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Review Article

Visual-cognitive Skills and Physical Qualities in Elite Soccer: Practical Considerations for Training and Return-to-Play Protocols

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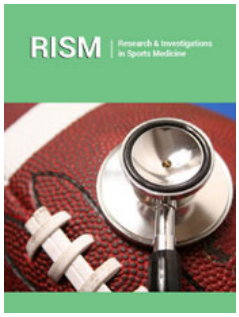

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Abstract

Elite soccer is increasingly demanding, requiring players to cover greater distances at higher speeds while making rapid decisions under high-pressure scenarios. These demands place significant strain on neurophysiological capacities, highlighting the need for integrated training that combines physical, technical-tactical and visual-cognitive development. This is particularly critical for athletes returning from long-term injury, who require both physical rehabilitation and neurocognitive re-adaptation to safely resume competition. Traditional Return-to-Play protocols often overlook compensatory central nervous system adaptations, increasing the risk of movement errors. Contemporary approaches emphasise visual-cognitive skills, supported by divided attention (managing multiple tasks) and selective attention (prioritizing relevant stimuli), while Blood Flow Restriction (BFR) training provides a promising adjunct during rehabilitation, especially when combined with Virtual-Reality (VR) techniques. Integrating these cognitive and physical strategies may enhance performance, reduce movement errors and facilitate safer re-integration into elite soccer.

Keywords: Blood flow restriction; Virtual-cognitive skills; Soccer RTP

Introduction

Elite soccer continues to evolve, with rising physical and technical-tactical demands across many European competitions. As the intensity of the modern game increases, players are expected to cover greater running distances at higher speeds and perform in more dynamic, high-pressure scenarios where decisions made in fractions of a second can determine match outcomes [1]. These evolving demands suggest that players' neurophysiological capacities are being tested to new limits [2,3]. In practical settings, this underscores the critical need to develop physical and technical-tactical abilities in tandem with visual-cognitive skills. This is especially pertinent for players returning from long-term injury, who must undergo physical rehabilitation and a period of re-adaptation before safely rejoining team training and competitive play [4]. These individuals face an elevated risk of movement errors, often due to compromised motor control under the complex and unpredictable demands of elite competition [4]. For example, evidence indicates that altered brain and spinal cord function (negative neuroplasticity) may persist for years after knee surgery, even following a return to full activity [5]. In addition, persistent biomechanical deficits have been observed long after knee reconstruction, particularly during the penultimate foot contact of the injured limb in change-of-direction tasks [6]. These findings suggest that RTP protocols should place greater emphasis on movement mechanics and sensorimotor control, alongside traditional performance outcomes. Ultimately, a paradigm shift is needed in rehabilitation. The one that integrates elements of "brain training" and cognitive training to may more comprehensively address the long-term consequences of injury.

Modern training and preparation must therefore utilize a deep analytical approach and explicitly integrate key visual-cognitive aspects into these processes. Skills such as perception, anticipation and rapid reaction should be considered essential components of contemporary training programs [7]. Both divided and selective attention are vital to stimulate visual-cognitive processes effectively. Divided attention (dual-tasking) refers to the ability to manage multiple tasks simultaneously or switch between them without attentional loss [8]. Selective attention (Table 1) involves identifying relevant and ignoring irrelevant stimuli [9].

Table 1: Definitions, divisions and examples of selective attention in football.

Process	Definition	Example in Football
Top-down	Internally driven, experience- and knowledge-based expectations that guide perception and action.	A striker anticipates where a cross will drop in the penalty box based on previous patterns, positioning before the ball arrives.
Bottom-up	Externally triggered, stimulus-driven responses guided primarily by the environment.	A defender reacts instantly to an opponent's sudden movement through ball or quick change of direction.

