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Neurocognitive Errors and Noncontact Anterior Cruciate Ligament Injuries in Professional Male Soccer Players

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Context: Evidence is emerging that core neurocognitive functions such as working memory and inhibitory control (ie, motor-response and attentional inhibition) are linked to the anterior cruciate ligament (ACL) injury risk. Research has been conducted in laboratory settings, but the contribution of neurocognition to actual ACL injuries under real-world conditions is unknown.

Objective: To describe the possible neurocognitive errors involved in noncontact ACL injury mechanisms.

Design: Case series.

Setting: Soccer matches.

Patients or Other Participants: A total of 47 professional male soccer players.

Main Outcome Measure(s): Three independent reviewers evaluated 47 videos of players sustaining noncontact ACL injuries. Neurocognitive errors in inhibitory control were operationalized as follows: (1) motor-response inhibition was scored when a player demonstrated poor decision-making and approached the opponent with high speed that reduced the ability to stop or change the intended action and (2) an attentional error was scored when a player shifted his selective attention away from the relevant task to irrelevant stimuli.

Results: Of 47 noncontact ACL injuries, 26 (55%) were related to a pressing-type injury, 19 (73%) of which involved a deceiving action made by the opponent, suggesting poor inhibitory control of the defender. Of the remaining 21 noncontact ACL injuries (45%), 16 (76%) could be attributed to attentional errors. Agreement among the 3 raters was very good for all items except poor decision-making, which showed fair to good agreement (Fleiss $\kappa = 0.71$). Interrater reliability was excellent (intraclass correlation coefficient = 0.99–1.00).

Conclusions: Errors in motor-response inhibitory control and attentional inhibition were common during noncontact ACL injury events in professional male soccer players. The interrater agreement in detecting neurocognitive errors in general was very good.

Key Words: injury prevention, neurocognition, stability, team ball sport, football

Key Points

- The most frequent noncontact anterior cruciate ligament (ACL) injury was related to pressing, during which the opponent made a deceiving action, which suggested poor inhibitory control of the defender.
- Attentional errors may cause a lack of temporospatial awareness of the direction of the player's movements, potentially compromising motor control and leading to ACL injury.
- Soccer players should delay their response until sufficient kinematic cues emerge from the opponent in relation to their contextual information to reduce the risk of sustaining an ACL injury.

An anterior cruciate ligament (ACL) rupture is a devastating injury for a professional soccer player, resulting in substantial time loss[1] and reduced career length.[2] Unfortunately, although players have access to injury-prevention programs, the rate of ACL injuries in professional soccer remains high.[3] Understanding the situations and mechanisms that lead to ACL injuries is crucial to designing effective injury-prevention programs to decrease this high incidence. Authors[4,5] who used video to analyze ACL injuries in male and female professional soccer observed that 44% and 54% of injuries, respectively, were noncontact injuries. The main focus of these studies was the ACL injury mechanism based on a biomechanics perspective. Bahr and Krosshaug[6] proposed that examinations of injury mechanisms should include information about not only the biomechanical characteristics but also the behavior of the athlete and the opponent(s).

Stuelcken et al[7] suggested a potential relationship between decision-making and temporospatial constraints of ACL injuries in netball. Similar to soccer players, netball players are immersed in a rapidly changing, unpredictable, and externally paced environment. The challenge for players is to arrive at particular locations on the pitch at specific times while making fast action decisions, such as staying close to an opponent, in response to moment-to-moment changes.[8] Thus, the mechanism of noncontact ACL injuries in soccer, especially for defensive injuries, may in part be explained by a high neurocognitive load.[9–11] Core neurocognitive functions control complex, goal-directed thoughts and behaviors, and they involve multiple domains, such as inhibitory control, working memory, and cognitive flexibility.[12]

In line with current research that addresses the effect of decision-making or selective attention paradigms on ACL injury-risk biomechanics,[13–15] the main focus of our study was to explore inhibitory control. *Inhibitory control* describes the ability to control attention, behavior, thoughts, emotions, or a combination of these to cancel strong internal predispositions or external temptations and instead act in a more appropriate way.[12] Two key cognitive processes that have been explained under the rubric of inhibitory control are motor-response inhibition and attentional inhibition.[16] *Motor-response inhibition* refers to the ability to stop unwanted and incorrect motor actions.[12] Motor-response inhibitory control blocks behaviors and stops inappropriate automatic reactions, changing one response for a better, more thought-out response adapted to the situation. For example, imagine a soccer player receives the ball from a teammate. Based on visual scanning of the pitch, the player decides to pass the ball to a teammate running toward an open space, but at the moment of initiating ball play, the player recognizes that a defender anticipated the decision and closed the passing lane in time. Successful inhibitory control is demonstrated if the player can cancel the execution of the passing action to avoid interception of the ball by the opponent.[17]

