroneous feedback for which the spinal stabilization system as a whole cannot adequately compensate. Thus, in this case, *clinical instability* is really a multi-subsystem dysfunction. Some patients seem to develop strategies to '**cope**' with the altered segmental movement and other patients do not.[11] The '**non-copers**' may then develop signs and symptoms of *clinical instability*. A similar situation exists in patients with ACL laxity where functional instability is not correlated with the degree of laxity, but rather with decreased quadriceps strength and delayed muscle timing.[28]

CLINICAL INSTABILITY

With the lack of a universally accepted operational definition studying clinical instability has been difficult. However, if clinical instability were defined as the clinical signs and symptoms created by dysfunction of one or more of the stabilizing subsystems of the spine, then literature addressing, or systematically investigating, the signs and symptoms of spinal instability could be of collective value in identifying characteristics of this subgroup of patients with MLBP. Much of the earlier literature and approach to this subgroup of patients was based on observations and expert opinion.[13] More recently however, researchers have investigated clinical signs and symptoms in patients diagnosed with segmental instability or in patients who responded positively to stabilization exercise training.[8,29,30] The following sections report the evidence regarding the clinical signs and symptoms of this subgroup and recommendations regarding intervention.

History and Symptoms of Clinical Instability

Table 1 contains a summary of the *symptoms* of clinical instability reported by several authors. The sources include observation and expert opinion,[13] consensus opinion obtained from a Delphi study,[31] questionnaires given to patients diagnosed with segmental instability,[1] a cross sectional study,[29] and a prospective cohort study.[30] Symptoms consistently noted by most authors included patient reports of the back 'giving out,' catching or locking, pain with transitional activities or sustained postures, and recurrent or chronic pain.

Physical Examination and Signs of Clinical Instability

Table 2 summarizes the *signs* of clinical instability obtained from the physical examination. No single sign of clinical instability was listed by all authors. However, several signs were listed by more than one author. These signs included segmental hinging during range of motion (ROM) testing, shaking, catching, or juddering during ROM testing, aberrant movement including changing lateral shift, Gower's sign (thigh climbing to return from a flexed to an upright position), hypermobility during spring testing (posterior-to-anterior (PA) glide), pain during spring testing, and increased muscle guarding or muscle spasm.

A Clinical Prediction Rule

The current best research evidence for identifying characteristics of patients with MLBP who responded favorably to trunk stabilization exercises was obtained through a prospective cohort study.[30] These characteristics were condensed into a clinical prediction rule (CPR) for patients likely to respond to stabilization exercises. The CPR for stabilization, like the one completed for spinal manipulation,[32] provides preliminary evidence and is a stepping stone toward randomized clinical trials.

The CPR is designed to assist clinicians in making better decisions regarding matching patients with the most appropriate intervention. The steps in creating a clinical prediction rule are to: (1) identify factors that may be predictive of a certain condition, (2)

Table 1. Summary of Evidence Related to *Symptoms, History, and Demographics* of Patients Diagnosed with Spinal Instability

Symptoms, History, and Demographics	Paris*	Cook et al**	O'Sullivan ***	Hicks et al+	Fritz et al^
Giving way or back giving out, feeling of instability	x	x	x		
Need to frequently crack or pop the back to reduced symptoms	x	x			
Frequent bouts or episodes of symptoms (recurrence, not first episode)		x	x		
History of painful catching or locking during trunk motions	x	x	x		
Pain during transitional activities	x	x	x		
Greater pain returning to erect position from flexion		x	x		
Pain increased with sudden, trivial, or mild movements	x	x			
Difficulty with unsupported sitting and better with supported backrest		x			
Worse with sustained postures or a decreased likelihood of reported static position that is not painful	x	x	x		
Condition is progressively worsening		x			
Long-term, chronic disorder	x	x	x	x	
Temporary relief with back brace or corset		x			
Frequent episodes of muscle spasm		x			
Fear and decreased willingness to move, high FABQ score		x		x	
Age less than 40 years old				x	x

* [13] Paris – personal observation and expert opinion
** [31] Cook et al – consensus opinion from a Delphi study involving fellows of the AAOMPT and certified orthopaedic specialists who identified spine dysfunction as their primary specialty
*** [40] O'Sullivan – questionnaires completed by patients diagnosed with segmental instability based on radiologic and clinical findings
\+ [30] Hicks et al – prospective cohort study looking at patients who responded to stabilization exercises
^ [29] Fritz et al – cross sectional study looking at subjects with positive flexion-extension radiographs

examine study participants for the presence of these factors, (3) administer an intervention and determine which study participants meet a certain reference standard of change following the intervention, and (4) analyze the data to determine which factors were predictive of the change.[33]

