Emergence of contact injuries in invasion team sports : an ecological dynamics rationale

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CURRENT OPINION

Emergence of Contact Injuries in Invasion Team Sports: An Ecological Dynamics Rationale

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Abstract The incidence of contact injuries in team sports is ~~considerable~~considerable, and ~~to adopt preventive measures,~~ injury mechanisms need to be comprehensively ~~understood.~~understood to facilitate the adoption of preventive measures. In Association Football, evidence shows that the highest prevalence of contact injuries emerges in ~~1 vs. 1~~one-on-one interactions. However, previous studies have tended to operationally report injury mechanisms in isolation, failing to provide a theoretical rationale to explain how injuries might emerge from interactions between opposing players. In this position ~~paper~~paper, we propose an ecological dynamics framework to enhance current understanding of behavioural processes leading to contact injuries in team sports. Based on previous research highlighting the dynamics of ~~performer-environment~~performer–environment interactions, contact injuries are proposed to emerge from symmetry-breaking processes during on-field interpersonal interactions among competing players and the ball. Central to this approach is consideration of candidate control parameters that may provide insights on the information sources used by players to reduce risk of contact injuries during performance. Clinically, an ecological dynamics analysis could allow sport practitioners to design training ~~sessions,~~sessions based on selected parameter threshold values as ~~primarily~~primary and/or secondary preventing ~~measures,~~measures during training and rehabilitation sessions.

~~Key points:~~

- Key Points

~~An ecological dynamics approach proposes how information constrains coordination tendencies between competing/cooperating players and the ball leading to changes in contact injury risks.~~

Future research needs to consider which information sources a performer needs to become perceptually attuned to as affordances (possibilities for action) to decrease injury risks.

~~Based on identified control parameter threshold values, training and rehabilitation sessions can be designed to encapsulate specific affordances which players may learn to become attuned to in order to prevent entering high-risk injury situations.~~

Background

Team sports encompass complex performance environments in which competing players are exposed to injury risks. For instance, in ~~elite level~~elite-level football, medical reports indicate that between ~~44% – 59%~~44 and 59 % of all acute match injuries are caused by contacts between opposing players during tackling and collisions [1]. Indeed, there has been an increase in the number of between-opponent contacts (heading and tackling duels) in the last decade [2].

van Mechelen ~~and colleagues (1992)~~et al. [3] postulated that measures to prevent sports injuries do not stand by themselves, rather, they form the 'sequence of ~~prevention' [3].~~ prevention'. After the magnitude of an injury problem is established in terms of incidence and severity, it is critical to identify risk factors and mechanisms of injury. The causation model of injury occurrence suggests that the mere presence of intrinsic (player characteristics) and extrinsic (environmental characteristics) risk factors is not sufficient to produce an injury [4]. Rather, the sum of intrinsic and extrinsic risk factors and the*interaction* between them promote the likelihood of an injury emerging [4]. ~~In team handball,~~ Olsen et al. [5] reported ~~that~~that, in team handball, female players (sex as the intrinsic factor) are more prone to an anterior cruciate ligament (ACL) injury when playing on hard pitch surfaces (playing surface as the extrinsic factor) than male players (for a review ~~see:~~see Alentorn-Geli et al. [6]). Based on this finding, studies have attempted to investigate how male and female players perform cutting actions, such as rapid changes of direction or jump landings, with the aim of determining which predictors of risk place the knee of female players in a vulnerable situation when ~~shoe-floor~~shoe–floor friction is high [7].

To date, studies investigating situations leading to injuries have provided important ~~information, which~~information that has helped to develop a deeper understanding in sports medicine and injury prevention, leading to changes in the laws of the game and strict enforcement of the rules by referees, with the aim of ensuring player safety [8–10]. For example, in 2006, on the basis of past findings, the International Football Association Board gave referees the authority to severely sanction fouls that were recognised to be dangerous, issuing a red card for players who tackled from ~~behind,~~behind or used an intentional elbow to the head [11]. These findings were derived from notational analysis, which is a useful technique for operationalising a variety of issues in a range of sports [12–14] as researchers can repeatedly and objectively record and assess the frequency of injuries and incidents [8–10,15–19]. For example, the Football Incident Analysis ~~(FIA),~~(FIA) was developed [20] and administered [15,16] in order to describe playing situations that lead to injuries and ~~high risk~~high-risk incidents. Findings indicated that most injuries resulted from ~~1 vs. 1~~one-on-one player interactions when a tackling player approached an opponent from the side. In addition, during most events the (to be) injured player seemed to be unaware of the opponent challenging him/her for ball possession [15,16,20].