Attentional inhibition refers to the ability to resist interference from stimuli in the external environment. In soccer, the unpredictable and constantly evolving sport environment presents players with a myriad of stimuli (eg, visual and auditory).[18] However, attentional capacity is limited, and a player must differentiate between stimuli relevant to the task and those that can be neglected.[19] Divided attention unfavorably affected lower extremity mechanics during changes of direction and landing, resulting in a greater risk for ACL injury.[20] Any deficit or delay in sensory or attentional processing may lead to coordination errors and result in high-risk knee movements.[21] Although the influence of neurocognition on the ACL injury risk has been demonstrated in cross-sectional studies,[9] our understanding of how neurocognitive factors contribute to the actual ACL injury mechanism needs to improve.[22] Therefore, the primary aim of our study was to describe the possible neurocognitive errors involved in noncontact ACL injury mechanisms. We hypothesized that errors in motor-response inhibition and attentional inhibition would contribute to noncontact ACL injuries in professional soccer players. We also hypothesized that interrater agreement for the neurocognitive assessment based on the video analysis of players sustaining ACL injuries would be high. Integrating neurocognition into the existing biomechanical and neuromuscular approach could enhance our understanding of the complexity of ACL injury mechanisms.

METHODS

This was a secondary analysis of a previously published video analysis study of ACL injuries in professional men's soccer.[4] All noncontact ACL injuries from that cohort ($n = 57$)[4] were included in the current study. Of the 57 injury videos, 47 considered of sufficient quality to permit identification

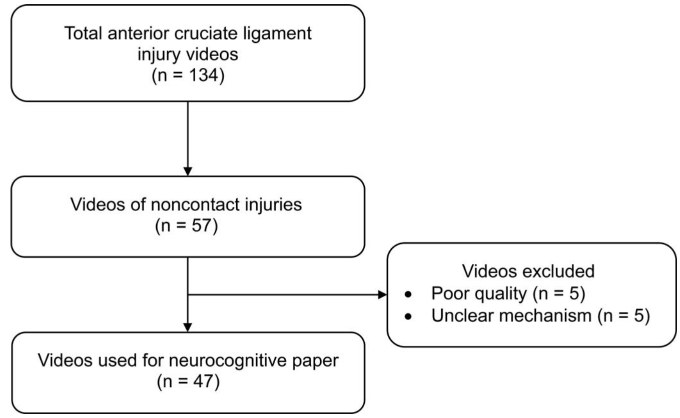

Figure 1. Detailed flowchart of the study.

of possible neurocognitive errors were included. A detailed study flowchart is presented in Figure 1. All videos were publicly available, data were treated confidentially, and no personal player information was accessed. Each video was downloaded to a personal computer and assessed using Kinovea (version 08.15). The video-analysis methods have been published[4,5] and are very similar to those of other researchers.[23,24] Boden et al[25] reported high reproducibility (intraclass correlation coefficient [ICC] = 0.95) for the assessment of lower extremity kinematics based on video analysis with a frame rate of 30 Hz. In sum, we believe that high-quality 3-dimensional video analysis offers a promising advance in our understanding of the mechanism of ACL injury.

In the first step, we documented all sequences independently to estimate the time of initial contact (IC) between the foot and the ground, as well as the assumed moment of the ACL tear, referred to as the *injury frame* (IF). Based on earlier findings, we considered the estimation of the IF to be within 40 milliseconds of IC, but each reviewer estimated the IC and IF.[4,23] The videos were independently evaluated by 4 reviewers (A.G., F.T., M.B., and F.D.V.), all of whom were experienced in sports medicine and orthopaedic rehabilitation practice. A series of views was used to determine the injury mechanism and situational pattern. The category of injury mechanism was *noncontact*, defined as an injury occurring without any contact (at the knee or any other level) before or at the IF.[4] The *situational patterns* described the situation leading to the injury. These were divided into defensive and offensive situations. The analyses were performed independently, with the reviewer blinded to the results of the other reviewers. The reviewers could view the video sequence in normal speed or slow motion back and forth, frame by frame, using the keyboard arrows. Every ACL injury video was cut to approximately 12 to 15 seconds before and 3 to 5 seconds after the estimated IF to accurately evaluate the playing situation that preceded the injury.