Visual-Cognitive Processes: Practical Applications

Practitioners might ask how visual-cognitive aspects could be applied in practical settings. In real-match scenarios, the concepts of anticipation and reaction can be utilized in various ways to enhance player performance and impose professional development. Table 2 & 3 depict real-world situations that offensive and defensive positions could experience during official matches. In practical settings, embedding visual-cognitive processes in individual and team-based training, including rehabilitation and Return-to-Play (RTP) protocols, is essential for a holistic and safe transition back to full match performance. When injuries limit movement and on-pitch sessions are not possible however, alternative approaches must be considered. A notable example is an Anterior Cruciate Ligament (ACL) injury. It is worth noting that rupture and reconstructive surgery lead to a disruption of sensory input from the knee to the Central Nervous System (CNS), resulting in altered motor behaviours [10]. Consequently, ACL injury should be regarded as a multifaceted musculoskeletal condition, as it encompasses not only mechanical and movement impairments but also cognitive and neurological disruptions. Failing to address these dimensions within rehabilitation, prevention and risk assessment strategies may result in incomplete management and a higher likelihood of recurrent problems [11]. In such cases, a long recovery and multi-staged rehabilitation are required, gradually transitioning from gym-based to pitch-based specific exercises [12] (Figure 1). Rehabilitation, even at early stages, should include tasks that challenge attention, working memory, and visual-spatial processing as shown in Figure 2 & 3. Training plans at more advanced stages must consider the individual's characteristics and positional demands, where soccer players anticipate, decide and quickly react to constantly changing environments that mimic game-like scenarios [12-15]. For instance, developing the ability to press aggressively, win the ball high and transition instantly into attack has been considered a decisive factor in modern soccer [13]. Figure 1 presents a drill designed to connect defensive pressing behaviors with a quick counter-attack, emphasizing perception, anticipation and reaction in high-tempo game situations. The main aim during this exercise is to condition players for repeated high-intensity efforts in realistic scenarios while enhancing individual and collective awareness in attack and defense [14]. Another practical and progressive approach is the Visual-Cognitive Control-Chaos Continuum (VC-CCC) proposed by Taberner and colleagues [15]. This framework outlines how RTP strategies can progressively integrate various physical and cognitive objectives, which is shown in Table 4. By adopting such structured, cognitively integrated training frameworks, practitioners can maximise the RTP protocols and better prepare athletes for complex, fast-paced scenarios of modern soccer and ultimately enhance their readiness for the match demands.

Table 2: Examples of anticipation scenarios for offensive players in football match-play.

Scenario	Description
Positioning for Passes	Footballers predict actions that might follow by positioning themselves in optimal spaces to receive passes between lines, using their understanding of the game and reading teammates/opponents behaviour.
Attacking Crosses	Players anticipate where to stand or move during attacking crosses, especially near the opposition goal, increasing chances to score or create a goal-scoring opportunity.
Second Balls	By positioning at the edge of the box during set pieces or attacking phases, players are ready to react to deflections or rebounds, enhancing their team's offensive forces.

Table 3: Examples of reaction scenarios for defensive players in football match-play.

Scenario	Description
Intercepting Passes	Defensive players react effectively by intercepting passes. This requires quick decision-making and the ability to read the opponent's intentions.
Tracking Movements	Reacting to deceptive body movements (feints) in all areas of the pitch is crucial for defenders. This prevents the opponent from gaining an advantage.
Blocking and Closing Down	Defensive players can also react by blocking runs, shots in the box, or closing down space in response to given stimuli. This involves quick reflexes and the ability to respond to the immediate threats.

