

# Core Training: Evidence Translating to Better Performance and Injury Prevention

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## SUMMARY

THIS REVIEW ARTICLE RECOGNIZES THE UNIQUE FUNCTION OF THE CORE MUSCULATURE. IN MANY REAL LIFE ACTIVITIES, THESE MUSCLES ACT TO STIFFEN THE TORSO AND FUNCTION PRIMARILY TO PREVENT MOTION. THIS IS A FUNDAMENTALLY DIFFERENT FUNCTION FROM THOSE MUSCLES OF THE LIMBS, WHICH CREATE MOTION. BY STIFFENING THE TORSO, POWER GENERATED AT THE HIPS IS TRANSMITTED MORE EFFECTIVELY BY THE CORE. RECOGNIZING THIS UNIQUENESS, IMPLICATIONS FOR EXERCISE PROGRAM DESIGN ARE DISCUSSED USING PROGRESSIONS BEGINNING WITH CORRECTIVE AND THERAPEUTIC EXERCISES THROUGH STABILITY/MOBILITY, ENDURANCE, STRENGTH AND POWER STAGES, TO ASSIST THE PERSONAL TRAINER WITH A BROAD SPECTRUM OF CLIENTS.

## INTRODUCTION

The well-trained core is essential for optimal performance and injury prevention. This article introduces several elements related to the core to assist personal trainers in designing the most appropriate

progressions for their clients. The core is composed of the lumbar spine, the muscles of the abdominal wall, the back extensors, and quadratus lumborum. Also included are the multijoint muscles, namely, latissimus dorsi and psoas that pass through the core, linking it to the pelvis, legs, shoulders, and arms. Given the anatomic and biomechanical synergy with the pelvis, the gluteal muscles may also be considered to be essential components as primary power generators (the synergy of these components is outlined elsewhere (36)).

The core musculature functions differently than the limb musculature in that core muscles often cocontract, stiffening the torso such that all muscles become synergists—examples in a wide variety of training and athletic activities are provided in Refs. (2,3,5,13,14,15,19,20,53,55). Thus, training the core effectively means training it differently than the limb muscles.

Evidence and common practice are not always consistent in the training community. For example, some believe that repeated spine flexion is a good method to train the flexors (the rectus abdominis and the abdominal wall). Interestingly, these muscles are rarely used in this way because they are more often used to brace while stopping motion. Thus, they more often act as stabilizers than flexors. Furthermore, repeated

bending of the spinal discs is a potent injury mechanism (10,61). Another example of misdirected practice commonly occurs when some trainers have their clients pull in their abdominals to “activate their transverse abdominis” to enhance stability. First, this does not target the major stabilizers of the spine because studies that measure stability show that the most important stabilizers are task specific.

For example, sometimes the quadratus lumborum is most important, yet many trainers neglect this muscle (19). Second, drawing the abdominals inward reduces stability (57). Third, evidence on transverse abdominis shows that activation disturbances may occur in some people with specific types of back disorders, but that these same disturbances are not unique to transverse abdominis because they occur in many muscles (11,59). People are unable to activate this muscle in isolation beyond very low levels of contraction because it is designed to activate with internal oblique muscle for athletic tasks (18). It would appear that trainers who focus on this muscle are misdirected.

Other evidence shows how the core makes the rest of the body more capable. For example, in our work

## KEY WORDS:

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quantifying the tasks of strongman training, we documented how the core assisted hip function to allow the competitors to accomplish tasks that they did not have the hip strength to perform (53). Specifically, the quadratus lumborum assisted in pelvis elevation to allow the swing leg to make a step. This was the first evidence suggesting that a strong core allows strength to radiate out peripherally to more distant regions of the body. Similarly, in training, our recent work (58) demonstrated how an individual can only bench press half of their body weight when standing—otherwise they would push themselves over. While laying, bench press performance was primarily governed by the chest and shoulder musculature, whereas standing press performance was governed by core strength, particularly one-arm presses. Thus, the limiting factor in standing press ability was core strength.

The core, more often than not, functions to prevent motion rather than initiating it, which is contrary to the approaches that many trainers employ in designing exercise for their clients. Good technique in most sporting, and daily living tasks demands that power be generated at the hips and transmitted through a stiffened core (37). Pushing, pulling, lifting, carrying, and torsional exertions are enhanced using this basic technique of hip power generation but are compromised when the spine bends causing what is often referred to as “energy leaks.” Interestingly, these task classifications greatly assist the organization of program design (think of building exercises to fulfill a push, pull, lift, carry, and a torsional buttressing task rather than specific isolationist exercises for the abdominals, back extensors, latissimus dorsi, and the like).

As a contribution to this special issue, I thought about how best to assist increasing the competency of trainers. But after writing 2 textbooks (25,35) based on our hundreds of scientific publications, I feel as though I have already said what is necessary and important in a cohesive story.

Thoughts are provided here for exercise professionals who deal with issues related to the assessment and design of therapeutic exercise for the core. Core training is of interest given the prevalence of back pain among clients. Core training is associated with spine stability and instability that results from back disorders. Evidence from the back disorders’ literature shows that poor movement patterns can lead to back disorders. In this way, trainers should consider the quality of movement patterns in all clients and by default should consider beginning any exercise program with corrective exercises.

Many trainers follow a “recipe” for assessment, corrective exercise, or performance training. Using this generic approach ensures “average” results—some clients will improve and get better, but many will fail simply because the approach was above or below the optimum level necessary to address the deficit. The program and approach principles introduced here are based on principles intended to assist development of elite corrective exercise and training specialists.

