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An Integrated Approach to Training Core Stability

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summary

Despite the widespread popularity and application of core training, confusion remains regarding the precise performance benefits of and optimal approach to training the core. This article attempts to resolve the components that comprise lumbopelvic stability and suggests an approach to training each element in an integrated fashion.

Introduction

The profile of core stability training has risen massively in recent years, with growing use by both athletes and recreational trainers (6, 17). Core work has become an integral part of athletes' training regimens, with the aim of improving performance, and core exercises are commonly prescribed for therapeutic training applications (5). Walk into any gym or health club and you are likely to find stability balls and a personal trainer extolling the virtues of core training.

Core stability is described in the sports medicine literature as "the product of motor control and muscular capacity of the lumbo-pelvic-hip complex" (16). In reality, the term "core training" has become an all-purpose label for any exercise that addresses some aspect of lumbopelvic stability.

A number of different muscles are associated with the lumbar spine, pelvis, and hips. In view of this, core training could refer to any mode of exercise that addresses any one of the various different systems of muscles involved in providing lumbopelvic stability. This ambiguity likely lies behind the misconceptions regarding the effectiveness of core training for different health and performance goals (29, 31). Much of the confusion is caused by lack of clarity about what constituted the core training employed in a given study and thus what aspect of lumbopelvic stability was in fact addressed.

Training the core is therefore considerably more complex than the global term "core training" implies.

Importance of Training for Lumbopelvic Stability

The spine depends heavily upon active stability provided by various muscles (7). This is illustrated by the finding that, when stripped of muscle and left to rely upon passive (bone and ligament) support, the human spine will collapse under 20 lb (≈ 9 kg) of load (3). Obviously this does not occur in healthy individuals, and it is the muscular components that contribute to lumbopelvic stability that take up the slack.

It has been demonstrated that submaximal levels of muscle activation are usually adequate to provide effective spine stabilization (7). Continuous submaximal muscle activation therefore appears to be crucial in maintaining lumbopelvic stability for most daily tasks (19).

Stability provided by the muscles of the trunk is also identified as critical for whole-body dynamic balance (1). To maintain whole-body stability while sustaining and/or generating external forces, athletes require both strength and endurance in these muscles (3).

Movements in athletic events and team sports occur in multiple directions. As a result, athletes must possess lumbopelvic stability in all 3 planes of motion (16). Furthermore, these capabilities are required under both static and dynamic conditions during competition. The combination of muscles that act to provide stability varies with posture, the direction of movement, and the magnitude of loading on the spine (16, 5). Hence, a wide variety of muscles contribute to different degrees according to the demands of the situation.

The lumbar spine is the site through which various compressive and shearing forces are transmitted between the lower and upper body (7, 30). A strong and stable lumbopelvic region facilitates the efficient transfer of forces from the ground to produce movement and/or generate torque at the extremities (4, 8, 19).

Despite this, studies to date have generally failed to find improvements in performance measures following core training interventions (29, 31). However, this is likely a result of lack of consistency in terms of what constituted core training in the studies and the nature of the exercises employed. Anecdotally, improvements in lumbopelvic stability following appropriate training can have a pronounced impact upon performance.

Lumbopelvic Stability and Injury

Muscles that prevent excessive spine motion at the segmental level and help maintain the desired pelvis and lumbar spine posture reduce stresses on the lumbar spine and thereby protect against injury (10, 19). The muscles that provide active lumbopelvic stability also serve to spare the spine and resist external forces under conditions of higher loading (19).

Accordingly, low or unbalanced scores on various tests of trunk muscle function, indicative of poor lumbopelvic stability, are frequently identified as risk factors for injury (19). Scores of trunk muscle endurance in particular have been consistently shown to correlate with the incidence of low back pain or injury (19).

Lumbopelvic instability can be both the cause and the result of injury (19). Impaired passive stability and disrupted motor patterns (which compromise active stabilization) are commonly observed following injury (19, 20). It follows that addressing these issues via appropriate training will offer a protective effect in terms of both guarding against initial injury and reducing subsequent incidence in those with a history of previous injury.

The efficacy of training the various areas contributing to lumbopelvic stability in reducing the incidence of injury is supported by the majority of studies (3, 9, 13, 31). Lumbopelvic exercise training incorporating a Swiss ball is proven to improve measures of spine stability—specifically extensor and side bridge endurance times—in sedentary individuals (6). As mentioned previously, these measures are associated with a lowered incidence of low back pain and injury (19).

The importance of this preventative function is emphasized by the observation that the lower back is often reported as the third most common site of injury in sports, after the ankle and knee (22). Low back pain and injury are commonplace among both recreational and competitive athletes and can severely impair the athlete's ability to train and compete (20). This type of injury is particularly prevalent in female athletes; a study of injury incidence in National Collegiate Athletic Association collegiate athletes for the 1997–98 season indicated almost twice the number of lower back injuries in female athletes compared to male athletes (21).

Lumbopelvic stability issues can affect all lower-extremity joints by disrupting the integrated function of the kinetic chain of joints between the planted foot and the lumbar spine, where forces are transmitted upward (16, 22). Most movements in sports are closed kinetic chain—that is, executed with one or both feet planted. Consequently, lumbopelvic stability has the potential to affect the function and risk of injury at all lower-extremity joints, particularly the knee and ankle (16).

Components of Lumbopelvic Stability

The core muscles are generally described to include the abdominal and low back musculature (30). Lumbopelvic stability in effect comprises different functional components: deep muscles that stabilize the lumbar spine, the abdominal musculature, the posterior muscles of the lower and middle back, and the hip muscles, which help support and stabilize the pelvis. In addition, neural coordination and motor control play key roles (3).

The contribution of different muscle groups to lumbopelvic stability is dynamic and varies according to the movement and postural demands of a given activity (5, 25). Furthermore, weakness or impairment at any point in the integrated system of support can lead to damage to structural tissues (ligament and joint capsule), causing injury and pain (3). Hence, any 1 or 2 muscles cannot be viewed as relatively more important to lumbopelvic stability (5).