For the second step, the reviewers independently analyzed all videos again, using a checklist to determine whether neurocognitive errors were present. Before independent assessment of all videos, the reviewers met for a 2-day comprehensive consensus training session to discuss the neurocognitive error patterns related to noncontact ACL injury. In the event of disagreement among reviewers, the group discussed the item and reached consensus.[4,24]

For the neurocognitive analysis, we were interested in inhibitory control: motor-response inhibition and attentional

Table. Details of Injury Mechanism and Situational Pattern Classification According to a Predetermined Checklist

Item	Noncontact Anterior Cruciate Ligament Injuries, No. (%)		
	All (N = 47)	With Possible Error in Motor Response Inhibition	With Possible Error in Attentional Inhibition
Playing phase	Defensive: 30 (64) Offensive: 17 (36)	Defensive: 26 (100)	Offensive: 17 (81) Defensive: 4 (19)
Poor decision-making in relation to the context	Yes: 43 (91) No: 4 (9)	Yes: 24 (92) No: 2 (8)	Yes: 2 (10) No: 19 (90)
Deceiving action by the opponent before injury	Yes: 20 (43) No: 27 (57)	Yes: 19 (73) No: 7 (27)	Yes: 1 (5) No: 20 (95)
Did the player shift his attention away from the playing situation before the injury?	Yes: 21 (45) No: 26 (55)	Yes: 4 (15) No: 22 (85)	Yes: 16 (76) No: 5 (24)
If yes, to where or what was the attention drawn?	Not applicable	Ball: 4 (100)	Ball: 15 (94) Other: 1 (6)

inhibition.[12,16] As noted, *motor-response inhibition* was defined as the ability to stop unwanted and incorrect motor actions.[12] However, a delay exists between the presentation of a stimulus and generation of an appropriate motor response.[12] Based on previous studies, we operationalized the definition as a time frame of approximately 450 to 1200 milliseconds for soccer players to change the motor action (usually in response to a deceiving action).[26–28] A key feature in team ball sports is that players hide information (*disguise action*) or provide misleading cues (*deceptive action*) about their current intentions regarding their future actions.[29] An example of a disguised action is a soccer player trying to hide cues for as long as possible regarding playing the ball to the right or left side of the field.[29] An example of misleading cues is a head fake, in which a player passes to the right side while simultaneously looking to the left side. To score this response, an item on the checklist was added to determine whether a deceiving action occurred before injury. In that case, the Δ between the onset of the deceiving action and the IC was calculated. Good motor-response inhibition includes early selection in which goal-relevant information is actively monitored to optimally bias attention, perception, and action systems to facilitate response inhibition.[30] Hence, an error in motor-response inhibition was scored when a player demonstrated poor decision-making and approached the opponent with high speed, which reduced the ability to stop or change the intended action. Top-level male soccer players typically cover 10 to 13 km during a game and perform about 1200 discrete bouts of activity change every 4 to 6 seconds; 150 to 250 brief, intense actions; and 200 to 400 m of sprinting (distance covered >7 m/s).[31–33] They also perform numerous high-intensity accelerations and decelerations (8 times as many accelerations as reported sprints per match).[34]

Selective attention was defined as a player focusing on a particular situation on the field for a certain period.[12] An error in attentional inhibition was scored if the player shifted his selective attention away from the relevant task to irrelevant stimuli on which he had no direct influence, such as the ball or playing situation. A relevant stimulus can aid in correct performance. A high-level player is able to block out irrelevant cues and pay selective attention to the cues that are deemed relevant. Any irrelevant cues can be termed *distraction*, and this loss in attentional focus can lead to poor performance. Specific to our study, loss of attention to the task at hand (eg, looking at the ball rather than allocating attention to landing from a jump) may cause spatial unawareness and subsequently disturb neuromuscular control of the landing.

Statistical Analysis

The response variables assessed were categorical and continuous variables. We analyzed (1) the frequency (number) of neurocognitive errors associated with inhibitory control, including motor-response inhibition (number) injury events when approaching an opponent with high speed and attentional-inhibition (number) injury events when the player shifted attention away from the relevant task to irrelevant stimuli (ball, playing situation, or other); (2) the timing (milliseconds) of events, including the time of IC, time of IF, and time of deceiving action; and (3) the frequency (number) of injury events per playing-condition characteristic, including playing position (offensive or defensive), player action (pressing, heading, kicking, or other), and deceiving action of the opponent (yes or no).