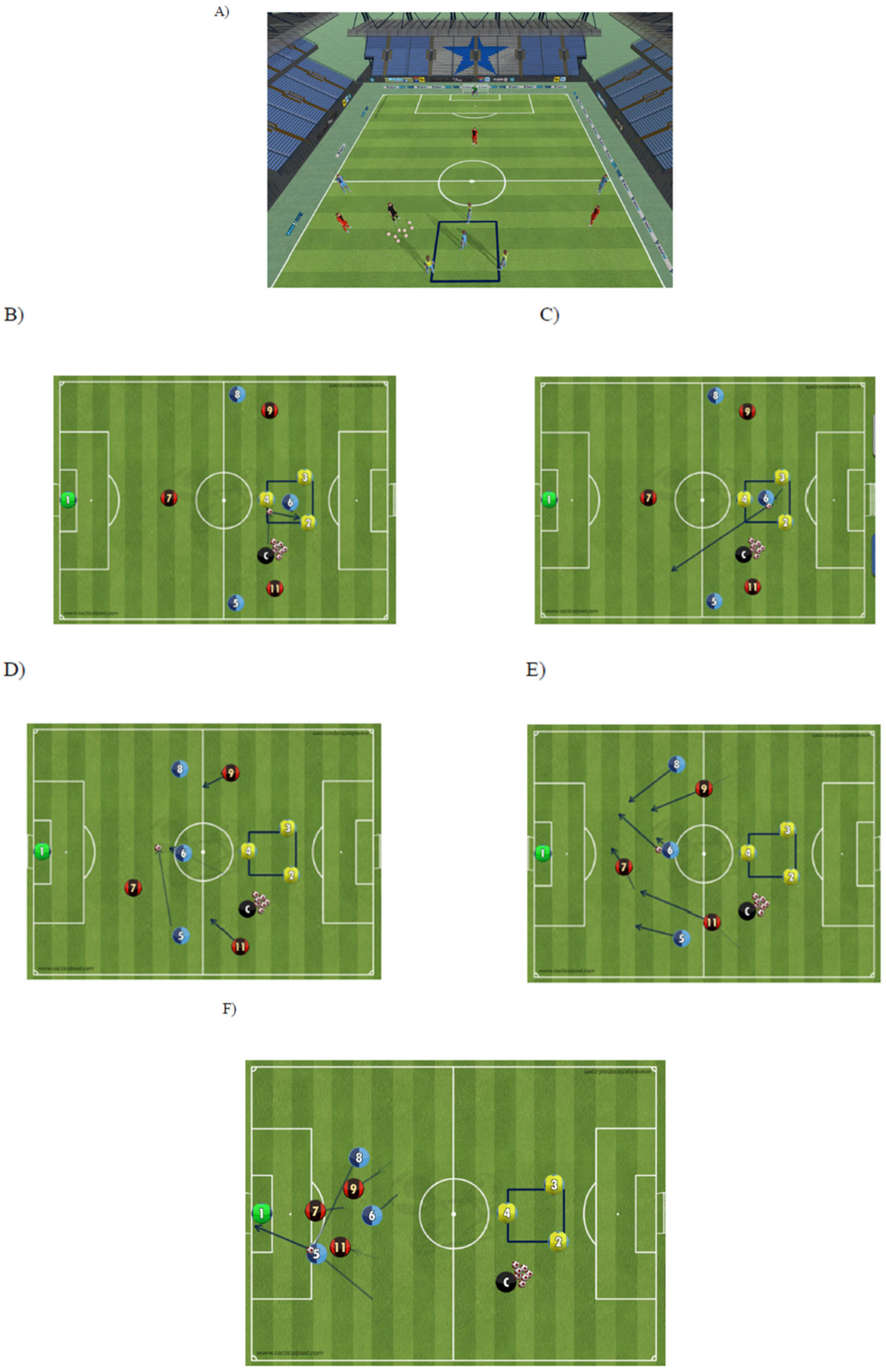

Figure 1: Specific offensive-defensive drill (3v1 high pressure and counter-attack): a) 3D drill set up; b) 3v1 possession where player nr 6 (blue) applies high pressure to win the ball; c) once possession has been re-gained, counter-attack is initiated; d) 3 blue players counter-attack and 1 red defends (3v1); e) 2 red players are making recovery runs to support defense (3v3); f) blue players quickly enter the box to finish an attack, which must be performed as quickly as possible to use numerical advantage in its early phase. Perform 2 sets of 6-8 actions lasting 20-30 seconds. Use 1:2-3 work-to-rest-ratio. Group activity: 9-15 players. Perception/Anticipation/Reaction. Adopted from Bortnik L [14].

Figure 2: VR goggles used during an ACL rehabilitation.

A) B)

Figure 3: Virtual reality applications used to improve cognitive skills: A) Inhibition & eye-hand coordination; B) Scanning ability & reaction.

Table 4: Examples of integrated objectives during the Visual-Cognitive Control-Chaos Continuum (VC-CCC).

Desired Objective	Practical Examples
Restoration of physical qualities that are aligned with match demands.	Gym-based exercises are implemented to develop proprioception and balance, as well as to enhance muscle strength, power, speed, and muscular endurance. Pitch-based conditioning sessions target both the aerobic and anaerobic energy systems, preparing athletes for the specific physical & physiological demands of competition.
Dual-tasking under fatigue.	Reactive decision-making. Athletes perform a primary strength exercise (e.g., squats) but must immediately switch to an alternative movement (e.g., reverse lunges) in response to a visual cue or an arithmetic task. For example, if the solution to a math problem is even, the athlete performs squats; if odd, they perform lunges (33). Players perform tactical or technical exercises (e.g., offensive pattern play or passing drills) while simultaneously reacting to secondary tasks, such as opponents' movements, coaches' instructions, or external stimuli (visual, auditory, or memory-based). For example, footballers may execute passing patterns but must adapt based on a sudden color cue, an unexpected whistle, or a new instruction requiring a change in decision.

