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Despite the consistent complaint of low back pain and the well documented fiscal impact, there is little consensus among health care practitioners regarding the management of individuals with such complaints. There is questionable efficacy of general back exercises as a method to restore function, decrease pain, and prevent recurrence dependent on method of study and stage of injury.<sup>1</sup> Although it is difficult to conclude that a specific type of exercise is more effective than another in the treatment of low back pain, a greater breadth of literature describing deleterious changes in muscular stabilizers after bouts of low back pain is contributing to renewed interest and attention to these muscles in the rehabilitation setting.<sup>2-10</sup> There is adequate literature base to support the use of stabilization exercises. However, the use of stabilization exercises must be scrutinized in relation to the presence or absence of signs and symptoms indicative of hypermobility or instability. The presence of abnormally large intervertebral motion is occasionally associated with pain, but working diagnosis and treatment progression is not dictated solely on the presence or pattern of pain.

This focused review serves to support the use of stabilization exercises in the rehabilitation process. A more concrete description of inclusion criteria for such a stabilization program based upon the literature is included. Principles and concepts allowing for greater efficacy of treatment as related to rehabilitation of those with low back pain are presented. This review further serves to outline anatomical contributors to lumbar spinal stability.

### **The concept of stability**

There exists controversy regarding the precise definition and relevant inclusion criteria related to joint stability.<sup>11</sup> Mechanically, stability is dependent upon position, motion, and load.<sup>12</sup> Instability is prevented by increasing passive stiffness or by increasing the activity and thus stiffness of muscles.<sup>6,8,13-15</sup>

Radiographs demonstrate disruption of passive structures in a qualitative fashion and also demonstrate hypermobility quantitatively, but radiographs perhaps more concisely demonstrate the consequences of hypermobility or instability.<sup>16</sup> Such signs include articular degeneration and osteophytes. The use of radiographs to solely rule in or rule out instability is not sufficient. Relevant stability thresholds via use of radiographs are debatable given the high level of variability related to intersegmental motion in those without low back pain.<sup>11</sup> Paris<sup>17(p181)</sup> defines instability as “a condition in which the normal integrity of the spinal ligaments and muscles are insufficient to prevent normal forces from producing aberrant motion such as slips, slides, buckles and juddering”. From a clinical standpoint, a definition that includes both a quantitative and qualitative description of motion within accepted mechanical boundaries is meaningful.

Panjabi<sup>12</sup> describes stability as being provided for by the inter-working of three subsystems: passive, active, and neural. The passive subsystem is comprised of the vertebrae, discs, and ligaments.<sup>12</sup> A role of the passive subsystem is to monitor spinal motion and position.<sup>12</sup> The muscles and tendons surrounding the spinal column comprise the active subsystem.<sup>12</sup> The active and passive subsystems are monitored and coordinated by the neural subsystem which is comprised of the nerves and central nervous system.<sup>6,12,18-21</sup>

Although conceptually distinct, these subsystems are functionally interdependent.<sup>12</sup> These subsystems must be in balance to provide for stability under dynamic conditions and must be adaptable.<sup>12</sup> Compromise of one of the subsystems leads to immediate or long-term compensation(s).<sup>12</sup> Cholewicki and McGill<sup>22</sup> demonstrated through fluoroscopic analysis the buckling of L2-L3 during a semisquatting activity whereby there was segmental motion into

flexion to end range and beyond.<sup>22</sup> This motion correlated with an injury. The resultant overstressing of passive restraints and injury is attributable to inadequacies on the part of the active and neural sub-systems to control motion.<sup>22</sup>

From a mechanical and quantitative perspective, a single muscle or other anatomical entity with a stability role that is in a dysfunctional state would produce less stiffness and could cause instability in a three dimensional model.<sup>15</sup> However, no one muscle in isolation reasonably appears to be able to significantly impact spinal stability.<sup>21</sup> At any one time, there are, in synchronicity, various anatomical contributors to stiffness throughout the musculoskeletal linkages of the spine.<sup>15</sup> This makes precise reference to a particular muscle providing for segmental stability at any one instant indistinct in a clinical sense.

