Strategies for Optimal Core Training Program Design

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A well-balanced core program should form an integral part of an athlete's training regimen. Core training is an evolving science, and the art of core program design encompasses many facets. In this article we will hash out some fundamental topics currently surrounding core training and provide recommendations for designing a comprehensive athletic core training program. The focus will be on core training for healthy, athletic populations; core training for rehabilitative purposes is beyond the scope of this article.

What Comprises the Core?

Richardson et al. states that the core is a box with the abdominals in the front, the paraspinals and gluteals in the back, the diaphragm as the roof, and the pelvic floor and hip girdle musculature as the bottom (14). Willson et al. defines the core as the lumbopelvic hip complex, consisting of the lumbar spine, pelvis, and hip joints and the active and passive tissues that produce or restrict motion of these segments (19). Fig describes the core as all the anatomy between the sternum and the knees with a focus on the abdominal region, low back, and hips (7). Tse et al. states that the core musculature includes muscles of the trunk and pelvis that are responsible for maintaining the stability of the spine and pelvis and are critical for the transfer of energy from larger torso to smaller extremities during many sports activities (16). Behm et al. provides the most expansive definition, describing the core as the axial skeleton and all soft tissues with a proximal attachment originating on the axial skeleton, regardless of whether the soft tissue terminates on the axial or appendicular skeleton (upper and lower extremities) (2).

It is important to understand that the core musculature receives substantial work during the course of an athletic workout. Structural exercises such as squats, deadlifts, and rows heavily involve the muscles of the core. For this reason, we propose that targeted core exercises should supplement a good strength training session for structural balance.

What Types of Core Training Exist?

The core can be trained for multiple purposes including activating muscles and correcting dysfunction, increasing different types of stability, and/or developing muscular strength, power, and endurance. The following sections cover these topics.

Activation and corrective exercise

Strength coaches often include low-load activation work into programs during warm-ups or in between sets of compound exercise for the purpose of corrective exercise or "prehab" (i.e., future injury prevention). While corrective exercise is intended to restore fundamental movement patterns by increasing joint mobility, joint stability, or motor control, the premise behind prehab methodology is to enable muscles that typically become dormant to keep firing. Furthermore, even though corrective exercise is proactive while prehab is preventative, the exercises and drills used for both methodologies are similar. Placing these movements at the beginning of a training session into a dynamic warm-up confers several benefits including warming the muscles, controlling the joints through full ranges of motion, priming the nervous system, and correcting or preventing future dysfunction. Alternatively, these drills can be employed during rest periods to increase training session density and make productive use of downtime. Bird dogs and x-band walks are two examples of "prehab" exercises that can be utilized to activate vital core muscles in efforts to keep them contributing properly to functional movement and prevent overcompensation from synergistic musculature.

More recently, activation work performed prior to explosive movement has been shown to increase strength and power. Specifically, seven glute activation exercises including glute bridges and side-lying clams were shown to increase peak power in the countermovement jump by 8% (3). Moreover, a case study by Wagner et al. found that

activation drills significantly increased hip extension strength while diminishing extraneous hamstring activation during terminal swing and the first half of stance phase in a triathlete suffering from recurrent hamstring cramping (18). Activation work should be performed with low loads at lower neuromuscular thresholds with the focus on correct form.

Stability

Core stability training can refer to exercise intended to improve segmental, spinal, or whole-body stability (11). Since the core has been said to provide "proximal stability for distal mobility," a weak and unstable core can be associated with issues further down the kinetic chain (6). Core stability training includes both functional balance training as well as traditional core stability exercise.

Functional balance and sensorimotor training are sometimes included in an athletic training program to improve proprioception and coordination. Several studies have found that sensorimotor training can have a favorable impact on power production (9). Unstable surface training is often included in this category, which involves the use of devices such as BOSU balls, inflatable discs, and wobbles boards. It should be noted, however, that balance training does not require specialized equipment as any single-leg movement that involves dynamic extremity motion, such as the single-leg Romanian deadlift, pistol squat, or high step-up with knee lift, will effectively challenge the sensorimotor system provided that loading is matched according to the athlete's abilities. For this reason, strength coaches should incorporate a mixture of bilateral and unilateral movements in their programs.

Though dynamic contractions can be used to increase segmental stability of the spine, typical core stability exercises require isometric contractions in the core to prevent the lumbar spine and pelvis from buckling and enable efficient transfer of energy throughout the entire body. There are two common types of core stability exercise; whole-body isometrics and core isometrics with dynamic limb movement. An example of a whole-body isometric exercise is a plank, where the entire body is maintained in a fixed position. An example of a core isometric with dynamic limb movement exercise is a 3-point plank, where the core remains stable while one limb moves through a range of motion. Many sports require high force and high-velocity isometric core contractions, which likely warrants combined training methods.