Hicks et al[34] used tests and measures of clinical instability that they had found to have acceptable interrater reliability as potential predictive factors. These consisted of standard measures of hip and trunk ROM and muscle performance tests, as well as special tests related to observing trunk movement, testing lumbar segmental mobility, and the ability of the spinal musculature to stabilize the spine (prone instability test).[30] In addition, demographic information and self-report variables were recorded. Fifty-four subjects with nonradicular MLBP were evaluated. These patients had a primary complaint of MLBP with or without leg pain and the following characteristics: sex (23 men; 31 women), mean age (42 years), average symptom duration (41 days), prior history of LBP (70.4%), and history of more than 3 episodes (59%). Patients with prior spinal surgery, signs of nerve root compression or pain attributed to current pregnancy, spinal fracture, infection, or tumor were excluded. The intervention was an 8-week program of specific stabilization exercises with specified progression criteria. Successful intervention was defined as a minimum of a 50% improvement on the Oswestry Disability Questionnaire. Factors significantly associated with success were determined using chi square or independent *t* tests and accuracy statistics (see Box 1). Operational definitions of the variables that compose this CPR are located in the Appendix.[30]

The presence of at least 3 of the 4 tests predictive of *success* resulted in a 67% chance that patients would experience a significant improvement after performing 8 weeks of stabilization exercises. When at least 3 of these 4 variables listed under *some improvement* were positive, patients had a 97% chance of experiencing clinically significant improvement on the Oswestry Disability Questionnaire.[30]

CPRs are criticized because frequently no control groups are used. In these studies, changes may have occurred solely due to the passage of time. Therefore, CPRs should not be used independently to select one intervention over another.[35] However, in this case, no higher levels of evidence currently exist regarding the clinical characteristics of those patients with MLBP who respond positively to stabilization exercises. In addition, the findings presented by Hicks et al[30] are consistent with the other levels of evidence (see Tables 1 and 2). Thus, using this rule to predict which patients might benefit from stabilization exercises is currently appropriate.[35]

STABILIZATION EXERCISES

Stabilization exercises have been used successfully to treat patients with segmental instability,[8] clinical instability,[30] and chronic pain.[36] Although the details of the exercise programs vary among studies, the principles and theoretical underpinning of stabilization exercises remain the same. This exercise approach was developed based on the theory of spinal dysfunction proposed by Panjabi[6] and on an anatomical and biomechanical model of trunk muscle function proposed by Bergmark.[37] Bergmark hypothesized that 2 main muscle systems, a global system and a local system, control movement, and stability in the spine. The global system consists of the phasic or primary movers of the spine such as the rectus abdominus, external oblique, and portions of the iliocostalis lumborum. These muscles move the trunk but have no direct attachment to the lumbar spine. The local system includes the tonic, postural, or

Table 2. Summary of Evidence Related to *Signs* from Physical Examination of Patients Diagnosed with Spinal Instability

Signs from Physical Examination	Paris*	Cook et al**	O'Sullivan ***	Hicks et al+	Fritz et al^
Observed patterns or poor coordination during trunk motion testing:					
Segmental hinging, pivoting with movement		x	x	x	
Excessive motion at one or two segments		x			
Perceived poor proprioceptive function		x			
Juddering, catching, shaking	x	x		x	
Changing lateral shift	x	x			
Gower's sign		x	x	x	
Decreased willingness/ apprehension during movement (includes painful arc)		x		x	
Reversal of lumbopelvic rhythm				x	
Observed or Noted:					
Muscle guarding or spasms	x	x			
Poor posture and postural deviations that include lateral shift and changes in lordosis		x	x		
Frequent catching, clicking, clunking, and popping heard during movement		x			
Step off palpated in standing that disappears in prone lying	x				
Absence of neurologic signs			x		
Inability to control neutral spine position during functional movements or transitions (e.g. sit to stand)			x		
Provocation or Change of Symptoms by:					
Sustained position or posture		x			
Prone instability tests				x	
Spring test (PA provocation test)	x	x			
Negative neural provocation tests			x		
Reduced pain with deep abdominal muscle activation			x		
Muscle Performance/Activation:					
Decreased strength and endurance of local muscles at level of segmental instability		x			
Inability to activate or co-contract lumbar multifidus			x		
Inability to activate transverse abdominus using an abdominal draw-in maneuver			x		
Segmental Mobility Assessment:					
Hypermobility during posterior-anterior (PA) spring test	x	x			x
Hypomobile segments adjacent to hypermobile segments		x			
Lack of hypomobility during intervertebral motion testing				x	x
Amount of Mobility:					
Lumbar flexion greater than 53 degrees					x
Total trunk extension greater than 26 degrees					x
SLR greater than 91 degrees				x	
Beighton scale greater than 2					x

