Analysis of circumstances leading to injuries in elite football players

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A thesis submitted in partial fulfilment of the requirements of Edinburgh Napier University, for the award of Doctor of Philosophy

April 2023

Abstract

Understanding injury mechanisms is key to developing prevention strategies. Information concerning injury mechanisms can be obtained by analysing the sport-specific activities during which injuries occur (i.e., inciting circumstances). Despite the recognition that inciting circumstances are crucial for the understanding of mechanisms of injuries and for the development of injury prevention strategies, there are no summaries of evidence currently available, therefore a systematic review was performed to analyse and summarise the available literature on inciting circumstances in football. From the systematic review it emerged that the studies currently available in the literature used different systems and terminology to report the inciting circumstances, which made summarising the literature and providing information for the development of prevention strategies difficult. Therefore, it seemed essential to develop a standardised classification system to analyse and report inciting circumstances in football which could be used both in research and in professional settings. Ten practitioners and researchers with experience of working in elite football and of conducting research on injury were involved in a modified Nominal Group Technique and such a classification system was developed. Subsequently, the system was utilised to analyse inciting circumstances leading to injury in elite football. A retrospective observational study was conducted to analyse data previously collected by one elite European football club. Inciting circumstances were analysed using video-analysis and GPS and reported using the classification system previously developed.

Publications associated with this research

- Aiello, F., Impellizzeri, F. M., Brown, S. J., Serner, A., & McCall, A. (2023). Injury-Inciting Activities in Male and Female Football Players: A Systematic Review. Sports medicine (Auckland, N.Z.). https://doi.org/10.1007/s40279-022-01753-5
- Aiello, F., McCall, A., Brown, S. J., Serner, A., Fortington, L. V., Huurman, S. A. E., Lewin, C., Nagao, M., O'Brien, J., Panossian, A., Pruna, R., Ramos, G. P., Whalan, M., & Impellizzeri, F. M. (2023). Development of a Standardised System to Classify Injury-Inciting Circumstances in Football: the Football Injury Inciting Circumstances Classification System (FIICCS). Sports medicine (Auckland, N.Z.), 10.1007/s40279-023-01857-6. Advance online publication. https://doi.org/10.1007/s40279-023-01857-6

Author declaration

This thesis is submitted in partial fulfilment of the of the requirements of Edinburgh Napier University, for the award Doctor of Philosophy.

I, Francesco Aiello, hereby declare that:

a) I have composed this thesis,

b) This thesis is wholly my own work unless otherwise referenced or acknowledged and

c) This work has not been submitted for any other degree of professional qualification except as specified

[redacted]

Francesco Aiello

29/09/2022

Date submitted

Acknowledgements

I would like to thank my supervisors for their invaluable support during the numerous challenges I faced over the past three years. Susan, you taught me the importance of being patient and helped me with so many things I can't even name them all. If you ever get quarantined rest assured, I'll bring you groceries! Alan, you taught me how to collaborate with people and large organizations, and how to handle the countless difficulties and setbacks encountered during research without ever losing humour. You have always been there for advice, support, or for just sharing random pictures from our trips. I know you will always have a GIF for any conversation and you will always "know a guy". Franco, I've always been very curious and critical, but you showed me a completely different level. I have never met anyone so curious, thorough, and competent. In the past years you pushed me so hard that I almost fell. You made sure I never rested on my laurels, kept pushing me and reminding me that there is always something new to learn. I will never thank you enough for everything you taught me. You all made me a better sport scientist, a better researcher, and most importantly, a better person. Thank you.

I also want to thank my friends from Napier who shared the difficulties, joys, and cakes of this journey. A special thanks to Bea, Mike, Agata, and Muna for making the last year of the PhD as normal as it could be. I also want to thank Andreas Serner, Maurizio Fanchini, Christian Di Claudio, all the people I was lucky enough to collaborate with during this project, and everyone at the Edinburgh Napier School of Applied Sciences for the support during these past three years. A final thank you to my "Enci" friends who have always been there, and to Arsenal FC for the support during this PhD.

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List of abbreviations

ACL	Anterior cruciate ligament
AFC	Asian Football Confederation
AMSTAR	A MeaSurement Tool to Assess systematic Reviews
CAF	Confedération Africaine du Football
CB	Central back
COMET	Core Outcome Measures in Effectiveness Trials
CONCACAF	Confederation of North, Central American and Caribbean Association Football
CONMEBOL	South American Football Confederation
COS	Core Outcome Set
EQUATOR	Enhancing the QUAlity and Transparency Of health Research
FC	Football club
FIA	Football Incidence Analysis
FIICCS	Football Injury Inciting Circumstances Classification System
FIFA	Federation Internationale de Football Association
GDPR	General Data Protection Regulation
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
ICECI	International Classification of External Causes of Injury
IQR	Interquartile range
IT	Information Technology
LB	Left back
LCB	Left central back
NGT	Nominal Group Technique
NHE	Nordic Hamstring Exercise
NIH	National Institute of Health
OFC	Oceania Football Confederation
OIS	Optional Information Set
OSF	Open Science Framework
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RB	Right back
RCT	Randomized Controlled Trial
SAS	School of Applied Science
STROBE	STrengthening the Reporting of OBservational studies in Epidemiology
STROBE-SIIS	STROBE Extension for Sport Injury and Illness Surveillance
TIP	Team-sport Injury Prevention
TRIPP	Translating Research into Injury Prevention Practice framework
UEFA	Union of European Football Associations
USA	United States of America

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1 Introduction

Football is practiced all around the world by people of all ages and sexes.

The most recent figures report that there are 265 million of football players globally (Figure 1.1), with an increase of circa 23 million people from the Big Count 2000 (FIFA Communications Division, 2007). Male participants represent 90% (239 million) of the total, while women represent only 10% (26 million). Therefore, as will be discussed throughout the thesis, most of the available literature on injuries focuses on men, while the literature on women footballers is limited. However, women's involvement in football has been on the rise, with male participation number increasing by 8% from 2000, and female participation increasing by 19% for the same period (FIFA Communications Division, 2007).

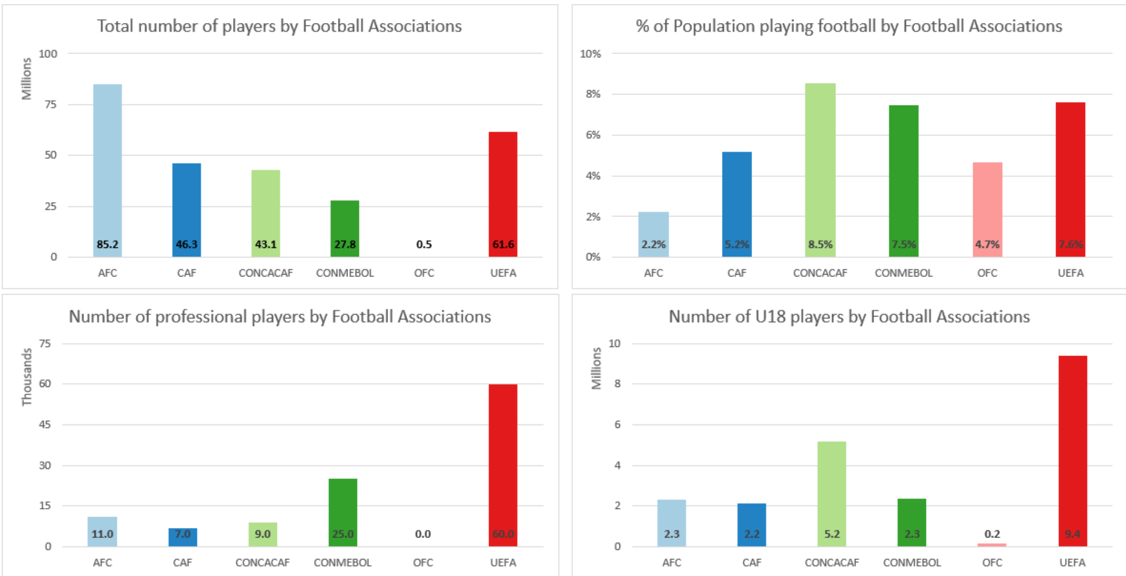

Figure 1.1 Distribution of football population by Football Associations
AFC: Asian Football Confederation; CAF: Confederation of African Football; CONCACAF: Confederation of North, Central American and Caribbean Association Football; CONMEBOL: South American Football Confederation; OFC: Oceania Football Confederation; UEFA: Union of European Football Associations. Data re-elaborated from FIFA Communications Division (2007)

The wellbeing of football participants can be negatively impacted by injuries and for elite athletes, injuries have been reported as one of the key stressors (Rice et al., 2016). Furthermore, it seems that injuries can lead to a feeling of loneliness and a loss of identity in youth players (Von Rosen et al., 2018) while Niederer et al. (2018) reported that severe injuries suchas anterior cruciate ligament injuries (ACL) may impact career length and performance indicators (i.e., minutes played, number of successful dribbling) in elite football players. At the same time, injuries have a significant impact on club's finances and performance. According to the Football Injury Index report, during the 2018/2019 season the injury cost to English Premier League clubs was £221 million, with a 15% increase in injuries and a 3% increase of injury cost from the previous season (Marsh JLT Specialty, 2019). These data are aligned with the long-term trend that shows that the number and cost of injuries have been increasing since the 2012/2013 season, albeit this cost increase may also be associated with other factors such as an increase in player wages. Secondly, a correlation between player availability and team performance has been reported in the literature. Carling et al. (2015) investigated data from a football team across five consecutive seasons, reporting that high player availability may be correlated with team success. Additionally, Hagglund et al. (2013) followed 24 football teams for 11 consecutive seasons and reported that higher player availability was associated with both higher ranking points and a higher UEFA season club coefficient.

The development of strategies to reduce injuries is important to preserve players' wellbeing and clubs' financial and sportive interests. Before the models for the development of injury prevention strategies are explored, their components should be described. The main aspects composing such models are injury extent, injury mechanisms and injury risk factors. Injury extent can be evaluated through an analysis of incidence, severity and burden of injuries (O'Brien et al., 2019). Injury incidence is calculated as "the number of injuries per 1000 player-hours" (Fuller et al., 2006, p. 101) and it may be appropriate to report the incidence of match and training injuries separately due to performance differences which will be further discussed subsequently within this thesis. Injury severity is defined as "the number of days that have elapsed from the date of injury to the date of the player's return to full participation in team training and availability for match selection" (Fuller et al., 2006, p. 98) and is usually reported as follows: slight (0 days); minimal (1–3 days), mild (4–7 days), moderate (8–28 days), severe (>28 days), career ending. In addition to these two measures, it has recently been suggested to include a third measure, injury burden, that is the product of incidence and severity and can help to assess the extent of sport injuries (Bahr et al., 2018).

Risk factors are variables (e.g., age, sex) that modify a person's risk to suffering an injury. Their identification requires conceptual frameworks that can guide the discussion of causation, considering and mitigating problems such as confounding and data dredging (Rothman, 2013). After a framework is developed, the risk factors that composed within it can be evaluated and eventually modified (Kalkhoven et al., 2020). As will be discussed further in Chapter 2.1.3.1, mechanisms of injury are the mechanical deformations and physiological responses that lead a specific tissue to be exposed to a load that exceeds its load tolerance (i.e., injury) (Institute of Medicine (US) and National Research Council (US) Committee on Trauma Research, 1985). Their identification requires a detailed description of the event leading to the injury (i.e., the inciting event) (Bahr & Krosshaug, 2005). Specifically, the description of the inciting event should include a sport-specific description of athletes' actions and playing situations, as well as a detailed biomechanical description of the event.

van Mechelen et al. (1992) proposed a model for the development of injury prevention strategies which consists of the following four steps: 1) establishment of injury extent; 2) identification of risk factors and mechanisms of injury; 3) development of injury prevention strategies; 4) evaluation of the prevention strategies through a re-evaluation of injury extent. The van Mechelen model guided the research on injury in the 90s but presents some important limitations. For example, it did not consider the difficulties of implementing such prevention measures in the real world. A successful implementation of prevention strategies requires adequate levels of compliance and adherence (Carroll et al., 2007; McCall et al., 2016), which can be achieved only through ensuring a good buy-in from athletes, coaches, and support staff. It has been demonstrated that higher compliance with the prevention strategies is associated with lower injury risk (Soligard et al., 2010; Verhagen et al., 2011). Therefore, to guide research in sports injury prevention, Finch (2006) proposed the Translating Research into Injury Prevention Practice framework (TRIPP), a new framework which considers the implementation process. The TRIPP consists of six stages: 1) injury surveillance, 2) establishment of aetiology and mechanism of injury; 3) use of results from stage two to develop prevention measures; 4) evaluation of prevention measures in controlled settings (e.g., small groups, laboratory) 5) translation of research outcomes into real-world actions; 6) implementation and evaluation of intervention. It can be noted that Finch's model is similar to Van Mechelen's one in stages 1 to 3, but before implementing the prevention strategies (stage 4 in van Mechelen model) it includes additional steps to evaluate the effectiveness of the prevention strategies in a small and controlled setting and a subsequent implementation of these results for the development of the final protocol. These additional steps may help to identify potential barriers that may limit the implementation and the compliance to the prevention strategy in the real world.

The Finch model tried to consider the differences between prevention strategies developed in research settings and their implementation in elite sport practice. However, its linear structure did not consider the cyclical nature of real-world strategies, which require a daily evaluation and adaptation to the team context (O'Brien et al., 2019). With the aim of developing a model which reflects the daily approach of sports practitioners, O'Brien et al. (2019) recently proposed the Team-sport Injury Prevention (TIP) cycle. This model includes three phases: 1) (re)evaluate; 2) identify; 3) intervene (Figure 1.2). Unlike the previous models that focus only on the evaluation of injury extent, in phase one the O'Brien model focuses on the analysis of the current injury situation in the team (e.g., injury incidence, type, and severity) and an evaluation of which prevention strategies are implemented within the team and how they are implemented and perceived by players, coaches and support staff.

As in other models, phase two comprises an evaluation of the mechanisms and the risk factors of the injuries recorded during phase one. However, unlike other models, this phase also involves an evaluation of factors that may obstruct or facilitate the implementation of prevention strategies. Once those mechanisms, risk factors, facilitators and barriers are evaluated, the following stage (phase three) includes the planning of the prevention strategies considering both their content and their implementation. While other models simply suggest developing prevention strategies using information collected in the former steps, the O'Brien model suggests that while using this information, prevention strategies should be developed involving the key subjects (e.g., coaches, players) and considering also the factors that may help or limit their implementation.

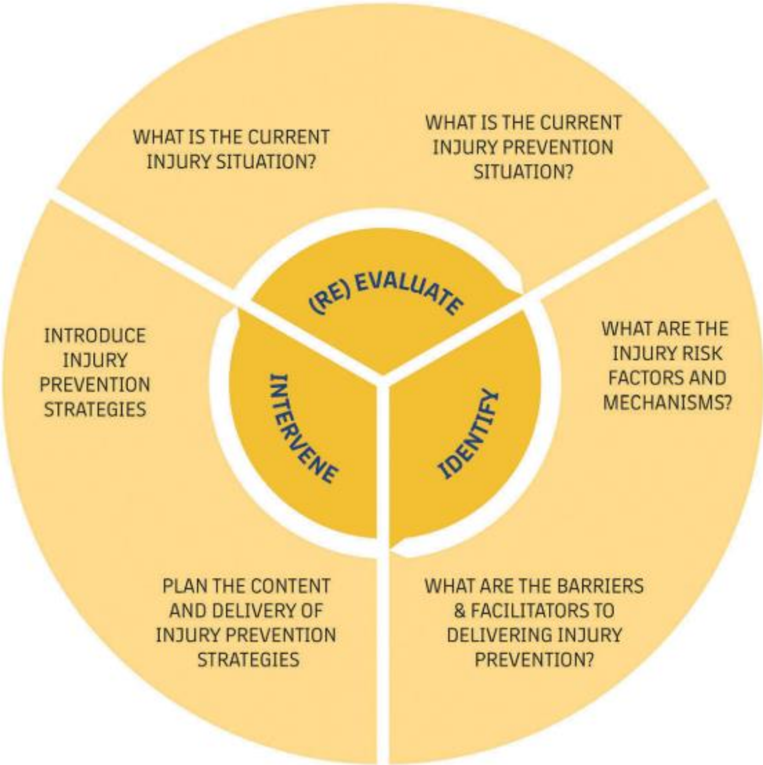

Figure 1.2 The Team-sport Injury Prevention (TIP) cycle (O’Brien et al., 2019)

To recap, the O’Brien model differs from the van Mechelen and Finch models in two main aspects: the cyclic structure and the level of attention paid to team context. The cyclic structure seems to adapt well to the real-world context, where it is important to be able to adapt to unexpected new situations (e.g., change of coaching staff). However, obtaining perceptions on injury prevention strategies from some key figures such as sport administrators and head coaches may be difficult and take a long time, which would delay the implementation of such strategies. Scheduling meetings with the various stakeholders may be challenging, especially in busy periods in which teams have short recovery times between matches. As suggested by the authors, the use of online surveys may be of help, although it is not clear how the subjects may engage with such activities. Nevertheless, although different to some extent, all three models for the development of injury prevention strategies follow the path originally described by van Mechelen et al. (1992), which proposes to develop prevention strategies based on analyses of injury extents, mechanisms, and risk factors.