Strength

Core strengthening movements can include dynamic or isometric exercises. The previous section described core stability exercises, which encompassed isometric strength. The focus in the next section will be on dynamic exercise, which includes concentric and eccentric contractions. Many sport actions require core actions that are relatively slow but with higher levels of force. For example, the deadlift has been shown to involve dynamic spinal flexion with elite powerlifters, and many situations in mixed martial arts require sustained lumbar flexion, especially in the clinch or on the ground (10). Dynamic core exercises are likely superior to isometric exercises for the purpose of muscular hypertrophy (5).

Power

The core must also be able to produce powerful dynamic contractions in many sport actions. This often involves a rapid stiffening effect to transfer kinetic energy between the lower and upper bodies. For example, most throwing, swinging, and striking motions involve varying levels of hip and spinal rotation, and even sprinting requires high levels of core contractions to produce, reduce, and transfer force. A variety of training methods and contraction velocities involving core stability exercise, ballistics and plyometrics, explosive strength exercises, and heavy resistance training can help to maximize core power.

Endurance

Core endurance is an integral component to many different sports and sport actions such as rowing, boxing, and rugby. Higher repetition sets are likely valuable to enhance core muscular endurance for these purposes. Core muscle endurance is purported to be more important for the prevention of low back pain and injury than core strength (12).

Program Considerations

A strength coach needs to take into consideration many different factors when designing a proper core training regimen. The following sections will cover many of these considerations and help strength coaches address the necessary factors when designing a training program.

Joint actions

Since generally accepted definitions of the core loosely revolve around the muscles attaching at the spine, pelvis, and hips, it therefore follows that all of the joint actions and types of contractions involved in these joints must be considered when designing a core training program. The lumbar spine can flex, extend, laterally flex, and rotate. The pelvis can tilt posteriorly, anteriorly, laterally, in addition to being able to rotate. Finally, the hips can flex, extend, adduct, abduct, and produce internal and external rotation. It is important to note that each of these joint actions can occur dynamically (concentric and eccentric actions) or statically (isometric action).

In general, the spine, pelvis, and hip joints work as a unit to produce synchronized, coordinated movement. Spino-pelvic stiffening is modulated to prevent or allow for varying amounts of movement depending on the task. During sprinting, for example, the lumbar spine extends and the pelvis anteriorly rotates to allow the hip extensors to produce greater torque (15,20). A weak core will not be able to control accessory movement, which will result in energy leaks, thereby impairing the ability of the hips to produce maximum ground reaction force. Moreover, a lack of hip mobility can alter the normal functioning of the lumbopelvic region. For example, if hip flexion mobility is limited during a hurdle step, the lumbar spine will overcompensate by inadvertently flexing to allow the desired range of motion to be reached. Finally, postural issues

related to force couples across the lumbopelvic region can affect flexibility. For example, an individual who exhibits excessive posterior pelvic tilt will likely struggle to keep an arch at the bottom ranges of a squat or to maintain athletic positions in sports. Given these factors, it is apparent that the lumbopelvic-hip complex requires optimal strength, flexibility, and coordination to produce maximum power and movement efficiency.

Force vector specificity

All of the aforementioned types of core training, including core activation, core stability, core strength, core power, and core endurance, are specific to the vector of force. For example, squats and deadlifts primarily tax the strength of the erector spinae and therefore act predominantly on spinal extension and anterior pelvic tilt, or more accurately the prevention of spinal flexion and posterior pelvic tilt. Though this quality is a vital component of strength training, it would be of limited utility to a fighter who is on his back with an opponent straddling him or to a soccer player trying to throw a ball in bounds. We believe multiple vectors must be trained through varying methods in order to maximize or increase overall athleticism.

Safety

Based on available evidence, dynamic spinal exercises appear to be safe as long as three different criteria are met (5). First, athletes must progress gradually along a continuum to allow for positive structural adaptations to take place within the discs. Progressing too quickly will likely have deleterious effects on the discs, whereas proper progression will likely confer a positive effect on disc health. Second, excessive end-range spinal motion must be avoided in every direction. It is important to remember that some sports require end-range flexion. Some motion in the spine appears to be beneficial to spinal health, but too much motion may be detrimental. Proper form during dynamic spinal exercises must be taught and strictly enforced, with a blend of motion occurring across the spinal motion segments and no individual segment approaching the end of its range of motion. For example, a crunch should involve approximately 30° of trunk flexion with the majority of movement occurring in the thoracic spine while cable woodchops should have most of the motion occurring at the hips and thoracic spine with minor amounts of motion in the lumbar spine. Finally, volume must be kept in check with dynamic spinal movements. For the purpose of core strength, we recommend 2–4 sets of 8–15 reps for most dynamic core exercises.

Sport actions

A good strength coach will always rely heavily on tried and true core strengthening exercises. For example, squats, deadlifts, bent-over rows, and loaded carries, such as farmer's walks, will strengthen the core. Provided the lumbopelvic region is kept stable, pull-ups and push-ups will strengthen the anterior core musculature. Targeted core exercises such as side planks, ab wheel rollouts, and hanging leg raises can be employed to ensure a comprehensive core workout.