### CONSIDER THE CAUSES OF BACK DISORDERS

Here is a disturbing fact: many of the back pain patients I see have been exacerbated by poor training programs because the mechanism of injury was unknowingly incorporated. The first step in any exercise progression is to remove the cause of pain or potential pain, namely, the perturbed motion and motor patterns. For example, the flexion intolerant back is very common in today’s society (i.e., pain is produced after repeated or prolonged back flexion). Giving this type of client stretches such as pulling the knees to the chest may give the perception of relief (through the stimulation of erector spinae muscle stretch receptors), but this approach only guarantees more pain and stiffness the following day because the underlying tissues sustain more cumulative damage.

Eliminating spine flexion, particularly in the morning when the discs are

swollen from the osmotic superhydration of the disc that occurs with bed rest, has been proven very effective with this type of client (60). Furthermore, typically, when this client bends to pick up a weight, they flex the spine adding to the cumulative trauma. This often continues without correction from the trainer. This is a missed opportunity. Realize that the spine discs only have so many numbers of bends before they damage (10). Keep the bends for essential tasks such as tying shoes rather than using them up in training. Many lifestyle and occupational examples have been provided elsewhere (28) to guide the elimination of the cause of a client’s back troubles; the trainer will find that half of their initial effectiveness will be because of preventing the cause (i.e., a flawed movement pattern). This need not be so complicated. Consider the client who stands slouched where the back muscles are chronically contracted to the point of chronic muscle pain. The family doctor typically prescribes muscle relaxants, which fail to relax the muscle. The trainer addresses the postural cause and corrects standing to effectively silence the muscles and remove the associated crushing load from the spine (Figure 1) (32).

### BUILDING THE SCIENTIFIC FOUNDATION

Myths and controversies regarding spine function and injury mechanisms are common. Consider “the cause” of back troubles, specifically the common perception regarding common injury pathways in which the back is injured from an “event.” Generally, statistics are compiled from epidemiological approaches, which ignore the large role of cumulative trauma. Compensation board data are often used, however, and they ask clinicians to fill out reports and name the “event” that caused the “injury.” For example, “Mr X lifted and twisted at the time that the injury occurred.” Kinesiologists and trainers know that twisting is different from generating twisting torque, but very few of the individuals filling out the reports will know. So, was it twisting torque that caused the injury?



**Figure 1.** (a) Poor standing posture causes constant spine load and chronic contracture of the erector spinae muscles causing muscular pain. (b) One approach for correction is to externally rotate the arms about the shoulders (steering the thumbs out). (c) Correcting the posture with chin and shoulder retraction reduces the chronic muscle contraction reducing pain and building training capacity.

Or, was it being twisted that caused the injury? Furthermore, despite the injury/incident reporting system geared to the reporting of the “event” associated with the “injury,” very few back injuries occur this way.

Evidence of the process of disc herniation provides a proof of principle. For example, the damaging mechanism leading to herniation, or prolapse, is repeated lumbar flexion requiring only very modest concomitant compressive loads (10). This trauma accumulates with little indication to the future patient. With repeated flexion cycles, the annulus breaches layer by layer with progressive delamination of the layers (61). This allows gradual accumulation of nucleus material between the delaminated layers. The location of the annulus breaches can be predicted by the direction of the bend. Specifically, a left posterior lateral disc bulge will more likely result if the spine is flexed with some additional right lateral bend (1). Subsequent twisting leads circumferential rents in the annulus that tends to make McKenzie extension approaches for these clients useless or even exacerbating (23). This is critical information for the trainer, both in terms of prevention and in

treatment. Avoiding this specific directional cause will lead to optimal therapeutic exercise design together with elimination of activities in the patient’s daily routine identified as replicating the cause.

Many training programs have the objectives of strengthening muscle and increasing spine range of motion. This is problematic for some because those who have more motion in their backs have a greater risk of having future back troubles (56). Strength may, or may not, help a particular individual because strength without control and endurance to repeatedly execute perfect form increases risk. Interestingly, the differences between many “troubled backs” (the chronic back with recurrent episodes) and matched asymptomatic controls performing the same jobs have been shown to be variables other than back strength or mobility. Rather deficits in motion and motor patterns have been documented as being more critical and thus should be targets for therapeutic exercise.

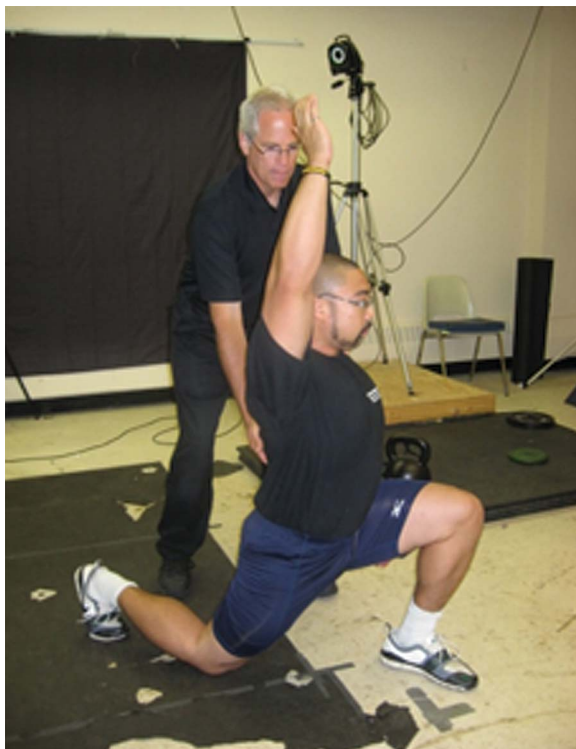
For example, people with troubled backs use their backs more. Generally, they walk, sit, stand, and lift using