For the interrater agreement, we calculated Fleiss κ coefficients and ICCs (using a 2-way random model) for the categorical and continuous variables, respectively. For the interrater agreement, we calculated Fleiss κ coefficients and 95% CIs. Fleiss κ was interpreted as *poor* (<0.40), *fair to good* (0.41–0.75), or *very good* (0.75–1.00), with >0.75 used as the cutoff for the clinically acceptable measure of interrater agreement.[35] To determine interrater reliability, ICCs using a 2-way random model were calculated. The ICC values (Cronbach α) were interpreted as *poor* (<0.50), *moderate* (0.50–0.74), *good* (0.75–0.89), or *excellent* (0.90–1.00).[36] We set the α level a priori at .05. Data were analyzed using SPSS (version 26; IBM Corp).

RESULTS

A total of 47 noncontact ACL injuries were analyzed (Table). Injuries consisted of 26 (55%) to the right and 21 (45%) to the left knee, with 36 primary injuries, 6 contralateral injuries, and 5 ipsilateral reinjuries. The situational pattern of ACL injuries was classified as *pressing* in 26 cases, *regaining balance after kicking* in 7 cases, *landing from a jump* in 4 cases, and *other* in 10 cases.

The 2 neurocognitive factors assessed were motor-response inhibition and selective attentional errors. Of 30 ACL injury cases in which the player made a defensive action, 26 were related to a pressing action. Of those 26 cases, the opponent made a deceiving action in 19 cases (73%) that led to the ACL injury in the defender, suggesting poor motor-response inhibition. A common noncontact ACL injury pattern attributed to an error in motor-response inhibition is presented in Figure 2. Among 21 ACL injuries, an attentional inhibitory

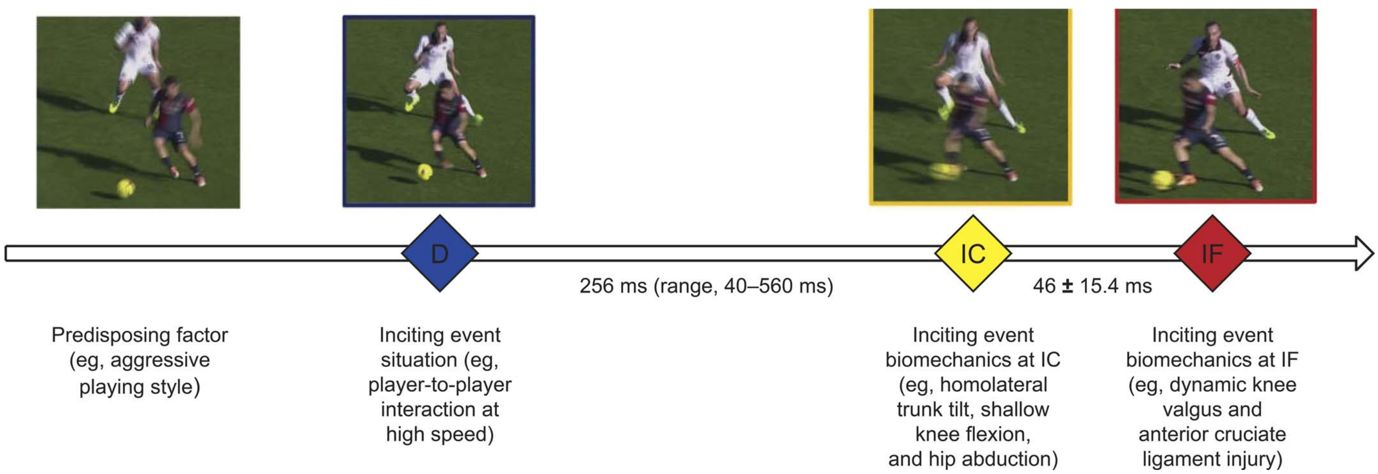

Figure 2. Example of the cascade of events leading to a noncontact anterior cruciate ligament injury attributed to motor-response inhibition errors. Abbreviations: D, deceiving action; IC, initial contact; IF, injury frame.

error was present in 16 cases (76%), and this was related to an attentional error on the ball in 15 cases. An error in attentional inhibition is illustrated in Figure 3.