It is important to highlight that the models previously described have been developed using a reductionist paradigm, which involves the identification of elements associated with injuries. However, it must be considered that such an approach may be useful to identify single factors related to injuries, but fails to consider the interaction among such factors and how such interaction may relate to injuries (Bittencourt et al., 2016). This means that even when a factor has been identified, it will be important to consider that it is likely that injuries are not caused by that factor alone but also by the interaction with the other factors of the system (e.g., risk, inciting event, psychosocial) that can occur at different points in time. For example, factors such as training load history, medical history, and psychological stress may occur before the inciting event but still play a role in injury occurrence. This approach, named complex paradigm, can be seen as an advancement of the reductionism paradigm. Recent studies have proposed a shift from reductionism to complex paradigm in injury research and have proposed new models for injury prevention (Hulme & Finch, 2015; Mendiguchia et al., 2012). Despite the differences between reductionism and complex paradigms, all the models built on the basis of such paradigms include the identification of injury extent, risk factors, and injury mechanisms. These factors can be connected to injuries considering either a linear relationship only (reductionism paradigm) or both the linear relationship and the interaction between such factors (complex paradigm). As a consequence, numerous studies have been performed with the aim of analysing injury extent, risk factors, mechanisms, and the effectiveness of prevention strategies. However, to date results seem to be inconsistent. Despite the number of studies on football injuries having increased in the last 15 years, it has been argued that the quality of the available literature is not sufficient for the development of prevention strategies and as will be discussed further on in this thesis, the evidence supporting the effectiveness of prevention strategies currently implemented in football seems weak (Fanchini et al., 2020). This could explain the fact that the burden of injuries in football has not changed over the last 18 years (Ekstrand et al., 2021).

It seems evident that the information used for the development of the prevention strategies directly influence their effectiveness. As described by the models available within the literature above (Finch, 2006; O'Brien et al., 2019; van Mechelen et al., 1992), the development of injury prevention strategies builds on information regarding injury extent, injury mechanisms and risk factors. However, the available literature on these topics seems to be limited. With reference to injury extent, as will be further discussed in subsequent chapters of this thesis, numerous studies implement injury definitions which differ from the ones recommended by international guidelines (Fuller et al., 2006). This introduces heterogeneity and makes comparing results between studies difficult (Alahmad et al., 2020; Jones et al., 2019; Lopez-Valenciano et al., 2019; Pfirrmann et al., 2016). With reference to risk factors, it has been suggested that most studies that investigated injury risk factors interpret associations as causal relationship, even if such studies did not implement causal inference methods and did not measure confounding factors (Impellizzeri et al., 2020c; Wang et al., 2020). Considering mechanisms of injury, most studies focus only on biomechanical aspects of some injuries such as ACL, while there is less information regarding other injuries and other sport-specific aspects of the inciting events (Bahr & Krosshaug, 2005).

The limited and/or low quality of the literature concerning injury extent, risk factors, injury mechanisms, and prevention strategies may be a factor that has led to the failure of injury reduction in football. The limited knowledge on injury mechanisms may negatively influence both the development of prevention strategies and the research on risk factors. Indeed, without knowing the mechanisms of injury, hypothesising the risk factors may be difficult. Taking ACL injuries as an example, knowing that the combination of movements such as knee internal rotation and valgus put the ACL under high stress (Alentorn-Geli et al., 2009a; Shimokochi & Shultz, 2008) guided researchers to identify dynamic knee valgus as a risk factor for ACL injuries (Bisciotti et al., 2019; Griffin et al., 2018; Price et al., 2017). As will be discussed in 2, information on the sport-specific activity performed at the time of injury is important to guide research on injury mechanisms and to help practitioners and football governing bodies to develop prevention strategies. Therefore, the aim of this thesis is to develop a better understanding of the sport-specific activities performed by players at the time of injury.

The aims of the thesis are:

1.1 Aim of the thesis

1. To examine the available literature on sport-specific activities leading to injury in professional football players.
2. To develop methodological guidance and standard terminology for future studies investigating this topic.

3. To evaluate whether such guidance can be used to analyse data routinely collected in football.

To achieve these aims, the following studies will be performed:

1.2 Studies

1) Injury inciting circumstances in male and female football players: a systematic review
2) Development of a standardised system to classify injury inciting circumstances in football: the Football Injury Inciting Circumstances Classification System
3) Analysis of inciting circumstances in elite football players: a video and GPS based approach

Initially, a review of the literature on injury reporting and on mechanisms of injury in football injuries will be conducted to present the current knowledge on the topic.

Firstly, it will be discussed how injury data are collected and how the limitations in collection and reporting of such data can limit the practical application of research. Subsequently, given the limitations of the methods for collection of data on injury mechanisms and the need to develop a new system to allow a standard collection and reporting of such data, the systems currently used in football to collect such data will be discussed to evaluate which information could be collected without the need to implement new data collection procedures. Despite the limitations of the literature, practitioners use such information to guide their practice, therefore the literature currently available on injury mechanisms will be discussed to understand if there is consistency within the literature and how such literature can be used by practitioners. Finally, the ways in which research can be used to help practitioners to guide their practice will be discussed and considered alongside the importance of ensuring that the information provided are reliable and consistent.

2 Literature review

2.1 What is an injury?

Accurate and consistent recording and reporting of outcomes is key to being able to combine, compare, and generalise findings across studies and then provide robust information which can be used by practitioners to make decisions (Clarke & Williamson, 2016). Unfortunately, the issue of inconsistent reporting of outcomes is common in sports medicine literature and more broadly in the healthcare field, where it has been shown that the use of different classification systems may lead to outcome reporting bias and to the implementation of inadequate interventions for reducing a targeted outcome (Williamson et al., 2017). Therefore, ensuring standardised reporting of outcomes is crucial to ensure reporting consistency and provide guidelines to researchers and practitioners. This is the aim of several initiatives such as the EQUATOR network and, specifically within the sport medicine field, the development of detailed guidelines for the definition and reporting of injury data through consensus statements such as the STROBE Extension for Sport Injury and Illness Surveillance (STROBE-SIIS) (Bahr et al., 2020).

In sports, injuries are defined as “tissue damage or other derangement of normal physical function due to participation in sports, resulting from rapid or repetitive transfer of kinetic energy” (Bahr et al., 2020) and are one of the health problems that reduce players’ state of health (Clarsen et al., 2020). A description of all the aspects that should be reported for injuries (e.g., onset, type) is outside the aim of this section and can be found in the STROBE-SIIS (Bahr et al., 2020), however, some aspects show limitations and will therefore be discussed. These aspects are injury definition, body region, and injury mechanisms.

2.1.1 Injury definition

In football an injury is defined as “any physical complaint sustained by a player that results from a football match or football training” (Fuller et al., 2006). Injuries can be classified as “medical attention” if they just lead players to receive medical attention, while a health problem which impedes players to complete the current and/or subsequent match or training session is defined as “time-loss”. Health problems that don’t afflict players’ participation nor require medical attention are defined as “any complaint”. Although medical-attention injuries pose financial burden on clubs (e.g., examinations, treatments), as discussed in 1 time-loss injuries are the health problems which reduce players’ availability hence cause performance and financial loss, therefore most research focuses on time-loss injuries.

Although clear guidelines have been provided to define injuries and specifically time-loss injuries, such guidelines are not always followed in research. Despite guidelines recommending that a health issue is reported as a time-loss injury if it impedes players to complete the current and/or subsequent match or training session, several studies define injuries as time-loss using different definitions such as 24-hour time-loss, 48-hour time-loss, one week time-loss, or one match time-loss. A recent systematic review on injury incidence in football conducted by Jones et al. (2019) reported that, despite guidelines for injury definition in football being developed more than 15 years ago (Fuller et al., 2006), more than 50% of the studies included in their review used one of the non-standard definitions reported above. Similar findings have been reported in other systematic reviews (Alahmad et al., 2020; Diemer et al., 2021; Lopez-Valenciano et al., 2019; Pfirrmann et al., 2016).

A heterogeneous injury definition is an important consideration in applying findings from research on football injuries. Indeed, an inaccurate case definition may lead to inaccurate reporting of injury incidence and burden. This would impact both the evaluation of injury extent but also the analysis of risk factors, injury mechanisms, and prevention strategies. When risk factors and injury prevention strategies are analysed, the injury incidence of two groups (e.g., intervention and control group) are compared to evaluate whether a factor (e.g., a hypothesised risk factor or a prevention strategy) changes the injury incidence. For example, if one wants to evaluate whether low hamstring strength increases the risk of hamstring injuries, they will calculate the incident rate ratio which is the ratio between the injury incidence of players with low hamstring strength and the injury incidence of players with high hamstring strength. Therefore, a heterogeneous injury definition will influence the number of injuries which occurred in each group, which will in turn influence the injury incidence and the injury rate ratio, hence influencing the results on whether low hamstring strength constitutes a risk factor for hamstring injuries. Of course other factors may introduce bias such as confounding factors and competing events should also be considered when analysing risk factors (Hernán & Robins, 2020; Hernán, 2021; Hernán et al., 2019; Rothman, 2012; Rothman, 2013), but this simplification helps to explain how an inaccurate case definition can lead to inaccurate results of analysis of risk factors and prevention strategies. An example of how inaccurate case definition can lead to inaccurate results on injury mechanisms will be described in the section referring to injury mechanisms.

2.1.2 Body region

The second element of injury recording that shows some limitation is the definition of the injured body region. Reporting the injured body region is recommended by guidelines for reporting of injuries in sport and specifically in football (Bahr et al., 2020; Fuller et al., 2006). Reporting this element is clearly crucial to try and reduce injuries. Indeed, since injuries occur when a tissue is exposed to a load that exceeds the tissue's tolerance (Bahr & Krosshaug, 2005), injury mechanisms are likely to differ according to body area. For the same reason risk factors clearly differ according to body area. Current guidelines recommend reporting the body area, although not in great detail. For example, lower-limb injuries are recommended to be grouped by the following body areas: hip/groin, thigh, knee, lower leg, ankle, and foot (Bahr et al., 2020; Fuller et al., 2006). Thigh injuries include both hamstring and quadriceps injuries, while knee injuries include injuries occurring to the patella, meniscus and several ligaments such as ACL and collateral ligaments. However, greater detail on body areas are probably needed in order to try to reduce injuries. For example, risk factors and extent of hamstring injuries differ from those of quadriceps injuries (Ekstrand et al., 2011; Green et al., 2020a; Mendiguchia et al., 2013) and as will be discussed in this thesis, injury mechanisms of hamstring and quadriceps injuries are not identical.

Since risk factors and injury mechanisms change within the same body region, it seems important to report not only the generic body region (e.g., thigh) but also the specific injured muscle or ligament (e.g., hamstring, quadriceps). This would allow a more detailed analysis on all the elements necessary to reduce injuries (i.e., injury extent, risk factors, injury mechanisms, prevention strategies). For example, Ekstrand et al. (2011) reported that hamstring injuries are the most prevalent muscle injuries in football and their incidence is more than double the incidence of quadriceps injuries. As a consequence, hamstring injuries have been one of the most researched injuries in football. Some studies have reported more specifically on the injured muscle and a few studies even reported the muscle region injured. For example, Askling et al. (2012) and Askling et al. (2007) not only distinguished between hamstring and quadriceps injuries, but also between the injuries that occurred to the different muscles which compose the hamstring (i.e., long head biceps femoris, semimembranosus, and semitendinosus). Similarly, Geiss Santos et al. (2022) reported the specific injured region (e.g., myotendinous junction, free tendon) of the rectus femoris where the lesion occurred using magnetic resonance imaging. This detailed reporting is not restricted to thigh injuries but is also applied to injuries of other body regions such as the knee (Buckthorpe et al., 2021; Della Villa et al., 2020; Lundblad et al., 2020) or calf (Green et al., 2020b).

Requiring practitioners to report the specific area of the muscle or ligament where the lesions occurred may pose excessive burden on them but reporting the specific injured muscle or ligament (e.g., hamstring or rectus femoris, meniscus or ACL) instead of reporting only the body region (e.g., thigh or knee) seems feasible and important when trying to reduce injuries. This level of detail is already reported in some studies (for a review see Jones et al. (2019)) although is not required by guidelines for injury reporting. While the definition of body region may not be deemed as important as the definition of injury, including more detailed information about body region in the reporting guidelines could improve the analysis of all the elements required to reduce injuries. Following the publication of reporting guidelines from the International Olympic Committee, it would be ideal if scientific journals required the use of such guidelines when publishing studies reporting on injuries. Many journals already require authors to follow specific guidelines when conducting studies such as systematic reviews (Page et al., 2021). This means that to be accepted, authors would need to use the definitions and classifications provided by such guidelines, which would improve the quality and consistency of reporting that as previously discussed is important for summarising the literature and providing guidelines to practitioners.

2.1.3 Injury mechanisms

As discussed in the previous chapter, detailed descriptions of the mechanisms of injury are essential for the development of injury prevention strategies with purposeful guidance (Bahr & Krosshaug, 2005; O'Brien, 2017). However, important limitations are present in current methods used to collect and report such information. Before such limitations are discussed, it is important to define the terminology. Indeed, as will be thoroughly discussed in this thesis, the inconsistent terminology implemented within the available literature makes interpreting the literature challenging and therefore it is difficult to use it to provide recommendations for practitioners.

2.1.3.1 Terminology

Bahr and Krosshaug (2005) proposed that researchers describe all the elements of the inciting events using the term *injury mechanism*. Specifically, they suggested that *injury mechanism* can include the description of playing situation, players' behaviour, and body biomechanics at the time of injury (Figure 2.1). Therefore, in the last 17 years this term has been used in the literature to describe all of these elements. For example, Brophy et al. (2015) use the term "injury mechanism" to refer to game situation (i.e., team with or without ball), sport-specific activity (e.g., kicking, running, landing), contact situation (i.e., direct contact, indirect contact, non-contact), and body biomechanics (e.g., hip position, knee position). However, this may lead to inaccuracies and confusion. The term *mechanism* describes the mechanical deformations and physiologic responses that cause an anatomic lesion or functional change (Institute of Medicine (US) and National Research Council (US) Committee on Trauma Research, 1985), therefore reporting activities such as sprinting or landing, or game situations such as ball possession as mechanisms of injury does not seem accurate. Indeed, injuries (i.e., tissue lesions or functional changes) are not caused by the activities per se (e.g., sprinting, jumping) or by the game situation (e.g., player or team with or without ball), but by the sum of the mechanical forces occurring during such activities which exceeds the load tolerance of the tissues, which cause the mechanical deformations and physiologic responses, which finally cause an anatomic lesion or functional change (i.e., injury). Therefore, it seems that the term *injury mechanism* has not always been used appropriately in the literature and more accurate terminology should be implemented. Taking the study conducted by Brophy et al. (2015) as an example, claiming that defending (i.e., injured player facing an opponent with the ball) is the most prevalent mechanism of ACL injury may be confusing, because defending does not describe either a specific activity (e.g., running, tackling, jumping), nor a specific body position (e.g., knee or hip angles).

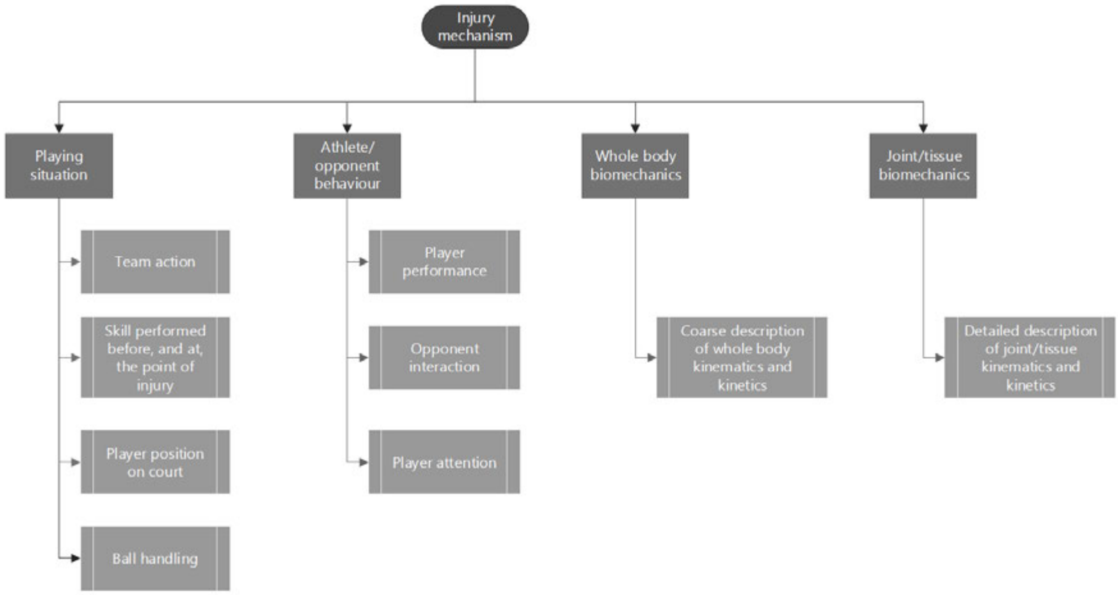

Figure 2.1 Descriptors of injury inciting events proposed by *Bahr and Krosshaug (2005)*

The American Agency for Healthcare Research and Quality (Agency for Healthcare Research and Quality), the International Classification of External Causes of Injuries Coordination and Maintenance Group (ICECI Group, 2004), and the World Health Organisation guidelines for injury surveillance (World Health Organization, 2001) suggest that the term *injury circumstance* can indicate the environmental factors that surround an injury such as the activity performed by the injured person and the time and place of injury. The context of these guidelines is focused on Health and Safety reporting, therefore this term was not developed to refer to the context being discussed herein. However, since to the best of my knowledge there is no consensus on how to define the sport-specific activity performed by the injured player at the time of injury and considering the limitations about the terminology currently implemented which have been discussed above, the term *(injury) inciting circumstances* will be used in this thesis to refer to all the factors describing the inciting events (i.e., the environmental factors during which injuries occur such as team action, player position, and pitch condition, inciting activities, and mechanisms). The term *(injury) inciting activity* will be used to specifically refer to the sport-specific activity during which injuries occur (e.g., landing, sprinting), and the term *injury mechanism* will be used to refer to the joint angles, muscle strain and forces which lead to injuries (Figure 2.2).