mechanics that increase back loads. Many of them have stronger backs but are less endurable than matched asymptomatic controls (47). They tend to have more motion in their backs and less motion and load in their hips. A common aberrant motor pattern is known as “gluteal amnesia” (27), which may be both a common consequence of back troubles and possibly a cause of them as well. The general principle that joint pain causes inhibition of the extensors and chronic facilitation of the flexors to the point of “tightness” appears to be true with hip or back pain. Obviously, for this category of client, exercises to enhance the integration of the gluteal muscles will enhance back function while also sparing knees. Hip flexor mobility is also needed (but special technique is needed to separately target psoas from iliacus) (Figure 2) (38). Optimal back exercise therapy results from the identification of these clients with perturbed patterns followed by specific corrective exercise—this precedes all other exercise progressions.

#### **THE SCIENCE OF CORE STABILITY**

Effective core/spine stabilization approaches must begin with a solid





**Figure 2.** Lunging with the arm directed overhead helps to differentiate and target psoas from iliacus during hip flexor stretching. Hip extensor patterns are simultaneously trained on the opposite side of the body. When this exercise is performed as walking steps, holding the posture for 2 seconds and pulsing the arm upward through the core, then taking a step and repeating, it becomes a facilitator and a good “warm-up” exercise.

understanding of what stability is. From a spine perspective, it has little to do with the ability to balance on a gym ball. This is simply the ability to maintain the body in balance, which is important but does not address the unstable spine. In fact, in many instances, the unstable spine is also flexion intolerant and with associated intolerance to compression. Sitting on an exercise ball and performing movement exercises increases spine compression to a flexed spine (52). This retards progress—it is generally a poor choice of back exercise until quite late in a therapeutic progression. True spine stability is achieved with “balanced” stiffening from the entire musculature, including the rectus abdominis and the abdominal wall; quadratus lumborum; latissimus dorsi; and the back extensors of longissimus, iliocostalis, and multifidus. Focusing on

a single muscle generally does not enhance stability but creates patterns that when quantified result in less stability (20). It is impossible to train muscles such as transverse abdominis or multifidus in isolation—people cannot activate just these muscles. Do not perform abdominal hollowing techniques because it reduces the potential energy of the column causing it to fail at lower applied loads (39). Interestingly, a recent clinical trial (22) compared the efficacy of many of the exercises quantified and published in Physical Therapy (24), with the same exercises combined with specific transverse abdominis training reduced efficacy. Instead, the abdominal brace (contracting all abdominal muscles) enhances stability. Target contraction levels for bracing and training

techniques are described (38). Finally, some provocative tests, such as a shear test, will help reveal which classification of client is best suited for a stabilization approach (17).

It is also interesting to consider the studies that have quantified training devices, which claim to enhance spine/core stability. For example, Moreside et al. (54) quantified stability when using the “Bodyblade” (Mad Dogg Athletics, Venice, CA), which is a flexible foil that is shaken at a resonant frequency. As with virtually all other tools, the technique determines the actual stability achieved. Poor body blade technique can actually reduce stability, whereas good technique, where the core is locked into an isometric contraction to control motion, enhances core stability. The role of the trainer is to be aware of this science, its implication on technique, and devote their attention to exercise form in the client.

### TOLERANCE AND CAPACITY

Suppose a trainer wants to include a lifting pattern to challenge the posterior components of the core. They are wondering if a squat with a weighted bar would be better than the bird dog exercise. The choice is assisted by determining the tolerance and capacity of the individual to ensure that a given exercise dosage is matched to the client. Each individual has a loading *tolerance* which, when exceeded, will cause pain and ultimately tissue damage. For example, a client may tolerate a “bird dog” extension posture but not a “superman” extension over a gym ball, which imposes twice the compressive load on the lumbar spine. For a more highly trained person with a higher tolerance may find “supermans” very appropriate. A person’s *capacity* is the cumulative work that he or she can perform before pain or troubles begin.

For example, someone who can only walk 20 m before pain sets in has a low capacity. This kind of person will not benefit from therapeutic exercise that is performed 3 times per week; instead,

he or she has a better chance with 3 short sessions per day. Corrected walking in 3 short sessions per day, never exceeding the current tolerance and capacity, is an alternate approach to building capacity. Typically, clients will progress to 1 session per day as their pain-free capacity grows and then be tolerant of a session with their trainers.

### INTERPRETING CLIENT PRESENTATION

Our approach to client assessment incorporates a strong biomechanical foundation and blends expertise from various disciplines. First, an impression is formed from the first meeting of the client, their sitting posture, how they rise from the chair, their initial gait pattern, and so on. Then, a history is taken looking for possible candidate injury mechanisms and perceived pain exacerbators and relievers. Observation continues during some basic motion patterns as the evaluation process proceeds delving further into the mechanics and nature of the symptoms. Then, provocative tests are performed to identify motion and motor patterns that are tolerated. Specifically, we include a range of

motions, postures, and loads. All information is used to formulate the exercise progression plan starting with corrective exercise and the starting dosage of tolerable therapeutic exercise. This process concludes with functional screens and tests that were chosen based on information obtained in the preceding process—the assessment process is well documented (29). These results are used to substantiate some speculation as to the existence of perturbed motion and motor patterns and for considering exercise choice and rates of subsequent exercise progression.