Current ~~research limitations~~Research Limitations

The notational analysis studies described have tended to focus on operationally cataloguing playing situations that lead to injuries. A potential limitation is that these methods are often lacking two of Kipling's[1] servants, ~~that is:~~i.e. how and why do particular behaviours lead to injuries [21]. To address this limitation, we propose that an ecological dynamics framework could further understanding on the role of ~~performer-environment~~performer–environment interactions in sport injury aetiology, impacting on ~~prevention,~~both prevention and the design of rehabilitation programmes [21–23]. We consider how an ecological dynamics approach could enhance current methodology by providing a theoretical rationale to explain*how* players (inter)act relative to the movement of other players and the ball prior to injury onset. An injury in team sports is the result of a complex interaction between internal and external risk factors [5]. Thus, it is necessary to develop an in-depth understanding of the different constraints that emerged across different timescales, leading to the emergence[2] of injuries during ~~performer-environment~~performer–environment interactions [24]. This approach contrasts with current top-down[3] approaches in which sport governing bodies currently aim to protect players by modifying laws of the game or allowing stricter enforcement by match officials.

In existing research, Arnason et al. [25] assessed the effectiveness of a video-based awareness ~~program~~programme on contact injuries in a randomised controlled trial. The researchers introduced a ~~15-minute~~15-min presentation with information on the risk of playing elite football, typical injuries, and their mechanisms. The players worked in groups while analysing video sequences to

[1]Kipling servants in past studies include description ~~of:~~of who ~~(e.g.,~~(e.g. the player), what ~~(e.g.~~(e.g. the player's action), where ~~(e.g.,~~(e.g. the pitch location) and when ~~(e.g.,~~(e.g. the match time ~~and-or~~and/or match ~~score line)~~score line) injuries ~~happened~~happened.

[2]Emergence of contact injury is understood as a process in which a stable dyadic system state without injury suddenly ~~change~~changes into a de-stabilised state with an injury to either or both of the competing players.

[3]Top-down approach refers to the assumption that predictive sets of responses acquired*a priori* will lead to a particular outcome (an injury) during actual playing conditions.

develop preventive strategies. During the season, team physical therapists recorded all acute injuries, while coaches recorded training exposure. Injury incidence was compared between groups and between previous seasons for teams receiving the intervention (experimental group) and for a control group. No significant differences were observed in injury incidence between the intervention and control ~~group.~~groups. Furthermore, there were no differences between injury incidents in past ~~seasons, compared with the~~seasons and annual injury incidence when the intervention was employed. The researchers indicated that, even when the players appeared to interpret the main injury mechanism on video, such performance did not transfer onto the pitch [25]. Recent research [26] in the movement science literature indicates that video training in isolation may not facilitate sport performance, as perception-only video observations are unlikely to support players in developing the necessary links with action ~~(information-movement~~(information–movement couplings) that underpin skilled performance [27]. Moreover, research indicates that prior to the onset of non-contact injuries, a contact often occurs between a player and an opponent that, in turn, leads the injured player to produce a sudden change of movement [28]. Due to the likely changes that will occur in movement control following this initial contact, it is possible that a subsequent injury will be a (direct) consequence of changes in a player's ability to exploit the necessary ~~information-movement~~information–movement couplings that support reduction of injury risk. As ~~player-opponent~~player–opponent interactions are important for understanding injury mechanisms in team sports, past studies that have failed to study such performance aspects prior to ~~contact[~~contact [2,10,15,16,29–31], and behaviours in non-contact [13,28,32] injuries, tend to provide limited understanding on the ~~information-movement~~information–movement couplings that players exploit in order to reduce injury risk.