According to Bergmark<sup>23</sup>, the muscles responsible for maintaining spinal control are classified as global or local muscles. The mechanical differentiation is rooted in the varying roles of the muscles which include to either transfer load between the thoracic region and the pelvis, the former, or to act directly on the lumbar spine, the latter.<sup>23</sup> The local muscles have direct attachment to the lumbar spine. Muscles most responsible for segmental stabilization have an attachment to the lumbar vertebrae and would include the transverses abdominis (TA) and the multifidus as well as the posterior fibers of the internal oblique (IO) among others.<sup>23,24</sup> The local system controls the spinal curvature.<sup>23</sup> Also, the tonic characteristics of these muscles is reflective of their role in postural support.<sup>25</sup> The mechanism whereby the local muscles contribute to stability is inherent in the translation of generated forces along the compressive axis of the spine.<sup>21</sup>

Although the global system also impacts stiffness, the influence is on the entire spinal column in contrast to a few joints.<sup>21</sup> The global system consists of the rectus abdominis, the internal and external obliques, the global erector spinae muscles, and a portion of the quadratus lumborum.<sup>23</sup> The role of the quadratus lumborum as related to stability demands is associated with its increased activity during periods of lumbar sagittal moments and compression.<sup>9</sup> Despite the muscles spanning between the pelvis and ribcage being able to provide for spinal column stability, it is the intrinsic muscles or 'local stabilizing muscles' which are necessary to maintain stability.<sup>13</sup>

More than 66% of the stiffness intersegmentally at L4/L5 has been shown to be attributable to the multifidus.<sup>26</sup> Without stiffness provided for by the multifidus and the erector spinae, the spine buckles with activity.<sup>6</sup> The neural control system calls upon these muscles during loading periods<sup>12</sup>, and the inability to provide a contraction of needed intensity leads to injury of passive structures.

This description of stability is not meant to be exhaustive. Reduced lumbosacral position sense is evident in those with low back pain.<sup>4</sup> Proprioceptive changes in those with low back pain undoubtedly impact to some extent the stabilizing process. Further investigation regarding this relationship is warranted and although particular discussion regarding neural changes with low back pain is beyond the scope of this review, effects of such dysfunctions are inseparable from considerations of stability. Cognitive awareness of muscle action and accurate lumbopelvic positioning is critical and serves as the base from which therapeutic progression advances.

### **‘Neutral Spine’ and ‘Neutral Zone’**

The cornerstone of enhancing neutral spine mental awareness is to recognize the functional limits of the spine and to stay within those limits.<sup>27</sup> In terms of force attenuation, an optimal neutral spine position is asymptomatic, is able to be controlled, and is one that maintains the normal lumbar curve. This is in contrast to asking a patient to rigidly maintain a particular lumbar position at all times, which is impractical.<sup>27</sup> Maintaining and attending to a neutral spine posture requires neuromuscular skill allowing for adjustment to loads.<sup>27</sup>

The arc of motion within available spinal range of motion in which there is minimal internal resistance from passive or osseoligamentous structures has been termed by Panjabi as the neutral zone.<sup>28,29</sup> Decreased resistance from the passive sub-system necessitates compensation from a combination of the muscular and neural sub-systems in order to maintain stiffness. However, with injury, the neutral zone expands<sup>28</sup> and muscle control decreases.<sup>13,30</sup> There exists, then, a hypothetical relationship between increased injury risk and decreased stability.<sup>13</sup> Maintenance of stiffness within the neutral zone is closely linked to muscle control and particularly that of the multifidus. As described by Panjabi<sup>12</sup>, muscle function is one component of the active subsystem responsible for spinal stiffness

### **Active Subsystem**

Contributory elements of the active subsystem include: intra-abdominal pressure, thoracolumbar fascia, and muscle function.

Activation of the transversus abdominis (TA) and, to a lesser extent, the internal oblique correlates with changes in intra-abdominal pressure (IAP).<sup>14</sup> Activation of the TA seems vital in controlling and maintaining IAP.<sup>14</sup> This particular role of the TA separates it functionally from the other abdominals<sup>14</sup> and additionally supports the role of this muscle as related to stability. IAP is responsible for a direct bracing effect caused by a pressurized abdominal cavity. IAP contributes to maintaining segmental stability through resistance of shear forces and because of its potential to maintain alignment.<sup>5,14</sup>

The thoracolumbar fascia is engaged passively by flexion of the lumbar spine, by tension of the abdominal muscles, gluteus maximus, or hamstrings, and is engaged actively via direct action by the latissimus dorsi, TA, or internal oblique.<sup>14</sup> Stability, then, as related to the active subsystem is a result of IAP and also results from both indirect muscle action via blending of the TA with the thoracolumbar fascia<sup>31</sup> and direct muscle action via spinal attachment.

