Review

THE EFFECTIVENESS OF CORE STRENGTHENING EXERCISES IN THE REHABILITATION AND PREVENTION OF SPORTS INJURIES IN FOOTBALL PLAYERS

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ABSTRACT

This article highlights the global importance of core training in sports physiotherapy, focusing on improving performance and minimizing injuries. The core, encompassing regions from the scapula to the gluteals, plays a crucial role in athletic performance and injury prevention. The concept of the core has been at the center of attention in many media and scientific journals from the end of the last decade to the present. Since the core is the area that connects the upper and lower limbs, control of core strength, balance, and movement can optimize the entire kinetic chain, which includes isolated athletic gestures of both the upper and lower limbs. Several studies have shown that excellent core stability is associated with better physical performance across all sports. A strong and stable core enhances mobility, speed, and the performance of the lower limbs in athletes. The aim of this article is to highlight the literature examining whether postural variations and core stability are functionally related to performance in sports that require body balance and proper posture, identify gaps and deficiencies in the literature, and suggest further reviews in this area. The literature for this article is based on scientific sources such as MEDLINE, Scopus, Web of Science, PubMed, and the Cochrane Library. It is supplemented by Google Scholar, Springer Link, and Elsevier. A total of 27 publications were reviewed. This article underscores the importance of a comprehensive approach to core training in sports physiotherapy for improving athletic performance and reducing injuries. The results and recommendations presented contribute to advancing knowledge in sports physiotherapy and provide a valuable resource for professionals working with athletes at all levels.

KEYWORDS: *core training, physiotherapy, prevention, rehabilitation, stability, posture*

INTRODUCTION

Football is one of the most popular sports in the world. It is considered a sport with a very high-intensity level and a significant risk of injuries among players. Physical fitness is one of the most crucial elements influencing football performance due to the high physical demands during play.

As a high-impact sport with injuries occurring in both contact and non-contact situations, football has the highest risk of injury. It has been demonstrated that the risk of injury for professional players is 1,000 times higher compared to other individuals (1).

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The frequency of direction changes, frequent accelerations, and sudden decelerations during the game increase the possibility of muscular injuries for football players. Power and speed play a crucial role in the most decisive moments of the sport, which is why sprints and direction changes are more common during goal-scoring situations.

It has been shown that during a high-level football match, a player performs a sprint every 90 seconds, each lasting an average of 2-4 seconds (2). Some studies have found that sprints in matches are short and explosive. Although evidence is limited, integrating basic stabilization exercises into injury prevention programs, especially for the lower extremities, has demonstrated a reduction in the injury rate (3-6).

Men are at higher risk for muscular and joint injuries, so the importance of core strength and muscle strengthening for injury prevention has increased in recent years. Today, core strengthening is crucial in many preventive programs, such as "FIFA 11+."

Even though there is extensive knowledge about the biomechanics of the trunk region, defining the advantages and disadvantages of many analytically researched exercises, the focus has shifted toward a more global view of the human body. In this view, specific movement training tends to replace mere muscle conditioning, aiming for balance in a system where individual components interact harmoniously to achieve a desired function.

Thus, there has been a gradual and parallel shift from the concept of "abdominal muscles" to that of the "core region." The core concept, particularly "Core stability," has been at the center of attention in many media and scientific journals from the end of the last decade to the present. The muscles of this region are responsible for maintaining the stability of the spine and pelvis and assist in generating and transferring force from the trunk to the limbs and vice versa during daily and sports activities. The ability to maintain functional stability and good neuromuscular control of the lumbopelvic region plays a crucial role in preventing and recovering from musculoskeletal pathologies, postural control, and enhancing sports performance.

Some authors have proposed a more functional perspective, describing the core as kinetic chains that facilitate the transfer of force and energy between the lower and upper extremities (7, 8).

Core muscle strengthening protocols are widely practiced today by people of all ages and athletes at various levels. These protocols are composed of different types of exercises. The literature contains many studies demonstrating the effectiveness of "Core training" compared to traditional exercises, but it is not yet fully clear which method is the best to apply. Many muscles acting on the knee joint and the surrounding areas originate from the lumbopelvic region; thus, a loss of control and strength in the core muscles can increase the rotational forces acting on the knee, particularly during the landing phase after a jump, which may lead to ACL injury.

The aim of this article is to demonstrate the existence of therapeutic modalities for the re-education and training of the core and "core stability" based on different rehabilitative specifics, as well as various preventive modalities for muscular and joint injuries. To achieve this goal, it is essential first to identify the aspects that characterize a specific core training regimen.