### Interpreting client presentation

Specific exercise programs for a client with back pain are derived from the following process (it is assumed that appropriate medical screening has transpired):

1. Observe everything, starting with the client rising from a chair.
2. History—link injury mechanisms, pain mechanisms with specific activities, and past exercise regimens. Of course, if “red flags” appear, make the appropriate referral.
3. Perform provocative tests—what loads, postures, and motions exacerbate, what relieve?

4. Perform movement screens and tests—Are there perturbed postural, motion, and motor patterns? Do they move well in daily activities such as getting out of a chair or up off the floor? If not, the trainer should recognize corrective squat, and lunge training is needed before any loaded resistance progressions.
5. If the clinical picture is complex and beyond your comfort zone, develop a referral relationship with a competent corrective exercise specialist. This is reciprocal and will serve you well with more clients in the future.

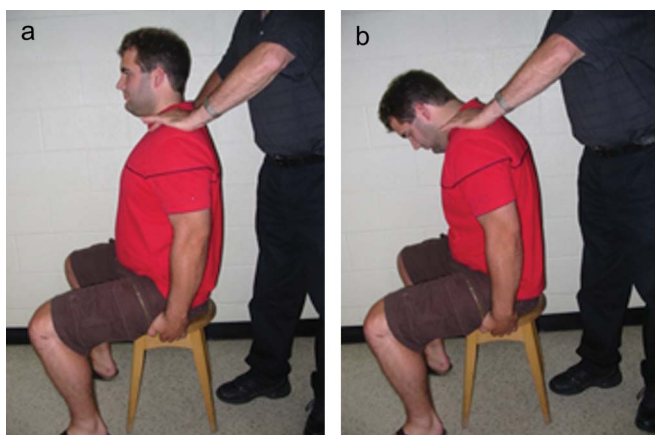
### AN EXAMPLE OF A PROVOCATIVE TEST THAT IS HELPFUL

Provocative testing is a potent tool in the assessment of back problems and is easily performed. A wide variety of provocation tests together with some corrective techniques are in a DVD (see Ref. (34)) because the expertise gained by viewing the technique cannot be obtained from written text. Figure 3 (31) illustrates an example of provocative testing for compressive load tolerance. This posture-modulated tolerance test provides powerful information and can serve as a guide to avoid damaging/exacerbating activity, and it also helps to design appropriate therapy.

More practical information can be gleaned from simply asking whether a client has better and worse days in relation to pain. Even though it seems straightforward, it cannot be stressed enough that if there are indeed better and worse days, it means that some activities help and others hurt. Find out what they are and eliminate the exacerbating elements. For example, if prolonged sitting is not tolerated, avoidance of flexion by using a lumbar support will help, together with organizing tasks to eliminate prolonged sitting. This is known as “spine hygiene” and will build more capacity for the client to work with you. Specific exercises designed to combat the cumulative stresses of sitting should then be prescribed.

### REDUCING THE RISK OF INJURY

No exercise professional can be fully successful without removing the



**Figure 3.** An example of provocative testing. The patient compresses the spine by grabbing the side edges of the seat and pulling up. When doing this with an upright back (a), the torso is stiffened with muscle activity. The test is then repeated in a slouched posture (b); discomfort in this position as compared with an upright back shows a lower tolerance when the spine is flexed (and a flexion intolerant patient). This reveals where the spine tolerance is highest, and therefore, a posture to begin therapeutic exercise (i.e., no spine flexion).



**Figure 4.** (a) Curl-up over a gym ball motions stresses the discs, mimics a potent disc injury mechanism, and unwisely uses pain-free training capacity. (b) The “stir the pot” exercise spares the painful discs of motion and builds abdominal athleticism.

movement flaws that are the cause of back troubles in clients throughout the day. Recommendations such as “when lifting, bend the knees and keep the back straight” rarely address the real issue, despite their popularity. Few patients are able to use this strategy in their jobs; furthermore, this is often not the best strategy. For example, the “golfers lift” is much more joint conserving for repeated lifting of light loads from the floor. Here, one leg is raised behind, the torso tilts forward about a flexed hip of the stance leg forming a fulcrum. No spine or knee bending occurs. Another example illustrates the poor choice of movement strategies for a particular task. For example, observe the client who transitions to laying on the floor by using a deep squat—this overloads their back. Squatting may be appropriate for getting off a toilet or chair but not necessarily for dropping to the floor. Instead a lunge that does not bend the spinal discs may be a much more appropriate choice. Again, this builds capacity for them to accomplish more in their training session with you (see Ref. (30) for full explanation and evidence for spine sparing guidelines). Although it is not the expertise of this author, “core stability” training has been shown to be effective for both preventing and rehabilitating shoulders (21) and knees (16,55).

### LINKING ANATOMY WITH FUNCTION

Consider the usual and popular approach to train the abdominal wall muscles by performing sit-ups or curl-ups over a gym ball for example. But consider the rectus abdominis where the contractile components are interrupted with transverse tendons giving the “6 pack” look. The muscle is not designed for optimal length change but rather to function as a spring. Why have these transverse tendons in rectus abdominis? The reason is that when the abdominals contract, “hoop stresses” are formed by the oblique muscles that would split the rectus apart (26). In addition to the spring-like architecture of the muscle, consider how it is used. People rarely flex the rib cage to the pelvis shortening the rectus in sport or everyday activity. Rather they stiffen the wall and load the hips or shoulders—if this is performed rapidly such as in a throw or movement direction change, the rectus functions as an elastic storage and recovery device. When lifting weights, it stiffens to efficiently transmit the power generated at the hips through the torso. Those individuals who do actively flex the torso (think of cricket bowlers and gymnasts) are the ones who suffer with high rates of spine joint damage and pain. Now, revisit the

common training approach of curling the torso over a gym ball that replicates the injury mechanics while not creating the athleticism that enhances performance. This is a rather poor choice of exercise for most situations. Yet many clients will expect that a gym ball be used. Disguise your intentions with these clients and retain the gym ball, but change the exercise from a spine compromising curl-up to a plank where the elbows are placed on the ball. Now, perform a “stir the pot” motion to enhance the torso/abdominal spring and spare the spine—this is often a much superior exercise for most people (see Figure 4) (41).