### **Relevant anatomy**

The erector spinae muscle mass is formed by four separate bundles of muscle fiber fascicles: the more medial longissimus thoracis and more lateral iliocostalis lumborum both of which could be divided into thoracic and lumbar segments regionally.<sup>32</sup> The multifidus is a transversospinal muscle. The transversospinal muscles include from superficial to deep the semispinales, multifidus, and rotators.<sup>33</sup> The multifidus is deep to the semispinales but is superficial in the lumbar region where there is no semispinales muscle.<sup>33</sup> As a result of the contribution by the multifidus to intersegmental stiffness, subdivision of the transversospinal group from a clinical standpoint is warranted.

The multifidus is innervated segmentally by the medial branch of the dorsal ramus at a particular spinal level.<sup>34</sup> The dorsal ramus of a particular level innervates the multifidus attaching to the spinous process of the same level.<sup>34</sup>

The origin and insertion of the multifidus is bipennate.<sup>10</sup> The multifidus is formed by five segments or bands with generally oblique orientation.<sup>32</sup> The band corresponding to a more cranial vertebrae lies most laterally and superficially with bands of lower origin lying more medially and deep.<sup>32</sup> Each band consists of several fascicles.<sup>10</sup> The muscle takes origin at the inferior tip of the spinous processes and also to a point along the spinous process more towards the lamina.<sup>10</sup> The shortest fascicles of each band has an attachment to the mamillary processes two segments lower while the longer fascicles traverse more superficially inserting sequentially onto mamillary processes or the dorsal surface of the sacrum three or more segmental levels lower.<sup>32</sup> In addition to an attachment on the mamillary processes, the multifidus has an attachment to the adjacent superior capsule below and the inferior capsule above.<sup>10</sup> The intimacy of the multifidus to the capsule points to a role of this muscle to prevent painful catch of the pain sensitive tissue between the articular surfaces with movement.<sup>10</sup> This muscular arrangement including variable orientations of the fascicles supports independent actions of various segments of the muscle during trunk or limb movements.<sup>34</sup>

Electrical activity via EMG has shown contralateral activation of the multifidus during trunk rotation, and the continued activity of the muscle during the return of the trunk may further lend support to the stabilizing role of the muscle.<sup>34</sup> The multifidus balances flexion and rotatory forces of the abdominals and also contributes to extension of the spine as well as lateral flexion.<sup>32</sup>

Anatomically, the multisegmental muscles may be more intimately linked to direction-dependent stability whereas the smaller, intersegmental muscles function under conditions requiring more precision and efficiency of stability.<sup>21</sup> In a general sense, the deep muscles, or stabilizers, are recruited in preparation of a load whereas superficial muscles respond to the disturbances.<sup>18, 19, 35</sup>

### **Muscle dysfunction with injury**

Both the transverses abdominis (TA) and the multifidus have been found to be to some degree dysfunctional in those with low back pain.<sup>2,4-7,36</sup>

Motor control research describes contraction of the TA in a pre-movement manner which may be interpreted as a “feed-forward mechanism”. In this manner, stiffness, or spinal stability, is augmented prior to movement.<sup>4,37</sup> The activity of the TA is less linked to direction of movement or the direction of external forces but instead provides for stability in a non-direction specific manner.<sup>39</sup> Consistent activation patterns of the TA regardless of direction of limb movement<sup>18</sup> again highlights the role of this muscle as a segmental stabilizer and also supports the notion of this muscle being controlled independently of other trunk muscles.<sup>39</sup> In patients with low back pain, there is a loss of protective reaction of the transverses abdominis including changes in independent motor control, changes from tonic to phasic reactions, and delayed feed-forward contraction with extremity movements.<sup>4,7,19</sup>