In sum, present methodologies aimed at alleviating injury risks in team sports tend to emphasize operational ~~preventative~~preventive measures that only engage players in an indirect manner. That is, players are required to adapt to the constraints of new laws, or learn to avoid injuries without the opportunity to ~~"actively"~~'actively' learn to exploit the most useful information sources for the reduction of injury risk. As we outline below, players need to be able to perceive which actions*afford* a higher injury ~~risk,~~risk so that they can regulate movements to avoid them.

Ecological Dynamics

In studies of complex systems in sport [33], an increasing number of researchers have drawn on an ecological dynamics approach as a theoretical explanation of the relationship between adaptive behaviours[4] and coordination between performers [23]. Ecological dynamics has its origins in ecological psychology and dynamical systems theory. Ecological psychology postulates that behaviour emerges as a function of interactions between an individual ~~(i.e.,~~(i.e. an athlete) and his/her performance environment [34] (for other ecological psychology schools that were influenced by Lewin's ~~(1951)~~1951 seminal formula B = f(PE)[5], see ~~Araújo,~~Araújo and Davids [35]). The interactions of a ~~player-environment~~player–environment system rely on a constant exchange of energy surrounding the players and objects in the environment (e.g. light energy reflected from other players, ball, and playing surface) [36]. According to Gibson ~~(1966),~~[34], movement causes changes to energy ~~flows~~flows, which provide specific information to players on the properties of the environment [36]. By acting in the environment, a player can perceive affordances (possibilities for action) that enable him or her to gain knowledge of the environment [36], following a circular causality between perception and action. Ecological psychology predicates that players can exploit information from the surrounding distribution of energy to specify action-relevant properties of the performance environment [36]. In essence, players with limited abilities to act on the environment will not only have fewer possibilities to change the structure of the environment, but will have less accuracy in their control of movement, which could enhance injury risk [37].

Drawing on the previous ACL example, excessive joint ~~laxity~~laxity, prevalent among female players [6], may provide proprioceptive information[6] that affords excessive knee valgus rotation. In this sense, the information perceived by the (to be) injured player in specific ~~1 vs. 1~~one-on-one game situations invites specific actions that may trigger the inciting event (i.e. adaptive behaviours leading to action). Therefore, the behaviour leading to a cutting movement may be analysed as a function of the player being exposed to injury and the spatio-temporal interactions ~~B = f (P~~$B = f(P_{injured\text{-}player}$ ~~* E~~ $\times E_{opponent\text{-}player})$ that emerge under specific task and environmental constraints of playing on a particular pitch surface (e.g. natural grass vs. on artificial turf). Such an approach emphasises the need to consider which information source a performer became perceptually attuned to as an affordance that prevented emergence of excessive knee valgus rotation. This notion is based on the idea that performers learn how to exploit specific information sources in the performance environment to constrain inherent self-organization tendencies in

[4]Adaptive behaviour encompasses perception, ~~decision-making~~decision making, and action functions.
[5]Where adaptive behaviour (B) is a function between the person (P) and his or her environment (E) interaction.
[6]Afferent signals that travel to the central nervous system (CNS) from mechano-receptors located in the ~~joints~~joints, among other places.

forming functional*multi-joint movement synergies*[7] that prevent risky actions emerging (e.g. valgus knee rotation). This theoretical proposition emphasises the need to design training programmes that will allow players to perceive affordances that will invite behaviours leading to a reduced injury risk [38]. It is contrary to current schools of thought [7], which mandate an approach that investigates differences between how male and females perform cutting actions, in order to determine how extensive joint laxity places the female knee at risk of knee valgus rotation. Traditionally, an adopted behaviour leading to an inciting event is formally analysed to identify intrinsic and extrinsic risk factors B = f (P$B = f(P_{gender}$* E $\times E_{floor\ surface})$. Arguably, such perspectives seek to gain insight about how therapeutic modalities (e.g. stability and proprioceptive training) might reduce the risk of a player to injury. Based on those intervention,interventions, a performer is assumed to acquire neuromuscular control*a priori* that will be triggered during actual playing conditions and there is little consideration about the process in which information guides*emergent behaviours* during performance. For example, neuromuscular training interventions designed to prevent ACL injuries aim at increasing the magnitude of stabilizing forces that are required to be generated to resist the destabilising load applied to the knee prior to ligament damage [39]. However, these training programs neglect to consider the process in which affordances may be perceived by the player for generating required movement synergies (i.e. the required resistant forces) for reducing the risk of ligament injury.