Core concept

The core concept has been a focal point in media and scientific literature since the end of the last decade (9). However, a precise and universally accepted definition remains elusive, with variations in interpretation based on different authors and contexts.

Historically, the core has been described as a "cylindrical box" encompassing the abdominal muscles in the front, the gluteal and paraspinal muscles in the back, the diaphragm at the top, and the pelvic floor/coxofemoral joint as the base.

Some authors have expanded this definition to describe the core as the "lumbopelvic complex," which includes the lumbar vertebral column, pelvis, coxofemoral joint, and all associated muscles that produce or limit movements of these segments (10).

As suggested by other researchers, the definition of core endurance is context-dependent, varying between biomechanical laboratories, rehabilitation clinics, and sports centers (11-13). This definition must be grounded in engineering and biomechanics principles and the core structures' morphological and functional characteristics. In light of these considerations, some researchers propose defining the core as the ability of osteoarticular and muscular structures, coordinated by the motor control system, to maintain or return to a desired trunk position or trajectory when subjected to internal or external forces. In training or sports medicine contexts, core endurance can be viewed as a physical quality that can be modified through training or rehabilitation, though it remains context-specific.

In sports, the core is often defined as "the group of all anatomical components between the sternum and the knees, focusing on the abdominal region, lumbar spine, and coxofemoral joint." This perspective is supported by other researchers who suggest that "core muscles" include "all muscles between the shoulders and pelvis that facilitate the

transfer of forces from the vertebral column to the extremities" (11, 12). Consequently, the core is considered a muscular corset that functions as a unit to stabilize the entire body, particularly the vertebral column, both during limb movements and at rest. It acts as a bridge connecting the upper and lower body, where forces are transmitted and generated.

Researchers have highlighted the core's role in improving balance, strength, and proprioception during trunk examination, daily activities, and sports (14). In alternative medicine, the core is often viewed as "energy," serving as the source of all limb movements and the origin of all energy, referred to as the "inferior dan tian.".

The core comprises passive and active elements: passive structures include the thoracolumbar column and pelvis, while active structures involve the trunk muscles. These muscles are crucial for maintaining the stability of the vertebral column and pelvis, as well as generating and transferring forces between the trunk and limbs during sports activities.

Since the core connects the upper and lower limbs, controlling strength, balance, and movement in this region can optimize the entire kinetic chain, including upper and lower-limb athletic gestures. Some criteria for enhancing the sports specificity of core stability training programs involve performing exercises on the feet and incorporating three planes of motion. While some studies have analyzed core stability programs (15, 16), there is a noted lack of research specifically evaluating sport-specific core stability programs that apply these criteria, highlighting a limitation in existing studies. It is also important to train core muscles independently, despite their interdependence, through fascial connections, which form a dynamic system that enables efficient movement and force transmission throughout the body.

Core anatomy includes all structures between the scapula and gluteals. Core structures can be categorized into stabilizers, such as the internal and external oblique muscles, which control movement angles eccentrically, and mobilizers, such as the *rectus abdominis* and *iliocostalis*, which accelerate movement concentrically.

The muscles constituting the core are responsible for maintaining posture in various positions and facilitating safe and effective movement through different planes and directions. The core, represented by the coxo-lumbo-pelvic complex, is the center of the kinetic chains from which all upper and lower limb movements originate.

"CORE TRAINING" protocols

In addition to terminological and conceptual changes, "Core training" programs focus on improving strength and neuromuscular control of the core region (17). Core muscle strengthening protocols are used by athletes across various sports and consist of different types of exercises. The definition of a "Core training program" encompasses various types of exercises as follows (18):

- balance training;
- plyometric exercises;
- sport-specific movement exercises;
- proprioceptive exercises;
- joint stabilization exercises.

In the clinical sector, proprioceptive exercises play a crucial role, using unstable surfaces such as Fitballs, Bosu balls, Freeman tables, etc. Some authors (17) believe it is essential to perform training with various loading thresholds, as outlined below:

1. **"Motor control stability"**: stability at low loading thresholds where the central nervous system (CNS) integrates global and local muscles;
2. **"Core strength training"**: high loading thresholds for global stabilizer muscles leading to hypertrophy and functional adaptation;
3. **"Systematic strength training"**: traditional high loading for global mobilizing musculature.

It is essential that the primary objective focuses on local muscles and utilizes a low training threshold to avoid injuries. In the early stages of training, it is crucial for athletes to understand their neuromuscular patterns by training muscles with low loads and then progressing to positions and movements with functional applicability (19, 20).

