Return to Play After an Anterior Cruciate Ligament Injury: Prioritizing Neurological and Psychological Factors of the Decision-Making Algorithm

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Take-Home Points

- The CNS demonstrates neurophysiological changes during an ACL injury.
- Traditional orthopedic treatment based on principals of musculoskeletal rehabilitation may not be sufficient to address CNS deficits.
- The CNS is neuroplastic and able to change with neuromotor rehabilitation that focuses on the CNS.
- Psychosocial factors may contribute to impairments after an ACL injury, and adversely affect functional outcomes.
- Assessment of RTP criteria should consider psychosocial, and central neural factors to minimize risk, and optimize outcomes.

Although anterior cruciate ligament (ACL) rehabilitation has evolved considerably over the past 2 decades, the basic paradigm has remained consistent: normalize strength and range of motion, reduce swelling and pain, achieve limb symmetry with functional tasks, and return to sport-specific activities gradually over a 6 to 12-month period. There have been some slight additions to this basic premise, such as evaluating knee and hip mechanics in the frontal plane, but the requirements here are vaguely defined and are typically only evaluated within the context of controlled clinical testing.

It is interesting to note that the typical ACL injury pattern occurs during a normal sport-specific movement, yet most rehabilitation protocols fail to recognize the potential causes of the aberrant movement pattern and how to best modify it so that the risk of repeated stress to the ACL can be minimized. It should be understood that movement occurs through the interaction of 3 discrete factors: the individual, the task being performed, and the environment in which it is performed.[1] All of these factors will play a role in how the final movement pattern is produced. For example, a soccer player (individual) may backpedal and pivot to the left 60° and accelerate to sprint after a player moving towards the touchline (task) while receiving instructions from teammates and monitoring the movements of opposing players (environment). A small variance in any 1 of these factors could significantly impact the movement pattern as the player completes the task.

In most rehabilitation programs, each of these factors may be treated in a singular, non-specific manner, but if these factors are not coordinated effectively throughout the program to produce the desired sport-specific movement, a faulty pattern may persist, leaving the player at risk for injury. Current rehabilitation programs seem to have a strong focus on creating stability, mobility, and strength, but these are trained in silos, with an internal focus of control, which only solves the biomechanical equation. Often, it is difficult for the player to coordinate good biomechanics into an efficient, protective movement pattern that is specific to the tasks performed on the field during the normal course of play. The missing link here is the central nervous system (CNS).

Limitations to the current ACL protocols may be that they rely heavily on musculoskeletal rehabilitation and that they have limited emphasis on neurological rehabilitation. As will be discussed later, the CNS has a large impact on the final movement selected by the player. In fact, cognition, perception, and action are the three factors that comprise the individual's part of the movement paradigm,[1] yet rarely are these factors addressed in most ACL rehabilitation programs. These elements are a large part of the movement equation, so it is easy to understand how failing to address these features can lead to poor movement quality and subsequent ACL re-injury.

In addition to central neurological factors, cognitive issues may play a role in the player's ability to return to sport. Determining optimal readiness for return to play is a difficult task for the medical community, with many variables to consider. Previous research studies have assessed the variability in return to play for various sports, including football, rugby, soccer, skiing, running, and tennis, with return-to-play rates ranging from 18% to 100%.[2,3,4-10] The risk of secondary injury may cast doubt and fear on athletes as they contemplate their successful return to play.[8,11] Although robust functional testing has become commonplace for determining athlete readiness after injury,[12-20] the assessment of psychological readiness, persistent fear, and loss of confidence are often neglected and not as commonly integrated into the return-to-play algorithm.[21-24] The purpose of this paper is to assess the various cognitive and central neural factors affecting a soccer player's ability to recover from an ACL injury and offer suggestions for integrating treatments into the protocols to address these issues.