Conscious and even automatic muscle activation patterns are favorably altered during motor tasks through performance of exercises designed to enhance stability.<sup>38</sup> Over a 10 week period, O’Sullivan et al<sup>38</sup> demonstrated that an exercise group performing stabilization exercises showed a statistically significant change in the ratio of activation of the internal oblique to the rectus abdominis. The authors indicate that a change in the ratio of activation when comparing changes in EMG activity during a double leg raise and an abdominal drawing correlated with an advantageous shift in muscle activation patterns.<sup>38</sup> The shifts in muscle activation identified become even more pertinent when considering that in those with chronic LBP there is a

preponderance of altered muscle activation patterns with a bias towards activation of global muscles.<sup>24,38</sup>

The lumbar multifidus atrophies after first-episode acute low back pain.<sup>2</sup> The atrophy or asymmetry of cross sectional area of the multifidus is on the painful side.<sup>2</sup> Recovery of the muscle is not spontaneous after resolution of pain.<sup>2</sup> Select atrophy of the multifidus is also evident in those with chronic low back pain.<sup>40</sup> Those with chronic low back pain demonstrate reduced capacity to voluntarily recruit the multifidus during coordination exercises and demonstrate less EMG activity of the multifidus during strength exercises.<sup>41</sup>

Specific localized exercise increases cross sectional area of the multifidus<sup>2</sup>, and this may have a role in not only the acute management of low back pain but also in decreasing the risk of secondary dysfunctions as well as recurrence of low back pain. Multifidus atrophy is changeable<sup>42</sup>, and recovery is more rapid and complete with the performance of specific exercise.<sup>2</sup>

### **Clinical identification of instability**

Causes of hypermobility include things such as excessive or repeated stresses, genetic factors, or compensatory joint changes.<sup>17</sup> The presence of spinal segmental hypermobility does not necessitate that a segment is unstable.<sup>16</sup> It would seem that if a segment is unstable, however, it would also be hypermobile. Instability, therefore, may to some degree be influenced by the same causative factors as hypermobility.<sup>17</sup> Hypermobility, however, is classified as non-pathological and although the range of motion is "...somewhat in excess of the expected..."<sup>16(p277)</sup>, it serves to mark one side of the spectrum of "normal" motion.<sup>43</sup> Presumably, both hypermobility and instability may, under certain circumstances, serve as sources of discomfort. "Signs" such as reports of "giving away" or descriptors such as "aching", "tiring", or "stabbing" are possible indicators of instability.<sup>16</sup> Palpation serves as a common method whereby hypermobility or instability can be identified. The presence of a bony anomaly such as a "step" in the vertebral segments which changes with body position(s) is indicative of instability while a structural observation which is stable despite changes in position indicates hypermobility without instability.<sup>16</sup> Stability is contingent upon the motion and motor patterns chosen by the individual<sup>20</sup> supporting the qualitative as well as quantitative aspects of the stability construct. Differentiating hypomobility from instability is done through passive intervertebral motion testing using a rating system of 0-6 (Fig 1).<sup>43(p 438)</sup> A grade of 5 or 6 is a physical sign of instability.<sup>16(p279)</sup> In cases of both hypermobility and instability, treatment will focus on segmental stabilization, addressing neighboring hypomobility, postural correction, and generally, decreasing stress--particularly asymmetrical stresses and rotational moments.<sup>16</sup>

**Figure 1**  
Rating system for evaluating passive mobility of the spine

Grade	Description	Criteria
0	Ankylosed	No detectable movement within the segment. Requires stress film radiology for confirmation.
1	Considerable restriction (hypomobility)	Significant decrease in expected range. Significant resistance to movement.
2	Slight restriction (hypomobility)	Limitation expected in range. Some resistance to movement.
3	Normal	Expected range for body type. Uniform movement throughout range.
4	Slight increase (hypermobility)	Some increase expected in range. Less than normal resistance to movement.
5	Considerable increase (hypermobility)	Excessive range (but eventually restricted by capsular and ligamental structure).
6	Unstable	Excessive range (as in Grade 5) but without the restraint of capsular and ligamental structure.