Therefore, the choice of exercises plays a fundamental role, including the duration of muscle activation and the required patterns, which vary depending on the load and the objective pursued ("Core stability" or "Core strength"). The author (17) reviewed several scientific studies, and the results are presented as follows:

- in the case of "Core strength," activation should exceed 60% of maximal voluntary contraction (MVC) to achieve strength gains, while for "Core stability," activation should be below 25% MVC to achieve benefits in resistance and neuromuscular control;
- "Core stability training" should vary from isolated deep local muscle activations using weights on irregular surfaces; considering the different functional roles of muscles, it is recommended to vary exercises to stimulate the core in a three-plane level and develop stability under global conditions;

- "Core strength" development programs should include flexibility exercises for the abdominal muscles, lower back, hip flexors, and extensors, performed on unstable surfaces accompanied by static and dynamic contractions;
- since a low level of trunk muscle activation (1-3% MVC) is required to stabilize the spine, "Core endurance" plays a primary role compared to "Core strength." Essential exercises include:
    1. curl up;
    2. bird dog;
    3. side bridge;
    4. prone bridge;
    5. weighted squat to strengthen anterior, posterior, and lateral musculature without exceeding the load threshold that poses multiple injury risks (21).

Before using any protocol, a detailed assessment of each individual should be conducted, including their physical condition, goals achieved thus far, and future ones (pain reduction and performance enhancement).

In the field of sports, the predominant use of core training is in the prevention of injuries: it has been established that muscular and joint injuries at the level of the shoulders, knees, and variable movements are often related to deficits in the trunk and abdominal stabilizer muscles (22).

Identifying and correcting any weaknesses in this area by examining their connection to injuries is crucial. High-intensity training leads to changes in muscle structure (hypertrophy) and neural adaptation to external stimuli. These neural adaptations facilitate force generation, increase tissue mobilization, and accelerate the alleviating mechanisms of the nervous system.

Methodology

The training program aims to correct local body weaknesses by improving segmental and global control. This control is achieved by working through the appropriate training threshold. The protocols used have the following objectives:

- increase in joint range of motion (ROM);
- increase in joint stability;
- improvement of muscular performance;
- optimization of movement function.

However, many sports rely on high-threshold training that exclusively conditions global muscles and alters the functionality of local stabilizers, favoring "Core Strength" rather than "Core Stability." Therefore, the ideal approach would be to work with both low-threshold and high-threshold loads, as both are beneficial for enhancing both components. Low-threshold load training primarily focuses on postural control, muscular adaptation, and motor efficiency. High-threshold load training is performed through overload exercises that place more stress on the muscles and induce structural changes (18, 23).

From the literature review, it is still unclear which methods and exercises are most effective for improving performance within a specific discipline. Despite the widespread use of "Core training" in every sport for recovery and prevention, its characteristics need to be better understood.

Athletic gestures in many disciplines are often performed under asymmetric and unstable conditions (one-legged balance, flight phase), involving global movements across three planes (17). Considering the role of the core, to strengthen its musculature and to have a "Core training" program specific to a sport, it is important to:

- perform exercises on unstable surfaces;
- perform exercises while standing, not sitting;
- use body weight instead of machines for muscle development;
- perform unilateral rather than bilateral movements (asymmetric loading);
- execute global rotational movements with a medicine ball.

A comprehensive "Core Training" program should improve strength, power, agility, coordination, body balance, functionality, speed, aerobic and anaerobic mechanisms, flexibility, and both static and dynamic stability of the spine (24). This article uses programs designed to prevent injuries in football players through core strengthening and core stability exercises. Here are three injury prevention programs for football players, focusing on fitness and injury prevention. Incorporating these programs into a regular training schedule can help improve strength, flexibility, stability, and overall conditioning, thereby reducing the risk of injuries.

Program 1: Comprehensive Strength and Conditioning Program (Table I);
Goal: Enhance overall strength, flexibility, and stability to prevent injuries;

Frequency: 3 times per week.