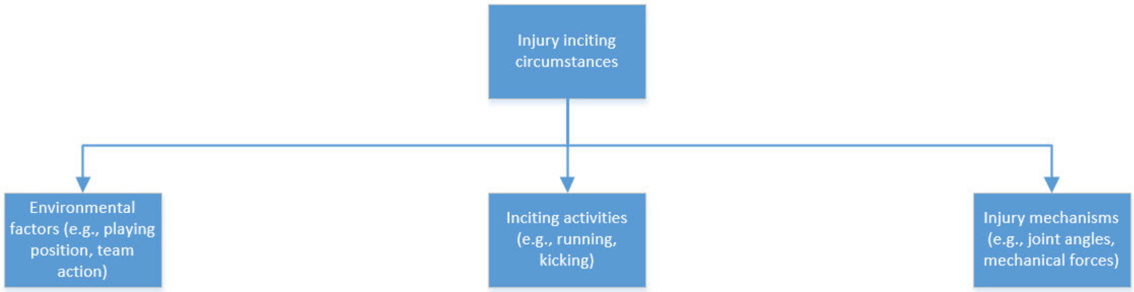

Figure 2.2 Structure of proposed terminology

Now that the terminology which will be used in this thesis has been presented, the limitations of the collection and reporting of inciting circumstances will be discussed.

2.1.3.2 Standard reporting of inciting circumstances

As previously mentioned, ensuring reporting consistency is essential in order to combine and generalise findings from different studies and provide information which can be used by practitioners to guide their practice. This is the main reason which led the International Olympic Committee to develop the STROBE-SIIS. However, while most aspects such as body region, injury severity, and injury type are universal (e.g., injuries that lead to more than 28 days of unavailability are categorised as severe in all sports), the inciting circumstances are not the same between all sports (Bahr et al., 2020). Different sports have different rules and require different activities, hence it is intuitive that the inciting circumstances differ across sports. For example, volleyball players slam the ball with one hand (i.e., spike) to try to make the ball touch the opponents' court, while football players hit the ball with the legs (or other body parts excluding the upper limbs) to try and send the ball over the goal line. Therefore, volleyball players may get injured while spiking but football players cannot since such activity is not allowed in football. Similarly, football players may get injured while they kick the ball but since volleyball players kick the ball very rarely, injuries in volleyball players have never been reported to occur during kicking activities (Chandran et al., 2021).

Given that different sports involve different activities such as kicking the ball in football codes, spiking in volleyball, and hitting the ball in baseball, it is not possible to develop a universal system to classify and report inciting circumstances, but sport-specific classification systems should be developed. For this reason, the STROBE-SIIS does not provide guidelines for reporting inciting circumstances, with the only exception being the mode of onset and the description of the nature of contact (i.e., direct contact, indirect contact, and non-contact, which in the STROBE-SIIS is referred to as injury mechanism), and refers to further consensus studies for the development of sport-specific classification systems which may include details such as sport-specific activities, movements, or rule infractions (Bahr et al., 2020). To the best of my knowledge, only one attempt was made to develop a football-specific system to standardise the collection and reporting of inciting circumstances, which is the Football Incident Analysis (FIA) proposed by Andersen et al. (2003).

Despite Andersen et al. (2003) developing the FIA more than 15 years ago, important limitations still persist in the collection and reporting of data concerning the inciting circumstances in football. Indeed, as will be extensively discussed in 3, the FIA has rarely been used in the literature to report inciting circumstances, which have been reported using arbitrary classification systems instead. The limited usage of the FIA may be explained by its limitations. Firstly, the system was developed and tested by football coaches only, without involving other stakeholders (e.g., researchers, sport science and sport medicine practitioners). Classification systems, usually referred to as Core Outcome Sets (COS), are developed through different consensus methods such as Delphi and Nominal Group Technique (NGT) which require the involvement of key stakeholders to decide which variables need to be measured, how they should be measured and defined, and whether they should be included in the core set or in additional sets. It is also recommended to consider the outcomes reported in the literature when developing a Core Outcome Set, which are usually identified through systematic reviews (Williamson et al., 2017). Involving stakeholders in the development of a Core Outcome Set is key because they are the ones that will use the Core Outcome Set to collect and analyse data and will use such data to inform their practice, therefore developing a Core Outcome Set without the involvement of the relevant stakeholders may limit its spread and usability.

A second limitation of the FIA is the method used to develop it. As mentioned previously, Core Outcome Sets should be developed using specific methods such as Delphi or NGT, but the authors of the FIA do not seem to have used any formal method to develop their system. Formal approaches are necessary for the development of Core Outcome Sets because they support the implementation of transparent methods and increase scientific credibility and the quality of the Core Outcome Sets (Black, 2006; Williamson et al., 2017). Another limitation of the FIA is that it has been specifically developed for video analysis and it requires both medical information and video recording of the inciting circumstances, therefore it is not implementable in environments were video recordings of training and matches are not available or not practical. Additionally, as will be discussed in 5, using video-footage to analyse inciting circumstances is time consuming, which could impact the usage of the FIA in a football environment. These limitations may be attributed to the lack of involvement of relevant stakeholders in the development of the FIA and may, at least partially, explain its limited use in research environments.

The limitations of the FIA, its subsequent limited usage, and the lack of other standardised systems to classify and report inciting circumstances led to a heterogeneous classification of these injury details which in turn could make it difficult to interpret and summarise the data and provide clear information to practitioners and researchers. For this reason, the main aim of this project is to develop and test a new system to classify and report inciting circumstances in football. Since one of the biggest problems of the FIA is its limited usage, it seems important to discuss how such information are currently collected in football and research. Indeed, if possible it would be preferable to develop a classification system which does not require clubs or researchers to implement new procedures for data collection, which could add barriers to the usage of the classification system and reduce its usage.

2.2 Methods for analysis of injury inciting circumstances

As discussed in the previous chapter, detailed descriptions of the inciting circumstances are essential to develop injury prevention strategies with purposeful guidance (Bahr & Krosshaug, 2005; O'Brien, 2017). A description of the inciting circumstances can be obtained through video-analysis, injury report forms, and questionnaires.

As mentioned above, it is important to consider the methods currently used in football to collect data to try to avoid the introduction of barriers which may limit the usage of new classification systems. Therefore, it seems important to discuss how data are collected in football, because limitations in data collection will inevitably influence the quality of the data and consequently the quality of the information. The methods most used to collect and report data on inciting circumstances are report forms, video analysis, and questionnaires and each method has its own strengths and limitations which need to be considered to understand the reliability of the data reported.

2.2.1 Report forms

Medical reports constitute a method commonly used to record injury data in sports (e.g., injury onset, location, severity, type). Report forms are easy to use and can be embedded in injury surveillance systems which are commonly implemented in football clubs, therefore this method has probably the highest usability of all the methods which will be discussed in this section. Specifically, football clubs embed such report forms in excel files which facilitate the data collection and analysis or in athlete management systems, which are software that help organisations to collect and store data. Therefore, when an injury occurs the sport medicine person responsible for data collection conducts the diagnosis of the injury and includes such information (e.g., date of injury, injury type, injury location) in the report form.

Despite their good usability, which constitutes an important advantage, report forms have some limitations. The most important limitation is that the information included in the report is influenced by what the person filling out the report has observed. This could be a limit when, for example, the person who fills out the report had a limited view of the inciting circumstance, as this may cause the information provided in the report to be inaccurate. Asking the players to report such information may partially solve this issue but may create others. Indeed, it is unclear how accurately players are able to recall the inciting circumstances following injury retrospectively and the information provided by the players may be influenced by external factors (e.g., other players, coaches, media) (Krosshaug et al., 2005). Therefore, there is a risk of recall bias which should be considered when this method is implemented. Despite these limitations, report forms seem to be the most common and usable method to collect information on the inciting circumstances in football and so overcoming their limitations would help football practitioners to collect reliable data on inciting circumstances. For example, if the person responsible for reporting the inciting circumstances has access to a video of the injury there would not be any risk of them having a limited view. Similarly, asking the player to review the video of the injury may limit the risk of recall bias. This method will be further discussed in the section referring to video-analysis.

2.2.2 Questionnaires

Questionnaires constitute another method used for the analysis of inciting circumstances. Questionnaires are usually structured similarly to report forms, with the main difference being that instead of them being filled out by the sport medicine staff shortly after the injury occurrence they are completed by players or their parents (in case of young players) at some point after the injury occurrence. Therefore, the same limitations discussed for report forms apply to questionnaires, with the main difference being that the information are entirely reported by the athletes which, where there is a time gap, may increase the risk of recall bias. Indeed, the time gap between injury occurrence and when the questionnaire is completed can go from a few days or weeks (Azubuike, 2009) to several months (Rochcongar et al., 2009), and it is not clear how accurate information on the inciting circumstances can be when reported months after injury occurrence. Indeed, when participants are questioned (through questionnaires or interviews) after the outcome occurrence they may not accurately remember or report previous events or experiences, which leads to recall bias. Several studies have reported how memories of specific events may diminish over time and can lead to recall bias (Spencer et al., 2017). With specific reference to the reporting of inciting circumstances, participants may mistakenly remember the circumstances during which injuries occurred and/or may report such information inaccurately. Therefore, questionnaires seem to be the method with the biggest limitations among the ones currently implemented in football to collect data on inciting circumstances. However, they may still be useful to obtain a general overview of the inciting circumstances in those settings in which other methods cannot be implemented.

2.2.3 Video analysis

Video-analysis is another useful tool to evaluate the injury circumstances because it allows a detailed evaluation of the inciting circumstances to be performed without some of the limitations of injury report forms (e.g., limited view, possible players' recall bias). Video-analysis can also be used to analyse the mechanisms of injuries. The biggest advantage of this method is that it is possible to review the video as often as required, therefore it is possible to report any type of information (e.g., environmental factors, player's activities) with greater accuracy. Andersen et al. (2003) were the first to publish their work using video-analysis to analyse inciting circumstances in football, but aside from within this research group this method has not been used to analyse the inciting circumstances until few years ago when studies restarted to use video analysis to investigate the biomechanics of ACL injuries (Lucarno et al., 2021) and the inciting circumstances of ACL, adductor, and hamstring injuries (Buckthorpe et al., 2021; De Carli et al., 2021; Della Villa et al., 2020; Gronwald et al., 2021; Krutsch et al., 2021; Lucarno et al., 2021; Serner et al., 2019; Waldén et al., 2015).

Despite the advantages of video analysis described above, this method is not without limitations. The biggest limitation is that in a research context, finding injuries on video is time consuming if reliable medical data are not available. For example, if a research group wants to use this method to analyse the inciting circumstances of hamstring injuries in the English Premier League, they would need to watch all relevant matches, locate the hamstring injuries on video, and then analyse them. To overcome this limitation, research groups use online databases (e.g., media reports, websites such as Transfermarkt.com) to identify the matches in which injuries have occurred and then access the footage to analyse injury circumstances. However, recent studies reported low reliability for data reported on such databases (i.e., not all the injuries reported in online databases have actually occurred and not all injuries occurred are reported in online databases) with the only exception being ACL injuries, probably due to the clear onset of the injury which makes it easily recognisable (Hoenig et al., 2022; Krutsch et al., 2020). Another limitation of this method is that it may fail to identify injuries on video if players do not suddenly interrupt the activity. For example, a player is running at 30 km/h to chase an opponent that is going toward the goal. Once he reaches the opponent he performs an intense deceleration, engages in a 1vs1 duel, kicks the ball out, and then lies on the ground and points at the medical staff to indicate that he is injured. According to the available literature which will be discussed in the next section, the hamstring injury could have occurred 1) during the high running speed, 2) during the intense deceleration, 3) during the kicking action or 4) during any contact or activity within the duel. However, without detailed medical data and the possibility of talking to the injured player it would be difficult to evaluate by video alone when the injury occurred in order to analyse the circumstances.

A final limitation of this method is that it is commonly used to analyse match injuries only. However, given the important differences in injury incidence and physical performance between training and matches (Coutinho et al., 2015; Larruskain et al., 2018; Martín-García et al., 2018), it may be possible to observe similar differences in injury circumstances between training and matches. Therefore, despite video analysis may have positive outcomes it seems important to use it only when reliable medical data are available. This would not only allow practitioners and researchers to easily and clearly identify the time at which injuries occurred, but would also allow them to accurately identify the injury which occurred during the circumstances recorded on video. Indeed, without medical information it is difficult to identify with precision the body region which suffered the injury. It could be possible to identify from the video if the injury occurred to the calf, the knee, or the thigh, but identifying the precise body regions (e.g., long head bicep femoris, semitendinosus, or semimembranosus) by video inspection only seems difficult. This is important because, as will be discussed in the next section, tissues within the same body region (e.g., long head bicep femoris, semitendinosus, or semimembranosus) may suffer injuries during different circumstances, therefore having medical information available is important to easily and clearly identify the time of injury occurrence and to report with appropriate detail the type of injury which occurred during the circumstance analysed through video analysis. This approach has previously been used by Serner et al. (2019) who were able to analyse inciting circumstances with greater detail. The study was conducted prospectively and injuries that occurred during football matches were recorded by trained sport medicine practitioners and body region was evaluated using MRI. Furthermore, the authors involved the players in the video analysis to identify the time of injury with great precision. Although only match injuries were analysed, the authors successfully identified and analysed the inciting circumstances leading to all 17 injuries which had occurred during the research project. Although the inciting circumstances were collected and reported using an arbitrary classification system, this approach seems very interesting and, as will be discussed in the following section and in 1, may be very valuable for the analysis of inciting circumstances.

It is important to highlight that typically, neither report forms, questionnaires, nor video analysis use systems to objectively measure players' physical activity at the time of injury. Doing so would allow more accurate information to be obtained about, for example, the speed at which players are running when injuries occur. Including the objective measure of players' physical activity at the time of injury could provide important information for injuries which occur during running activities such as sprinting, changing direction or decelerating. For example, the objective reporting of the velocity at which players are running when injuries occur may provide information to practitioners on whether certain velocities expose players to higher risk of incurring certain injuries, which could then be used to try and develop prevention strategies. This would be particularly important for injuries such as hamstring and ACL injuries and will be extensively discussed in the following sections. This analysis could be conducted using Electronic Performance & Tracking Systems such as Global Positioning Systems

(GPS) and Optical Systems which are routinely implemented by football clubs to monitor players' physical performance during training and matches (Buchheit & Simpson, 2017; Schulze et al., 2021).

As discussed in this section, data concerning inciting circumstances are usually collected and reported through video-analysis, report forms, and questionnaires, although some aspects such as mechanical forces require more advance techniques such as laboratory analysis (Krosshaug et al., 2005). Due to clear ethical reasons, it is not possible to replicate injuries during laboratory analysis, therefore studies which aim to use this method conduct laboratory analysis to evaluate the activities which are believed to lead to injuries. For example, on the basis that hamstring injuries occur during high-speed running, laboratory studies focus on investigating the hamstring activation at different running velocities (Hegyi et al., 2019; Kivi et al., 2002; Schache et al., 2013). Therefore, it is important to identify the activities which lead to injury both to guide the research on risk factors and prevention strategies and to guide laboratory research on biomechanical characteristics of injuries, which in turn will contribute to guide the research on risk factors and prevention strategies. As previously discussed, there are important limitations on how data concerning injuries, and more specifically inciting circumstances, are collected and reported. Notwithstanding, as will be discussed in Chapter 2.4 this information is used by practitioners and researchers to try and develop injury prevention strategies. Therefore, it seems relevant to discuss the literature currently available on inciting circumstances of the most substantial injuries (i.e., high incidence and/or high severity) and to try to evaluate whether, despite the limitations previously discussed, the information available within the literature is consistent, what additional information would be useful, and how such information could be used to develop prevention strategies.