Deep Lumbar Spine Stabilizer Muscles

The deep lumbar spine stabilizers consist of muscles that originate from or insert directly onto the lumbar vertebrae (1, 3). These muscles are in a unique position to provide rigidity for the lumbar spine at the segmental level. The small cross-sectional area of many of these muscles limits the amount of torque they can generate, so their role is more concerned with providing local support and corrective action (19). In doing so, these muscles act to maintain the integrity of the lumbar spine in opposition to internal forces generated during movement performed both with and without external loading. For such reasons, these muscles are termed "postural" muscles, or collectively, "the local stabilizing system" (6, 17).

The importance of these muscles can be inferred from the finding that they are atrophied in individuals with chronic lower back pain (3, 10). These deep muscles also play a key role in kinesthetic awareness and proprioception (3). This is reflected in the density of proprioceptors in these muscles, particularly the rotatores (19). Associated benefits of specific training for these muscles therefore are improved neuromuscular function and postural control.

Exercises to specifically develop these deep muscles typically consist of a sequence of static postures, each held for a brief period (Figures 1 and 2). A study assessing the cross-sectional area of the multifidus following training highlighted the fact that this isometric element appears to be key in developing these local stabilizer muscles (10).

Abdominal Muscles

The abdominal muscles are taken to comprise the rectus abdominis and the muscles of the abdominal wall: the external and internal obliques and the transverse abdominis (8). Whereas the deep lumbar spine stabilizer muscles are implicated in handling internal forces, the large superficial abdominal muscles serve a key role in handling external loads and support during dynamic movements (3, 15).

The individual abdominal muscles act in a load- and velocity-specific manner to assist in stabilizing the trunk during rapid actions, such as athletic activities (3). These muscles thus serve an important function for team sports by allowing players to handle heavy loads in training and competition, in addition to providing stability and mobility to the trunk during sports movements.

The larger trunk muscles and muscles of the abdominal wall attach to the anterior abdominal fascia and posterior lumbodorsal fascia (19). These muscles and passive structures form a loop around the abdomen: the abdominal fascia at the front, the abdominal muscles at the sides, and the lumbodorsal fascia at the back. Together they serve as a stabilizing corset, with the attaching muscles (including the pectoralis major anteriorly and the latissimus dorsi posteriorly) providing additional stiffness to the fascia when activated (19).

In athletes with impaired deep lumbar muscle strength or function, these superficial abdominal muscles may try to compensate (3). These muscles are not mechanically able to stabilize the lumbar spine as effectively, so attempting to perform this stabilizing role actually compromises their effectiveness. Excessive cocontraction of the superficial abdominal musculature may interfere with normal movement and restrict breathing (3). Some authors have advocated neuromuscular training for athletes with overactive abdominal muscles to selectively isolate and recruit the deep lumbar stabilizer muscles (23).

Muscles of the Lower and Middle Back

These muscles include the large extensor muscles longissimus and iliocostalis. Both these muscles have thoracic and lumbar components. The thoracic portions of these muscles generate the most extensor torque because of their long moment arm, whereas the lumbar parts generate posterior shear forces to stabilize anterior shear on the lumbar spine (19).

This group of large posterior muscles is completed by the quadratus lumborum and the latissimus dorsi. The quadratus lumborum appears to serve an isometric stabilizing role for a variety of movements and is observed to increase tension in response to increasing loads and stability demands (19). The latissimus dorsi is included with these large posterior muscles on the basis that it provides tension to the lumbodorsal fascia that forms the posterior aspect of the stabilizing corset described previously (19).

Hip Muscles

The hip musculature has a major role in all dynamic activities, particularly those performed in an upright stance (22). These muscles are implicated in various phases of the gait cycle, for example, helping to stabilize the pelvis and providing assistance to the supporting leg during the swing phase (22). In fact, in all dynamic movements the hip extensors and rotators particularly play a part in efficient transmission of forces from the ground upward. The hip flexors—which include the psoas (15)—play a crucial role in rapid and efficient action of the recovery leg during sprinting, which is identified as a determining factor in sprint performance.

The importance of the hip muscles' role in stabilizing the lower limb joints during dynamic movements is seen in that the function of these muscles affects the incidence of lower limb injury, particularly in female athletes (16). Inadequate hip muscle function combined with anatomical differences can predispose female players to excessive motion in the lower limb joints, placing these joints in positions where they are at risk of noncontact injury. Tests scores for isometric hip abduction and external rotation strength are found to be significant predictors of subsequent lower limb injury during the competitive season in collegiate athletes (16).

Side-to-side imbalances in hip muscle strength are commonly observed in athletes. Right-handed athletes typically exhibit greater strength in their opposite (left) hip extensors (22). This may well be due to the use of the left leg as the supporting leg during these right leg–dominant sports activities, such as kicking. Likewise, right hand–dominant athletes will tend to take off from their left leg when jumping. Both these instances place greater demands on the leg hip extensor muscles. Conversely, right hip abductor strength is generally greater in right-handed athletes (22). This can be explained by phenomena such as the dominant right hip abductor involvement in fine motor skills, for example the kicking action.

Impaired function of the hip extensors and hip abductors is observed in athletes suffering lower back pain (21). Strength imbalances in these muscles are also implicated in lower back injury, particularly in female athletes (21). Correction of hip abductor strength imbalances via a core-strengthening program shows the potential to reduce subsequent lower back pain incidence (21). Specific training to address these factors therefore can help guard against the incidence of injury and lower back pain.

The hip rotators are often overlooked in physical preparation, despite the recent finding that isometric hip external rotation strength has been shown to be the single best predictor of lower back and lower extremity injury incidence in collegiate athletes (16). Inflexible or weak hip rotators can predispose an athlete to poor pelvic alignment (24). Excessive lumbar spine motion can also occur in an attempt to compensate for impaired hip rotator function. Both of these factors can lead to pain and increased incidence of lumbar spine injury (24). It follows that these muscles must also be specifically addressed in training.