### DESIGNING STAGED CORE EXERCISE—BIOMECHANICS AND CLINICAL PRACTICE

Exercise progression is a staged process. Several sources are available (30,40) that expand on the many considerations and techniques to hone clinical skills at each stage some of which are listed below:

Stages of progressive exercise design:

1. Corrective and therapeutic exercise
2. Groove appropriate and perfect motion and motor patterns
3. Build whole-body and joint stability (mobility at some joints such as the hips and stability through the lumbar/core region)



#### 4. Increase endurance

For occupational/athletic clients:

#### 5. Build strength

#### 6. Develop speed, power, and agility

The first stage of designing the appropriate corrective exercise emanates from the identification of any perturbed motion and motor patterns. Every exercise is considered within the working diagnostic hypothesis such that the first time the exercise is performed, it is considered a provocation test. If it is tolerated, the client proceeds. If it is not tolerated, the technique is reexamined and adjusted and/or a more tolerable variation is tried—see Ref. (51) for some examples where technique adjustments with stabilization exercise make them tolerate much more challenge but without pain. Examples of corrective exercise are introduced here, although many are provided in Ref. (33).

For example, gluteal muscle activation retraining based primarily on the original work of Janda has been honed in our laboratory (Figure 5). This cannot be accomplished with traditional squat training (37). Chronic back pain tends to inhibit the gluteal muscles as hip extensors, and as a result, clients create hip extension using the hamstrings as a substituting pattern. Subsequent back extension overactivating the spine extensors creates unnecessary crushing loads. Gluteal

muscle reintegration helps to unload the back. Another critical concept for this stage of exercise design is that technique “details” are important. It is not a matter of client performing an exercise, but it is a matter of the client performing the exercise with perfection. Exercise form, subtle maneuvers to eliminate pain, pacing, duration, and other coconsiderations are all extremely important (51). The next stage in the progressive algorithm is to encode movement and motor patterns to ensure stability. Stability is considered at 2 levels—both joint stability (in this case spine/core stability) and whole-body stability. Quantification of stability proves that these 2 objectives are fundamentally different and need 2 different exercise approaches.

Our observation is that the 2 types of stability are often confused in the clinic/gym. Variations of our “Big 3” stabilization exercises (modified curl-up, side bridge, and quadruped bird-dog) have been quantified and selected for their ability to ensure sufficient spine stability and optimal motor patterns; they spare the spine of many injury mechanisms and pain exacerbators and are designed to build muscle endurance (see Figures 6–9) (49). Then, specific muscle group endurance is enhanced. Spine stability requires that the musculature be cocontracted for substantial durations but at

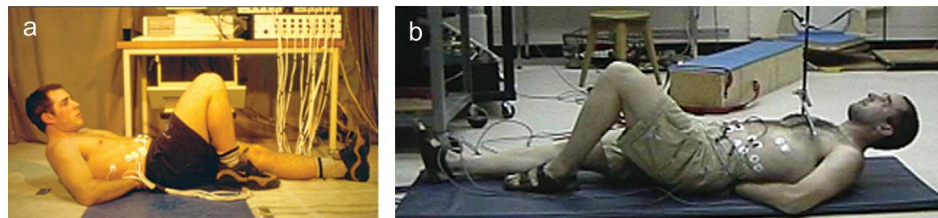
relatively low levels of contraction. This is an endurance and motor control challenge—not a strength challenge. For many clients wanting to accomplish tasks of daily living pain free, this is sufficient. In the preceding progressions, of course, strength is enhanced as are specific patterns, such as the ability to squat, push/pull, lunge, and so on. But strength is not specifically trained because this requires overload and elevated risk—this is reserved for performance training. Many people, whether they have athletic objectives (such as wanting to play golf) or have demanding occupations will fall into this category.

On the other hand, many clients confuse health objectives (minimizing pain, developing joint sparing strategies) with performance objectives (which require risk) and compromise their progress with specific strength training too early in the progression. Many exercises typically prescribed to patients with low back pain are done so without the trainer having knowledge of the spine load and associated muscle activation levels. For this reason, we have quantified exercises in this way (see Ref. (2,9,19,20)) to allow evidence-based decisions when planning optimal exercise progressions. Consider developing progressions with some exercises shown in Figures 10 and 11 (14,43).



**Figure 5.** Chronic back pain tends to cause people to use their hamstring muscles, instead of their gluteals to extend the hip. This changes patterns that increase spine load when squatting. Performing the back bridge, squeezing the gluteal muscles, and eliminating hamstrings helps to establish gluteal dominance during hip extension. Clinical cues are presented in McGill (37)—one is shown here as the trainer palpates the hamstrings, and if they are active, the client is cued to push the feet with knee extension and externally rotate the hips to ensure gluteal dominance.