With that said, the principle of specificity should always be a primary consideration when designing an individualized core routine. Many sports require unique core movements and therefore exercises can and should be adopted to specifically address these movements. For example, a throwing motion might involve varying amounts of spinal lateral flexion, flexion, and rotation. A long bar or rope handle attached to a high cable can be used to mimic this core contraction which could strengthen the core in the desired range of motion and therefore add to power production via increased neural drive and muscle physiological cross-sectional area, especially when performed in concert with the specific sport skill.

Exercise order

The ideal placement for core exercises within a workout is often debated by strength coaches. As previously noted, core training is occurring throughout the entire session. We believe that activation work should be performed in the dynamic warm-up and possibly interspersed between rest periods between sets of heavy exercise if workout time is limited. Power and speed work for the core consisting of various sprints, agility drills, towing, plyometrics, ballistics, and explosive strength movements should follow the dynamic warm-up. Next, total body strength training should be performed with a focus on multi-joint movements. Finally, targeted core exercises should be performed at the end of the workout to avoid prematurely fatiguing the core.

Rotary training

Standing rotary exercises are usually performed with loads held at arm's length which create exceptionally long levers and high torques at the spine which are countered through ground reaction forces at the feet. For this reason, all of the joints between the arms and the feet are called into play, making rotary training a highly effective form of "total body training." Despite the fact that modest levels of resistance are often used during rotary training, the long levers and multiple muscles involved in producing or preventing rotation produce large compressive loads on the spine and require high thresholds of neuromuscular and metabolic activity. We believe that rotary training is a vital component to total athleticism and that rotary training helps bridge the gap between general weight room strength and rotational power on the field or court.

Recent research has shown that standing rotary training can improve landing mechanics in the absence of jumping exercise (13). Elite golfers show greater angular velocities of trunk rotation than less-skilled golfers (21). Furthermore, research found that rotary motion was indeed healthy for the lumbar discs as long as end ranges were avoided (4). Standing rotary exercises can be performed with bands and cables to simulate various chopping and lifting motions in different positions including kneeling, half-kneeling, split stance, and parallel stances.

Hollowing, bracing, or neither

Many fitness professionals have made broad recommendations as to how the core should function during exercise. Hollowing and bracing are two of the most popular recommendations. It is important to know several things regarding this topic. First, although abdominal hollowing has been advocated following low back injury, it should never be used during heavy strength training (1). Abdominal hollowing decreases spinal stability, thereby impairing one's ability to generate force and potentially leading to injury (17). Bracing has been shown to offer much more stability than hollowing and should be the preferred strategy during heavy strength training (8).

Progressions and regressions

A good strength coach understands how to adjust the difficulty of a core exercise depending on the level of fitness of the athlete. Lever lengths, ranges of motion, and amounts of resistance can be modulated to place athletes at their precise levels of fitness and provide the optimal challenge to their core. Beginners should master the basics before attempting more challenging core exercises. For example, the front plank must be mastered before a more challenging exercise such as the ab wheel rollout is ever attempted.

Core Exercise Categorization

Table 1 is intended to serve as a guideline to assist in creating customized core routines. Exercises labeled as "anti" are intended to resist force and therefore are performed for core-stability purposes, whereas the other exercises are intended to produce or reduce force and thus are performed for dynamic purposes.

Several things should be noted when reading Table 1. First, the core musculature is worked during the performance of traditional strength training exercises. Second, core training requires many different types of actions and movement patterns, and it is simply not realistic to target each of these aspects in a single session. Hence, strength and conditioning coaches should strive to cover a broad range of these categories in a given training week to ensure the athlete receives complete core conditioning. ■

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Table 1: Core Exercise Movement Patterns and Example Exercises

Type of Core Movement	Exercise Examples
Anti-spinal extension/Anti-anterior pelvic tilt	Push-ups, front planks, ab wheel rollouts
Anti-spinal flexion/Anti-posterior pelvic tilt	Squats, deadlifts, good mornings
Anti-spinal lateral flexion/Anti-lateral pelvic tilt	Side planks, suitcase holds, farmer's walks
Anti-spinal rotation/Anti-pelvic rotation	Cable anti-rotation presses, landmines, single-arm dumbbell bench presses
Spinal extension/Anterior pelvic tilt	Supermans, 45° spinal extensions
Spinal flexion/Posterior pelvic tilt	Reverse crunches, hanging leg raises
Spinal lateral flexion/Pelvic lateral tilt	Side bends, 45° side bends
Spinal rotation/Pelvic rotation	Cable chops, Russian twists
Anti-hip extension	Band hip flexor holds, Bulgarian split squat (rear leg), static lunge (rear leg)
Anti-hip flexion	Standing cable chest presses, half-kneeling anti-rotation presses
Anti-hip abduction/adduction	Side planks, top leg elevated side planks
Anti-hip external/internal rotation	Cable anti-rotation presses, landmines
Hip extension	Squats, deadlifts, lunges, 45° hip extensions
Hip flexion	Cable standing hip flexion, band lying hip flexion, ankle weight standing hip flexion
Hip abduction/adduction	Cable standing abduction, cable standing adduction, x-band walks
Hip external/internal rotation	Side-lying clams, band standing hip rotation, cable woodchops