2.3 Circumstances of injury according to body area

Since injuries occur when a tissue is exposed to a load that exceeds the tissue's tolerance, inciting circumstances are likely to differ according to many variables such as sport, injury type, and body area (Bahr & Krosshaug, 2005). Therefore, it seems pertinent to analyse inciting circumstances specifically for each body area. As previously discussed in Chapter 1, it is important to reiterate that since injuries are multifactorial, a complex approach is more appropriate to analyse injuries. As a consequence, it is acknowledged that injuries do not simply occur during the inciting circumstances that will be discussed in this chapter but occur due to the interaction of such inciting circumstances with other factors which play a part in the system (e.g., training load history, medical history, socioeconomical factors).

Given the presence of physiological differences between males and females such as bone mineral density, free fat mass, and physical performance characteristics (Abe et al., 2003; Baker et al., 2020; Bradley et al., 2014), the inciting circumstances may differ according to sex and so it is important to report such information separately. However, the literature on inciting circumstances leading to injuries in women is scarce, therefore the following sections refer to literature on male players unless otherwise specified.

2.3.1 ACL injuries

The incidence of ACL injuries in elite football is relatively low when compared to other injuries (0.07/1000 h, circa one every two seasons) but elite players require a median duration of 7.4 months to return to play after ACL injuries which makes this injury particularly troublesome for football players (Waldén et al., 2016). Additionally, history of previous ACL injury increases the risk of mid-age osteoarthritis (von Porat et al., 2004), therefore reducing ACL injuries is very important.

It is recognised that movements such as knee internal or external rotation, valgus or varus movements put the ACL under high stress although do not always cause enough stress to lead to an ACL rupture, but a sum of these moments may lead to ACL injuries, especially when combined with high proximal tibial anterior shear forces (Yu & Garrett, 2007) and/or hyperextension (Shimokochi & Shultz, 2008). Additionally, the stress on the ACL is even higher when these activities are combined with a high quadriceps force (Alentorn-Geli et al., 2009a). It has been reported that in both male and female players non-contact ACL injuries mainly occur with the knee mostly extended in a dynamic valgus rotation (Alentorn-Geli et al., 2009a). In football, the activities that may place great valgus load and therefore put the ACL at risk of injuries are high-intensity decelerations, landings (Alentorn-Geli et al., 2009a; Shimokochi & Shultz, 2008), and pivoting with a planted foot and with the knee extended (Alentorn-Geli et al., 2009a).

These results have been further confirmed by recent studies which analysed the inciting circumstances of ACL injuries in elite football (Della Villa et al., 2020; Grassi et al., 2017). However, the description of the inciting activities reported by these studies do not fully align to the biomechanical description reported in the literature. For example, it has been reported that the most common inciting activities in males and females are pressing, tackling, and being tackled (Della Villa et al., 2020; Grassi et al., 2017) which do not always specifically reflect the activities which are believed to lead to ACL injuries (e.g., non-contact activities, deceleration, landing). There are several reasons which may explain this inconsistency, one of which could be due to the usage of arbitrary classification systems for reporting inciting activities as discussed in Chapter 2.1.3.2. Another limitation of these studies is that they obtained the injury data and the video of the inciting circumstances through publicly available databases (e.g., transfermarkt.com, youtube.com), therefore although the reliability of such databases has been proved to be good for ACL injuries (Hoenig et al., 2022; Krutsch et al., 2020), video from training sessions are not publicly available therefore injuries occurred during training sessions could not be analysed during these studies. As previously mentioned, there are differences between physical activity performed during matches and training sessions, therefore it is plausible to expect that the prevalence of the inciting circumstances which lead to injuries would differ between matches and training sessions.

2.3.2 Ankle injuries

The incidence of ankle injuries in elite football is 1.1/1000 h which corresponds to around 5 injuries per team per season. On average, elite football players who incur ankle injuries miss 5 days and the average injury burden is 5.5 days/1000 h (Larruskain et al., 2018). The literature around the possible mechanisms of ankle injuries is extensive and mechanisms leading to specific ankle ligament injuries have been identified (for a review see Funk (2011)). The evidence suggests that ankle injuries mostly occur during a combination of inversion and plantar flexion (Bonnel et al., 2010; Kaumeyer & Malone, 1980; Walls et al., 2016; Wolfe et al., 2001) which commonly damages the calcaneofibular, posterior talofibular, and anterior talofibular ligaments which act as lateral stabilisers. Since inversion sprains usually occur with the foot in plantar flexion (Bonnel et al., 2010; Kaumeyer & Malone, 1980), it would be expected to see ankle injuries occurring in football during activities with the foot in plantar flexion such as landing and changing direction, as observed in other sports (Doherty et al., 2014; McKay et al., 2001). However, in football it has been reported that ankle injuries mostly occur during contact activities (Andersen et al., 2004a; Kofotolis et al., 2007; Krutsch et al., 2021). It is not clear if these differences are due to differences between sports or to limitations in data collection and reporting, however since Doherty et al. (2014) included in their meta-analysis sports such as rugby and American football which have a higher incidence of both ankle and contact injuries than football (Baker et al., 2021; Larruskain et al., 2021; Yeomans et al., 2018) it may be that the differences between data reported for other sports and for football are due to the limitations of data collection. This would need to be investigated by further studies, even because to the best of my knowledge no standardised systems to classify the inciting circumstances exist in other sports, therefore it is difficult to say which information may be correct.

2.3.3 Hamstring injuries

Hamstring injuries in elite football are the most common muscle injury with an incidence of 1.2/1000 h which corresponds to circa six injuries per team per season. On average, elite football players who incur hamstring injuries miss 17.3 days and the average injury burden is 19.7 days/1000 h (Ekstrand et al., 2016).

Hamstring mechanisms can be classified into two main categories: stretch-type (occurring mostly to the semimembranosus) and sprint-type (occurring mostly to the long head of the biceps femoris) (Huygaerts et al., 2020). Since around 80% of hamstring injuries occur to the latter of these long head biceps femoris (Woods et al., 2004) it has been reported that the sprint-type injuries are more common than the stretch-type, therefore most of the research focuses on this mechanism (Kenneally-Dabrowski et al., 2019).

Sprint-type injuries seem to occur mainly during the late swing and the early stance phases of running (Figure 2.3) which are also the two phases in which the force of the long head of the biceps femoris peaks (Huygaerts et al., 2020; Kenneally-Dabrowski et al., 2019; Liu et al., 2017). During the late swing phase hamstrings achieve their peak musculotendon length and mechanical work, which in combination with the eccentric activation exposes them to high risk of injury. Additionally, it has been hypothesised that the high ground reaction forces occurring during the early stance combined with hip flexion and knee extension make the early stance the most dangerous phase for hamstring injuries (for a review see Kenneally-Dabrowski et al. (2019) and Liu et al. (2017)). However, it is still unclear which of these phases expose the hamstring to the greatest risk of injury and it may be that they both put the hamstring at risk of injury (Huygaerts et al., 2020). Additionally, when players run at around 30 km/h they complete circa 2.1 strides per second (Kivi et al., 2002), meaning that each stride lasts less than 0.5 seconds, making it difficult to evaluate whether injuries occur during the late swing or the early stance phases. It might be that involving players in video analysis to identify the time of injury as done by Serner et al. (2019) would allow the identification of the running phase at which the injuries occur. This information could be useful for the development of prevention strategies. For example, if hamstring injuries are found to occur predominantly during the early stance phase, prevention strategies may focus on increasing the ability to resist higher ground reaction forces.

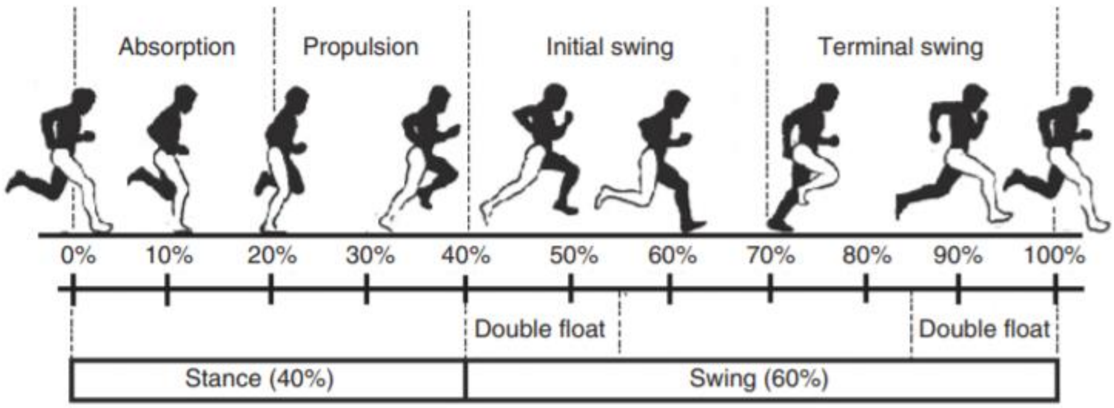

Figure 2.3 Phases of running strides from Burns and Smuck (2014)

With reference to inciting activities in football, hamstring injuries seem to mainly occur during high-speed running and kicking (Askling et al., 2007; Huygaerts et al., 2020; Woods et al., 2004). However, the number of studies reporting this information is limited and information regarding the running intensity during which such injuries occur is still scarce and mostly anecdotal, therefore further investigation is needed. As previously discussed the studies which reported that hamstring injuries occur during running do not report this level of detail on the running speed. The inciting activities of injuries occurring during running activities are reported in the literature as running, high-speed running and accelerating, which provides limited and heterogeneous information. In football, high-speed running refers to runs performed either between 15 and 18.9 km/h or between 19.8 and 25.1 km/h and a threshold of either 2, 2.5, or 3 m/s^2 has been used to define an effort as acceleration (measured with objective methods as GPS). The different thresholds used to classify player's actions could evidently lead to heterogeneity, but studies which report these data (e.g., studies investigating match physical demand or studies comparing physical load among sessions) usually report both the metrics (e.g., acceleration, high-speed running) and the thresholds (e.g., 19.8 km/h, 2 m/s^2) (for a review see Teixeira et al. (2021)). However, the studies currently available in the literature which analysed the inciting activities reported only the metrics without reporting the thresholds, which makes understanding the specifics of the inciting activities difficult. Since none of these studies used objective methods to evaluate running activities at the time of injury, it is very likely that an inciting activity was reported as running, high-speed running or accelerating from the research team according to their subjective judgment of player activities. Therefore, although running at high-speed seems to match the biomechanical description of hamstring injuries, it is not clear if hamstring injuries occur when players run above a certain speed (e.g., 15 km/h, 20 km/h), when they are running at steady speed or accelerating, or when players run at lower speeds.

Since hamstring activity during running depends on the relative running speed (Hegyi et al., 2019; Higashihara et al., 2010), reporting relative speeds seems more relevant than reporting absolute speeds. The maximal running speed of elite football players may range between 30 and 37 km/h (Chapter 5.3.1.1) therefore the same absolute speed may correspond to different relative speeds. For example, running at 25 km/h may correspond to 71% of maximal speed for a player whose maximal speed is 35 km/h and to 83% of maximal speed for a player whose maximal speed is 30 km/h. Therefore, both absolute and relative values should be reported. This would give more complete information to practitioners and researchers and make it possible to evaluate the interaction of other elements of the system with the inciting circumstances. For example, some evidence suggests that there may be a relationship between history of exposure to high-speed running and the risk of injury (Malone et al., 2017b). Therefore, if the hypothesis that hamstring injuries occur during high-speed running activities is confirmed, it will be possible to evaluate whether manipulating players’ exposure to the running activities at which hamstring injuries occur would reduce hamstring injuries, or whether improving a player’s maximal running speed would lead to a reduction in injury risk.

2.3.4 Quadriceps injuries

The incidence in elite football of quadriceps injuries is 0.41/1000 h which corresponds to circa two injuries per team per season. On average, elite football players who incur quadriceps injuries miss 16.9 days and the average injury burden is 7 days/1000 h (Ekstrand et al., 2011). The quadricep consists of four muscles, but the majority of injuries occur to the rectus femoris (see Mendiguchia et al. (2013) for a review). Literature regarding inciting circumstances of the rectus femoris and more generally of quadriceps injuries is limited, but since muscle strains commonly occur during eccentric contractions (Garrett, 1990), it can be hypothesised that activities that require quadriceps eccentric activity or high muscle elongation may put this muscle at greater risk of injury (Mendiguchia et al., 2013). The rectus femoris achieves its maximum length with the hip extended and knee flexed, such as that seen within the early swing phase of running or in the backswing phase of kicking (Kellis & Katis, 2007; Riley et al., 2010). During high-intensity accelerations and high-speed running, the hips and knees achieve high angular velocities which, combined with eccentric action, may put the rectus femoris at risk of injury (Mendiguchia et al., 2013). Additionally, since the rectus femoris is exposed to increased eccentric forces during high-intensity deceleration, such activity may also put this muscle at increased risk of injury.

There is limited evidence suggesting that kicking may be another activity leading to rectus femoris injuries (Mendiguchia et al., 2013; Woods et al., 2002). Mendiguchia et al. (2013) argued that this type of injury may occur during the swing phase of the kicking leg and the ground contact phase of the support leg. Indeed, as reported for running, the high angular velocity combined with the eccentric action that the rectus femoris performs to decelerate hip extension and knee flexion of the kicking leg during the swing phase may put the rectus femoris at risk of injury. Additionally, the ground reaction forces that apply to the rectus femoris of the support leg at the final step that precedes contact with ball may play a role in injury occurrence. Unfortunately, very few studies have actually analysed the inciting circumstances of quadriceps injuries, therefore the current knowledge is based on hypothesis formulated on the basis of anecdotes or general mechanisms of muscle injuries (i.e., not specifically quadriceps injuries). As a consequence, the level of evidence is low and it is difficult to provide reliable information to researchers and practitioners. Given that running and kicking are among the most frequent activities performed in football, clarifying whether they can increase the risk of quadriceps injuries would help practitioners to plan training sessions. For example, if research suggests that kicking leads to a high percentage of quadriceps injuries practitioners might decide to adapt training sessions and reduce the number of kicks performed, especially for those players who recently suffered a quadriceps injury or those who are believed to be at risk of suffering such injury. Additionally, if a specific kicking phase is identified as the riskiest activity, specific training programmes may be designed. For example, if research confirms that injuries specifically occur during the swing phase of kicking which precedes impact with the ball, specific prevention programmes (e.g., stretching, eccentric strengthening) might be developed and tested.

2.3.5 Adductor injuries

The incidence of adductor injuries in elite football is approximately 0.57/1000 h which corresponds to circa three injuries per team per season. On average, elite football players who incur adductor injuries miss 14 days and the average injury burden is 8 days/1000 h (Ekstrand et al., 2011).

It has been reported that circa 90% of adductor injuries occur at the adductor longus, (Kiel & Kaiser, 2020; Serner et al., 2019) but the literature on the mechanisms of adductor injuries is limited. It has been hypothesised that the adductor longus may be at risk of injury when the hip is close to its maximal extension and achieves its peak eccentric activation (Charnock et al., 2009; Garrett, 1990). However, a recent study conducted by Serner et al. (2019) reported that most adductor injuries in football occur when the injured hip is abducted and the injured knee is in flexion <45 degrees. Furthermore, adductor injuries are more common in sports involving accelerations, decelerations, and changes of direction (Crockett et al., 2015; Franklyn-Miller et al., 2017) therefore it can be assumed that these activities put greater stress on the adductor muscles. This is supported by the findings reported by Serner et al. (2019) who found that adductors injuries occurred during changes of direction, kicking, and reaching, all activities in which the hip is abducted or there is a transition from hip extension to hip flexion. To the best of my knowledge, the study conducted by Serner et al. (2019) is the only one which specifically analysed adductor injuries. Other studies have been conducted on the inciting circumstances leading to hip and groin injuries, but they did not report the inciting activities by specific tissues. For example, Ralston et al. (2020) reported inciting activities leading to hip and groin injuries analysing several tissues (e.g., adductor muscles, abductor muscles, iliopsoas, gluteus, greater trochanter). They reported the inciting activities leading to all injuries, without differentiating among different injuries (e.g., abductor muscle tears, adductor tears), hence it is difficult to evaluate the inciting circumstances leading to specific injuries.

Although Serner et al. (2019) conducted their study using prospective video-analysis combined with medical reports and player interviews, which as discussed in Chapter 2.2 seems a promising method, the arbitrary classification of the inciting circumstances constitutes an important limitation. Furthermore, only 17 adductor injuries were analysed, therefore these findings can be seen as starting point to understand the inciting circumstances leading to adductor injuries but need to be confirmed by further studies which specifically analyse adductor injuries with a larger sample.