* [13] Paris – personal observation and expert opinion
** [31] Cook et al – consensus opinion from a Delphi study involving fellows of the AAOMPT and certified orthopaedic specialists who identified spine dysfunction as their primary specialty
*** [40] O'Sullivan – questionnaires completed by patients diagnosed with segmental instability based on radiologic and clinical findings
\+ [30] Hicks et al – prospective cohort study looking at patients who responded to stabilization exercises
^ [29] Fritz et al – cross sectional study looking at subjects with positive flexion-extension radiographs

stabilizing muscles of the spine such as the psoas major, quadratus lumborum, lumbar portion of the lumbar iliocostalis lumborum, lumbar multifidus, internal oblique, and the transverse abdominis. These muscles are shorter in length and closer to the axes of rotation. They also have direct attachments to the vertebrae and can therefore provide stability.[37] Panjabi's and Bergmark's theories were then combined with research on spinal stability and control[25,38] and motor learning theory[39] to develop the basis for a progressive model of intervention (eg, core stabilization or dynamic lumbar stabilization).

Stabilization exercises emphasize use of specific *local stabilizing muscles* (transverse abdominus, internal oblique, and lumbar multifidus) to restore active control and stability to the trunk.[40] A widely used program that emphasizes training of these stabilizing muscles using isometric co-contractions and a progression based upon a motor learning paradigm can be found in Twomey and Taylor's *Physical Therapy of the Low Back*[1] or Richardson and colleagues *Therapeutic Exercise for Lumbopelvic Stabilization: A Motor Control Approach for Treatment and*

Box 1. Best Evidence for Identifying Patients Likely to Respond to Stabilization Exercises[30]	
Clinical Prediction Rule for **Success** with Stabilization Exercises • 67% chance of significant improvement with 3 of 4 criteria.	• positive prone instability test • presence of aberrant movements • average straight leg raise greater than 91 degrees • age less than 40 years
Clinical Prediction Rule for **Some Improvement** with Stabilization Exercises • 97% chance of some improvement with 3 of 4 criteria.	• positive prone instability test • presence of aberrant movements • evidence of hypermobility with lumbar spring testing • Fear Avoidance Beliefs physical activity subscale score less than or equal to 9

Prevention of Low Back Pain.[21] The reader is referred to these texts for additional discussion and detail on this approach. In general, approach is a progression through 3 stages of exercises. The first stage involves isolated, conscious activation of the local muscles. The second stage involves co-contraction of local muscles while superimposing extremity movements. The third stage involves an integration of local muscle system activation with daily activities.[40]

Stage 1

Stage 1 training emphasizes the patient's conscious awareness of neutral lumbar position and appropriate local muscle activation (see Box 2).[40] Patients with recurrent or chronic MLBP may have difficulty moving their pelvis independently from the thoracic spine and hips. Initial training involves teaching independent pelvic motion. After patients are able to isolate pelvic motion, they learn to move the pelvis to create a neutral position of their lumbar spine. The actual neutral position may vary depending on the individual patient and underlying pathology. For example, a patient with hyperextension of the lumbar spine needs to move into a slight posterior pelvic tilt while a patient with flattening of the lower lumbar spine needs to create a slight anterior tilt.[40]

Activation of the local stabilizing muscles, the transverse abdominus, and lumbar multifidus, with the spine in the neutral position is the next goal. The patient learns to perform an abdominal drawing in maneuver (ADIM) to activate the transverse abdominus and then learns to co-contract the lumbar multifidus. The therapist provides feedback by palpating the appropriate muscles or by using a pressure feedback device or ultrasound imaging. The patient practices at least 10 to 15 minutes daily. When the co-contraction can be held for 60 seconds, the patient can progress to Stage 2.[40]