### Assessing stabilizer function

In contrast to strength, variables of importance related to the spinal stabilizers include endurance, speed of contraction, and timing of contraction.<sup>4,25,44</sup> The lack of functional recovery in muscles integral to the stabilization process is a possible reason for the recurrence of low back pain.<sup>2</sup> Endurance is a bio-marker that may be of greater importance than other variables as related to decreasing risk of problematic low back episodes.<sup>45</sup> Also, impaired endurance appears to be a variable of muscle performance more closely linked to the many injuries that occur during submaximal tasks.<sup>46</sup> There is reference to several tests in the literature that are to be carried out with the intent of identifying dysfunction of muscles of the core.

Endurance times for isometric flexion, extension, and lateral flexion were identified by McGill et al<sup>47</sup> in 75 healthy, young individuals. Normal healthy men and women demonstrate different endurance profiles of the spinal stabilizers.<sup>47</sup> Women generally have longer endurance times than men for torso extension, but not for lateral flexion (side-bridge) or torso flexion.<sup>47</sup> Isometric lateral flexion holding times were found to be 65% of isometric extensor holding time in men and 39% for women.<sup>47</sup> Although the population studies included those without low back history, this data serves as a baseline or relative benchmark for both absolute hold times or for

ratio comparison of trunk musculature in those with current or previous history of spinal dysfunction. This test may function to elucidate on the endurance capacity of muscles but without specific intent to identify dysfunctions in local stabilizers regarding the ability to produce a quality contraction.

Clinically, frequently used criteria to establish stabilization capacity of the spine includes the ability to dynamically move the extremities while maintaining a static spinal position. Hagins et al<sup>37</sup> established a sequential stabilization program in the form of a modified isometric stability test that was used over a four week period to identify its impact on the ability to increase lumbar stability. The seven exercises that comprise the isometric stability test (IST) were issued as a stabilization program in half of the subjects in the study. Using a pressure transducer, asymptomatic subjects demonstrated over a 4 week period, with weekly instructional sessions, that there is an increased ability to perform more complex exercises successfully. The authors<sup>37</sup> attribute these changes to adaptations in the nervous system. This test incorporates movement quality and outlines common training errors or compensation patterns. The IST serves to some degree to measure the ability to perform progressively difficult stabilization exercises.<sup>37</sup>

The abdominal muscle test (AMT) serves as a standardized, objective means whereby the abdominal musculature is assessed with easier carry-over regarding inter-examiner performance. This test consists of four levels in which a posterior pelvic tilt is held progressing from: Level 1, a hook lying position in which the knees are flexed to 90 degrees while the right lower limb is extended and lowered to the horizontal; Level 2, hips are flexed to 90 degrees and one thigh supported by the hands; Levels 3 and 4, hips flexed to 90 degrees and are unsupported with level 4 including extending and lowering of both limbs.<sup>48</sup> An initial baseline pressure reading is obtained with the subject flexing the knees one at a time towards the chest while supporting the thighs with the hands while performing a posterior pelvic tilt with a sphygmomanometer placed horizontally under the lumbar spine.<sup>48</sup> The test score attained is indicative of the level in which the subject is able to maintain a baseline pressure reading to within 10mmHG while proceeding through the various test levels.<sup>48</sup> From extrapolation of surface EMG data, the activity of the muscles from pooled data at all levels showed from highest to lowest the lower rectus abdominis, upper rectus abdominis, external oblique, and internal oblique to be most active.<sup>48</sup> The relative contribution of the obliques was increased in level 4 of the AMT.<sup>48</sup> Although this test may generally measure abdominal function, its specific application to stability based upon muscle activity is questionable.

A lengthened stabilizer lacks the ability to maintain a full contraction within inner range.<sup>36</sup> This inability to maintain joint alignment with adequate inner range muscle control leads to loss of segmental control in the spine. This deficit serves as a means of assessment as well as training. Such a test would be given a grade of good endurance if inner range position could be maintained for upwards of 20 seconds. These tests would be applicable to the gluteus maximus and gluteus medius among others.<sup>36</sup> The isometric horizontal side support position challenges the lateral obliques without high compressive loading while emphasizing activity of the quadratus lumborum.<sup>46</sup>

A core muscle screen which assesses certain variables imperative for stability while also measuring general core functional strength and endurance is desirable. The following quick screen (Fig 2.) is adapted from a post IDET protocol and is, at times, useful during the evaluative process. For the dynamic extensor endurance\* portion of the screen, the patient is to be

positioned in a prone position over a 30 degree wedge. This test has been found to have acceptable inter-rater reliability.<sup>49</sup>

The core screen is graded with a 1,2, or 3 correlating with poor, fair, or good performance. Quality of movement is to be emphasized with the presence of compensatory movements limiting progression to the next stage. Although the “core screen” has not undergone scientific scrutiny, the movements included appear to be appropriate to assess given the diagnosis of low back dysfunction.