Past studies have demonstrated that patterns of movement coordination emerge through the self-organised, spatial-temporalspatial–temporal interactions of players under specific task and environmental constraints [40–42]. In dynamical systems theory, self-organisation is a principle used to explain how order spontaneously emerges among different system components (e.g. between different players and between players and ball, for a review see:see McGarry et al. [43]). An ecological dynamics approach has revealed how interactions between team players and the ball are constrained by information sources in the performance environment. These coordination tendencies lead to the emergence of patterns of stable behaviours (i.e.,(i.e. movement co-ordination within and between players) and variable actions (i.e.,(i.e. changes in movement coordination within and between players). Transitions between states of system stability and variability can be described by studying order parameters (i.e.,(i.e. a collective variable that synthesizes the relevant coordinated parts of the team game system) [41]. For example, Araújo et alal. [44] modelled an attacker-defenderattacker–defender dyad system as an order parameter in Rugby.rugby. This order parameter was computed as the angle connecting a vector between the players and the try line. The order parameter was based on the notion that an attacking player with the ball aims to de-stabilise the dyadic system formed with an immediate defender (defender positioned between the attacker and the try line),line) by attempting to move past an opponent, taking the most direct path to the try line for creating scoring opportunities. This order parameter may describe the dyadic system coordination tendencies. That is, a symmetry between sub-system componentcomponents (player or opponent) may be indicated when either attacker or defender locomotes towards the other. Player'sA player's movement pattern may be maintained until a specific phase in which either playersplayer will attempt to de-stabilize the system, causing a symmetry break in the state of the system, where one of the players gains an advantage for achieving the task goal (e.g. passing a defender for scoring or preventing the attacker forfrom doing so)[so) [44]. Control parameters are variables that influence order parameters and drive the dynamic system through different states. Studies of order-controlorder–control parameter interactions have identified how and why behaviours emerge in competing dyadic systems [41]. Past research has demonstrated that control parameters of interpersonal distance and relative velocity regulate a performer's actionsactions, leading to different performance outcomes [42]. For example, in rugby unionunion, results revealed specific threshold values for interpersonal distance of less than 4 m4 m, coupled with an inter-personal velocity of at least 1 m • s1 $m \cdot s^{-1}$, at which an attacker passes a defender [41]. Importantly, only below this inter-personal velocity did physical contact tend to emerge between attackers and defenders, likely increasing the risk of injury [41].

With reference to the dynamics of performer-environmentperformer–environment interactions, contact injuries are proposed to emerge from symmetry-breaking processes during player-opponent-ballplayer–opponent–ball interactions [45]. For example, based on the model of Araújo et alal. [44], it may be expected that, when a tackle is made by a defender, the contact that may emerge provides a greater risk of injury to one of the sub-system components (i.e. either the dribbling attacker or the defender who is making the tackle). A potential injury model may propose that, when contact emerges, with an unsuccessful tackle (i.e. attacker continues to dribble past the defender),defender) the player susceptibility to injury will be lower. However, according to the existing model, when contact between an attacker and the defender emerges during a tackle situation and the ball is lost, there is a higher risk of injury (based on the higher forces typically involved in dispossessing an attacker). When an attacker dribbles past the defender, avoiding contact, the system may still be de-stabilised, but with a lower injury risk. The Araújo et alal. [44] model may provide a testable framework for predicting levels of injury risk in football dyads since it may describe system symmetry (i.e.

[7]The CNS exploitexploits self-organization in a movement system to form temporarily assembled muscle complexes based on specific information picked-uppicked up by the performer.

when the players were approaching) and symmetry-breaking (when physical contact emerged or when attacker passed a defender without any physical contact).