Neuromuscular Control and Coordination

Neural control is critical in the activation and coordination of each of the supporting muscles described earlier (3). A key aspect of this is the coordinated firing of local deep lumbar stabilizer muscles and activation of the large superficial muscles when handling external loads (7). Also key are proprioception and kinesthetic awareness of the orientation of the pelvis, which directly influence lumbar spine posture. Poor control of the position of the pelvis can put the lumbar spine under undue stress (8).

Lumbopelvic stability in gross movements is underpinned by the firing of various core muscles in preparation for movement (3, 16). Thus, the muscles providing the base of support are activated before the muscles involved in the particular movement (1). The role of these anticipatory postural adjustments is to maintain the body's center of gravity within its base of support to minimize loss of balance (1). This also serves to prevent unwanted trunk motion and provide a stable base of support during movement.

The neuromuscular system must govern function of the stabilizing muscles, not only in anticipation of the expected direction and magnitude of forces but also in reaction to sudden movement or loading (3). In this way, postural control, whole-body balance, and proprioception are also heavily involved in neural control of lumbopelvic stability.

A reflection of the importance of neuromuscular control is that individuals with chronic lower back pain exhibit impaired neuromuscular feedback and delayed muscle reaction, which are accompanied by reduced capacity to sense the orientation of the spine and pelvis (3, 25). These factors are responsible for the poor performance of these individuals in balance and movement response tasks (3). However, these deficits in neuromuscular control can be reversed by appropriate training interventions (3).

Summary

The diverse nature of the integrated system of support described here calls for an integrated approach to training that addresses each of the respective components that contribute to lumbopelvic stability (25). Clinical approaches that focus on one specific area or muscle group (typically, the transverse abdominis or multifidus) to the exclusion of others are therefore fundamentally flawed.

McGill (19) has elucidated the fact that the diverse muscle groups that act in concert to support the lumbar spine must be in balance to ensure optimal stability. It follows that each of the separate components should be trained in a coordinated way to function harmoniously (19, 25). Again this contrasts with clinical approaches that promote independent activation of single muscle groups in isolation by employing practices such as "drawing in the belly button" (abdominal hollowing), which cannot be considered functional by any definition (5).

Practical Approach to Achieving Lumbopelvic Stability

It is important to differentiate between lumbopelvic stability training for athletic performance and that aimed at rehabilitation (18, 19). The training goals in each case are significantly different—and correspondingly, so should be the approaches taken in training. Injury and low back pain are often associated with disrupted motor control, which must be specifically addressed (18, 19). Rehabilitation is a complex and diverse area that is beyond the scope of the current article; the reader is referred to McGill (18). This section will instead focus on lumbopelvic stability training for improved performance in healthy athletes.

Rather than isolating particular muscle groups, a distinction should be made between lumbopelvic exercises requiring fine degrees of coordination and motor control and more dynamic gross motor tasks. This is analogous to the differentiation between the local stabilization system and the global stabilizing system, or "postural" versus "mobilizer" muscles (6, 17). Approaches to core training design have been described previously that include separate (isometric) stabilization exercises and dynamic core strength training (30).

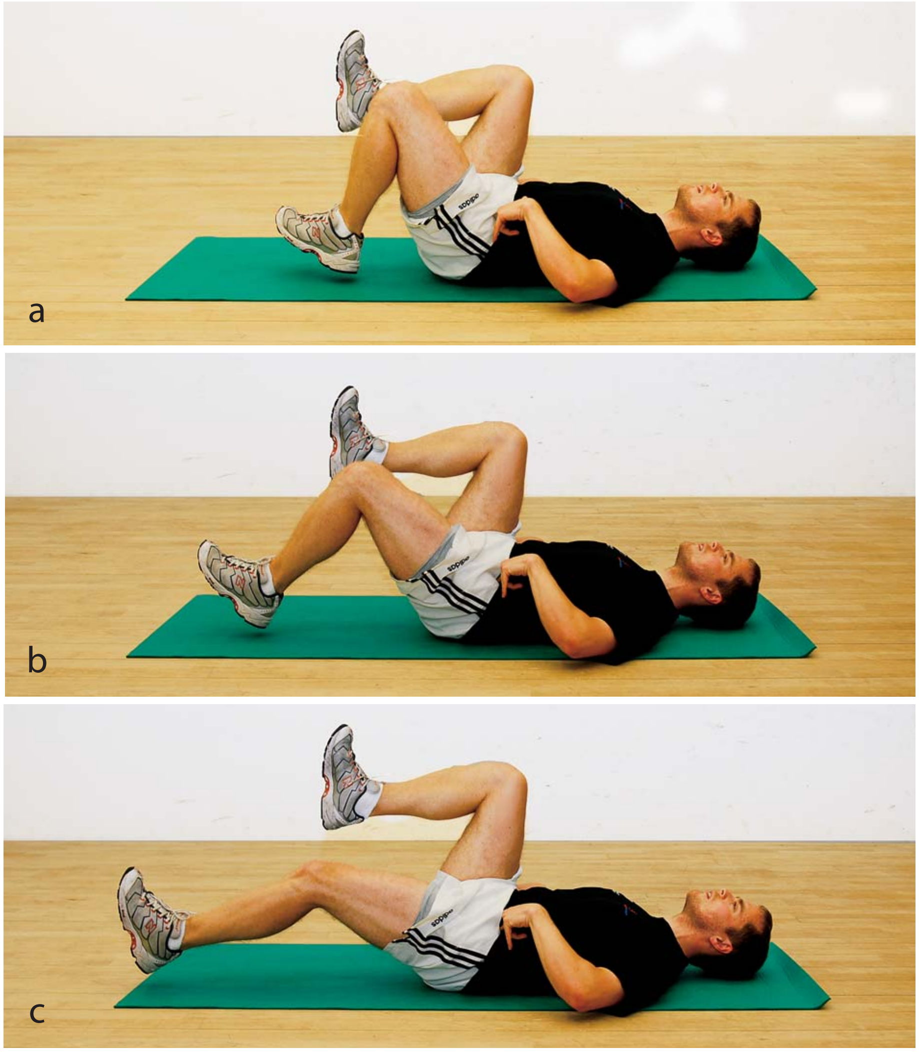


Figure 1. Single-leg lower-and-reach exercise.