**Figure 2**  
Core Screen

Position	Task (Poor)	Task (Fair)	Task (Good)	Score
1. Prone	Alt leg x 1 minute	Alt leg with 2s holds x 1 minute	Alt leg with 2s holds x 2 minutes	
2. Prone	Alt leg hip ext with knee flex 5 reps with 5s hold	Alt leg hip ext with knee flex 5 reps with 10s hold	Alt leg hip ext with knee flex 5 reps with 20s hold	
3. Prone*	Back extension to horizontal x 15 reps	Back extension to horizontal x 30 reps	Back extension to horizontal x 45 reps	
4. Sidelying	Side support bridge x 15 seconds	Side support bridge x 30 seconds	Side support bridge x 45 seconds	
5. Supine	TA hold x 1 minute	TA hold with marching x 1 minutes	TA hold with marching x 2 minutes	
6. Standing	Wall slide x 1 minute	Wall slide x 2 minutes	Wall Slide x 3 minutes	
<b>SCORE</b>				<b>/18</b>

### **Integrating exercise therapy with stabilization mechanisms**

The clinical usefulness and feasibility of introducing low intensity exercises (% of maximal voluntary contraction) while maintaining a neutral spine is based not only the fact that these movements will serve to target spinal stabilizers but that these movements will be better tolerated at the onset of therapy. An adequate hold time is necessary to again call upon the tonic role of stabilizers. The “arbitrary target” of “10 by 10 second holds” is an appropriate starting point.<sup>25</sup>

The precise nature of progression by which instability is treated is variable as presented in the literature.<sup>25,50</sup> Although the inherent importance of local muscles is recognized, there is not uniform agreement related to the need for isolated training of these muscles prior to global muscle training.<sup>50</sup> Comerford and Mottram emphasize addressing deficits in both local and adjacent global musculature through a progressive and integrated functional exercise program.<sup>50</sup> The suggestion that the global muscles assist with attenuation of forces and impact spinal stability along the spinal column<sup>30</sup> serves to support this view.

Richardson and Jull stress the imperativeness of establishing primary control of segmental stabilizers, particularly the multifidus and the transverses abdominis, in order to provide for stability.<sup>25</sup> These authors use a strong body of research to help guide their exercise approach.

Progression is from focus on isolated muscle contraction quality to co-contraction of muscles while being mindful of substitution patterns namely by the global muscles.<sup>25</sup> Many researchers agree that co-activation of trunk extensors and flexors is crucial for lumbar spine stability.<sup>8,51,52</sup>

The theoretical ideal of mastering 'local' muscle control before progressing has merit but is impractical clinically. Also, this progression is not clearly more beneficial than other approaches which incorporate global muscle activity before mastery of 'local' muscle action.

### **Training for muscular stabilization**

Isolated contraction of the transverses abdominis is taught by a gentle drawing in or "hollowing" of the lower abdominal area.<sup>9,25,30</sup> Inward displacement of the anterior abdominal wall or "hollowing" is primarily the result of transverses abdominis contraction.<sup>9,19,25</sup> A qualitatively ideal response is one in which the "hollowing" is performed without movement of the spine and without substitution including using the breath, performing a pelvic tilt, depressing the rib, etc. A quantitative assessment may be performed with the use of biofeedback as with the use of the pressure biofeedback by Chattanooga ("Stabilizer"). This assists in monitoring appropriate level of loading for training. In a prone over pressure biofeedback position, the unit is filled to 70mmHg and a pressure drop of 4-10mmHG is desired without substitution. However, the muscle action in this manner is different from that driven by motor control strategies in which muscle action is automatic and preparatory to limb movements.<sup>4,18,19</sup> Therefore, the ability to displace the abdominal wall and the latency period of the transverses abdominis related to limb movement may be a separate phenomenon associated with motor control.<sup>19</sup> The name of the muscle would indicate the need to train the transverses abdominis in multi-planar fashion for maximal benefit including the transverse plane. Although the TA is consistently active first in many movements, the intensity of contraction likely differs based upon the challenge.