The mean estimated time from IC to IF was 46 ± 15.4 milliseconds. The mean time from the deceiving action to IC was 256 milliseconds (range, 40–560 milliseconds), with 15 cases having an interval of $<$300 milliseconds (Figure 4).

The Fleiss κ measure of agreement among the 3 raters was very good for all items, except for poor decision-making, which showed fair to good agreement (Fleiss $\kappa = 0.71$; 95% CI = 0.55, 0.88). The other Fleiss κ values were as follows: playing situation before injury = 1.000 (95% CI = 0.83, 1.16); player action before injury = 0.95 (95% CI = 0.85, 1.05); deceiving action of the opponent = 1.00 (95% CI = 0.83, 1.16); and external distraction = 0.79 (95% CI = 0.63, 0.96). Interrater reliability was excellent. The ICC Cronbach α was 1.00 for IC, 0.99 for IF, and 1.00 for deceiving action.

DISCUSSION

Our main finding suggested that neurocognitive errors may have contributed to the events leading up to the ACL injury. Of 47 noncontact ACL injuries, 26 were related to a pressing-type injury, and of those, the opponent made a deceiving action in 19 (73%), suggesting poor motor-response inhibition of the defender. A total of 21 ACL injuries occurred during offensive (81%) or defensive (19%) actions. In these cases, 16 players (76%) moved their attention away from the playing situation, indicating attentional inhibition. All neurocognitive errors were identified by the 3 raters with very good agreement except for poor decision-making, which showed fair to good agreement. Therefore, errors in motor-response inhibitory control and attentional inhibition were commonly observed during noncontact ACL injury events in professional male soccer players.

Motor-Response Inhibitory Errors During Pressing

These results expand our understanding of the contribution of neurocognitive errors to the most frequent noncontact ACL injury mechanism reported in soccer: pressing with a defensive action.[4] Errors in motor-response inhibitory control are mainly expected to occur during pressing situations. Pressing may be considered the proxy to trigger impulsive responses from the pressing defender. In support, a deceiving action by the opponent was an initiating factor

Figure 3. Example of an error in attentional inhibition. After the ball loss, the player focuses solely on the ball without paying sufficient attention to planting the left foot. The loss of spatial awareness disrupts motor control. A, Attempt to pass the defender. B, Ball intercepted by defender. C, Visual attention directed at the ball and not at the foot landing. D, Visual attention at the moment of anterior cruciate ligament injury.

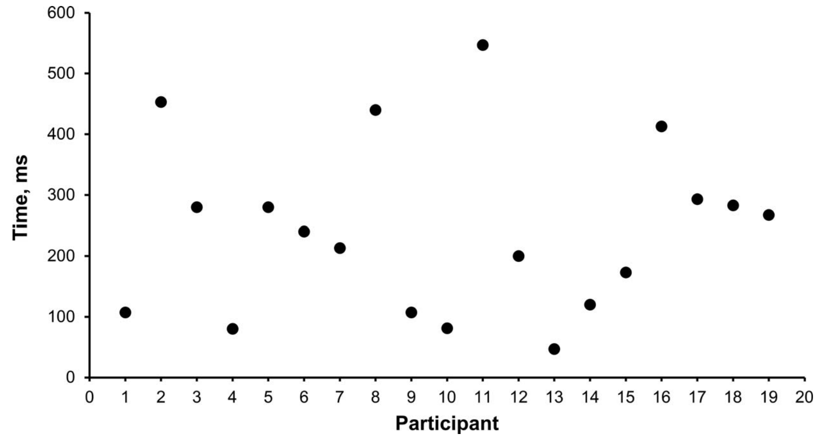

Figure 4. Scatterplot showing the time interval between the deceiving action and initial contact for all 19 affected players.

that led to a noncontact ACL injury in 19 cases (73%). The Δ between deceiving action and IC was a mean of 256 milliseconds. These temporospatial demands suggest that neurocognitive load could contribute to ACL injuries. Elite soccer players are true masters in making deceptive movements, and opponents must be able to predict the outcome of these deceptions. This means the defender must react very quickly, inhibit an already initiated response and plan, and execute a new movement, all within this short time window. In a meta-analysis, Giesche et al[13] reported that unplanned actions may result in at-risk knee biomechanics. More specifically, in laboratory movement studies, the median time was 500 milliseconds for the presentation of a stimulus indicating a change of direction. Compared with planned movements, the unplanned movements resulted in higher knee-abduction and tibial internal-rotation moments.[13]