The low-intensity exercises for the local stabilizers require high degrees of concentration and focused mental attention. As such, they are not amenable to the high levels of activity and psychological arousal that are characteristic of a weight room setting. Accordingly, it is recommended that these low-intensity exercises—which can and should be performed daily—should be undertaken as a stand-alone session and conducted in a quiet, controlled setting. Conversely, the more functional dynamic lumbopelvic stability exercises can be integrated into the athlete's strength training workouts. The recruitment of these global mobilizer muscles is dependent on posture and direction of movement, as well as loading conditions (1, 19); it follows that a range of exercises in different planes must be incorporated to fully address these muscles.

Daily Low-Intensity Lumbopelvic Stability Exercises

As mentioned, these exercises are proposed to comprise a stand-alone session to be performed on a daily basis by the athlete. These exercises require minimal equipment and are most suited to being performed in a quiet environment. Such a session may be undertaken early in the training day or as a recovery session between or after technical/tactical practices or bouts of physical training. A session of this type is most beneficial when performed daily (19).

These exercises focus primarily on the deep lumbar stabilizers and on low-intensity means of strengthening the hip musculature. The objective of these exercises is to develop motor control of the lumbar spine stabilizers and proprioception, particularly the ability to sense lumbar spine positioning and orientation of the pelvis (6). The emphasis when performing these exercises is on maintaining a neutral spine posture and holding the pelvis stable (6). More dynamic work, along with higher-intensity exercises that target the larger muscles of the trunk in a load- and movement-specific manner, is reserved predominantly for the weight room (see later section).

A key element when performing these exercises is that the athlete is instructed to hold each posture for a period while taking a full breath in and out. The addition of a static hold when performing dynamic strength training was found to elicit increases in the cross-sectional area of the multifidus in patients with chronic low back pain; such increases were not seen when performing the same dynamic training without a static hold (10). This finding suggests that an isometric element between the concentric and eccentric phases may be necessary to develop the size and function of these deep lumbar stabilizer muscles (10).

The instruction to take a full breath during these static-hold phases is designed to emphasize maintenance of stabilizer muscle activation in a way that is independent of breathing patterns. The ability to maintain muscle activation during challenged breathing is a key indicator of effective versus ineffective stabilizer motor control patterns (19). In addition, this deep breath facilitates (partial) relaxation of the larger superficial abdominal muscles (particularly the rectus abdominis), which encourages proper activation of the local lumbar stabilizers and deeper abdominal wall muscles.

The first 2 of the 4 suggested exercises have been described in detail elsewhere. For the bird dog exercise (2-point support from kneeling quadruped stance), the reader is referred to McGill (19) and Rogers (25). The kneeling side bridge is described in Jenkins (14) and McGill (19).

Deep Lumbar Stabilizer Muscle Training:

- Bird Dog (19, 25)
- Kneeling Side Bridge (14, 19)
- Single-Leg Raise and Reach (Figures 1a–c)
- Single-Leg Raise and Lateral Lower (Figures 2a and b)

A daily session that includes these exercises should also incorporate stretching exercises to develop hip flexibility (25). Tightness in the gluteal muscles and hamstrings is common among athletes with below-par lumbopelvic stability (14), so addressing this is of obvious benefit. This has been characterized as the crossed-pelvis syndrome (19). Good hip flexibility likewise helps to spare the spine by allowing the athlete to develop high levels of hip power while minimizing motion at the lumbar spine (19).

However, stretching should emphasize the hip muscles as opposed to the lumbar spine. Hyperflexibility in the lumbar region can only make this area more unstable, which may actually predispose the athlete to injury (19). Consequently, stretches that incorporate a neutral spine position should be favored.

Hip Muscle Flexibility Exercises:

- Hip Extensors (Seated Hamstrings) Stretch (19)
- Gluteal Stretch (Basic) (14)
- Gluteal Stretch (Advanced) (Figure 3)

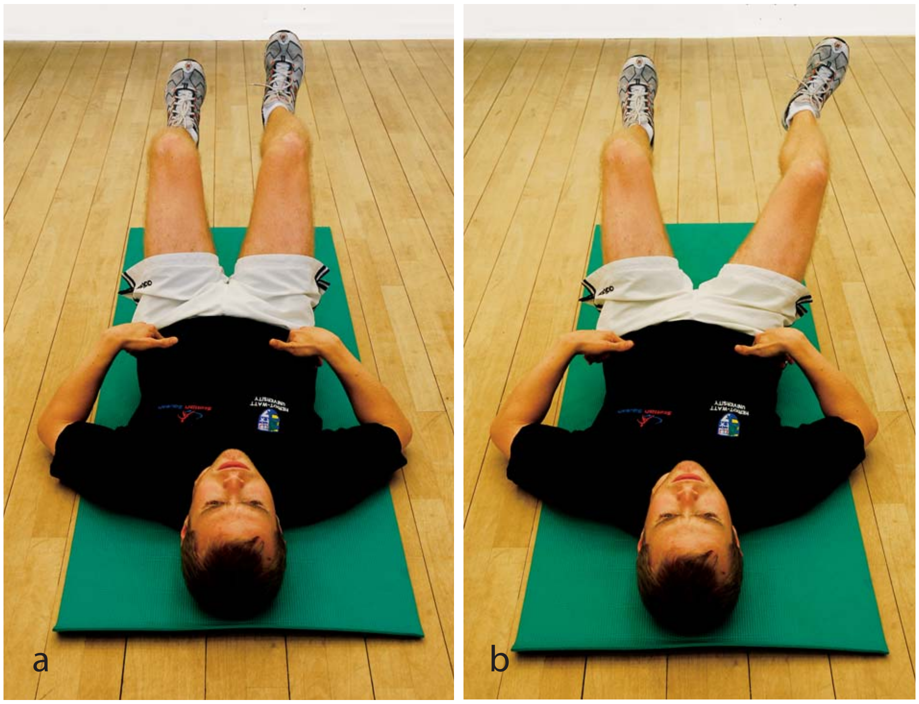


Figure 2. Single-leg lateral lower exercise.