Table I. *Comprehensive strength and conditioning program.*

Day 1: Lower Body Strength and Stability	Day 2: Upper Body and Core Strength	Day 3: Plyometrics and Agility
1- Warm-Up: -Dynamic stretches (leg swings, hip circles)–5 min -Light jogging – 5 min	1- Warm-Up: -Arm circles, shoulder shrugs- 5 min -Light jogging – 5 min	1- Warm-Up: Dynamic stretches (high knees, butt kicks) – 5 minutes Light jogging – 5 minutes
2- Strength Exercises: -Squats: 3 sets of 10 reps -Deadlifts: 3 sets of 8 reps -Lunges: 3 sets of 12 reps(each leg) -Calf Raises: 3 sets of 15 reps	2- Strength Exercises: -Push-Ups: 3 sets of 15 reps -Dumbbell Rows: 3 sets of 10 reps (each arm) -Overhead Press: 3 sets of 10 reps -Plank: 3 sets of 1 minute	3- Plyometric Exercises: -Box Jumps: 3 sets of 10 reps -Lateral Bounds: 3 sets of 15 reps -Tuck Jumps: 3 sets of 10 reps
3- Stability and Balance: -Single Leg Romanian Deadlift: 3 sets of 10 reps (each leg) -Bosu Ball Balance: 3 sets of 30 seconds (each leg)	3- Core Exercises: -Russian Twists: 3 sets of 20 reps -Leg Raises: 3 sets of 15 reps -Bicycle Crunches: 3 sets of 20 reps	3- Agility Drills: -Cone Drills: 3 sets of 5 minutes -Ladder Drills: 3 sets of 5 minutes -Shuttle Runs: 3 sets of 5 minutes
4- Cool-Down: -Static stretching focusing on lower body muscles – 10 minutes	4- Cool-Down: Static stretching focusing on upper body and core – 10 minutes	4-Cool-Down: Static stretching focusing on full body – 10 minutes

Program 2: Functional Movement and Flexibility Program (Table II);
Goal: Improve functional movement patterns and flexibility to prevent injuries;
Frequency: 3 times per week.

Table II. *Functional movement and flexibility program.*

Day 1: Functional Strength	Day 2: Flexibility and Mobility	Day 3: Stability and Coordination
1- Warm-Up -Foam rolling – 5 min -Dynamic stretches – 5 min	1- Warm-Up: -Light jogging – 5 min -Dynamic stretches – 5 min	1- Warm-Up: -Foam rolling – 5 min -Dynamic stretches – 5 min
2- Functional Exercises: -Turkish Get-Ups: 3 x 5 reps (each side) -Kettlebell Swings: 3 x 15 reps -Farmer's Walk: 3 sets of 1 min -Medicine Ball Slams: 3 x 10 reps	2- Flexibility and Mobility Exercises: -Yoga Flow (Sun Salutations): 10 min -Hip Flexor Stretch: 3 x 30 sec (each side) -Hamstring Stretch: 3 x 30 sec (each side) -Shoulder Stretch: 3 x 30 sec (each side)	2- Stability and Coordination Exercises: -Single-Leg Balance: 3 x 1 min (each leg) - Bosu Ball Squats: 3 x 15 reps - Coordination Drills (hand-eye coordination with a ball): 10 min - Resistance Band Walks: 3 x 20 steps
3- Cool-Down: -Static stretching focusing on full body – 10 min	3- Cool-Down: -Deep breathing and relaxation – 10 minutes	3. Cool-Down: Static stretching focusing on lower body – 10 minutes

Program 3: Aerobic and Anaerobic Conditioning Program (Table III);
Goal: Enhance aerobic and anaerobic fitness to improve overall conditioning and prevent injuries;
Frequency: 3 times per week.

Table III. *Aerobic and anaerobic conditioning program.*

Day 1: Aerobic Conditioning	Day 2: Anaerobic Conditioning	Day 3: Mixed Conditioning
1- Warm-Up -Light jogging – 5 min -Dynamic stretches – 5 min	1- Warm-Up: -High knees, butt kicks – 5 minutes -Dynamic stretches – 5 minutes	1- Warm-Up: -Light jogging – 5 min -Dynamic stretches – 5 min
2- Aerobic Exercises -Interval Running (3 minu fast, 2 min slow): 6 sets -Continuous Running: 30 min at moderate pace	2- Anaerobic Exercises Sprints: 10 x 50 meters with 1-min rest Hill Sprints: 6 sets of 30 meters Shuttle Runs: 5 sets of 20 meters	2- Mixed Conditioning Exercises: -Fartlek Training (varying speeds): 30 min -HIIT Circuit (1 min work, 1 min rest): -Jumping Jacks -Burpees, Squat Jumps -Mountain Climbers
3- Cool-Down: -Static stretching focusing on lower body – 10 min	3- Cool-Down: - Static stretching focusing on lower body – 10 min	3. Cool-Down: Static stretching focusing on full body – 10 min

Here are three different core strength programs for soccer players, each focusing on core stability and strength (Table IV).
General Tips:

- ensure proper warm-up and cool-down sessions to prevent injuries;
- focus on maintaining proper form throughout each exercise;
- gradually increase intensity and difficulty as the player progresses;
- incorporate these programs into a comprehensive training routine that includes strength, flexibility, and agility exercises.