## Core Training for Better Performance



**Figure 6.** The “Big 3” stabilization exercises selected to create muscle patterns that ensure stability in a spine sparing way include the curl-up (poor form with too much spine flexion resulting in disc stress is shown in (a)) (better form shown in (b)). Although we have quantified many variations and progressions, there are several cues for correct form. For example, during the curl-up, try and remove any motion from the lumbar spine and the cervical spine. Progression included prebracing of the abdominal wall, elevating the elbows off the floor, and breathing, to name a few.

### CAVEATS FOR THERAPEUTIC/ CORRECTIVE EXERCISE

1. Keep the duration of isometric exercises under 10 seconds and build endurance with repetitions (reps), not by increasing the duration of the holds. Near infrared spectroscopy of the muscles showed that this was the way to build endurance without the muscles cramping from oxygen starvation and acid buildup (48).
2. Use the Russian descending pyramid to design sets and reps to make

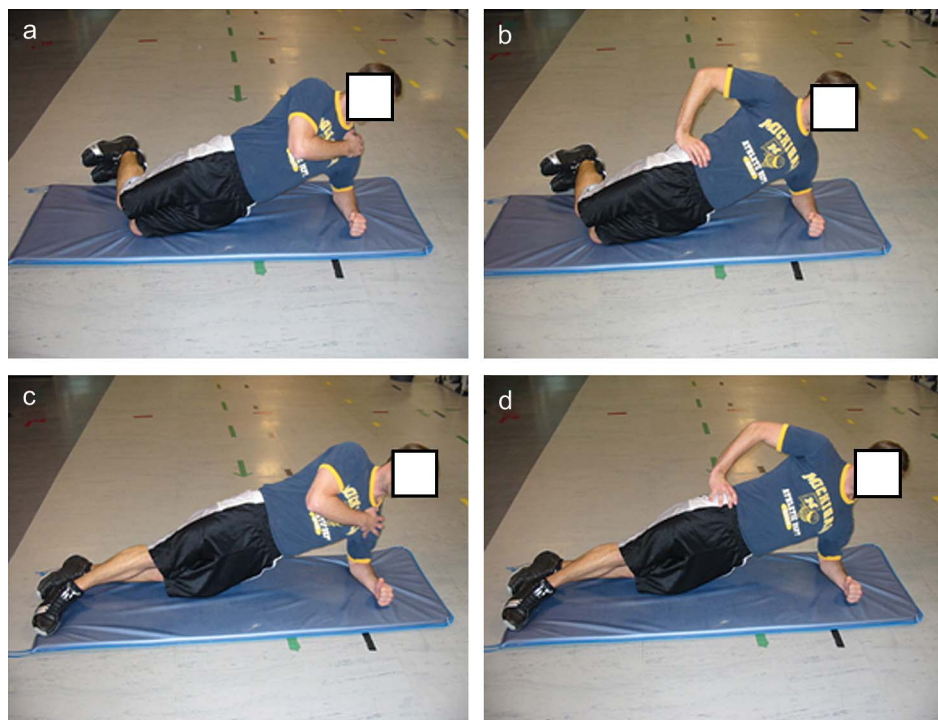
bigger initial gains in progress toward a pain-free back (see Ref. (42)).

3. Maintain impeccable form to enhance available strength and maintain the spine in its strongest (most tolerable) posture.

### CORE EXERCISE AS AN INJURY PREVENTION PROGRAM

The exercises that form the “Big 3” noted in the previous section have been used by many occupational and sporting groups as part of an injury prevention program.

For example Durall et al. (12) documented how training the flexors, lateral musculature, and extensors of the core with the Big 3 in the preseason for 10 weeks prevented any new back pain incidents and controlled the pain in those with a history of pain in a population of competitive collegiate gymnasts. Gymnasts form a high-risk group for back pain/disorders. Interestingly, similar exercises have been shown to prevent knee injuries in female intercollegiate basketball players (16).



**Figure 7.** The beginner's side bridge (a) is held for sets of 10-second contractions before more challenging progressions are attempted (b–d). Challenge is added by bridging from the feet and adding more mass to the bridge with arm placement.





**Figure 8.** The superman is a common extensor exercise but imposes double the compressive load on a spine, which is hyperextended compared with the much more tolerable birddog exercise. The capacity to train the superman exercise is greatly compromised because pain is usually developed before high levels of training can be achieved. Thus, it is rarely a good choice of exercise.

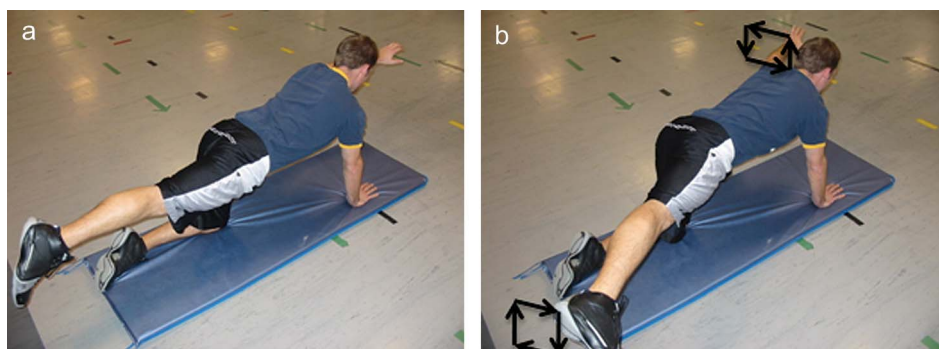
### TRAINING FOR PERFORMANCE

Training the back for performance (for either athletic or occupational application) requires different approaches and objectives than training to fulfill rehabilitation objectives. Some of the techniques developed in our work with world-class athletes are beyond the scope of this article and have been detailed extensively elsewhere (35). These include the progressions from establishing motor control patterns once the appropriate corrective exercise was performed, through stability, endurance, strength, speed, power, and agility. A note is needed here: power