Central Nervous System Neuroplasticity

Despite the vast amount of attention and research focused on the ACL, the re-injury rate still remains quite high. It has been reported that rehabilitation programs that employ traditional neuromotor training produce a re-injury rate as high as 30% after the athlete returns to sport.[25-28] The overall rate of sustaining a second ACL injury is 15%11 in all patient populations. For the general population <25 years of age, the re-injury rate is 21%, and for athletes <25 years of age, the re-injury rate rises to 23%.[11] With re-injury rates at this level, it is certainly fair to consider and be critical of the current rehabilitation methods being used with this population. One opportunity for improvement lies in the general approach used to rehabilitate ACL-injured patients. Therapy for this injury is protocol-driven, and the fact remains that most protocols prioritize restoration of peripheral systems, with minimal thought given to the cortical control necessary to manage those systems.[29,30] When neural factors are considered, it is usually within the context of increasing strength, balance, power, and biomechanical control,[31-34] which are certainly important but peripheral factors nonetheless. The missing element in many ACL protocols may be how to best manage the central neural components and cognitive factors associated with this injury.

If the CNS were to receive more consideration in ACL protocols, the opportunity for improved outcomes could be substantial because the CNS has been proven to be a very malleable system, as long as it receives the correct input. The CNS demonstrates neuroplasticity,[35] which means that it is capable of reorganization, based on the stimuli that it receives, whether internal or external.[36]

This is an important consideration in ACL rehabilitation because the ACL graft, while restoring the biomechanical properties to the knee, is not fully capable of producing the same neurosensory properties of the original ACL.[37-42] This is an important concept to understand because an ACL tear does indeed cause deafferentation in the ascending pathways to the brain.[37-40,42-46] This can lead to CNS reorganization and subsequent alterations in efferent output to the periphery.[37-40,42-46] Therefore, if a protocol with traditional musculoskeletal principles was used, then the mechanical function of the knee may certainly be remediated, but the neurosensory function will remain in a maladaptive state,[47-50] potentially leading to aberrant, non-protective movement strategies and a higher risk of re-injury.

The process of CNS reorganization may begin with the initial ACL injury. A peripheral musculoskeletal injury creates an inflammatory response that results in the arrival of chemical mediators such as histamine, substance P, calcitonin, and calcitonin gene-related peptide at the site of injury.[51] As edema accumulates in the joint, tension is applied to the capsule, which may adversely affect proprioception from the receptors located within.[45] The interruption of consistent input from the peripheral mechanoreceptors may lead to long-term differentiation of the ascending pathways.[52] This information is synthesized at 3 different levels of the CNS (spinal cord, brain stem, and motor cortex) to produce motor output.[53-56] Differentiation in the ascending circuitry can cause inhibition of motor neurons at the spinal cord.[45] Animal research has shown that this differentiation can cause a breakdown in the cuneate nucleus of the brainstem,[57] which provides sensory information from the upper body, while the gracile nucleus does the same for the lower body. These structures transfer proprioceptive input to the ventral posterior lateral nucleus in the thalamus, where it is then sent to the primary somatosensory cortex.[57] In general, the somatosensory, visual, and vestibular systems interpret afferent inputs to control movement, balance, and stability.[58,59] In a sport like soccer, where the movement tasks are dynamic and unpredictable, it is easy to see why even a slight deficit in somatosensory processing could disrupt a movement. Valeriani and colleagues[42,46] showed that somatosensory-evoked potentials were indeed altered in a cohort of ACL reconstruction (ACLR) subjects, indicating reorganization within the CNS. Additionally, the deafferentation could not be changed by other afferent input coming from the knee or by the new ACL graft placed in the knee.[42,46] The primary motor cortex has been found to have a substantial network of connectivity with the primary somatosensory cortex, which supports the theory that the motor cortex has a very strong linkage with the peripheral receptors in the joint.[60] The ligaments in the joint contain Ruffini, Pacinian, and Golgi receptors, all of which react to changes in the collagen fibers and send information regarding tension, length, speed, acceleration, position, and movement back to the CNS.[61-64] Unfortunately, the ascending pathway deafferentation can cause reorganization within the CNS, which makes the feedback provided from the periphery less effective in motor planning.