2.3.6 Calf injuries

The incidence of calf injuries in elite football is circa 0.31/1000 h which corresponds to circa 1.5 injuries per team per season. On average, elite football players who incur calf injuries miss 14 days and the average injury burden is 4.6 days/1000 h (Ekstrand et al., 2011). It has been reported that the gastrocnemius may be at higher risk of injury than the soleus since it crosses two joints (Bryan Dixon, 2009), however a recent study on Australian football players reported that soleus injuries are more common than gastrocnemius injuries (Green et al., 2020b). The literature on inciting circumstances of calf injuries is limited. In runners, most soleus injuries seem to have a gradual onset, while gastrocnemius injuries are predominantly sudden onset and occur with knee extension and ankle dorsiflexion (i.e., muscle elongated and/or eccentric action) (Fields

& Rigby, 2016). In Australian football running activities (high intensity running, steady speed running, and acceleration) were the most common inciting activities (Green et al., 2020b). As discussed above for hamstring injuries, no details were reported on the relative or absolute speed at which the injuries occurred, however these results seem to support what has been reported in runners. Inciting circumstances in football may be similar to the ones reported in Australian football, but this needs to be confirmed by further research. It is interesting to note that most research focuses on injuries with high injury burden (i.e., hamstring and ACL injuries), while as injury burden decreases the number of studies decreases. This further supports the importance of collecting and reporting injury data appropriately and in detail, because such information is used by researchers to prioritise injuries to focus their resources on.

From this review of the literature it seems apparent that research on inciting circumstances leading to injuries shows important limitations for all injuries and is very scarce in quantity for injuries with lower injury burden. Specifically, mechanisms reported for ACL and ankle injuries do not exactly match the inciting activities reported to lead to these injuries in football. The literature around inciting circumstances of calf, quadriceps, and adductor injuries is very scarce, while the evidence suggests that hamstring injuries may occur during kicking and running activities, but details such as running speed have not been reported objectively. Furthermore, there is limited quantity and quality of evidence available on inciting circumstances, and most studies do not acknowledge the limitations described above (e.g., definitions used to report injuries, systems used to classify and report inciting circumstances) but do include in the abstract and in the discussion of the studies statements suggesting that there is certainty about the circumstances leading to injuries. For example, Gronwald et al.

(2021) in their conclusions stated that “acceleration and high-speed running phases […] are key inciting events in non-contact and indirect hamstring injuries”, but given the limitations of their study (e.g., only injuries which caused more than seven days absences were included, data were obtained through online databases, and around two thirds of the injuries they aimed to analyse could not be analysed due to missing data) their results do not seem to be able to support such a claim.

As a consequence of these statements, practitioners who read the studies may give study findings more credit than they should which may result in inaccurate decision making. For example, if practitioners develop prevention strategies on the basis that hamstring injuries occur during high-speed running activities, if such information is not correct the prevention strategy built on this information is likely to be unsuccessful (Ioannidis, 2018; Pannucci & Wilkins, 2010; Simundić, 2013). This will inevitably impact the quality of practitioners’ work and the trust they place in research (Ardern et al., 2019). Since the main aim of this type of research is to support practice (Coutts, 2017), providing inaccurate information goes against such an aim. This aspect is extremely relevant for all research and for this project particularly, therefore in the next section the importance and impact of research in football practice will be discussed.

2.4 Guidance for the development of prevention strategies

As previously reported, investigating information on how injuries occur can guide (together with information on risk factors and injury extent) the development of prevention strategies. Albeit with some limitations, information about injury circumstances and risk factors is available within the literature and practitioners can use such information to guide their practice. Evaluating how practitioners find and use information to guide their practice could help to understand whether and how the available literature supports practice and, if not, what can be done to do so. However, before delving into how and why research is used in practice it is important to define what research is.

2.4.1 Research and evidence-based practice

Research can be defined as the application of systematic and constructed methods to obtain, analyse, and interpret data which in turn allows the advancement of knowledge (Erol, 2017). Scientific research can be split into pure (or basic) research and applied research. Pure research aims to advance scientific theories while applied research aims to apply findings to achieve a practical objective (Bunge, 1974; Organisation for Economic Co-operation and Development, 2015). Both pure and applied research need to use systematic methods in order to avoid bias, which is the presence of systematic error in any step of research (e.g., participants' recruitment, data collection, data analysis, publication) and may favour certain findings and lead to erroneous conclusions and practice (Ioannidis, 2018; Pannucci & Wilkins, 2010; Simundić, 2013). Since research contributes to the development of evidence-based practice, it is essential to ensure the quality of the research and limit the presence of bias. Additionally, considering that the number of scientific publications has been growing in recent years and the increasing complexity of research, researchers need to make numerous choices on how to conduct studies. Ioannidis (2018) estimated that with 20 binary decisions to make there are more than 1 million ways to conduct the same research study which could lead to numerous different results. Therefore, standard methodologies must be developed and implemented to ensure that research results are reliable. This is the purpose of a recent discipline, named meta-research, which aims to study and improve the way research is conducted.

Once conducted, research is combined with practitioners' expertise and athlete's values to guide practice. This is commonly referred to as "evidence-based practice" (Fullagar et al., 2019a). Evidence-based practice offers several advantages. For example, it provides a scientific basis to support decision making, which discourages the use of pseudoscientific practices and reduces uncertainty. Additionally, it provides up to date guidelines which increases practice efficacy.

2.4.2 Bringing research to practice in football

Sport practitioners work in a very fast-paced environment where they need to interact with coaches and players, take quick decisions, and deliver innovative and effective treatments or programmes. To inform their decisions in such a short time, sport practitioners rely on intuition, experience, and data which (due to the fast pace of the environment they work in) cannot be analysed with the same standards applied in research environments (Coutts, 2016). This is clearly not optimal and could lead to inaccurate decisions, therefore when possible practitioners try to implement evidence-based practices (Fullagar et al., 2019a). The development of evidence-based practices is a process which requires time and resources. This process is usually entrusted to researchers, who use the so-called "slow-thinking" system to develop evidence-based practices and communicate them to practitioners who use this information to guide their decisions. This is how it would ideally work, but there are questions over whether this is the reality.

The number of scientific articles published has been increasing over the past 20 years. Using PubMed for reference, in 2001 less than 300 studies were published on football related topics while in 2021 more than 2700 studies were published. Practitioners need to be able to find information, evaluate the quality and usability in their settings, and use the information to guide their decision making (Ardern et al., 2019). However, there are several barriers which make this process difficult. As mentioned in the previous section, practitioners have limited time therefore may not be able to systematically search the literature, evaluate their quality, and generate synthesis. For this reason practitioners prefer more informal and time-efficient ways to access research such as infographics and conversations. However, for a number of reasons researchers usually prefer more formal ways to disseminate research such as publication in scientific journals or conference presentations (Malone et al., 2019) which may not be as readily available to practitioners. Another barrier which makes accessing information difficult for practitioners is that they develop skills specific to their jobs hence their ability to find, interpret, and critically appraise research to translate into practice may be limited (Moseley et al., 2020). This may be linked with practitioners' preference toward more informal ways to communicate science. Other factors such as lack of staff, time, and "applied" research, coaches and players' buy-in, and misalignment between research and practitioner's needs have been reported as elements which constitute a barrier for practitioners (Fullagar et al., 2019a; Fullagar et al., 2019b).

Despite these barriers, practitioners still try to find information within scientific literature to guide their decisions. It is important to highlight that when they do so they may implicitly trust research to provide high quality and reliable information.

However, if research provides inaccurate information this trust can be lost and the gap between research and practice may widen. Science is not perfect, therefore errors are not only inevitable but are part of the scientific process. At the same time, it must always be considered that scientific errors can have an impact on practitioners and their trust in research as a mechanism for supporting decision making. For example, if a research article identifies a certain variable as a risk factor for injuries, practitioners may use this information to guide their practice. If subsequent studies prove that this variable is not a risk factor, practitioners who had used the first article to guide their practice might feel misled and reduce their trust in research. Therefore, it is important that researchers exercise caution when they provide guidelines and recommendations for practitioners.

As mentioned in the previous chapter, injury prevention strategies are built upon information on injury extent, risk factors, and circumstances, but important limitations are observed in the literature concerning all of these components. For example, several systematic reviews have reported that the studies available in the literature have used inconsistent injury definitions (e.g., 48h time-loss injury, match-loss injury) (Alahmad et al., 2020; Jones et al., 2019; Lopez-Valenciano et al., 2019; Pfirrmann et al., 2016) which as previously discussed inevitably influences the research on all components. More information on such limitations can be found elsewhere (Nielsen et al., 2019; Nielsen et al., 2020; Verhagen et al., 2018; Wik et al., 2019), but it seems clear that low quality or lack of information on injury extent, risk factors, and injury circumstances would lead to ineffective prevention strategies and in turn to failure to prevent injuries and the risk of losing practitioners' trust. Therefore, it seems equally clear that additional and more robust research is needed on these topics.

2.5 Statement of purpose of the thesis

Information on injury extent, risk factors, and circumstances are essential for the development of injury prevention strategies. The limitations of the literature on injury inciting circumstances play a role in the limited effectiveness showed by prevention strategies currently implemented in football. This is a problem because injury burden does not seem to be decreasing in elite football despite a plethora of published studies available for reference (Ekstrand et al., 2021), and because ineffective prevention strategies may widen the gap between research and practice. There are several limitations within the research on football injuries, some of which have been discussed within this chapter (e.g., definitions used to define injuries within the literature, inciting circumstances) and others have not (e.g., studies which interpret the presence of association as causal relationship, absence of methods to remove bias in observational studies which aim to analyse the presence of causal relationships), however it would be impossible to address them all during this thesis.

Since information on inciting circumstances is important to guide the research on risk factors and specifically on injury mechanisms and is an important factor for the development of prevention strategies, the remainder of this thesis will focus on this aspect. Therefore, the aim of this thesis is to try to improve the methods used to analyse the inciting circumstances during which injuries occur in football. As previously discussed, there is a lack of a standard method to analyse the inciting circumstances in football, which leads to inconsistent reporting. However, before the development of a new reporting system, it seems important to evaluate the current literature on the topic and the extent of the heterogeneity of reporting. Additionally, a systematic review of the literature is an important step in the development of reporting systems, therefore a systematic review of the literature will be conducted to evaluate the available evidence on the circumstances leading to injuries in football.

3 Injury inciting circumstances in male and female football players: a systematic review

3.1 Introduction

As described in 1, to effectively develop injury prevention strategies it is necessary to have information on injury extent, risk factors, and inciting circumstances (O'Brien et al., 2019). However, there seems to be inconsistency in how data on inciting circumstances are collected and reported, probably because there is a lack of standardised systems for the reporting of such data. Therefore, it is necessary to develop a system to standardise the classification of inciting circumstances.

Despite the recognition that information on inciting circumstances is crucial for the understanding of mechanisms of injuries and for the development of injury prevention strategies, there are no published consolidation studies such as systematic reviews on the topic. On the other hand, the literature on injury extent (Jones et al., 2019; Lopez-Valenciano et al., 2019; Pfirrmann et al., 2016) and risk factors (Alahmad et al., 2020; Green et al., 2020a) has previously been summarised. Systematic reviews are the best scientific tool to critically appraise and summarise the results of a high number of research studies. Such studies are used to develop guidelines and provide clinicians with summaries of the evidence currently available on a certain topic, on which they can base their decisions (Green, 2005; Higgins JPT et al., 2021; Moher et al., 2009; Mulrow, 1994; Shea et al., 2017). Additionally, a systematic review on inciting circumstances would allow theo evaluation of the current literature on the topic and the extent of the heterogeneity of reporting, which constitutes an important step in the development of reporting systems.

Therefore, this study aims to analyse the inciting circumstances leading to injury in male and female football players over 13 years of age. The objectives of this study are to summarise the available information on inciting circumstances which led to specific injuries and to evaluate the quality of evidence of the available literature. Given that, as discussed in the literature review, studies included in previous systematic reviews on injury risk factors and incidence showed high risk of bias (RoB) and implemented inconsistent injury definitions, and considering that studies on inciting circumstances used inconsistent systems for data collection and reporting, these aspects will be thoroughly evaluated in this review.

3.2 Methods

The protocol of this systematic review was developed following the guidelines provided by the Preferred Reporting Items for Systematic Reviews and Meta-analyses 2020 (PRISMA 2020) and A MeaSurement Tool to Assess systematic Reviews 2 (AMSTAR 2) (Page et al., 2021; Shea et al., 2017). The protocol was first registered at the Open Science Framework in April 2020 and updated in July 2020 after inclusion criteria were amended (10.17605/OSF.IO/U96KV).

3.2.1 Eligibility criteria

To be included, studies had to be English full texts and needed to report on the following criteria: football (soccer) players (any level) aged > 13 years old; number of injuries; and inciting activities leading to lower-limb injuries. Studies that involved recreational players, players < 13 years or elderly, military, or clinical populations were excluded because they may use different rules than the ones used by the population of interest. These differences may include different number of players involved, different playing time, different sizes of pitch, goals, and ball (The Football Association, 2019). Peer reviewed articles and grey literature were included, while review, meta-analyses, opinion pieces, and reports with abstract only were excluded.

3.2.2 Search strategy

A systematic search was carried out in PubMed (MEDLINE), Web of Science, SPORTDiscus (EBSCO) and Open Grey to include articles from inception to April 2020. Search criteria were based on the Population, phenomena of Interest, Context (PICo) framework (Lockwood et al., 2015) as follows: population was considered as football (soccer) players; phenomena of interest were considered as inciting circumstances in which injuries occurred; and context was considered as any match or training session. The following search strategy was used for all the databases: (football OR soccer) AND (injur* AND (mechanism* OR event* OR situation* OR circumstance* OR occasion* OR activit* OR characteristic*)) AND (training OR match* OR game* OR competition*) (Table 3.1). A second search was performed after completion of data extraction (July 2020) to ensure the inclusion of the most recent studies that may have not been available previously. Additionally, to ensure the inclusion of all relevant studies, further studies were searched for by consulting research experts, hand searching and checking the references of those obtained from the original search. Finally, after the completion of the full text selection the web source Connected Papers (https://www.connectedpapers.com/) was used to find additional relevant studies. Finally, a third search was performed in December 2021 to ensure the inclusion of the most recent studies.

Table 3.1 Search strategy

Database	Search Strategy	Results (n)
PubMed	(((injur*) AND (((((((mechanism*) OR event*) OR situation*) OR circumstance*) OR occasion*) OR activit*) OR characteristic*)) AND ((((competition*) OR game*) OR match*) OR training)) AND ((football) OR soccer)	1872
SPORTDiscus	"ALL FIELDS: (injur*) AND ALL FIELDS: (((((((mechanism*) OR event*) OR situation*) OR circumstance*) OR occasion*) OR activit*) OR characteristic*) AND ALL FIELDS: ((football) OR soccer) AND ALL FIELDS: ((((competition*) OR game*) OR match*) OR training) Refined by: LANGUAGES: (ENGLISH) AND DOCUMENT TYPES: (ARTICLE)"	1654
Web of Science	#1 ALL FIELDS: (training) OR ALL FIELDS:(match*) OR ALL FIELDS: (game*) OR ALL FIELDS: (competition*) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years #2 ALL FIELDS: (injur*) #3 ALL FIELDS: (mechanism*) OR ALL FIELDS: (event*) OR ALL FIELDS: (circumstance*) OR ALL FIELDS: (occasion*) OR ALL FIELDS: (activit*) OR ALL FIELDS: (situation*) OR ALL FIELDS: (characteristic*) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years #4 ALL FIELDS: (football) OR ALL FIELDS: (soccer) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years #5 #4 AND #3 AND #2 AND #1 Refined by: LANGUAGES: (ENGLISH) AND DOCUMENT TYPES: (ARTICLE) AND DOCUMENT TYPES: (ARTICLE) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years	2203
OpenGrey	(((injur*) AND (((((((mechanism*) OR event*) OR situation*) OR circumstance*) OR occasion*) OR activit*) OR characteristic*)) AND ((((competition*) OR game*) OR match*) OR training)) AND ((football) OR soccer)	5

3.2.3 Study selection

Two reviewers (myself – reviewer one and Professor Franco Impellizzeri – reviewer two) independently screened titles and abstracts of the studies using Endnote X9.3.3 (Clavirate, Philadelphia, USA). Reviewer one had limited experience and reviewer two had extensive experience (>10 publications) and formal education training in systematic review and meta-analysis (reviewers' experience is reported as suggested by AMSTAR 2.0). A comprehensive selection was applied as the reviewers believed that inciting activities are usually reported as additional analyses in the full texts. To be included for further assessment, titles had to specify a football or soccer population and to include the word "injury" or a synonym thereof, while abstracts had to report any information relating to injuries such as incidence or severity. Subsequently, reviewer one screened the full texts, and reviewer two checked a random selection of the included studies (52%) and all the full texts with initial inclusion uncertainty. Studies reporting data from a mixed population (e.g., various sports and ages) were included if it was possible to extract data for the specific population of interest. To evaluate inter-rater reliability of the inclusion process, Cohen's kappa coefficient between the two reviewers was separately calculated for abstracts and full texts selection (McHugh, 2012). Disagreements between the two reviewers were solved by a third reviewer (Dr. Alan McCall, with experience in systematic reviews and meta-analyses). None of the reviewers had a conflict of interest with the review topic.

3.2.4 Data extraction

Data regarding sample size, player characteristics, aims of the studies, results and methods implemented for injury data collection and analysis were extracted by reviewer one and a random sample was verified by a second reviewer (reviewer three) for accuracy. When needed, data from figures were obtained using a validated web-based app (WebPlotDigitizer V4.3, https://automeris.io/WebPlotDigitizer, Pacifica, California, USA) (Drevon et al., 2017). Once data were extracted, the percentage of injuries which occurred during each inciting circumstance was obtained from each study if it was reported, otherwise was determined by calculating the ratio between the number of injuries occurred during each inciting circumstance and the total number of injuries occurred. When both general (e.g., contact with another player) and detailed inciting activities (e.g., tackling and being tackled) were reported, only the detailed activities were analysed.