Position-specific perceptual-motor training that distinguishes positional differences.	Athletes can perform individual or group formation drills that replicate positional demands observed in football competition. In these tasks, players are required to make context-specific decisions and select optimal solutions during both attacking and defending phases, depending on their role and position. For example, an offensive central midfielder moving into space to receive the ball may either lay it off quickly if defensive pressure is applied (e.g., by the coach acting as a defender) or turn and initiate an attack that involves wingers and a striker positioned in the box.
Tactical alignment with the team's game model to ensure contextual relevance and better transferability.	This objective builds on the principles outlined in the previous section (position-specific training), but is specifically designed to closely reflect the game model and coaching philosophy related to the attacking and defending phases. This stage may also involve the active participation of the coaching staff to further optimise the training process and enhance its alignment with tactical concepts.

Blood Flow Restriction and Ischemic Preconditioning

Blood Flow Restriction (BFR), first developed in the 1990s, involves the application of external pressure to partially restrict blood flow during low-load exercise [16]. A growing body of evidence indicates that BFR training promotes muscle hypertrophy, strength, peak power, aerobic capacity, recovery and proprioception [17-21]. In addition to physical outcomes, BFR has been associated with enhanced cognitive performance, such as improved cognitive function in elderly populations [22] and increased cognitive flexibility in young athletes [23]. BFR shorts in particular have been shown to be feasible, practical and safe in applied environments [24] (Figure 4a). Importantly, low-load exercise with BFR elicits adaptations comparable to those achieved with high-intensity training [25]. This makes BFR especially relevant in contexts where high mechanical loads are undesirable, such as Anterior Cruciate Ligament (ACL) rehabilitation or in the days immediately before and after competition in soccer [26]. The primary physiological mechanisms underlying BFR include tissue ischemia, which induces metabolic stress, cellular swelling, anabolic hormone upregulation, and increased expression of neurotrophins such as Brain-Derived Neurotrophic Factor (BDNF) [27]. Together, these mechanisms support both physical and cognitive adaptations while reducing joint stress.

Ischemic Preconditioning (IPC) is a BFR method that involves periods of circulatory ischemia, usually 3 to 4 x 5 minutes, followed by circles of reperfusion of similar or shorter duration in the limbs [28]. This approach elicits high hypoxic stress inducing vasodilation, improving muscle blood flow, enhancing oxygen delivery and ultimately positively affecting various exercise performance [29]. Preconditioning efficacy has been widely reported on strength, power and endurance capabilities [30,31]. From a research perspective however, interests should be directed more towards the IPC effect on sensory-motor patterns and muscular coordination in various athletic populations including soccer players. Evidence suggests that IPC might enhance sensory and proprioceptive feedback during physical activity to correct movements and augment its quality. That might ultimately improve physical performance and reduce potential injury risk, which would be considered of high importance in an athletic population [20,21,26].

Virtual Reality: A Novel Technique in Practical Settings

Virtual Reality (VR) provides a computer-generated three-dimensional environment accessed through head-mounted displays and motion controllers, creating an immersive sense of presence in virtual space [32]. VR has been applied in both clinical and sporting contexts to enhance motor and sensory function, cognitive processes and perceptual skills, all of which play a critical role in decision-making in team sports [33]. Research has demonstrated that movement patterns and motor control are largely comparable between physical environments and virtual conditions [34]. Furthermore, VR has proven effective in the evaluation and rehabilitation of gait [35], highlighting its potential as both an assessment and training tool. This technique is particularly valuable when physical loading must be limited, for example during injury rehabilitation or recovery phases in a weekly micro cycle in soccer [26]. Although BFR and VR have each demonstrated significant promise, no studies to date have examined their combined use in sport [36]. Conceptually, their integration could provide synergistic benefits, enhancing proprioception, motor and cognitive skills, postural control and physiological adaptations such as muscle size, strength and endurance (Figure 4b). A potential protocol (Figure 5) could involve applying BFR at ~70% limb occlusion pressure (LOP; <200mmHg) bilaterally, as recommended by Neal BS et al. [24], for 3 sets of 5 minutes during VR training, interspersed with 2-minute reperfusion periods [21]. This combined approach may augment both sensorimotor and cognitive outcomes while supporting neuromuscular adaptation. Future research should examine this novel paradigm with particular attention to its relevance for soccer performance, rehabilitation and recovery [37].

Figure 4: New training and RTP methods including: A) Blood Flow Restriction (BFR); B) Combined VR and BFR.