Ward and colleagues[65] have reported that reorganization within the motor cortex is the primary cause of chronic neuromuscular movement deficits in peripheral joint injuries. Researchers have used functional magnetic resonance imaging, transcranial magnetic stimulation, and electroencephalography in ACL patients to demonstrate changes in cortical activity and subsequent CNS reorganization.[65] Kapreli and colleagues[41] reported that subjects with an ACL injury demonstrated higher cortical activation in the pre-supplementary motor area (pre-SMA). This is a region that is responsible for more complex motor planning.[66,67] This area becomes active before the primary motor cortex and is responsible for preparing the final movement pattern that the motor cortex executes.[41] As the task becomes more complex, activity in the pre-SMA will increase.[41] Additionally, they found that the posterior secondary somatosensory area and posterior inferior temporal gyrus showed increased cortical activity compared with controls.[41] Visual planning is processed in the posterior inferior temporal gyrus, and so, it appears that the difficulty in processing somatosensory information due to ascending pathway deafferentation places an increased reliance on the visual system for movement planning.[68-70] This was observed while ACL-injured subjects performed a simple knee flexion-extension movement encompassing 40°, indicating the need to incorporate higher central levels of planning for a very simple movement pattern.[41] Baumeister and colleagues[37,38] also showed that subjects with ACLR had higher levels of cortical activation in the areas of the brain that require attention and that process sensory input. They theorized that this occurred because of reduced efficiency of neural processing at lower levels in the CNS. Despite the higher levels of cortical activity observed, they found that subjects with an ACLR demonstrated proprioceptive testing that was deficient compared with that of controls. Heroux and Tremblay[71] also demonstrated that subjects with an ACLR had increased resting motor cortex activity. They believed that this occurred as the motor cortex attempted to maintain neuromotor output to the periphery in the face of diminished afferent input.

The reorganization that results in movement planning, transitioning from subcortical levels to cortical levels, is a phenomenon that researchers believe can lead to deficiencies even as the athlete has returned to sport. Grooms et al[72] revealed in a case report that a subject with an ACLR showed higher levels of activity in the crus region of the cerebellum. This area contains corticobulbar and corticospinal tracts that transmit neural input to maintain balance and coordination.[73] These changes in the cerebellum, combined with increased motor cortex activity, are thought to be indicative of a global neural strategy that uses higher levels of the CNS, as opposed to subcortical processing.[72]

The current research makes a clear and compelling argument for the importance of CNS reorganization after an ACL injury, placing increased reliance on higher cortical levels of control, as well as the visual system to coordinate balance and movement. It is thought that this reorganized method of neural transmission can then become imprinted within the CNS, if not corrected.[35,74] If this is the case, then traditional strength programs may not be sufficient to restore these connections to their pre-injury level. If the CNS has the ability to reorganize based on the aberrant input that it receives from the periphery, then it also certainly has the potential to adapt to more specific structured input via the ascending afferent pathways.[41,45] The rehabilitation program, however, needs to be structured specifically to target the reorganized regions of the brain. There needs to be an emphasis on rehabilitating not only the peripheral neuromotor structures but also the CNS.[75]

Central Nervous System Rehabilitation Principles

For a neurological rehabilitation to be successful, the interventions need to be repetitive and task-specific, involve learning, employ whole and part practice, and transition from using an internal to an external focus of control.[76] Movements that are repetitive, but which lack structured learning and skill, have been shown to have no effect on inducing neuroplastic changes in the primary motor cortex.[77,78] However, using neurological rehabilitation techniques that facilitate the acquisition of new motor skills by the CNS have been shown to cause neuroplastic adaptation in the motor cortex.[79-85] This occurs because neuroplasticity is determined by experience and practice.[78] The CNS operates on cues received in the ascending tracts by mechanoreceptors in the joint. If a new movement pattern is being learned by the athlete, then this new afferent input received from the periphery will start to initiate reorganization in the higher learning centers. If this occurs with optimal repetition and precision, then a positive reorganization can take place within the CNS that results in a higher percentage of motor planning and control being filtered down to a subcortical level. Essentially, the movements become instinctive, which is crucial in athletics, where attention in higher cortical areas is frequently diverted to external aspects of the competition and not solely used to focus on movement.