Table IV. *Core strength programs.*

Program 1: Stability and Endurance Focus Frequency: 3 times per week	Program 2: Power and Strength Focus Frequency: 3 times per week	Program 3: Functional Movement Focus Frequency: 3 times per week
Plank Variations -Standard Plank: 3 sets of 1 min -Side Plank: 3 sets of 45 seconds on each side -Plank with Leg Lift: 3 sets of 30 seconds each leg	Hanging Leg Raises 3 sets of 10-15 reps	Turkish Get-Ups -3 sets of 5 reps on each side
Dead Bug -3 sets of 15 reps on each side	Medicine Ball Slams -3 sets of 15 reps	Stability Ball Pike -3 sets of 10 reps
Russian Twists -3 sets of 20 reps on each side	Weighted Russian Twists -3 sets of 20 reps on each side	TRX Body Saw -3 sets of 15 reps
Bird Dog -3 sets of 15 reps each side	Ab Wheel Rollouts -3 sets of 10 reps	Single-Leg Romanian Deadlift -3 sets of 12 reps on each side
Bicycle Crunches -3 sets of 20 reps each side	Cable Woodchoppers -3 sets of 12 reps on each side	Lateral Band Walks 3 sets of 20 steps in each direction

RESULTS

One of the main reasons for core training is the development of the capacity to resist movement and create it. The importance of including exercises in the core training protocol that limit certain movements (in this case, rotation) is evident. Physiologically, training "core strength" and "core stability" leads to greater force and power generation in the shoulder, arm, and leg muscles, reducing the risk of injury and increasing speed, agility, power, and endurance (18, 25, 26).

Core stability plays a crucial role in athletic function and performance. Strengthening these muscles impacts the central nervous system, as these muscles help maintain trunk alignment and provide a stable pelvis foundation, thereby preventing instability. This stability enhances overall movement efficiency, dynamic control, and injury prevention during sports activities (27).

Core stability is closely related to preventing and rehabilitating lower limb injuries, as the core serves as the primary point where the lower limbs generate or resist forces produced during movement. A systematic review and meta-analysis evaluated the effects of injury prevention programs incorporating core stability exercises on knee and ACL injuries (27).

DISCUSSION

The aim of the article is to study the existence of therapeutic modalities in enhancing "core stability" by referring to rehabilitative objectives and highlighting the characteristics of the core region.

Many researchers question the significance of the connection between core training and performance, especially regarding injury prevention. Despite its importance in sports, scientific literature does not provide conclusive evidence about the actual impact of core training methods.

Various studies have the predominant view of abdominal muscles in preventing back pain. Lederman highlights the lack of evidence supporting the predictive role of the transversus abdominis muscle and its delayed activation in cases of lower back pain. He argues that common core stability exercises fail to restore the activation time of the abdominal muscles and that most exercises do not significantly improve core strength and endurance (26). "Core stability" is crucial in treating pubalgia, involving the synergistic training of the abdominal, adductor, and lumbar muscles to create a balanced muscular synergy among these groups.

In athletics, there is a lack of scientific evidence regarding the relationship between "core training" and performance. It is clear that all sports disciplines require good stabilization skills and neuromuscular control, considering the three-dimensional movements that demand adequate levels of strength in the trunk and pelvic regions. However, individual disciplines vary in terms of balance and symmetry, requiring a strong link between "core stability" and "core strength" (18).

Despite the lack of strong scientific evidence supporting core training's effectiveness, it remains widely used for prevention, sports performance, and rehabilitation, keeping the debate on its utility ongoing.

CONCLUSIONS

In conclusion, this article highlights the importance of a global approach to core training in sports physical therapy for improving athletic performance and reducing injuries. The core plays a crucial role in providing stability, force transmission, and preventing sports injuries.

Through a comprehensive study of core anatomy, function, various sports injuries, and clinical assessment techniques, this article provides insights for sports physical therapists. Implementing injury prevention programs for football players through core strengthening and core stability programs offers a clear, evidence-based framework for designing various effective programs. By following this approach, athletes can improve their core functions, stability, and performance while reducing the risk of injury.

Several studies have shown that a single exercise is insufficient to strengthen the entire core region; instead, a combination of exercises is needed to optimally strengthen the musculature (25).

Based on scientific research in the field of core stability rehabilitation, there is evidence that low-load exercises of this type can reduce injury rates and influence pain recovery. The results and recommendations presented in this article contribute to the enhancement of knowledge in sports physical therapy and provide a resource for professionals working with athletes of all levels.

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