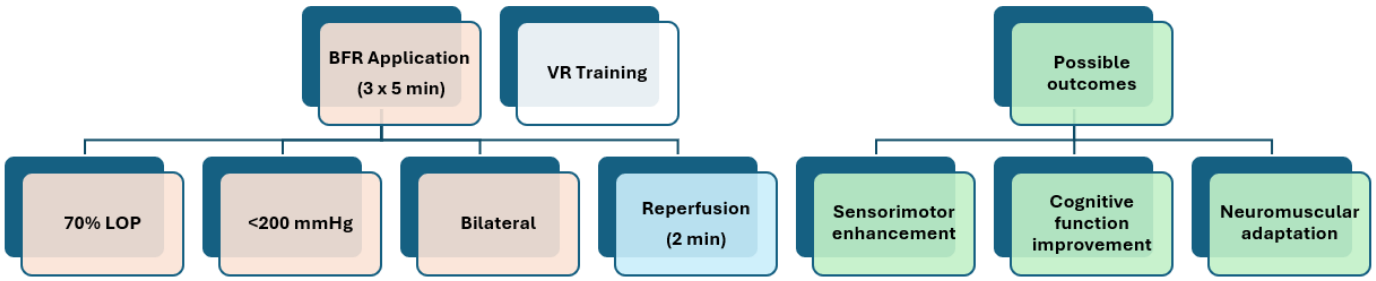

Figure 5: Practical protocol combining blood flow restriction and virtual reality training during rehabilitation and RTP.

Summary and Conclusion

Elite soccer is becoming increasingly demanding, requiring players to produce higher physical outputs while simultaneously making rapid decisions under complex, high-pressure scenarios. These evolving demands place significant strain on neurophysiological capacities, highlighting the need for integrated training approaches that develop physical and technical-tactical skills and visual-cognitive abilities. Such an approach is particularly important for athletes returning from long-term injuries, such as ACL ruptures, where Return-to-Play (RTP) protocols must address both physical rehabilitation and neurocognitive re-adaptation to ensure safe and effective reintegration into competition. Failure to address these cognitive and perceptual components may increase the risk of movement errors and compromise performance.

Emerging technologies provide promising tools to support cognitive development in soccer players. Virtual Reality (VR) offers a low-cost, low-impact method to enhance perception, reaction speed, inhibitory control, eye-hand coordination, scanning ability and visual processing efficiency. VR is particularly advantageous for injured athletes, allowing them to maintain cognitive engagement while minimising physical stress, thereby facilitating smoother transitions from controlled training environments to on-pitch

performance. Additionally, VR-based applications can complement conventional gym- and field-based training routines, providing a powerful adjunct for players at all ages and competitive levels. Furthermore, the integration of VR with Blood Flow Restriction (BFR) training may amplify cognitive and neurophysiological adaptations by combining perceptual-cognitive engagement with physiological stimulation. This synergistic approach may represent potentially a promising tool for rehabilitation and performance enhancement, particularly during periods when high-intensity physical training is not feasible. Systematic research is warranted to explore the efficacy, optimal protocols and long-term benefits of this combined methodology.

From a practical approach, coaches and performance staff could incorporate technology-enhanced cognitive drills alongside traditional physical conditioning, ensuring training scenarios replicate the attacking and defending demands of competition. Exercises should challenge decision-making, attention and perception under realistic constraints, while progression should be tailored to each player's injury status and readiness. Integrating VR and BFR into structured RTP programs may accelerate cognitive-motor re-integration, enhance tactical awareness and reduce the likelihood of re-injury, ultimately supporting safer and more effective preparation for elite match play.

Key Takeaways

A. Cognitive skills training should focus on perception, anticipation, decision-making and rapid reaction.

B. Divided and selective attention should be trained in practical settings.

C. Virtual Reality (VR) provides low-cost, low-impact cognitive training.

D. VR enhances cognitive skills and could facilitate smoother transition from controlled environments to on-pitch performance.

E. BFR can be combined with VR to potentially enhance neurophysiological and cognitive adaptations in addition to well-established physiological benefits.

F. Athletes could perform VR-based training while applying BFR at ~70% of limb occlusion pressure (<200mmHg), structured as 3 × 5-minute bouts with 2-minute reperfusion periods.

G. BFR can be useful when high-intensity physical training is not feasible (e.g., during injury rehabilitation or when fatigued).

Practical Implications

a) Design drills that replicate attacking and defending scenarios relevant to player positions.

b) Progress training based on injury status, readiness and competitive demands.

c) Integrate VR + BFR to potentially accelerate cognitive-motor re-integration and reduce re-injury risk.

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