This is why shifting neurological rehabilitation from an internal focus of control to an external focus of control is paramount. While using an internal focus of control is required early in rehabilitation to enable the athlete to understand the specific tasks required in a composite movement, a gradual transition to an external focus of control is necessary as the athlete begins to perform tasks that are more soccer-specific. This autonomous stage of motor learning is crucial because it transfers the burden of motor planning from higher to lower levels of the CNS and frees up the pre-SMA and primary motor cortex to handle more complex patterns.[58,86-88]

Anterior Cruciate Ligament Risk Potential in Soccer Players

If a comprehensive neuromotor rehabilitation program is to be used effectively with soccer athletes, then the first priority is to define how the players should move, so that they can demonstrate protective kinematics with all soccer-specific tasks and minimize stress to the ACL. As the ideal movement pattern becomes autonomous, then it should be trained within the context of a dynamic environment; remembering that environmental changes have a large impact on the final movement pattern selected by the individual. Brophy et al[89] evaluated videos of non-contact ACL injuries in male and female soccer players and determined that 45% occurred while cutting, 25% while landing, and 16% during deceleration. These 3 patterns represent 86% of the ACL injuries observed and offer an opportunity for evaluation and treatment with specific central neuromotor rehabilitation techniques.

The foundational movement patterns for the soccer player should focus on producing leverage that minimizes stress to the ACL during the 3 primary tasks outlined above. To achieve this, it is necessary to reduce posterior ground reaction forces at the hip and knee joint during these movements. There is a high correlation between the magnitude of the posterior ground reaction force, and anterior tibial shear, and subsequent displacement.[90,91] This stress can be reduced by increasing the hip and knee flexion angles during soccer-specific movements that involve pivoting, decelerating, and landing from a jump in a unipedal stance.[92]

This phenomenon can be explained by observing changes in the ACL elevation angle, hamstring insertion angle, and patella tendon-tibial tuberosity insertion angle. As the knee moves into flexion, the ACL takes on a more parallel orientation to the tibia, and its fibers are better able to resist elastic deformation accompanied by a posterior ground reaction force.[93,94] The quadriceps will produce less anterior translation on the tibia because the patella tendon insertion angle is reduced relative to the longitudinal axis of the tibia, and the mechanical advantage of the quadriceps is decreased.[95] Lastly, the hamstrings will be able to provide better leverage posteriorly because the resultant force trends toward a more parallel orientation to the tibial plateau, which enables the player to counter, more effectively, the posterior ground reaction force and the anterior pull directed by the quadriceps.[95]

This theory is supported by the work of Li and colleagues,[96] who showed that there is an inverse relationship between knee flexion angle and ACL loading. In their study, they applied a constant quadriceps force of 200 N at 15°, 30°, and 60° angles. The anterior shear force was obviously the highest at 15° and reduced by 20% at 30° and 60% at 60°. When hamstrings co-contraction was added, there was an additional 30% reduction in anterior shear at 15° and 50% at 30° and 60°. From a more flexed position, the hamstrings can increase joint compression and reduce the anterior translation by allowing the concave medial tibial plateau to limit the anterior drawer effect and absorb the forces that occur with excessive anterior shear, internal rotation, and valgus loads.[97] As the knee flexion angle approximates 60°, the hamstring leverage is increased, and the quadriceps leverage is diminished to the point where its ability to produce anterior tibial translation is neutralized.[98] Daniel and colleagues98 referred to this as the quadriceps neutral angle.

For soccer-specific movements that are potentially injurious to the ACL, it may then be beneficial to create a default movement pattern at the knee that approximates this value. In keeping with the information presented in this paper, it will be important to have the player reproduce this angle consistently during activities that involve pivoting, decelerating, and landing from a jump within the context of match play. This will certainly require that segments located both proximal and distal to the knee are able to function within specific parameters so that a cohesive protective synergy is produced throughout the lower quarter which minimizes posterior ground reaction forces and is protective of the ACL. This is where structured neuromotor training that is able to modulate networks within the CNS may be beneficial.