(force  $\times$  velocity) development in the spine is usually very risky. Instead, power is developed about the shoulders and hips to both increase performance and to minimize risk to the spine and related tissues. Specifically, if the force in the spine/core is high (e.g., deadlifting), then the spine velocity (i.e., bending to create muscle length change) must be low. If the spine velocity is high (e.g., golf), then the muscle force must be low (particularly when the spine is deviated). This is why the great golfers “pulse” when the spine is traveling through the neutral range just before ball contact.

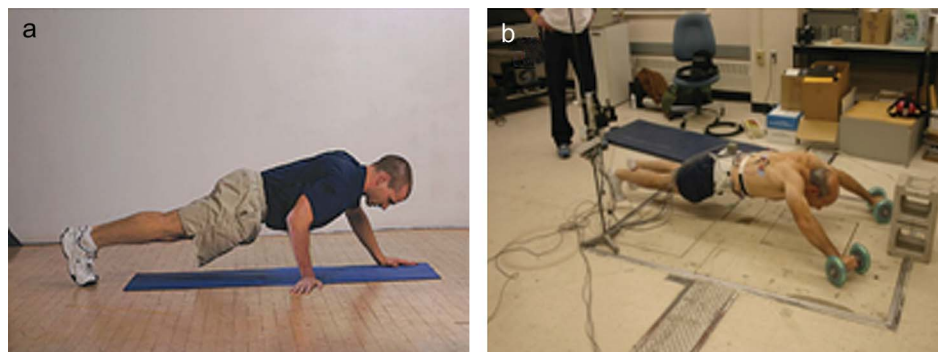
An interesting example is provided with speed training. Many train speed by using resistance exercise for strength gain. But speed technique, when measured, also usually requires superior rates of relaxation. This apparent paradox can be exemplified this way. Consider the golf swing. The initiation of the downswing involves some muscle contraction but too much actually slows the swing. Speed comes from compliance and relaxation. At the instant just before ball contact, the farthest ball hitters in the world then undergo a full-body contraction that creates superstiffness throughout the entire linkage (45). Then, just as quickly the stiffening contraction is released to allow compliance, speed in the swing follow through. This same cyclic interplay between relaxation for speed and contraction for stiffness is measured in the best sprinters in the world, the best strikers and kickers in mixed martial arts, the best lifters, and so on. Thus, the rate of muscle contraction is only important when the muscle can be released just as quickly—only a few in the world are able to do this.

These examples show why traditional strength training is usually a detriment to performance. Techniques of “superstiffness” used by strength athletes are important to understand when being mindful of the lower functioning client who may be able to grasp some of these concepts and, for the first time,



**Figure 9.** During the bird dog exercise, making a fist and cocontracting the arm and shoulder is a progression that enhances the contraction levels in the upper erector spinae (a). This is a better exercise than the superman because the spine loads are lower; the muscle contraction level can be similar using the “squares” technique (b), and the spine is neutral, not hyperextended that lowers the load tolerance.

## Core Training for Better Performance



**Figure 10.** There are many progressions of exercises to stiffen and balance the anterior chain in a spine sparing way such as a staggered hand push-up (a) and the rollout (b).

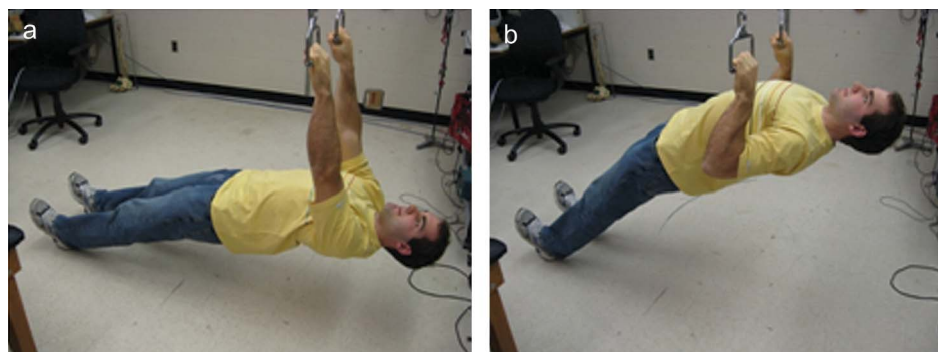
perhaps be able to rise from the toilet unassisted. In my consulting, I am often asked “How do you design a training program for a gymnast or wrestler” who must produce high force with a deviated spine posture? There are several potential strategies, and the choice depends on the body type, injury history, current fitness level, and fitness goals of the athlete (to name a few). Sometimes, it is necessary to avoid the injury mechanism (deviated spine posture) in training and save the “bending” for the competition. In this way, rigorous training can reach higher levels without injury. An example of this approach can be found with cricket bowlers in Australia who have reduced injury rates and maintained performance by limiting the number of bowling reps but still train other activities. These newest concepts are compiled (40).