The complexity and temporal pressure under real-world conditions as assessed in our work were arguably higher than for these movements in laboratory studies. Temporal pressure on players can push them to make inaccurate decisions at a rate double that when demand is low.[8] Our findings demonstrated that temporal pressure affected perceptual-motor processes. The extreme time constraints evident in soccer, coupled with the fact that opponents can disguise their intentions or present deceptive information, and the contextual information highlight the complexity for a player making judgments.[37]

Expert athletes are superior to novices at using advance visual information—specifically, kinematic information emanating from an opponent's motion—to inform their decisions.[38] Regarding perceptual skills, expert rugby players are more attuned to honest kinematic information that specifies future running direction, whereas novices are more attuned to deceptive signals.[39] Soccer players are immersed in a rapidly changing, unpredictable, and externally paced environment. In such an open-skill sport, perception-action coupling is crucial, as players must perceive their own action opportunities as well as those of opponents and teammates before deciding on a movement solution, all of these often under time pressure.

Perception of essential information from the rapidly changing playing environment is key to effective performance in soccer players, who must then process this information correctly to select the most appropriate response. Any deficit or delay in sensory or attentional processing may contribute to an inability to correct errors in complex coordination, resulting in knee positions that increase the ACL injury risk.[40]

Whether top-level athletes exhibit enhanced abilities in both proactive and reactive inhibitory control is not well understood. These 2 components refer to distinct temporal dynamic modes of motor-response inhibition.[41] *Proactive inhibition* refers to a form of early selection in which task-relevant information is actively monitored to optimally bias attention, perception, and action systems to facilitate response inhibition as needed; it is used to strategically restrain actions in preparation for stopping (eg, slowing down while approaching an attacker in possession of the ball). By contrast, *reactive inhibition* is a late correction process, triggered by external stimuli (eg, responding to the deceiving action of the opponent). Under proactive control, the change of movement direction is preactivated, rendering the actual change easier when it is needed.[30,41] Thus, proactive inhibition might be the key to the ability to refrain from behavioral tendencies in anticipating the need to stop, such as when an athlete has to adapt to cues signaling different levels of motor cautiousness.

Attentional Inhibition

Of those ACL injuries related to attentional errors, 94% occurred while the player's attention was directed at the ball. This outcome was similar to that in previous research in which ACL injuries commonly occurred while the injured player's attention was on the basketball rim, opposing player, or ball.[42] This externally directed attention may have resulted in attention being taken away from temporospatial awareness of the direction of the injured player's movements, possibly compromising motor control and leading to ACL injury. Supporting this finding, investigators have reported that athletes attending to a ball during the side-cut maneuver displayed greater peak hip abduction and hip abduction at IC, greater peak knee-flexion angle, and greater knee-abduction moment.[43]

Soccer players need to determine which of the many stimuli in the complex environment require selective or sustained attention, enabling them to ignore situations that are not important. As noted, *selective attention* is defined as focusing on a particular situation on the field for a certain period.[12] Lacking the capability to redirect or sustain attention from 1 stimulus to the next may result in a loss of spatial awareness and disrupt motor control.[44] An attentional error occurs when the player shifts the selective attention away from the task or goal. Expert soccer players show more flexible search strategies than novices, depending on the nature and temporal constraints of the task and the number of relevant information sources involved (individual or group offensive or defensive plays).[45] Elite soccer players are better able to rapidly shift attention, coupled with gaze, to sequentially absorb information from several relevant sources.[46]

Implications for ACL Injury Mechanism

Sport performance is a combination of physical and perceptual-cognitive factors governing athletes' ability to take appropriate actions to meet their goals in sport situations.[47] Two essential principles related to performance should be kept in mind. First, human performance is constrained by the context and conditions in which it takes place (the situation), and second, the perceptual-cognitive processes related to performance center on decision-making based on goal-directed coordination of controlled actions. This means that athletes' ability to accomplish goals and coordinate movements is shaped by the circumstances of the situation in which they perform.