Figure 3. Advanced gluteal stretch.

Dynamic Lumbopelvic Stability Training

In addition to the goals of neuromuscular coordination and proprioception training, exercises that involve higher levels of force and muscle activation are necessary to allow the athlete to develop strength and endurance of muscles that provide lumbopelvic stability (4). As mentioned previously, these may be integrated into strength training workouts in the weight room.

Progression can be implemented in exercise selection by incorporating an unstable base of support to elicit greater levels of abdominal activation for particular exercises (4, 8, 30, 32). Typically, a wob-

Figure 4. Static plank with leg raise exercise.

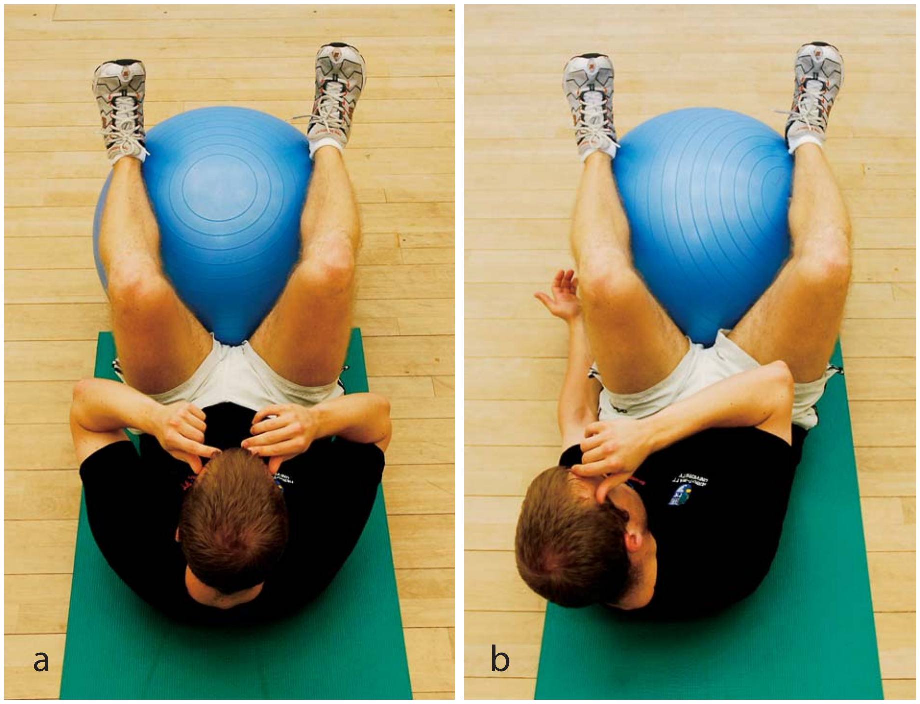


Figure 5. Swiss ball obliques exercise.

ble board or Swiss ball is used for the purposes of creating a labile supporting surface (4, 32). Imposing instability in this way is shown to increase trunk muscle activation (recorded electromyographically) for a variety of trunk muscle exercises (4, 32).

Another consideration is that there is often a trade-off between levels of muscle activation and compressive loads imposed upon the spine (2, 15). Again, there must necessarily be a distinction between training for performance improvement and training to rehabilitate the injured low back (15). These two scenarios will obviously involve different risk-to-benefit considerations in terms of exercise selection (2). However, in either case, the identification of exercises that optimize muscle recruitment and activation while sparing the spine is likely to prove beneficial.

No single exercise activates all abdominal muscles optimally (2, 15). It follows that a selection of various different exercises is required to develop strength and endurance for the respective muscle groups that contribute to lumbopelvic stability (2). As discussed previously, the trunk muscles work in different combinations, depending on the direction of movement, posture, and loading involved (3, 19). Individual considerations, such as injury history and specific areas of strengths and weakness, will also influence the choice of exercises.

Whether performed on a stable or unstable base, Behm et al. (4) reported that the side bridge exercise resulted in the highest levels of recorded lower abdominal muscle activation (including the internal obliques and transverse abdominis) from a selection of trunk muscle exercises studied. The side bridge exercise also has the ancillary benefit of low lumbar spine compressive loading and high activation of the quadratus lumborum (2).

Classically, exercises for the abdominal muscles have been based upon variations of sit-ups and curl-ups. Conversely, athletic tasks typically involve a fixed, neutral spine position; it follows that these muscles should therefore be trained under similar (isometric) conditions (19). Repetitive flexion of the spine under load, as occurs with sit-ups and curl-ups, can also be injurious (18).

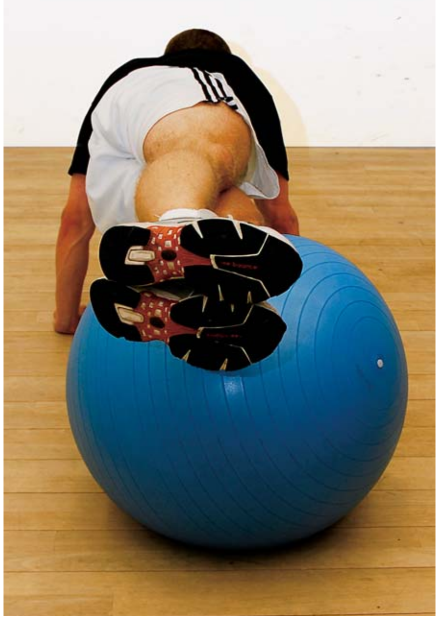


Figure 6. Swiss ball rotation exercise.