During the extraction process, reviewer one found that similar inciting activities were reported using different classifications. Therefore, it was decided to group similar inciting activities. Categorisations of inciting activities were not available in the literature, therefore such categories were created by the research team which included a physiotherapist, a biomechanist, and three sport scientists. Reviewer one developed the first version of the categorisation which was subsequently discussed with the research team until consensus was achieved. The research team decided to group inciting activities into the following categories: ball handling, blocking, changing direction, duel, general running, high intensity running, jumping, kicking, unspecified and other activities.

It was decided to group the inciting activities into the following categories due to the similarity of the activities included within each category. All those activities which descried injuries occurred because of a direct or indirect duel were included into the category “duel”. The events which described injuries occurring while the player was kicking the ball (e.g., passing, shooting, clearing) were included into the category “kicking”, and the other events that indicated that the player was in possession of the ball but did not indicate a kicking activity (e.g., receiving a pass, dribbling) were included into the category “ball handling”. Football-specific activities (e.g., defending, specific action) were included into the category “general play”. Finally, running activities were split into three categories. Firstly, activities that involved a change of direction (e.g., twisting, turning) were categorised as “changing direction”. Secondly, when it was stated that running activities were performed at high-intensity or high-speed (e.g., sprinting, high-speed running) or it seemed reasonable to assume that they were performed at high-intensity (e.g., acceleration, conditioning), they were categorised as “high intensity activity”, while other running activities were classified as “general running”. Finally, jumping activities (e.g., jumping, landing) were classified as such (Table 3.2). Data concerning playing phases and pitch position at time of injury were not merged and are presented as originally reported in the studies.

Table 3.2. Categorisation of inciting activities

Category	**Activities included (as originally reported by the included studies)**
Ball handling	Ball handling/dribbling Ball handling/controlling Ball possession Dribbling/shielding Dribbling Chasing a loose ball Pass cutting Passing/receiving pass Regaining balance after reaching Reaching Receiving pass / blocking shot Receiving Stretching
Blocking	Blocking Blocking a shot or pass

	Deflection
Changing direction	Changing direction
	Cutting
	Running, intention of turning
	Twisting/turning
Duel	Contact/collision
	Collision
	Player - player contact (Excluding slide tackle)
	Contact with another player
	Direct trauma
	Duel
	Foul
	Impact
	Stepped on/fallen/kicked
	Kicked
	Tackling/being tackled
	Slide tackle
	Receiving a charge
	Kick/knee from opponents
	Tackled
	Tackling
	Violent conduct
	Use of elbow
	Heading
	Pressing
	Stepped on
General running	Distorting
	Falling
	Lateral movements
	Planting
	Running or other individual activities
	Running
	Running/jumping
	Slipping
High intensity running	Accelerating
	Acceleration / cutting
	Conditioning
	Decelerating
	Running/sprint
	Sprinting/High speed running
	Sprinting
Jumping	Jumping/landing
	Jumping
	Landing
Kicking	Clearing
	Crossing
	Regaining balance after kicking
	Shooting/kicking
	Kicking
	Passing/shooting
	Passing
	Shooting
Other activities	Artificial turf
	Playing field conditions
	Turf
	Weather conditions

Unspecified activities	Ball non-possession Defending General play Specific action Technique Throwing

3.2.5 Assessment of Risk of Bias

To evaluate the quality of the available literature and to provide recommendations for further research, an assessment of RoB in the included studies was performed. The tools for the assessment of RoB were selected based on the included studies. Since the aim of this review was to summarise the inciting circumstances in football, the main issues to address were deemed to be the following: participants' representativeness, definitions of injuries and inciting circumstances, and methodologies for data collection and analysis. Therefore, since these issues are commonly addressed through tools to assess RoB in prevalence studies, a modified and validated version of the checklist developed by Leboeuf-Yde and Lauritsen (1995) for assessment of RoB in prevalence studies developed by Hoy et al. (2012) was adapted and applied to all the studies. The final tool was developed by two reviewers (FA and FMI). All but two items of Hoy's checklist (number 2 and 3) were deemed appropriate and applicable for the aim of this review. Item number 2 evaluates whether the sampling frame was a true or close representation of the target population and item number 3 evaluates whether some sort of random selection is used to select the sample. Since sampling frames were not used by the included studies these items were deemed as not applicable, and therefore removed. Furthermore, it was believed that descriptions of study samples should be as accurate as possible to understand what population these results may be applied to, therefore to evaluate this aspect one additional item (number 2) from the

NIH Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies was included (National Institutes of Health, 2014).

Finally, the adapted tool included 9 items addressing the following aspects: 1) study population representativeness of the target population, which if not clearly defined may limit the applicability of the results to the target make hard contextualising and applying results and conclusion of the study to the appropriate population; 2) description of the study subjects, which if not well defined may make it difficult to understand the external validity of the findings; 3) how missing data were dealt with, which could impact sample representativeness and induce selection bias; 4) data collection methods, as data coming from databases or internet sources may come from untrustworthy sources and have been reported or collected with various and inappropriate methods; 5) injury definition, because an unclear or inappropriate case definition may influence the number of cases and therefore the prevalence of each inciting event; 6) instrument for the measurement of the parameter of interest, because the usage of non-validated methods to evaluate inciting circumstances may limit validity of the results and afflict prevalence of the inciting circumstances; 7) homogeneity of data collection methods, because collecting data with different methods may influence the results; 8) length of shortest prevalence period, as an inappropriate length of prevalence or observation period may bias injury prevalence; 9) reporting of numerator(s) and denominator(s) for the parameter of interest, as an unclear reporting of such parameters may limit the understanding of prevalence. Items 1-3 were used to evaluate the internal validity (i.e., the extent to which study results are free from bias) and items 4-9 were used to evaluate the external validity (i.e., the extent to which the study results are applicable to the real world). A complete explanation of the adapted tool and of the criteria used to evaluate the RoB in the included studies is available in Appendix A.

The RoB of the included studies was assessed scoring each item as “Yes”, “Partially” or “No” if respectively all, some or none of the scoring criteria were respected. When information was not clear enough to score an item, it was rated as “Unclear”, while items deemed as not applicable were rated as such. Once agreement was reached, the same two reviewers who developed the tool piloted it on nine studies (round one). Subsequently, the reviewers further discussed the scoring criteria and evaluated five studies (round two). The agreement in round two was substantial (K = 0.67), therefore the same two reviewers further refined the scoring criteria and performed two further rounds until almost perfect agreement (K =0.87) was reached. Finally, the same two reviewers screened 51% (n=28) of the studies included and reviewer one scored the remaining studies. Each domain was assessed individually, and an overall rate of each domain was calculated, without trying to collate an overall score for each study (Shea et al., 2017). Items scored as “Unclear” and “No” were rated as “high RoB”, items scored as “Partially” were rated as “medium RoB”, and items scored as “Yes” were rated as “low RoB”. Not-applicable items were not included in the rating. Eventual disagreements between reviewers one and two were resolved by discussion and, when agreement was not achieved, a final decision was taken by reviewer three.

Table 3.3 Inter-rater agreement in the analysis of RoB

Round	**Number of studies**	**Studies**	**Percentage of agreement**	**Cohen’s Kappa**

Familiarisation	2	(Brophy et al., 2015; de Freitas Guina Fachina et al., 2013)	NA	NA
1	8	(Bjørneboe et al., 2014; Della Villa et al., 2020; Fitzharris et al., 2017; Grassi et al., 2017; Hawkins & Fuller, 1998; Khodaee et al., 2017; Meyers, 2017; Rahnama et al., 2002)	88%	0.81
2	5	(Andersen et al., 2004b; Bastos et al., 2013; Faude et al., 2005; Jacobs & Van Den Berg, 2012; Nilsson et al., 2016)	87%	0.67
3	5	(Carling et al., 2010; Cross et al., 2018; Hawkins et al., 2001; Kofotolis et al., 2007; Tscholl et al., 2007)	91%	0.87
4	8	(Azubuike, 2009; Gaulrapp et al., 2010; Hassabi et al., 2010; Rahnama et al., 2009; Ralston et al., 2020; Rochcongar et al., 2009; Sentsomedi & Puckree, 2016; Ueblacker et al., 2015)	92%	0.87

3.2.6 Data analysis

Data were presented narratively in tables for the inciting circumstances as reported by the included studies and in figures for the prevalence of the inciting activity categories. Due to high data heterogeneity performing a meta-analysis was not possible. Data were analysed using RStudio version 1.3.1056 and packages *reshape2* and *ggplot2* (RStudio Team, 2020; Wickham, 2007; Wickham, 2016) and an interactive dashboard was created with Tableau 2021.1 to allow the reader to explore the inciting activities according to injury location and by player characteristics reported by the included studies (playing level and sex).

3.3 Results

3.3.1 Search results

The systematic search provided 5734 articles, of which 1969 were duplicates, leaving 3765 studies for screening. After abstract selection, authors agreed to exclude 3568 studies and to include 197 studies for full texts screening of which 142 were excluded (Appendix B) and 55 were deemed eligible to be included in the review. Five additional studies were retrieved by reference checking and hand searching, and four were retrieved from Connected Papers. In total, following all searches and screening methods, 64 studies were included in the systematic review, all of which were peer-reviewed (Figure 3.1). Substantial agreement was shown in titles and abstract screening (K = 0.69; percentage agreement = 96%) and in compliance with AMSTAR 2 guidelines, perfect agreement was shown in full-text selection (K = 1; percentage agreement = 100%). Data from five studies (Andersen et al., 2004b; Arnason et al., 2004; Fitzharris et al., 2017; Gaulrapp et al., 2010; Hawkins & Fuller, 1998) were extracted using WebPlotDigitizer V4.3. The PRISMA checklist is reported in Appendix C.

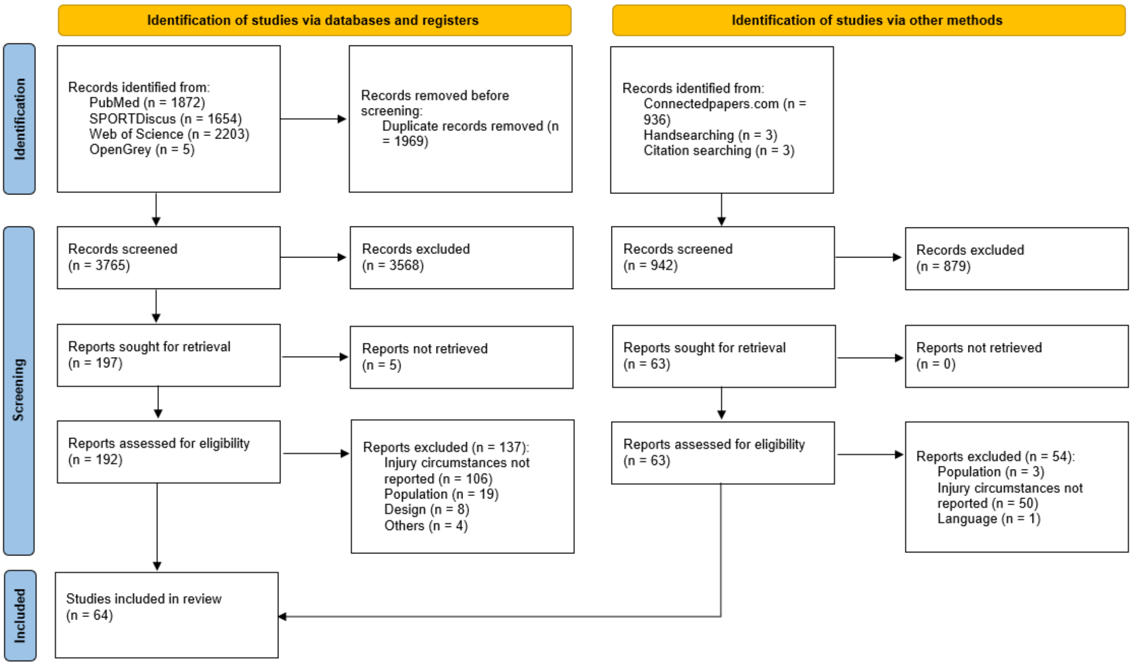

Figure 3.1 PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers, and other sources

3.3.2 Study characteristics

Most of the included studies involved male participants (43 studies, 67% of total studies), while the remaining studies involved females (13, 20%) or both males and females (8, 13%). Thirty studies (47%) included over 18 players aged over 18 and the remaining 34 studies (53%) involved players under 18 or did not report the age of the players. Of the 64 studies, 38 (59%) included professional players and the remaining 26 (41%) included semi-professional (2, 3%), amateur (2, 3%), and youth players (12, 18%). Ten studies (16%) did not clearly report the playing level of the players.

Twenty-eight studies did not aim to analyse inciting activities specifically, nevertheless reported them in the results. This supports the comprehensive approach applied in the selection process. The method by which data on inciting activities were collected were medical reports filled out by sports medicine practitioners (32, 50%), video-based methods (20, 31%), questionnaires (12, 18%), and interviews (4, 6%). Sometimes more than one method was used to collect injury data. Among the included studies, only 13 (20%) used the injury definitions recommended for studies in football provided by Fuller et al. (2006) and only three of the 20 which analysed inciting activities with video-analysis classified them using a standardised system. Thirty-eight studies analysed the inciting activities without detailing the location of injury (Table 3.4), while the remaining studies analysed the inciting activities of ACL (12) (Table 3.5), ankle and foot (5), knee (5), thigh (4), adductors/hip/groin (3), and hamstring (2) injuries (Table 3.6). Five studies reported injuries that occurred to multiple locations.

Table 3.4 Information of studies reporting inciting circumstances leading to overall injuries

Study	Sex	Age	Competitive level	Main aim	Tool	Injuries analysed (N)	Reported injury definition	Phase of play	Player location	Player activity (M-F)
Zeren and Oztekin [120]	M & F	24	Professional	Other	Interview	9	No	Score-celebration: 100%	Not reported	Sliding: 56% Piling up: 33% Racing away: 11%
Kittipong and Arth Na [121]	F	19.96 ± 2.23	Elite	Inciting activity analysis	Questionnaire	210	No	Not reported	Not reported	Collision: 16% Contact with floor: 4% Foul: 6% Kicked: 27% Tackled: 17% Kicking: 8% Overuse: 7% Running: 10% Other*: 6
Bastos et al. [111]	M	14.67 ± 2.08	Not stated	Inciting activity analysis	Questionnaires	56	Yes, supported by non-consensus reference	Not reported	Not reported	Impact: 57% Jumping: 14% Running: 33% Specific action: 25%
Hawkins et al. [114]	M	Adults	Professional	Other	Questionnaires	6030	Yes, not supported by any reference	Not reported	Not reported	Collision: 6% Kicked: 5% Tackled: 15% Tackling: 9% Use of elbow: 1% Diving: 1% Falling: 1% Heading: 1% Jumping: 2% Landing: 4%

										Passing: 4% Running: 19% Shooting: 4% Stretching: 6% Twisting/turning: 8% Other*: 14
Jacobs and Van Den Berg [113]	M	16.2 ± 1.13	Elite	Inciting activity analysis	Questionnaires	544	No	Not reported	Not reported	Collision: 3% Tackled: 8% Tackling: 4% Heading: 1% Jumping: 3% Landing: 3% Running: 6% Shooting: 6% Twisting/turning: 3% Other*: 64%
Sentsomedi and Puckree [117]	F	15.85 ± 1.32	High school	Other	Questionnaires	80	No	Not reported	Not reported	Collision: 18% Tackling/being tackled: 14% Burns: 5% Heading: 8% Jumping: 4% Kicking: 6% Landing: 14% Running: 19% Shooting: 19% Turning: 6%
Woods et al. [122]	M	Adults*	Professional	Other	Questionnaires	6030	Yes, not supported by any reference	Not reported	Not reported	Collision: 6% Kicked: 5% Tackled: 15% Tackling: 9%

										Use of elbow: 1% Diving: 1% Falling: 1% Heading: 1% Jumping: 2% Landing: 4% Passing: 4% Running: 19% Shooting: 4% Stretching: 6% Twisting/turning: 8% Other*: 14%
Azubuike [116]	M	20	Professional and amateur	Other	Questionnaires + interview	204	No	Not reported	Not reported	Collision: 2% Tackling/being tackled: 45% Jumping/landing: 12% Running: 7% Shooting: 9% Twisting/turning: 11% Other*: 15%
Arnason et al. [123]	M	25, range 18-34	Elite	Other	Report	129	Yes, supported by consensus reference	Not reported	Not reported	Tackling: 16% Cutting: 4% Overuse: 6% Shooting/kicking: 9% Sprinting: 11% Other*: 54%
Carling et al. [115]	M	Adults*	Elite	Inciting activity analysis	Report	10	Unclear	Not reported	Not reported	Duel: 40% Tackling: 10% Ball handling/controlling: 10% Jumping: 10%