Expert performance in sport is a combination of physical and perceptual-cognitive skills that address the ability of an athlete to locate, identify, and process this information and coordinate appropriate actions (ie, decision-making).[48] The dual-system theory assumes that 2 decision-making systems exist.[49] System 1 is intuitive and automatically modulates the perception and memory processes, thereby generating an almost immediate response. Conversely, the deliberate thought process of system 2 is slower and requires more time and cognitive effort for decision-making.[50] The 2 systems are complementary. Thus, in soccer, intuitive responses seem to allow players to make faster decisions with less cognitive effort in an environment where time is limited and a determining factor.[46] In this context, quick and intuitive decision-making takes into account the ability to optimize visual search strategies (the perceptual process) and prioritize neurocognitive skills for information processes and subsequent decision-making.

Professional soccer players are frequently immersed in situations that require intuitive decision-making, often at high speeds. These players have performed such actions thousands of times throughout their careers without any injury occurring from them. Usually, athletes cope with sport-specific situational demands and adjust their attention to focus on the appropriate environmental cues so they can plan movements accordingly. However, during high-speed, complex sport maneuvers, the cognitive capacities of athletes may be unable to reconcile the overabundant somatosensory information with the biomechanical demands of a rapidly changing physical environment. Unexpected joint loads during a sudden change occurring from an unplanned movement may be inconsistent with the brain's internal model of anticipated events. Such is the case for noncontact ACL injuries due to incorrect, preprogrammed knee-stiffness–regulation strategies and subsequent movement errors as potential consequences of neurocognitive errors.[10]

In addition, high-risk behavior may emerge in athletes due to poor inhibition. Schwebel and Plumert[51] found that athletes with poor motor-response inhibition overestimated their ability and were more prone to injury. Athletes who have (1) a low perception of risk[52] or (2) high self-efficacy and overestimate themselves are more likely to attempt high-risk behavior and therefore expose themselves to greater risk of injury.[53] These studies show that the ACL injury risk is related not only to biomechanical and neuromuscular factors but also to neurocognitive factors. Anterior cruciate ligament injury-prevention programs are based on linear relationships between the presence of risk factors and the actual occurrence of the ACL injury.[54] Bittencourt et al[55] proposed a complex systems approach to enhance the understanding of injury cause. Briefly, this approach highlighted a nonlinear interaction between risk factors from different dimensions (biomechanical, psychological, neurocognitive, physiological, and training characteristics) as a web of determinants and how these may result in injury.[55]

From an ACL injury-prevention standpoint, our findings may suggest that soccer players should delay their response until sufficient kinematic cues emerge from the opponent in relation to the contextual information to reduce the risk of sustaining an ACL injury. However, this could affect the player's performance if action is delayed. To optimize the balance between reducing the injury risk and maintaining performance, injury-prevention exercises should include neurocognitive load.

In sum, a growing body of literature indicates that neurocognitive factors may influence an athlete's risk of ACL injury.[21,56–58] Athletes have demonstrated alterations in lower extremity biomechanics during drop-landing trials that incorporated temporal constraints on decision-making compared with standard drop-landing trials.[56,57] Attending to a ball while sidestep cutting resulted in more trunk extension and less lateral trunk flexion toward the cutting direction.[59] Researchers[60] have reported that athletes' perceptual and decision-making ability for agile maneuvers can be trained. In other words, an athlete's ability to identify kinematic cues from their opponents can be developed.[60]

Limitations

Our study had limitations. Only motor-response inhibition and selective attention were inferred from video analysis of noncontact ACL injuries. This is a reduction of core executive functions. Although not examined in this investigation, working memory may also play an important role in the injury mechanism, as it is intricately related to inhibition. In complex situations, certain players may not be able to distinguish the irrelevant from the relevant information. Subsequently, they clutter the capacity of their working memory, which may affect their movement control.[15] In addition, we did not use eye tracking to identify where the attention of players was directed. However, point of gaze does not entirely reflect the athlete's allocation of attention, as covert attention to cues in the visual periphery is not detected by eye-movement registration systems.[61] Finally, cognitive function was not assessed with questionnaires or computerized tests. Nevertheless, our results may serve as a framework for future authors to evaluate an association between neurocognitive function and actual ACL injuries. Previous researchers[56] determined that athletes with lower baseline cognitive function were more likely to experience noncontact knee injuries during the season than those with higher-level cognition.

CONCLUSIONS

Mechanisms of ACL injury have been primarily viewed from biomechanical and neuromuscular perspectives. We found that errors in motor-response inhibitory control and attention inhibition were common during noncontact ACL injury events in professional male soccer players. The interrater agreement to detect neurocognitive errors in general was very good.

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