Twisting and turning actions are common, particularly in team sports, and it follows that dynamic lumbopelvic stability training should address these movements. It is suggested that initially this is best achieved with exercises on a Swiss ball, which use the athlete's body weight as the primary resistance. Higher twisting torque is associated with a higher risk of low back injury—as is twisting to the extremes of range of motion (18). Both these situations should therefore be avoided, at least in the initial stages of training, particularly for athletes with previous history of low back pain. As the athlete progresses, additional resistance using cables may be introduced.

Abdominal Muscles:

- Full Side Bridge (19)
- Plank with Leg Raise (Figure 4)
- Stability Ball Plank
- Stability Ball Obliques (Figures 5a and b)
- Stability Ball Russian Twist
- Stability Ball Hip Rotation (Figure 6)
- Stability Ball Jackknife and Single-Leg Variation (Figure 7)

The hip is a joint that allows movement in multiple axes. It follows that a variety of movements in different planes should be incorporated when training the hip musculature. In this way the approach to training the hip can be viewed much the same as training the shoulder rotator cuff in terms of the variety of exercises and planes of motion that are included (11).

These exercises should be performed with emphases on holding the pelvis in a horizontal position and on maintaining alignment of the pelvis in the frontal plane. Having the athlete palpate the anterior superior iliac spines on either side while performing many of these exercises facilitates the development of an enhanced feel for pelvic alignment and position.

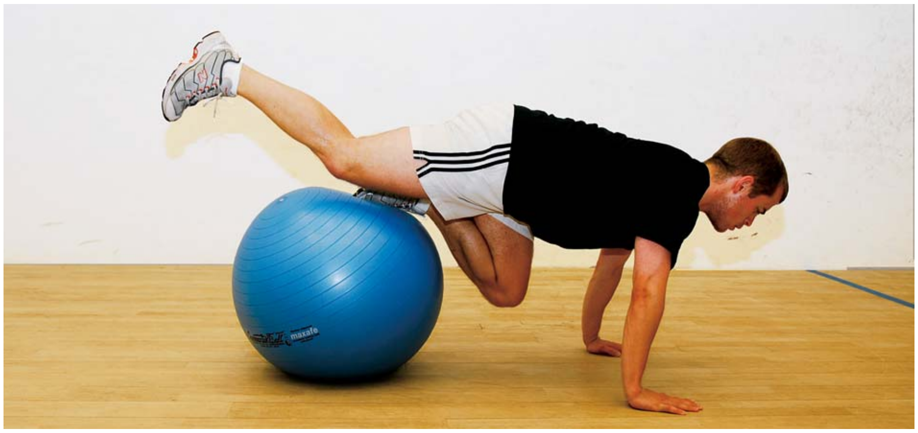


Figure 7. Single-leg Swiss ball jackknife exercise.

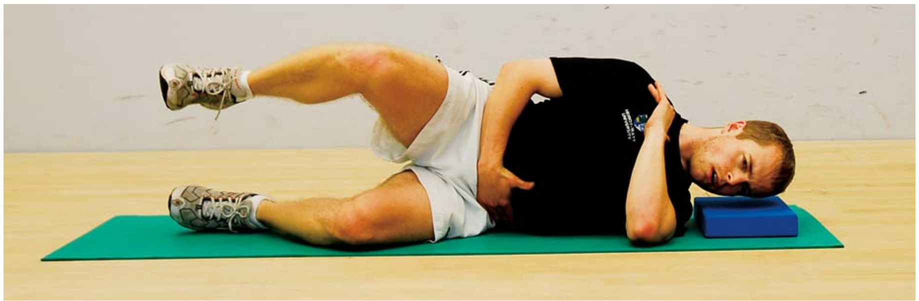


Figure 8. Side-lying raise-and-hold exercise.

Figure 9. Swiss ball single-leg bridge-and-curl exercise.

The hip muscles play a key role in stabilizing the pelvis during single-leg support (19), which characterizes the majority of movements in team sports and various track and field events. Unilateral support exercises are therefore a crucial part of any functional lumbopelvic stability training to incorporate the hip musculature (19).

Figure 10. Single-leg standing hip flexion/extension exercise.

Figure 11. Single-arm dumbbell overhead squat exercise.