										Landing: 10% Passing: 10% Running: 20% Sprinting: 80%
Chandran et al. [119]	M	Collegiate	College	Other	Report	2821	Yes, not supported by any reference	Not reported	Not reported	On the ball: 2% Blocking shot: 3% Conditioning: 2% Set pieces: 2% Defending: 11% General play: 32% Goalkeeping: 5% Heading: 5% Loose ball: 3% Passing: 3% Receiving: 2% Running: 11% Finishing: 4% Slide tackling: 5% Other*: 10%
Chandran et al. [124]	F	Collegiate	College	Other	Report	3932	Yes, not supported by any reference	Not reported	Not reported	On the ball: 2% Blocking shot: 3% Conditioning: 2% Set pieces: 2% Defending: 10% General play: 33% Goalkeeping: 6% Heading: 4% Loose ball: 3% Passing: 2% Receiving: 1%

										Running: 11% Finishing: 4% Slide tackling: 5% Other*: 11%
de Freitas Guina Fachina et al. [108]	M	25.7 ± 4.3	Professional	Inciting activity analysis	Report	95	Yes, not supported by any reference	Not reported	Not reported	Collision: 24% Decelerating: 5% Dribbling: 1% Falling: 4% Heading: 1% Jumping: 8% Kicking: 13% Lateral movements: 2% Passing: 6% Running: 16% Other*: 19%
DiStefano et al. [125]	F	High school and college	High school and college	Other	Report	8051	Yes, not supported by any reference	Not reported	Not reported	Tackled: 10% Tackling: 5% Ball handling/controlling: 1% Blocking a shot or pass: 2% Conditioning: 11% Chasing a loose ball: 8% Defending: 12% Diving: 6% General play: 31% Heading: 5% Passing: 5% Receiving: 1% Shooting: 3%

Ekstrand and Gillquist [126]	M	24.6 ± 4.6	Not stated	Inciting activity analysis	Report	256	Yes, not supported by any reference	Not reported	Not reported	Most contact injuries were caused by tackling or kicking, and most non-contact injuries occurred during running or cutting
Faude et al. [35]	F	22.4 ± 5.0	Professional	Other	Report	241	Yes, supported by consensus reference	Not reported	Not reported	Collision: 3% Contact with ball: 4% Foul: 10% Tackled: 15% Tackling: 15% Changing direction: 9% Jumping: 5% Shooting: 12% Slipping: 6% Other*: 18%
Fitzharris et al. [29]	M	23 ± 4.7	Semi professional	Other	Report	152	Yes, supported by consensus reference	Not reported	Not reported	Collision: 22% Contact ball: 1% Tackling: 11% Diving: 1% Falling: 1% Kicking: 1% Landing: 7% Running: 31% Stretching: 6% Twisting/turning: 8% Other*: 11%
Gaulrapp et al. [27]	F	22.8, range 16-35	Professional	Inciting activity analysis	Report	246	Yes, supported by consensus reference	Not reported	Not reported	Tackled: 9% Tackling: 26% Falling: 4% Fatigue: 24% Twisting: 4%

										Turf: 4% Other*: 29%
Hassabi et al. [118]	M	24 ± 3.0	Professional	Inciting activity analysis	Report	50	Yes, not supported by any reference	Not reported	Defensive third: 14% Mid-field third: 2% Offensive third: 8%	Contact: 44% Ball contact: 4% Diving: 1% Falling: 3% Overuse: 4% Running or other individual activities: 14% Other*: 30%
Hawkins and Fuller [127]	M	Adults*	Professional	Other	Report	744	Yes, not supported by any reference	Not reported	Not reported	Collision: 4% Tackled: 23% Tackling: 14% Heading: 2% Jumping: 2% Landing: 5% Overuse / Growth: 8% Running: 19% Shooting: 10% Twisting/turning: 8% Other*: 5%
Ibikunle et al. [128]	F	21.80 ± 4.55	Professional	Inciting activity analysis	Report	62	Yes, not supported by any reference	Not reported	Not reported	Collision: 10% Contact ball: 3% Kicked: 11% Tackled: 15% Tackling: 3% Diving: 3% Dribbling: 6% Heading: 5% Jumping/landing: 6% Running: 6%

										Shooting: 5% Slipping: 10% Stretching: 6% Twisting/turning: 8% Other*: 3%
Kerr et al. [129]	M	High school and college	Not stated	Other	Report	7677	Yes, not supported by any reference	Not reported	Not reported	Tackled: 3% Tackling: 2% Ball handling/controlling: 9% Blocking a shot or pass: 2% Conditioning: 4% Chasing a loose ball: 8% Defending: 11% Diving: 7% General play: 31% Heading: 7% Passing: 5% Receiving: 3% Shooting: 6%
Khodaee et al. [110]	M & F	High school*	Not stated	Inciting activity analysis	Report	6154	Yes, not supported by any reference	Not reported	Def middle: 13% - 13% Def side: 9% - 8% Def midfield: 32% - 37% Off midfield: 19% – 19% Off middle: 8% - 12% Off side: 9% - 8%	Contact ball: 11% - 14% Kicked: 10% - 10% Tackled: 2% - 2% Tackling: 6% - 4% Blocking a shot or pass: 2% - 2% Loose ball: 12% - 11% Conditioning: 4% - 5% Defending: 10% - 16% Diving: 8% - 6% Dribbling: 11% - 10% General play: 24% - 24% Heading: 9% - 6%

										Passing: 5% - 6% Receiving: 5% - 4% Shooting: 5% - 5%
Meyers [109]	M	Collegiate	Collegiate	Inciting activity analysis	Report	722	Yes, supported by non-consensus reference	Warmup: 4% Offensive direct play: 29% Possession buildup: 13% Offensive counterattack: 7% Defensive high pressure: 21% Defensive middle pressure: 13% Defensive low pressure: 6% Kicks penalty/corner /indirect: 7%	Not reported	Contact floor: 7% Stepped on/fallen/kicked: 9% Tackled: 19% Tackling: 5% Blocking a shot or pass: 4% Chasing a loose ball: 8% Diving: 4% Dribbling/shielding: 7% Heading: 8% Heat illness: 1% Non-contact rotation/jump/sprint: 12% Overuse: 3% Passing/receiving pass: 9% Shooting: 4%
Meyers [106]	F	Collegiate	Not stated	Inciting activity analysis	Report	693	Yes, supported by non-consensus reference	Kickoff: 3% Offensive direct play: 0 Possession buildup: 21% Breakdown: 15% Elaborate actions: 10%	Not reported	Contact floor: 14% Stepped on/fallen/kicked: 9% Tackled: 17% Tackling: 4% Blocking a shot or a pass: 6% Chasing a loose ball: 8% Diving: 4% Dribbling/shielding: 8% Heading: 8%

								Defensive middle pressure: 23% Defensive low pressure: 14% Set play: 6% Ineffective attack: 7%		Heat illness: 1% Non-contact rotation/jump/sprint: 10% Overuse: 4% Passing/receiving pass: 4% Shooting: 3%
Nilsson et al. [112]	M	17.7, range 15-19	Elite	Other	Report	61	Yes, supported by consensus reference	Not reported	Not reported	Kick/knee from opponent: 5% Tackled: 3% Blocking: 3% Falling: 8% Jumping/landing: 7% Overload: 16% Passing: 2% Running/sprint: 28% Shooting: 10% Stretching: 3% Twisting/turning: 2% Other*: 13%
Steffen et al. [130]	F	U17	Not stated	Other	Report	230	Yes, supported by consensus reference	Not reported	Not reported	Collision: 8% Tackling: 53% Heading: 4% Running: 21% Other*: 15%
Stubbe et al. [131]	M	24.6 ± 6 4.3	Professional	Inciting activity analysis	Report	286	Yes, supported by consensus reference	Not reported	Not reported	Contact with player: 33% Artificial turf: 2% Distorting: 7% Falling: 3% Fatigue: 11%

										Jumping: 12% Playing field conditions: 6% Receiving: 6% Shooting: 6% Twisting/turning: 8% Weather conditions: 2%
Yard et al. [132]	M & F	Not reported	High school*	Other	Report	1524	Yes, not supported by any reference	Not reported	Not reported	Contact another player: 40% - 46% Contact floor: 18% - 17% Tackled: 4% - 3% Tackling: 3% – 1% Blocking a shot or pass: 3% – 1% Chasing a loose ball: 12% - 14% Conditioning: 5% - 5% Defending: 8% – 14% Diving: 7% – 5% Dribbling/shielding: 14% - 14% General play: 21% - 21% Heading: 8% - 6% Overuse / Growth: 6% - 5% Passing: 6% - 6% Receiving: 4% – 3% Shooting: 5% - 4%
Drummond et al. [50]	M	26.53 ± 4.75	Professional	Other	Video	92	No	Not reported	Not reported	Run/sprint: 34% Twist: 4% Kick: 12% Pass/crossover: 2% Dribble: 1%

										Jump/landing: 6% Fall: 2% Stretching: 1% Slipping: 1% Overuse: 5% Hit by ball: 3% Collision: 2% Heading: 3% Being tackled: 2% Tackling: 1% Being kicked: 5% Blocked: 2% Other*: 14%
Klein et al. [60]	M	Adults*	Professional	Inciting activity analysis	Video	345	No	Ball possession: 52% Ball non possession: 41%	Not reported	Running: 27% Sprinting: 23% Jumping: 20% Lunging: 10% Dribbling: 16% Attacking the ball/opponent: 14% Heading: 13% Tackling: 16% Duels: 83%
Andersen et al. [62]	M	U21	Professional	Inciting activity analysis	Video	52	Yes, not supported by any reference	Attacking phase: 71% Defensive phase: 29%	Def midfield: 35% Off midfield: 23% Opponents penalty box: 13%	Screening: 2% Tackling: 69% Heading: 12% Running: 2% Other*: 15%

									Defensive third: 17% Offensive third: 12%	
Bjørneboe et al. [64]	M	Adults*	Professional	Other	Video	1287	Yes, supported by non-consensus reference	Not reported	Not reported	Contact another player: 88% Contact ball: 4% Other*: 8%
Hawkins and Fuller [26]	M	Adults*	Professional	Other	Video	578	Yes, supported by non-consensus reference	Not reported	Not reported	Collision: 9% Tackled: 18% Tackling: 11% Heading: 16% Other*: 45%
Rahnama et al. [63]	M	Adults*	Professional	Inciting activity analysis	Video	20	Yes, not supported by any reference	Not reported	Def middle: 5% Def side: 5% Def-mid middle: 20% Def-mid side: 15% Off-mid side: 25% Off middle: 15% Off side: 15%	Receiving a charge: 5% Tackled: 70% Tackling: 15% Diving: 5% Kicking: 5%
Tscholl et al. [61]	F	Adults and collegiate *	Professional	Other	Video	230	Yes, supported by consensus reference	Not reported	Not reported	Tackled: 48% Tackling: 39% Hit by ball: 6% Changing direction: 1% Running: 6% Shooting: 8% Other*: 5%

Andersen et al. [28]	M	Adults*	Professional	Inciting activity analysis	Video, football incident analysis	52	Yes, supported by consensus reference	Attacking phase: 57% Defensive phase: 42%	Def middle: 25% Def side: 8% Def-mid middle: 15% Def-mid side: 13% Off-mid middle: 8% Off-mid side: 11% Off middle: 2% Off side: 9% Off score box: 26%	Blocking: 6% Screening: 2% Clearing: 6% Diving: 4% Dribbling: 11% Heading: 21% Passing: 8% Receiving: 8% Shooting: 8% Other*: 27%
Arnason et al. [30]	M	Adults*	Elite	Unclear	Video, football incident analysis	28	Yes, supported by non-consensus reference	Breakdown: 14% Elaborate actions: 6% Long pass attack: 3% Set play: 6% Ineffective attack: 23% Good opp defense: 17% Attacking phase: 16% Defensive phase: 14%	Def middle: 9% Def side: 1% Def-mid middle: 3% Def-mid side: 2% Off-mid middle: 4% Off-mid side: 5% Off middle: 3% Off side: 2% Off score boxe: 2%	Duel: 75% Foul: 18% Screening: 29% Tackled: 29% Tackling: 17% Crossing: 7% Deflection: 39% Flick: 7% Heading: 10% Passing: 50% Running or sprinting: 75%

Competitive levels are reported as originally described by the studies. Participants' age is reported as originally described in the studies. If this was not described it was either deduced by the study or, when this was not possible, it was reported as unclear and indicated in this table with an asterisk (*). Percentages are calculated dividing the total number of injuries that occurred during each activity, phase of play, or location by the total number of injuries that occurred. Activities reported as "Other" indicate the percentage of injuries whose activities were not reported or reported as other or unknown.

Table 3.5 Information of studies reporting inciting circumstances leading to ACL injuries

Study	**Sex**	**Age**	**Competitive level**	**Main aim**	**Tool**	**Injuries analysed (N)**	**Reported injury definition**	**Phase of play**	**Player location**	**Inciting activity (M-F)**
Faunø and Wulff Jakobsen (2006)	M	25.6, range 16-45	Elite and lower levels	Inciting activity analysis	Questionnaires	105	Unclear	Not reported	Opponents field: 59% Home field: 41% Opponents penalty box: 17% Home penalty box: 6%	Landing: 25% Turning: 63% Other*: 12%
Kaneko et al. (2017)	F	17.4 ± 1.9	Not reported	Inciting activity analysis	Questionnaires	90	No	Attaching phase: 40% Defensive phase: 60%	Not reported	Clearing: 1% Cutting: 27% Dribbling: 16% Goalkeeping: 4% Heading: 3% Landing: 13% Loose ball: 7% Pass cutting: 4%

										Passing: 4% Pressing: 32% Shooting: 4% Sliding: 2% Stopping: 8% Trapping: 12%
Rochcongar et al. (2009)	M	25.5 ± 2	Unclear	Inciting activity analysis	Questionnaires	611	Yes, not supported by any reference	Not reported	Not reported	Tackled: 12% Tackling: 3% Accelerating/cutting: 2% Jumping: 2% Kicking: 6% Landing: 21% Pivoting: 33%
Faude et al. (2005)	F	22.4 ± 5.0	Professional	Other	Report	11	Yes, supported by consensus reference	Not reported	Not reported	Changing direction: 64% Foul play: 10% Tackling: 27%
Gupta et al. (2020)	M & F	High school	High school	Other	Report	277	No	Not reported	Not reported	General play: 17% - 24% Chasing lose ball: 18% - 22% Defending: 16% - 21% Passing/shooting: 16% - 12% Ball handling/dribbling: 13%- 10% Receiving

										pass/blocking shot: 10% - 7% Heading: 0% - 2% Other*: 10 % - 2%
Takahashi et al. (2019)	M & F	M: 16.6 ± 0.9 F: 16.4 ± 0.9	High school	Inciting activity analysis	Report	100	No	Not reported	Not reported	Cutting and stopping: 13% - 21% Landing: 8% - 6% Other*: 79% - 73%
Brophy et al. (2015)	M & F	Adults and collegiate*	Professional and not	Inciting activity analysis	Video-analysis	52	No	Ball possession: 27% No ball possession: 73%	Not reported	Tackled: 13% Tackling: 41% - 65% Cutting: 13% - 17% Dribbling: 3% Jumping: 3% Heading: 9% Kicking: 9% - 4% Receiving: 6% - 5% Running/jumping: 3% - 9%
De Carli et al. (2021)	M	Adults*	Professional	Inciting activity analysis	Video-analysis	128	No	Not reported	Offensive half: 63% Defensive half: 37%	Dribbling: 9% Passing: 6% Ball protection: 8% Shooting: 3% Stationary shooting: 1% Ball control: 8% Ball reception: 5% Ball recovery: 40% Other*: 20%

Della Villa et al. (2020)	M	Adults*	Professional	Inciting activity analysis	Video-analysis	134	No	Attaching phase: 32% Defensive phase: 68%	Defensive third: 37% Midfield third: 34% Offensive third: 29% Left side corridor: 25% Middle corridor: 50% Right side corridor: 25%	Tackled: 18% Tackling: 11% Cutting: 1% Diving: 1% Dribbling: 1% Jumping: 1% Regaining balance after kicking: 14% Landing: 6% Pressing: 30% Receiving: 2% Other*: 12%
Grassi et al. (2017)	M	Adults*	Professional	Inciting activity analysis	Video-analysis	34	No	Ball possession: 47% No ball possession: 53%	Opponents field: 68% Home field: 32%	Tackling: 15% Ball handling: 3% Crossing: 3% Defending: 9% Diving: 6% Dribbling: 18% Passing: 12% Pressing: 26% Running: 3% Shooting: 6%
Waldén et al. (2015)	M	Adults*	Not reported	Inciting activity analysis	Video-analysis	39	Yes, not supported by any reference	Attaching phase: 23% Defensive phase: 77%	Defensive middle: 21% Offensive middle: 23% Defensive	Collision: 10% Screening: 8% Tackled: 15% Clearing: 8% Diving: 3%

									third: 36% Offensive third: 21%	Dribbling: 3% Heading: 13% Regaining balance% after kicking:13% Passing: 3% Pressing: 28% Receiving: 5% Running: 10% Shooting: 3% Twisting/turning: 3%
Lucarno et al. (2021)	F	Adults*	Professional	Inciting activity analysis	Video-analysis	35	No	Attaching phase: 31% Defensive phase: 69%	Defensive third: 28% Midfield third: 37% Offensive third: 12% Left-side corridor: 20% Middle corridor: 40% Right corridor: 40%	Being tackled: 11% Pressing: 40% Tackling: 11% Landing: 3% Preparing to kick: 3% Regaining balance after kicking: 20%

Competitive levels are reported as originally described by the studies. Participants' age is reported as originally described in the studies. If this was not described it was either deduced by the study or, when this was not possible, it was reported as unclear and indicated in this table with an asterisk (*). Percentages are calculated by dividing the total number of injuries that occurred during each activity, phase of play, or location by the total number of injuries that occurred. Activities reported as "Other" indicate the percentage of injuries whose activities were not reported or reported as other or unknown.