Facilitation techniques for the multifidus include verbal and tactile cuing such as manual contact of the multifidus<sup>25</sup> or envisioning a muscle "swell".<sup>25,30</sup> Arkoski et al using intramuscular multifidus EMG monitoring at different spinal levels found the highest EMG activity of the multifidus muscle in the following exercises: trunk lifts to the horizontal plane in a prone position, holding the trunk in the horizontal position in the prone position, unilateral hip extension with the knees bent in a prone position, and alternating shoulder flexion with weights while standing on a balance board.<sup>53</sup> Adding loads in the form of hand weights while walking on a trampoline or standing on a balance board increases the average EMG amplitude.<sup>53</sup>

Co-contraction of the multifidus and the transverses abdominis is facilitated by activation of pelvic floor muscles.<sup>18,54</sup> The anatomical intimacy of the abdominal and pelvic floor muscles is predictive of coordinated muscular efforts during tasks that challenge postural stability.<sup>54</sup>

It appears that, at the very least, selective, low-level co-contraction of trunk muscles to create a bracing effect can reduce the risk of spinal buckling under compressive loads.<sup>20</sup> However, these training regiments as with others would seem to include, at least at some level, a degree of risk. The risk in the case of emphasis of co-contraction is the introduction of compressive loading. Optimal stability would include a balance between stabilizing forces as to provide for a margin of safety without the introduction of deleterious forces.<sup>15</sup> The unilateral leg extension hold while on the hands and knees offers a sufficient challenge to the lumbar extensors without the presence of excessive compressive or shear forces.<sup>15</sup>

Torsional components may be trained by raising a hand-held weight while supporting the upper body with the other arm and abdominally bracing--bent-over modified row.<sup>15</sup> The obliques are selectively emphasized with diagonal movements with the internal oblique active during curl-ups or trunk rotation to the same side and the external obliques are selectively activated in the curl up and diagonal or trunk rotation towards the opposite side.<sup>9</sup> The side-bridge appears to be the optimal method to activate the quadratus lumborum without unnecessary spinal loading.<sup>15</sup>

The relatively low levels of electromyographic abdominal recruitment and trunk and hip extensor recruitment in the dying bug and quadruped alternating arm and leg exercises respectively would not support the use of these exercises as the most effective means to provide for a stabilization or muscular retraining effect.<sup>55</sup>

### **Summary**

Physical therapists are perhaps best suited to identify dysfunction(s) related to the neural or active subsystems and to treat such dysfunction(s). Choice of intervention should include stabilization exercises once hypermobility or instability is identified. Activation and training of stabilizers although fundamental to stabilization efforts is one aspect of the total program. Stability is a dynamic concept rather than an intrinsic predisposition. The stability of the spine fluctuates in accord with the demand of task. Therapeutic activity and exercise progression should be from simple to complex, from isolation to integration, from known to unknown, and should complement a gradual shift of focus from stability statically to stability dynamically. In the later stages of stabilization training, a greater degree of motor experiences in varied positions and under varied loads would challenge stability better simulating an uncontrolled, manual work environment. This may be more relevant considering that core muscles simultaneously have several roles depending on the specific demand.<sup>21</sup>

To train for stability, at some point through the continuum, literature would support the notion that efforts are to focus on the multifidus and transverses abdominis with progression into introducing motor patterns that require synchronicization.<sup>21</sup> Because the same anticipatory reaction(s) of stabilizing muscles is not seen in those with low back pain, an exercise program that focuses to some extent on these muscles is warranted. Also, the inclusion of such exercises in the management of pain is prudent.<sup>25</sup> Greater muscular control with regard to the stabilizing process is linked to less recurrence of pain and less early progression of degenerative changes.<sup>50</sup> Exercise selection, among other things, should be based on clinical findings as well as patient generated / clinical goals. Specific exercise for those with low back pain is associated with positive outcomes and serves as a situationally dependent necessary intervention to include over a general strengthening program.<sup>2,3,7,11,24,25,38,44,46,50,56,57</sup>

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