The ideas signify that the importance of studying the emergence of injuries in team sports are predicated on analysing spatio-temporal positional data[8] of players during interpersonal interactions that lead to high and low injury risk situations. A key research task is to identify order and control parameters (especially critical threshold values) that might lead a dyadic system towards a performance region where a player remains at low or high risk of injury. Once this empirical programme of work has been completed, practice and training environments in team sports can be designed to encapsulate specific information sources as affordances to which players need to become attuned ~~to~~ in order to prevent a player in a competing dyadic system entering a phase transition and increasing the probability of injury emerging. An important aspect to consider here is that by converging on a specific threshold value of a key ~~spatio-temporal~~spatio–temporal variable, a player might become exposed to affordances that invite the emergence of specific actions. Identified control parameter values might explain how competing dyadic systems enter such dysfunctional states. Despite the need for more research on these compelling theoretical ideas, there is some available support in practical data on injury risk in ~~high performance~~high-performance team sports. For example, FIA findings evidence that the attention of an injured player is often predominantly directed to the ball prior to injury [15,20]. From an ecological dynamics perspective, at specific threshold values of key performance parameters ~~(e.g.,~~(e.g. for variables such as interpersonal distance and displacement velocity), the attention of an at-risk player should be educated to a spatio-temporal variable, such as time-to-contact information or*tau* to specify the time to contact of an oncoming opponent attempting to tackle [46]. With this in mind, there is a need to identify the ~~spatio-temporal~~spatio–temporal variables that result in functional and dysfunctional behaviours that are likely to increase injury risk.

Identification of control parameter thresholds can provide the informational basis for the emergence of actions to avoid contact injuries. In ecological dynamics, it is proposed that the*education of attention* of performers to those parameter thresholds[9] during practice sessions can improve the ~~decision-making~~decision making of players to reduce injury risk. For example, during training in small-sided games, players can learn to pick up affordances ~~which~~that invite specific actions that achieve intended performance goals and minimise the possibility of players entering high-risk situations [42]. Hristovski ~~and colleagues (2006)~~et al. [47] showed ~~that~~that, during practice, the actions (punch selection) of boxers were constrained by the distances they stood from the ~~bag [47].~~ bag. Either side of this critical region, behaviours were constrained to emerge in limited areas of the ~~perceptual-motor~~perceptual–motor workspace. These results indicate that players can learn to utilise information to adapt emerging behaviours and achieve task goals ~~efficiently, effectively,~~efficiently and effectively and avoid undue injury risk. However, at other regions of the performance workspace, players can be constrained to perform ~~actions, which~~actions that may be more risky or conservative (with respect to achieving team performance goals), decreasing or enhancing their exposure to injury risk. Individuals can be influenced to adapt to specific performance regions by adhering to particular coach instructions, depending on the competitive needs of the team (as illustrated by the work of Cordovil et al. [48] on basketball dribbling). This interpretation of the dynamics of affordance perception during injury avoidance has received support from the work of Hristovski et ~~al~~al. [49~~]~~], identifying how functional adaptability of action was constrained by perception of 'harmability' or injury risk.

Conclusion

In this position paper, we have considered an ecological dynamics approach for the study of*emergent* actions and injury prevention in team games. This approach emphasizes the need to explore how ~~information-movement~~information–movement couplings regulate the emergence of affordances for preventing contact injuries during team game performance. There is a need for an extensive programme of empirical work to examine the feasibility of implementing an ecological dynamics perspective on emergence of injuries in team games. As a result, coaches and sports clinicians may be able to re-design affordances in team sports training programmes based on established analysis of values of variables identified as control parameters in dyadic system interactions. In addition, incorporating affordances into training may be implemented as part of player rehabilitation, in order to safely bring an individual back to full playing ~~capacity,~~capacity with enhanced knowledge about the environment. Ecological dynamics may prove to be a pertinent approach for discovering why players are injured and how to prevent contact injuries from emerging in team sports.

[8] Currently only available in ~~2-dimensional coordinates~~two-dimensional coordinates.
[9] It is likely that threshold values are individual for each dyad and may change within ~~individual~~individuals during the playing ~~season~~season.

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