Central Nervous System Treatment Techniques for the Soccer Player

The ultimate goal is to create a foundational movement pattern that optimizes leverage and is protective of the ACL during decelerating, pivoting, and landing in a unipedal stance from a jump. The composite segments that are necessary to achieve this include local core stability to create lumbopelvic stiffness, and global core activation to enhance posterior chain stability. This should enable the player to feel more balanced when placing the pelvis in a more posterior and inferior position while still maintaining the trunk in a position that is parallel with the tibia, as the knee is flexed to an approximate 60° angle (**Figure 1**). From a frontal plane perspective, the acetabulum should bisect the malleoli of the stance leg, with a neutral tibiofemoral joint alignment (**Figure 1**).

The neuromotor training for the composite segments of this movement can begin in the “acute postoperative phase” (**Table 1**). Because the surgical repair will limit the player’s capabilities in this stage, this is a good time to break down the foundational movement pattern into its component parts and ensure that the CNS receives a high number of quality repetitions of parts. In this phase, the player may begin an isolated training for the transversus abdominis, multifidus, and pubococcygeus. This can start in a supine position using biofeedback with an isometric contraction, progress to a standing position, and incorporate deep core activation with stance-phase gait training, mini squats, and lunge variations. This phase will require an abundance of visual and verbal feedback with an internal focus of control as the player gets used to activating the deep core and quad/hip synergy during functional lower extremity movements. Even in this early phase, the player should look to minimize anterior and/or posterior pelvic tilting and maintain a stiff thoracolumbar segment that remains parallel with the tibia during all functional movements.

As the player moves into the “subacute postoperative phase” (**Table 1**). He or she will continue to use an internal focus of control to activate the local/global core synergy with functional movements progressing from double-leg, to single-leg positions. Partial practice, instead of whole practice, is still the predominant theme of the neural training process. In this phase, the knee and hip flexion angles can increase, and the player’s trunk and pelvic position should be critiqued in a single-leg position so that the trunk remains parallel with the tibia in the sagittal plane with a slight forward hip hinge. The pelvis should remain level throughout single-leg stance to ensure adequate activation of the lateral hip stabilizers. This is the stage where the player can learn to isolate closed kinetic chain hip rotation for pivoting, and so, single-leg hip internal and external rotation drills are useful, both with and without resistance. Skill acquisition is crucial in this phase because the patterns that the CNS adopts will form the foundation for more dynamic patterns that will occur in the later soccer-specific stages. Higher levels of cortical planning are still needed in this phase. For this reason, it is important that poor quality repetitions are recognized by the player and clinician so that he or she can learn to perform them correctly, albeit still with an internal focus of control. This is also a good time to begin to employ constraint-induced movement therapy as the player is able to replicate the desired pattern with more precision. For example, by eliminating the use of the upper extremities as a source of balance, the CNS is forced to program alternate synergies such as the lumbopelvic, and foot and ankle segments to maintain the desired alignment.

The “lower quarter static stability phase” (**Table 1**) marks a point where it may be useful to use direct strategies that have the capability to change CNS efferent owutput from a primary reliance on the visual processing areas in the posterior-inferior temporal gyrus back to the somatosensory area. It is critical that the player is able to make this transition in cortical reorganization and control, because ACL-injured subjects have been shown to have balance scores similar to healthy controls when they are able to use their vision, but this is reduced when vision is taken away.[99-105] Their balance will diminish even further if vision is modulated during more complex landing and pivoting maneuvers.[99-105] This may certainly explain why defending is a riskier task for ACL-injured players[89] as their visual system is focused more on tracking a player than attending to precision with movement planning.