Eight essential components of superstiffness

1. Use rapid contraction, then relaxation of muscle. Speed results from relaxation for speed but also stiffness in some body regions (e.g., core) to buttress the limb joints to initiate motion or enhance impact (of a golf club, hockey stick, fist, and the like) (50).
2. Tune the muscles. Storage and recovery of elastic energy in the muscles require optimal stiffness, which is tuned by the activation level. In the core, this is about 25% of maximum voluntary contraction for many activities (4,8,5).
3. Enhance muscular binding and weaving. When several muscles contract together, they form a composite structure where the total stiffness is higher than the sum of the individual contributing muscles (6). This is particularly important in

the abdominal wall formed by the internal and external obliques and transverse abdominis, highlighting the need to contract them together in a bracing pattern (15).

4. Direct neuronal overflow. Strength is enhanced at one joint by contractions at other joints—martial artists call this “eliminating the soft spots.” Professional strongmen use this to buttress weaker joints using core strength (53).
5. Eliminate energy leaks. Leaks are caused when weaker joints are forced into eccentric contraction by stronger joints. For example, when jumping or changing running direction, the spine bending when the hip musculature rapidly contracts forms a loss of propulsion. The analogy “you can push a stone but you cannot push a rope” exemplifies this principle.



**Figure 11.** Posterior chain progressions usually begin with pull-ups with the body stiffened.



**Figure 12.** The asymmetric kettlebell carry uniquely challenges the lateral musculature (quadratus lumborum and oblique abdominal wall) in a way never possible with a squat. Yet this creates necessary ability for any person who runs and cuts, carries a load, and so on. The suitcase carry is another variation suitable for many advanced clients.

6. Get through the sticking points. The technique of “spreading the bar” during the sticking point in the bench press is an example of stiffening weaker joints.
7. Optimize the passive tissue connective system. Stop inappropriate

passive stretching. Turn your athletes into Kangaroos. For example, reconsider if a runner should be stretched outside of their running range of motion. Many of the great runners use elasticity to spare their muscles or to potentiate them to

pulse with each stride. However, do consider stretching to correct left/right asymmetries shown to be predictive of future injury.

8. Create shock waves. Make the impossible lifts possible by initiating a shock wave with the hips that is transmitted through a stiff core to enhance lifts, throws, strikes, and the like.



**Figure 13.** The lateral cable hold begins first with the hands close to the core and then placed further increases the twisting torque challenge (note no twist is allowed). Different levels and distance of the handles to the body modifies the challenge.

## ORGANIZING THE LATE-STAGE PROGRAM

Finally, consider exercises such as the squat. Interestingly, when we measure world-class strongmen carrying weight or National Football League players running planting the foot and cutting—neither of these are exclusively trained by the squat (see Ref. (44)). This is because these exercises do not train the quadratus lumborum and abdominal obliques, which are so necessary for these tasks (53).

In contrast, spending less time under a bar squatting and redirecting some of this activity with asymmetric carries such as the farmers’ walk (or bottoms-up kettlebell carry—see Figure 12) (53) builds the athleticism needed for





**Figure 14.** Composite exercises such as whirling a slamball overhead challenges strength and endurance of the core about all 3 axes. When we add pulses at 12 o'clock, 6 o'clock, and so on, it becomes a favorite for training Ultimate Fighting Championship fighters who need tremendous core control endurance and strength but then must develop very rapid pulses for strikes and kicks.

higher performance in these activities in a much more “spine friendly” way. The core is never a power generator as measuring the great athletes always shows that the power is generated in the hips and transmitted through the stiffened core. They use the torso muscles as antimotion controllers, rarely motion generators (of course, there are exceptions for throwers and the like, but the ones who create force pulses with larger deviations in spine posture are the ones who injure first). Thus, the core musculature must be very strong and capable of control to optimize training of other body regions and to facilitate best performance. But power training should be reserved for the hips, not the core.

Once your client has excellent movement patterns and the appropriate blend of stiffening and mobility, they may progress from corrective to performance enhancing exercise. Here, you may consider organizing training to include a push, pull, lift, carry, and a torsional buttressing task. The exact exercises are tuned to the client. For example, a push may be a push-up (14,49,51) or a one-armed cable push with a controlled and stiffened core. A pull may be a pull-up or a sled drag (13). A carry may be a one-armed suitcase carry, which uniquely trains the quadratus lumborum and lateral musculature, or a one-handed

bottoms-up kettlebell carry to enhance core stiffening and the skill of steerage of strength through the linkage. A lift may be a bar lift, kettlebell swing, or snatch. A torsional task is not a twist but a torsional challenge with no spine twisting, such as a lateral cable hold where the arms are moved to different positions anteriorly (see Figure 13) (44). Finally, composite exercises may be introduced for special situations that require core strength, endurance, and control but then assist the development of rapid force (see Figure 14) (46).

I am concerned that this short article shortchanges the reader as it simply cannot convey the components necessary to be an elite trainer but, at least, it may elevate awareness of some of the issues. I wish you a similarly enjoyable journey as I have enjoyed in conducting scientific studies and application of the principles to reduce pain and enhance performance.



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The poster features a background image of the Walt Disney World Swan and Dolphin Resort at night, with a large swan sculpture on a building. The NSCA logo is in the top left. A blue circular badge in the center reads "CEUs NSCA 2.0 NATA 20". Three circular inset images show athletes: a person on a rowing machine, a person lifting a barbell, and a portrait of Steve Mesler. The main text at the bottom reads "33<sup>rd</sup> National Conference & Exhibition" followed by the dates and location. The contact information "800-815-6826 • www.nsca-lift.org/NatCon2010" is at the bottom left. The keynote speaker information "Keynote: Steve Mesler 2010 Olympic Gold Medalist Four-Man Bobsled" is at the bottom right.

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