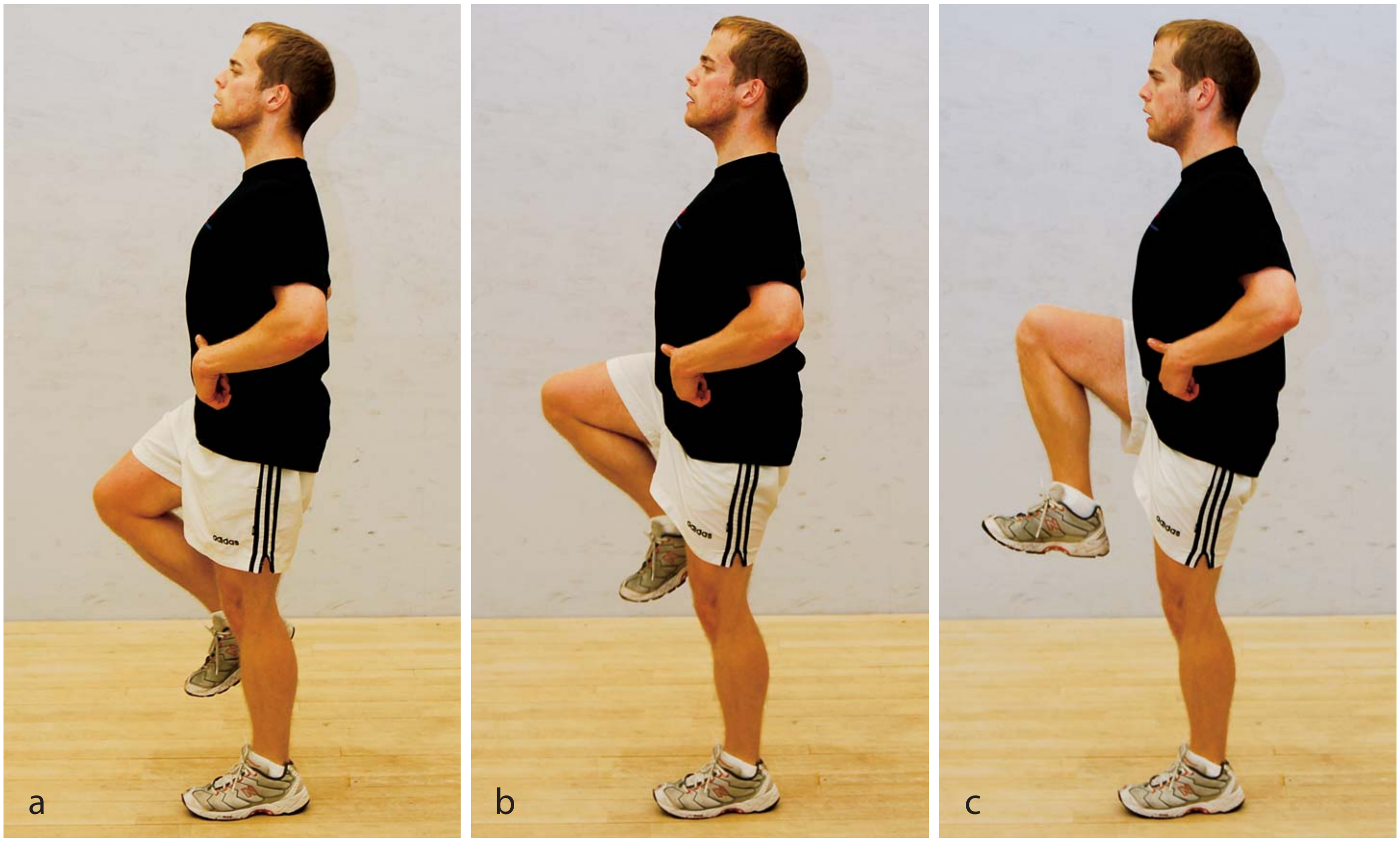


Figure 12. Standing single-leg 3-phase exercise.

From a standpoint of lumbopelvic stability, many of the relevant hip muscles cross both the hip and knee joints (26). It follows that exercises must be performed in various hip and knee joint angles (19). Lumbopelvic stabilization during hip flexion is crucial, particularly when sprinting. Single-leg support exercises that incorporate resisted hip flexion are frequently used by athletes to develop sprint performance (27). However, activation of the psoas and iliacus muscle groups during hip flexion exerts large compressive forces on the spine, which is compounded when performed at high velocities (19). As a result, these resistance exercises should be performed in a controlled manner, rather than at high velocity.

Hip Muscles

- Supine Bridge with Leg Raise (25)
- Stability Ball Bridge with Leg Raise (26)
- Side-Lying Raise-and-Hold (Figures 8a and b)
- Stability Ball Bridge with Curl and Single-Leg Variation (Figure 9)
- Standing Single-Leg Hip Flexion/Extension (Figure 10)

The key to all of the exercises described in this article is for the athlete to gain an appreciation of what is occurring in the lumbo-pelvic-hip complex. Challenging the athlete's balance and postural control via appropriate exercises can facilitate the development of a heightened sense of the position of the lumbar spine and the orientation of the pelvis during the performance of various activities.

The emphasis for all proprioception/neuromuscular training exercises is on maintaining neutral lumbar spine posture while controlling the alignment of the pelvis in both frontal and horizontal planes. During these exercises, the athlete is simultaneously challenged to retain balance in either a bilateral or a unilateral stance, by keeping the center of mass within the base of support (ideally with weight through the heel/midfoot of the supporting leg[s]). Thus these exercises develop both proprioception and whole-body stability (28).

Proprioception/Neuromuscular Training

- Single-Leg Bench Squat (28)
- Overhead Squat with Dumbbell (Figure 11)
- Single-Leg 3-Phase Raise-and-Hold (Figures 12a–c)

Conclusions

A systematic approach to athletic training for the core requires that the strength and conditioning coach account for all the different aspects described that support lumbopelvic stability. It is suggested that daily lumbo-pelvic stability training should be undertaken in combination with higher-intensity dynamic exercises that can be incorporated into strength training sessions in the weight room.

As with all training, lumbopelvic stability training should incorporate progression and specificity (8, 30). In the case of dynamic lumbopelvic stability training in particular, the intensity of loading and exercise selection should be implemented within the context of the athlete's training plan (30).

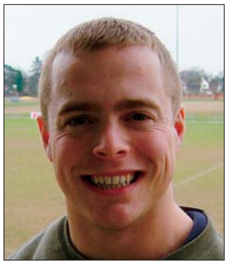
Furthermore, the approach taken should reflect the needs of the individual athlete, based upon his or her training and injury history (30). This will necessarily include relevant screening or fitness test data, such as the relationships between flexor, extensor, and side bridge test endurance times (19).