To enhance this cortical reorganization within the context of soccer-specific movements, it is useful to start from a foundational single-leg position, with the knee approximating 60° of flexion and the trunk parallel to the tibia. In the frontal plane, the pelvis should be level, the trunk vertical, and the acetabulum bisecting the malleoli of the stance leg (**Figure 1**). The player may initially work on getting into this foundational position with vision either partially obstructed using stroboscopic eyewear or completely obstructed if this equipment is unavailable.[106-108] The pattern can be progressed by constraining the upper extremities to force reliance on the lumbopelvic and foot/ankle strategies for balance. Head and/or trunk turns can be added to simulate the external focus of control that is required with movement in soccer. These should progress from slow to fast and anticipated to unanticipated as the player demonstrates competence in maintaining stability at each segment within the foundational stance position. Once this is in play, a ball should be introduced into the drills. As the player maintains the foundational position with vision diminished and upper extremities constrained, they should attempt to reach for or trap a ball from this position. If vision is completely obstructed, then the player can be instructed to open his/her eyes just as the ball arrives to induce a reactive response. Again, quality repetitions are essential for learning to occur, and subsequent skill acquisition to take place in the CNS; thus, close scrutiny should be paid to the qualitative essence of the movement patterns to ensure pristine biomechanics during this phase.

The “lower quarter dynamic stability phase” (**Table 1**) should continue with the same neuromotor training principles employed in the previous phase, except that the drills will now involve plyometrics. The player should ultimately progress from double-leg, to single-leg jumps and then linear to diagonal. Vision should still be obstructed and upper extremities constrained to channel the lumbopelvic region for force production and balance. Movement quality in the foundational position remains paramount with these drills to ensure that skill acquisition is occurring and injury risk is being mitigated. An external focus of control can be introduced by applying an unanticipated perturbation during a jump. Additional learning opportunities should include unanticipated head and trunk turns while landing in a unipedal stance from a jump. The task can be made more specific by having the player trap a pass while doing linear or diagonal single-leg hop progressions. In this manner, the player’s CNS can become reorganized to program the requisite synergies to maintain a protective foundational position on the stance leg, as the contralateral limb is required to perform work that is far outside the player’s base of support.

The final segment of the CNS neuromotor rehabilitation program is the “lower quarter dynamic agility phase” (**Table 1**), when the player will learn to perform an unanticipated directional change in a foundational position for the pivot leg. The player can begin this phase by initiating sprint-deceleration-pivot efforts, progressing at 45°, 90°, 120°, and 180° turns. This should be trained in both a forward and backpedal position. Close attention should be paid to the deceleration phase of the sprint-pivot effort, as this will set the player up to demonstrate protective kinematics during the pivot phase of the task. In this phase, the center of mass should become lower and move posteriorly, so that a deeper knee and hip flexion angle, supported by posterior chain synergies, can occur at the pivot point. This is an important skill for the player to acquire, as Cortes and colleagues[92] have reported that female collegiate soccer players tend to perform a pivoting task with a more erect trunk position. In the same cohort, they also measured the mean knee flexion angle at initial contact during pivoting to be 24°.[92] Movement patterns that reflect an elevated center of mass, with arms abducted away from the trunk, should be discouraged here. The drills can be progressed to have the player react to a command and perform unanticipated pivots within a 5 × 5-meter box to simulate defending. This should be progressed from eyes open and arms unconstrained, to vision disrupted and arms constrained. From here, an external focus of control can be added by playing a ball to the athlete. Vision should be withheld until the instant that the ball arrives at the player, when he/she is required to play the ball to an unanticipated spot. As is the case in all other phases of the neuromotor training, the quality of movement is the most important parameter to critique with each drill. From a qualitative standpoint, the player should demonstrate stiffness throughout the thoracolumbar region and power and control through the pelvis with each directional change. In addition, he or she should maintain a low and posteriorly oriented center of mass to optimize leverage in the hamstrings/gluteals compared with the quadriceps and reduce posterior ground reaction forces.

Psychological Readiness for Return to Play

After an injury is sustained, an athlete is often subjected to a range of psychological responses in addition to the functional impairment, including stress, hesitancy, alterations in self-esteem, depression, fear of re-injury, and anxiety.[43,109-111] The aforementioned responses are often at their height in the time immediately following an injury and generally subside over time during the rehabilitation process.[110] The rates at which athletes experience psychological distress following an injury range between 5% and 19%; the levels are comparable with patients receiving treatment for mental health illness.[43] However, these elements may persist, or even increase, in the later stages of the rehabilitation process as the topic of return to play is deliberated.[112,113] If these fears are left unresolved, then a significant delay can be incurred during the rehabilitation process, which might ultimately jeopardize the successful return to play.[114,115]