Stage 2

In the second stage, patients learn to maintain the co-contraction of the transverse abdominus and lumbar multifidus with other movement patterns and activities (see Box 3).[40] Further training of the transverse abdominus can be addressed by performing the ADIM in conjunction with heel slides, leg lifts, bridging, standing, and walking.[30] The quadratus lumborum, another important stabilizer of the lumbar spine, can be strengthened with the horizontal side support exercise (see Figure 3). This exercise targets the quadratus lumborum and the abdominal obliques without introducing a large compressive load to the lumbar spine.[38] Further strengthening of the erector spinae and lumbar multifidus can be achieved through performance of arm lifts, leg lifts, and opposite arm and leg lifts in quadruped.[30]

When designing exercise programs for patients with low back pain, endurance of trunk muscles may be a more important consideration than strengthening. Therefore, exercises should be performed daily and emphasize low loads and high repetitions.[38] In addition, this stage should include some form of aerobic training.

Finally, patients should identify pain provoking movements and activities and practice these with local muscle co-contraction. Component movement training may be used for more complicated activities.[40] For example, if a patient has pain with rising from sitting, the patient should attempt to maintain the neutral position of the lumbar spine and the local muscle co-contraction while sitting, while shifting weight anteriorly, and while extending the hips and knees. Practice of local muscle co-contraction dur-

Box 2. Stage One Stabilization Exercises

Activity	Key Points
Neutral lumbar position	• create independent movement of the pelvis • then find and maintain a neutral position of the lumbar spine
Diaphragmatic breathing	• proper breathing technique without the use of accessory respiratory muscles
Activation of transverse abdominus	• abdominal drawing-in maneuver (ADIM) • first in quadruped then prone • monitor with palpation or a pressure feedback device • patient lies prone on pressure feedback device pumped to 70 mmHg; patient should be able to lower pressure 6-10 mmHg and hold for 10 seconds
Co-contraction of lumbar multifidus with transverse abdominus	• reinforce the lumbar multifidus contraction • monitor with palpation; feel a "deep development of tension in the multifidus" • no tension felt under the fingers indicates that the patient cannot activate the multifidus; rapid development of tension indicates that the patient is substituting with the erector spinae
Maintain co-contraction	• maintain co-contraction of local muscles for longer periods of time and with activities • progress to Stage 2 when contraction held for 60 seconds

ing functional activities should begin to decrease pain levels and improve function with daily activities. When patients are able to maintain local muscle co-contraction while performing transitional movements and activities of daily living, they can progress to Stage 3.

Stage 3

Stage 3 training attempts to bring local muscle co-contraction to a subconscious level (see Box 4).[40] Training typically involves exercises that include an element of mental distraction. The patient attempts to maintain local muscle co-contraction while performing an exercise that involves a dynamic challenge. For example, a patient may stand on a balance board while attempting to catch a ball. A patient may balance on foam rollers in the quadruped position while attempting to grasp an object in front of him (see Figure 4). A patient may lie supine over an exercise ball while pulling on elastic tubing. The goal of Stage 3 training is to integrate local muscle co-contraction into work and recreational activities and should be adapted to the patient's functional needs and goals.[40]

CONCLUSIONS

Although no universally accepted definition of *spinal instability* exists, using our definition of *clinical instability* allows consensus across a number of studies that can be collectively used to identify characteristics of individuals with MLBP who respond well to stabilization exercises. Using these characteristics appears to improve the ability to identify these patients and achieve clinically significant improvements in patient outcomes. Of course, further work is needed to validate these recommendations, including performing randomized controlled clinical trials. A more accurate understanding of these characteristics will improve not only the classification of patients with MLBP but will also enhance outcomes by matching interventions with the appropriate patients.