Practices on competition day—such as warming up and athletes' activity while waiting to perform—should also not be overlooked with regard to lumbopelvic function and lumbar spine health. A particular concern for nonstarting players in team sports is the increase in lumbar spine stiffness during sitting on the bench while waiting to enter the game, which reverses any positive effects of the prematch warm-up (12). ♦

References

1. Anderson, K., and D.G. Behm. The impact of instability resistance training on balance and stability. *Sports Med.* 35:43–53. 2005.
2. Axler, C.T., and S.M. McGill. Low back loads over a variety of abdominal exercises: Searching for the safest abdominal challenge. *Med. Sci. Sports Exerc.* 29:804–811. 1997.
3. Barr, K.P., M. Griggs, and T. Cadby. Lumbar stabilization: Core concepts and current literature, part one. *Am. J. Phys. Med. Rehabil.* 84: 473–480. 2005.
4. Behm, D.G., A.M. Leonard, W.B. Young, W.A.C. Bonsey, and S.N. Mackinnon. Trunk muscle electromyographic activity with unstable and unilateral exercises. *J. Strength Cond. Res.* 19:193–201. 2005.
5. Brown, T.D. Getting to the core of the matter. *Strength Cond. J.* 28(2): 50–53. 2006.
6. Carter, J.M., W.C. Beam, S.G. McMahan, M.L. Barr, and L.E. Brown. The effects of stability ball training on spinal stability in sedentary individuals. *J. Strength Cond. Res.* 20:429–435. 2006.
7. Cholewicki, J., and S.M. McGill. Mechanical stability of the in vivo lumbar spine: Implications for injury and chronic low back pain. *Clin. Biomech.* 11:1–15. 1996.
8. Cissik, J.M. Programming abdominal training, part one. *Strength Cond. J.* 24(1):9–15. 2002.
9. Cusi, M.F., C.J. Juska-Butel, D. Garlick, and G. Argyrous. Lumbopelvic stability and injury profile in rugby union players. *N. Z. J. Sports Med.* 29:14–18. 2001.
10. Daneels, L.A., G.G. Vanderstraeten, D.C. Cambier, E.E. Witrouw, J. Bourgois, W.

Dankerts, and H.J. De Cuyper. Effects of three different training modalities on the cross sectional area of the lumbar multifidus muscle in patients with chronic low back pain. *Br. J. Sports Med.* 35:186–191. 2001.
11. Fabrocini, B., and N. Mercaldo. A comparison between the rotator cuffs of the shoulder and hip. *Strength Cond. J.* 25(4):63–68. 2003.
12. Green, J.P., S.G. Grenier, and S.M. McGill. Low-back stiffness is altered with warm-up and bench rest: Implications for athletes. *Med. Sci. Sports Exerc.* 34:1076–1081. 2002.
13. Hides, J.A., G.A. Jull, and C.A. Richardson. Long-term effects of specific stabilizing exercises for first-episode low back pain. *Spine.* 26:E243–248. 2001.
14. Jenkins, J.R. The transverse abdominis and reconditioning the lower back. *Strength Cond. J.* 25(6):60–66. 2003.
15. Juker, D., S.M. McGill, P. Kropf, and S. Thomas. Quantitative intramuscular myoelectric activity of lumbar portions of psoas and the abdominal wall during a wide variety of tasks. *Med. Sci. Sports Exerc.* 30:301–310. 1998.
16. Leetun, D.T., M.L. Ireland, J.D. Willson, B.T. Ballantyne, and I.M. Davis. Core stability measures as risk factors for lower extremity injury in athletes. *Med. Sci. Sports Exerc.* 36:926–934. 2004.
17. Liemohn, W.P., T.A. Baumgartner, and L.H. Gagnon. Measuring core stability. *J. Strength Cond. Res.* 19: 583–586. 2005.
18. McGill, S.M. *Low Back Disorders: Evidence Based Prevention and Rehabilitation.* Champaign, IL: Human Kinetics, 2002.
19. McGill, S.M. *Ultimate Back Fitness and Performance.* Ontario, Canada: Wabuno, 2004.
20. Montgomery, S., and M. Haak. Management of lumbar injuries in athletes. *Sports Med.* 27:135–141. 1999.
21. Nadler, S.F., G.A. Malanga, L.A. Bartoli, J.H. Feinberg, M. Prybicien, and M. Deprince. Hip muscle imbalance and low back pain in athletes: Influence of core strengthening. *Med. Sci. Sports Exerc.* 34:9–16. 2002.
22. Nadler, S.F., G.A. Malanga, M. Deprince, T.P. Stitik, and J.H. Feinberg. The relationship between lower extremity injury, low back pain, and hip muscle strength in male and female collegiate athletes. *Clin. J. Sports Med.* 10:89–97. 2000.
23. Pool-Goudzwaard, A.L., A. Vleeming, R. Stoeckart, C.J. Snijders, and J.M.A. Mens. Insufficient lumbopelvic stability: A clinical, anatomical and biomechanical approach to a specific low back pain. *Manual Ther.* 3:12–20. 1998.
24. Regan, D.P. Implications of hip rotators in lumbar spine injuries. *Strength Cond. J.* 22(6):7–13. 2000.
25. Rogers, R.G. Research-based rehabilitation for the lower back. *Strength Cond. J.* 28(1):30–35. 2006.
26. Santana, J.C. Hamstrings of steel: Preventing the pull, part II—Training the "triple threat." *Strength Cond. J.* 23(1):18–20. 2001.
27. Sheppard, J.M. Strength and conditioning exercise selection in speed development. *Strength Cond. J.* 25(4): 26–30. 2003.
28. Shiner, J., T. Bishop, and A.J. Cosgarea. Integrating low-intensity plyometrics into strength and conditioning programs. *Strength Cond. J.* 27(6):10–20. 2006.
29. Stanton, R., P.R. Reaburn, and B. Humphries. The effect of short-term swiss ball training on core stability and running economy. *J. Strength Cond. Res.* 18:522–528. 2004.
30. Stephenson, J., and A.M. Swank. Core training: Designing a program for anyone. *Strength Cond. J.* 26(6): 34–37. 2004.
31. Tse, M.A., A.M. McManus, and R.S.W. Masters. Development and validation of a core endurance intervention program: Implications for performance in college-age rowers. *J. Strength Cond. Res.* 19:547–552. 2005.
32. Vera-Garcia, F.J., S.G. Grenier, and S.M. McGill. Abdominal muscle response during curl-ups on both stable and labile surfaces. *Phys. Ther.* 80:564–569. 2000.



Gamble

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