When athletes have been cleared to return to sport, fear tends to be the most common reason for their decision to not return to play.[21,116] The persistence of fear has clinical implications and warrants close monitoring to ensure that the athlete feels adequately supported in the decision to return to sport.[117,118] Building the athlete's confidence by addressing hesitation, lack of confidence, heightened awareness of risk or re-injury, and safe reintegration into athletic participation are important themes identified to encourage a safe return to play.[43] A variety of validated tools can be integrated into an existing return-to-play decision-making algorithm (**Table 2**).[118-120]

By integrating the necessary screening of patients for kinesiophobia and assessing patient expectations after enduring an ACL injury, clinicians may be able to identify patients who are at risk for poorer functional outcomes. A consideration of psychosocial elements such as activity avoidance, fear of movement and re-injury, loss of confidence and expectations/assumptions during the continuum of the rehabilitation process, and the decision to return to play may favorably impact the individual's ability to safely return to sport. It is critical to address both the physical and psychosocial factors during the rehabilitation process to more optimally transition individuals back to their prior level of athleticism.

Conclusion

Psychosocial factors may play a role in determining a player's readiness to return to sport, as well as a potential for re-injury. A number of tests are available for use with this patient population to identify mental deficits that may impact player performance upon return. Additionally, the CNS should be considered as a source of impairment in players with ACL injuries. Current protocols may not fully appreciate the CNS’ impact on the player’s functional outcome. Therefore, an approach that includes CNS neuromotor training with traditional musculoskeletal rehabilitation, which also incorporates cognitive and psychosocial factors, may define an improved paradigm for treating soccer athletes following an ACL injury and assessing return-to-play capability.

Key Info

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Figures/Tables

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Table 1. Adjunct CNS Treatment Principles for ACL Reconstruction in Soccer Athletes

Phase	**Goal**	**CNS Rehabilitation Techniques**
Acute postoperative	Local core activation with weightbearing exercise. Produce trunk stiffness with lower extremity movements.	High repetitions. Verbal or tactile cues. Internal focus of control. Partial practice.
Subacute postoperative	Lumbopelvic, foot or ankle, and posterior chain segments learn to participate in movement effectively.	Requires higher levels of cortical planning. Internal focus of control. CIMT.
Static stability	Able to adopt foundational movement pattern consistently with vision eliminated.	Somatosensory vs visual processing. Partial-to-whole practice. Use internal and/or external focus of control.
Dynamic stability	Able to perform plyometrics in a single-leg position using foundational movement pattern with subcortical processing.	Increase velocity with movement challenges. Occlude or eliminate vision. Heavy reliance on an external focus of control. Prioritize movement quality.

Dynamic agility	Pivoting, decelerating, and landing are performed with hip flexion/knee flexion synergy, trunk stiffness, and posterior chain activation.	Unanticipated movement challenges. Whole practice. Ball reaction drills with vision obstructed or occluded. Contact drills with vision obstructed or occluded. Use external focus of control to include soccer-specific tasks.

Abbreviations: ACL, anterior cruciate ligament; CNS, central nervous system; CIMT, constraint-induced movement therapy.

Table 2. Self-Report Measurement Tools to Integrate into Return-to-Play Decision-Making Algorithm

Self-report Measurement Tools
13-item Tampa Scale for Kinesiophobia
Anterior Cruciate Ligament Return to Sport after Injury Scale (ACL-RSI)
Global Rating Scale (GRS)
International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form
Knee Injury and Osteoarthritis Outcome Score (KOOS)
Lysholm Knee Scoring Scale
Short Form-36 Health Survey (SF-36)
Subjective Patient Outcome for Return to Sport (SPORTS)
Patient Health Questionnaire-9

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Multimedia

Product Guide

Product Guide

- STRATAFIX™ Symmetric PDS™ Plus Knotless Tissue Control Device
- STRATAFIX™ Spiral Knotless Tissue Control Device
- BioComposite SwiveLock Anchor
- BioComposite SwiveLock C, with White/Black TigerTape™ Loop

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