Box 3. Stage 2 Stabilization Exercises

Activity	Key Points
Unloaded trunk ROM exercises	• lumbar spine flexion and extension in quadruped
Hip flexibility exercises	• adequate hip flexibility decreases stresses on the lumbar spine and allows the patient to more easily maintain the neutral position
Aerobic exercise	• aerobic exercise performed to enhance endurance
ADIM maneuver performed with: supine heel slides	 • supine with hips and knees flexed • slide one heel out and back and then repeat on opposite side • progression –both heels simultaneously
supine leg lifts	• supine with hips and knees flexed • extend one leg so the foot is just above the table surface • repeat on opposite side • progressions- opposite arm with leg movements; starting with feet off table
supine bridging	• supine with hips and knees flexed • perform bridging first with both legs • progression - one leg (note: pelvis must remain level)
sitting, standing, walking	• perform and maintain ADIM
standing row exercises	• perform ADIM while performing a rowing or scapular retraction exercise with tubing
Lumbar multifidus emphasis: unilateral arm lifts in quadruped	• lifts one arm and then the other while in quadruped • pelvis and lumbar spine must remain stationary and level for all tasks • progression—single leg lifts; simultaneous opposite arm and leg lifts
ADIM with side support exercise: knees flexed	• side lying propped on one elbow with hips straight and knees flexed • perform ADIM and then raise pelvis off table so trunk is straight • progression side lying propped on one elbow with hips and knees extended
Functional activities: practice pain provoking activities while maintaining local muscle co-contraction	• pain provoking activity broken down into components • each component practiced while patient maintains local muscle co-contraction • progress to Stage 3 when can maintain local muscle co-contraction during activity

Box 4. Stage 3 Stabilization Exercises

Activity	Key Points
Distracting exercises	• maintain local muscle co-contraction while performing other activities that distract from concentration on local muscle co-activation
Maintain local muscle co-contraction with simulated work and recreational activities	• maintain local muscle co-contraction while performing work or recreational activities

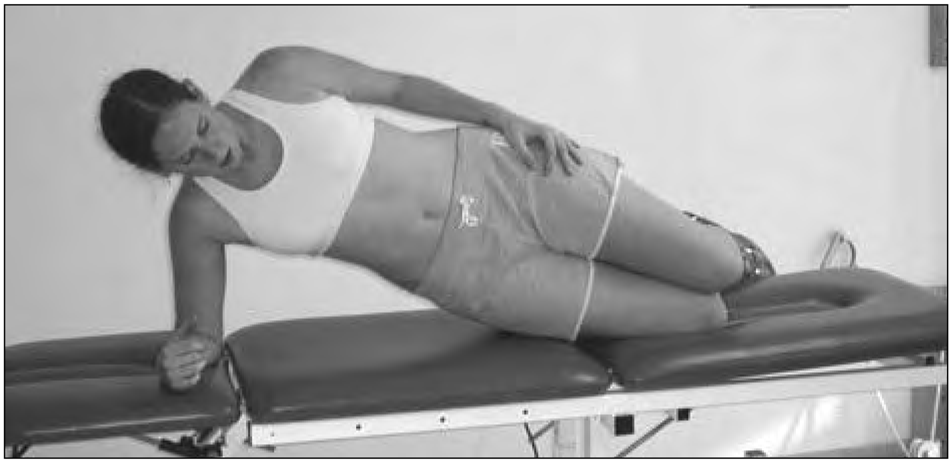

Figure 3. Horizontal side support exercise with abdominal draw-in maneuver.

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Figure 4. Use of a foam roller to introduce further dynamic challenge to exercises.

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Appendix

Operational Definitions of Signs of Patients Diagnosed with Spinal Instability (Hicks et al30)

1. Aberrant movement
   - positive if at least one of the following movement abnormalities present:
     1. painful arc in flexion
     2. painful arc with return from flexion
     3. instability catch
     4. Gower's sign or thigh climbing
     5. reversal of expected lumbopelvic rhythm
2. Prone instability test
   - performed with the subject lying prone over the end of a table so the feet rest on the floor
   - spring testing performed on all lumbar vertebrae
   - spring testing repeated with the subject lifting his/her feet off the floor
   - positive when pain provoked with the first part of the test but not the second
3. Hypermobility during posterior-anterior (PA) spring test
   - all lumbar vertebrae tested and rated as either hypermobile or not hypermobile
   - positive for hypermobility if at least one lumbar vertebra was rated to be hypermobile
4. Beighton Ligamentous Laxity scale
   - measures ligamentous laxity throughout the body
   - nine point maximum score consisting of the following:
     1. R or L knee hyperextension > 10 degrees
     2. R or L elbow hyperextension > 10 degrees
     3. R or L fifth finger hyperextension > 90 degrees
     4. R or L thumb abduction to contact forearm
     5. able to place palms flat on floor during trunk flexion with knees extended positive if score greater than 2