Table 3.6 Information of studies reporting inciting circumstances leading to other specific injuries

Study	Injury type	Sex	Age	Competitive level	Main aim	Tool	Injuries analysed (N)	Reported injury definition	Phase of play	Player location	Inciting activity (M-F)
Serner et al. (2019)	Adductors	M	27.5 ± 3.2	Elite	Inciting activity analysis	Video-analysis and interview	17	Unclear	Defensive phase: 53% Attacking phase: 41% No possession: 6%	Home penalty box: 24% Defensive third: 24% Mid-field third: 29% Offensive third: 12% Opponent penalty box: 12%	Changing direction: 35% Reaching: 24% Passing: 18% Jumping: 12% Shooting: 12%
Kofotolis et al. (2007)	Ankle	M	24.8 ± 4.63	Amateur	Others	Questionnaire	139	Yes, supported by non-consensus reference	Not reported	Not reported	Contact w another player: 50% Landing: 9% Twisting/turning: 8% Running: 4% Falling: 2% Shooting: 2% Jumping: 2% Heading: 1% Diving: 1% Dribbling: 1% Passing: 1% Stretching: 1% Other*: 11%

Andersen et al. (2004a)	Ankle	M	Adults*	Professional	Inciting activity analysis	Video-analysis and questionnaire	26	Yes, not supported by any reference	Not reported	Not reported	Tackling: 15% Being tackled: 38% Clearing/shooting: 15% Running: 15% Landing: 8% Other*: 8
Giza et al. (2003)	Ankle and foot	M	Adults, U20, U17*	Professional	Inciting activity analysis	Video-analysis	76	Yes, not supported by any reference	Not reported	Not reported	Tackler on his feet: 57% Tackler sliding: 37% Tackle from the side: 68% Tackle from behind: 24% Tackle from front: 8%
Krutsch et al. (2021)	Ankle and knee	M	Adults*	Semi professional	Inciting activity analysis	Video-analysis	630	Yes, supported by non-consensus reference			Collision with teammate: 2% Collision with opponent: 12% Being kicked: 68% Being hit by opponent: 8% Tilting: 16% Distortion: 9% Blocking: 4% Sliding: 1% Overload: 4% Falling: 16%
Cross et al. (2013)	Hamstring	M & F	Collegiate	College	Other	Report	519	Yes, not supported by any reference	Not reported	Defensive half: 50% - 60% Offensive	Running: 69% - 71% Defending: 12% - 7% Passing/shooting: 10% - 12%

										half: 50% - 40%	Ball handling: 8% - 10%
Drummond et al. (2021)	Hamstring	M	26.53 ± 4.75	Professional	Other	Report	92	No	Not reported	Not reported	Kicked: 6% Running/sprinting: 51% Kicking: 23% Jumping/landing: 6% Stretching: 3% Slipping: 3% Overuse 9%
Lundgårdh et al. (2019)	Hip/groin	M	25±5	Professional	Others	Report	467	Yes, supported by consensus reference	Not reported	Not reported	Change of direction: 6% Collision: 6% Jumping: 1% Landing: 1 % Overuse: 27% Running: 6% Shooting: 15% Slipping: 2% Sprinting: 6% Stretching: 9% Other*: 20%
Ralston et al. (2020)	Hip/groin	F	Collegiate	Collegiate	Other	Report	439	Yes, supported by consensus reference	Not reported	Not reported	General play: 44% Conditioning: 11% Diving: 9% Shooting: 8% Defending: 5% Passing: 4% Running: 4% Other*: 15%
Lundblad et al. (2020)	Knee	M	Adults*	Professional	Inciting activity analysis	Report	134	Yes, supported by	Not reported	Not reported	Being tackled: 12% Collision: 6% Twisting/turning:

								consensus reference			9% Being kicked: 1% Other*: 72%
Rahnama et al. (2009)	Knee	M	23 ± 5.6	Professional	Other	Report and interview	43	No	Not reported	Not reported	Kicking: 27% Landing: 11% Pivoting and turning: 8% Falling: 2% Running: 2% Other*: 50
Buckthorpe et al. (2021)	Knee	M	Adults*	Professional	Inciting activity analysis	Video-analysis	37	No	Defensive: 54% Offensive: 41%	Defensive third: 8% Midfield third: 46% Offensive third: 46% Left-side corridor: 6% Middle corridor: 57% Right-side corridor: 27%	Pressing/tackling: 38% Being tackled: 13% Other*: 51%
Nielsen and Yde (1989)	Knee, ankle, foot, groin/thigh	M	Youths, adults	Unclear	Inciting activity analysis	Report	109	Yes, not supported by any reference	Not reported	Not reported	Tackling: 40% Running: 39% Shooting: 6% Other*: 15%
Cross et al. (2018)	Thigh	M & F	M: 16.14 + 1.22 F: 15.90 + 1.18	Amateur (high school)	Inciting activity analysis	Report	350	Yes, not supported by any reference	Not reported	Defensive half: 41% - 7% Offensive	Ball handling: 3% - 5% Defending: 11% - 6% Passing/shooting:

										half: 59% - 93%	28% - 28% Running activities: 57% – 61% Other*: 4% - 5%
Ueblacker et al. (2015)	Thigh	M	Adults*	Elite	Other	Report	2003	Yes, supported by consensus reference	Not reported	Not reported	Foul: 7% Shooting: 12% Sprinting/high-speed running: 53% Stretching: 3% Other*: 25%
Gronwald et al. (2021)	Thigh	M	Adults*	Professional	Inciting activity analysis	Video-analysis	52	No	Not reported	Not reported	Acceleration: 27% High-speed running: 19% Kicking: 15% Landing: 4% Lunging: 31% Other*: 4%
Klein et al. (2020)	Thigh	M	Adults*	Professional	Inciting activity analysis	Video-analysis	81	No	Not reported	Not reported	Sprinting: 43% Running: 23% Lunging:18% Other*: 16%

Competitive levels are reported as originally described by the studies. Participants' age is reported as originally described in the studies. If this was not described it was either deduced by the study or, when this was not possible, it was reported as unclear and indicated in this table with an asterisk (*). Percentages are calculated by dividing the total number of injuries that occurred during each activity, phase of play, or location by the total number of injuries that occurred. Activities reported as "Other" indicate the percentage of injuries whose activities were not reported or reported as other or unknown.

3.3.3 Inciting circumstances leading to overall injuries

In total, 107 different inciting activities were reported by the included studies (Table 5), with the most reported being tackling (reported by 38 studies), shooting (34) running (33), being tackled (29), heading (25), and passing (24). Additional information regarding the inciting circumstances were player location on the pitch (reported by 16 studies), playing phases (e.g., attacking or defensive phase, 15 studies), ball location (4), team action before the injury (2), and player focal attention (1).

The 64 studies included in the review reported inciting activities of 49845 overall injuries ((32357 occurred in males, 17488 occurred in females). 14914 (30%) injuries occurred during duels, 12846 (26%) during unspecified activities, 6376 (13%) during ball handling, 4089 (8%) during kicking, 3807 (8%) during general running, 1950 (4%) during high intensity running, 1184 (2%) during changing direction, 1012 (2%) during jumping, 772 (1%) during blocking, and 39 (<1%) for other activities. Inciting activities of 2857 injuries (6%) were not described.

In males, the categories duels, general running and unspecified activities were the most prevalent (Figure 3.2) and more injuries occurred while the team was in the attacking phase (Figure 3.4). With respect to pitch position, results were unclear as the studies implemented different pitch partitions (Figure 3.4). Ten studies described the inciting activities according to session type. In males, the prevalence of ball handling injuries was slightly higher in matches than in training, while the prevalence of unspecified activities and high intensity running injuries was slightly higher in training than in matches (Figure *3.5*). In females, the categories duels and unspecified activities were the most prevalent while information about pitch position was unclear, as reported for males. As similarly reported in males, the percentage of injuries which occurred during ball handling and duels was slightly higher in matches than during training, while the percentage of injuries occurred during high intensity running was higher in training than in matches. Eight studies (Andersen et al., 2003; Andersen et al., 2004b; Arnason et al., 2004; Bjørneboe et al., 2014; Hawkins & Fuller, 1998; Klein et al., 2020; Rahnama et al., 2002; Tscholl et al., 2007) analysed the inciting activities using video-analysis. In males, duel and high intensity running were the most prevalent categories (Figure *3.3*). In females, the category duel was the most prevalent, while few injuries occurred during kicking, general running, and changing direction.

Arnason et al. (2004) and Andersen et al. (2003) analysed the injured player focal attention at the time of injury and the team action that preceded injuries. Arnason et al. (2004) reported that in 46% of injuries, players' attention was toward the ball on ground, while Arnason et al. (2004) and Andersen et al. (2003) reported that injuries were mainly preceded by short passes (36% and 50%, respectively), deflections (36% and 17%, respectively) and long passes (14% and 21%, respectively). Finally, Zeren and Oztekin (2005) reported inciting activities of nine injuries which occurred during scoring celebration, reporting sliding (55%) and piling up (33%) as the most frequent.

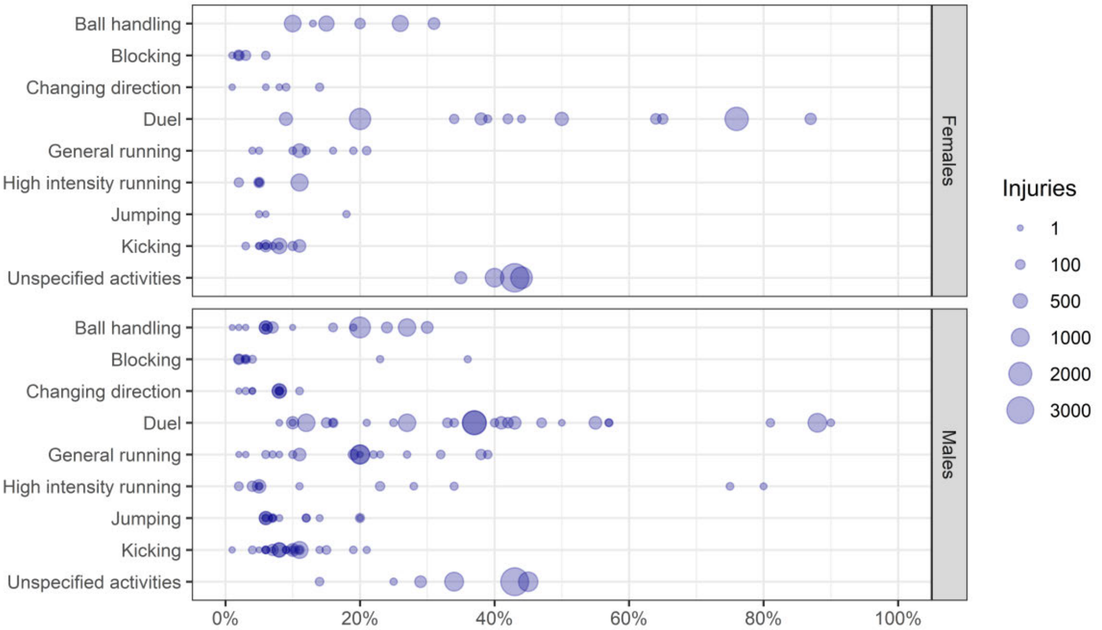

Figure 3.2. Percentage of injuries that occurred during specific inciting activities by sex. Size of the dot represents the number of injuries. Number of injuries reported: Females = 17488, Males = 32357

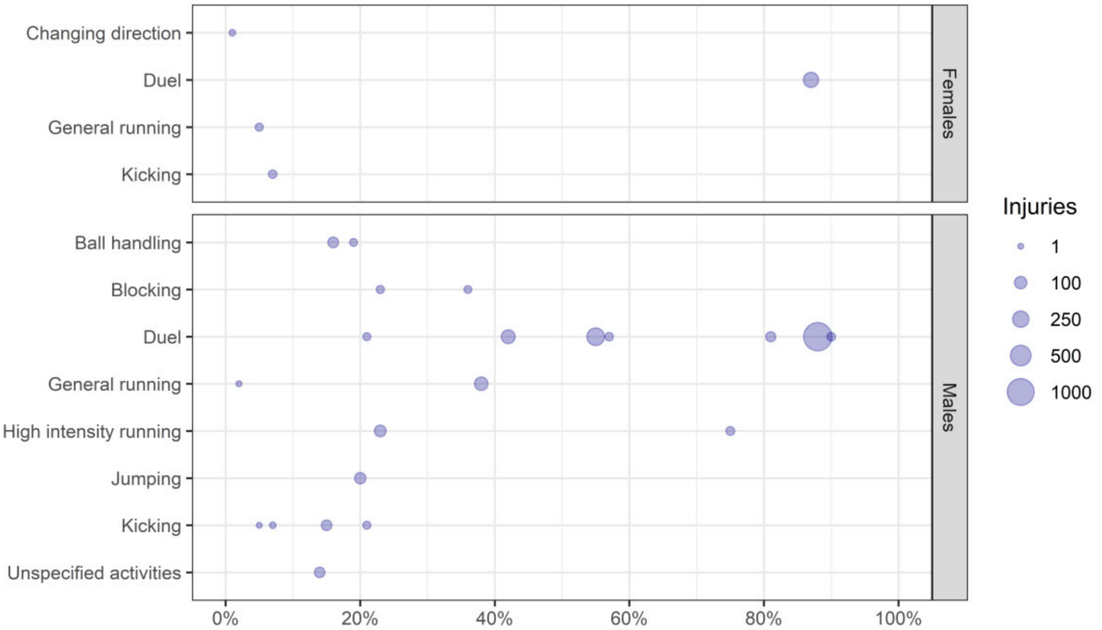

Figure 3.3 Percentage of injuries that occurred during specific inciting activities analysed through video-analysis by sex. Size of the dot represents the number of injuries. Number of injuries reported: Females =293, Males = 2528

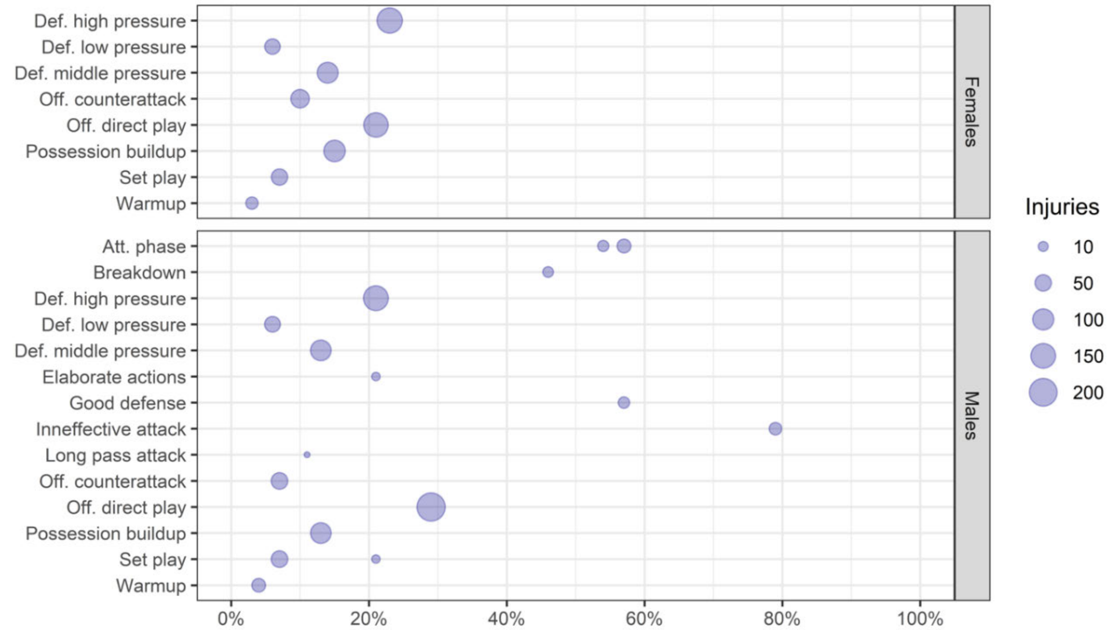

Figure 3.4 Percentage of injuries that occurred in different playing phases by sex. Size of the dot represents the number of injuries. Number of injuries reported: Males = 802, Females = 693. Att = attacking, Def = defensive, Off = offensive.

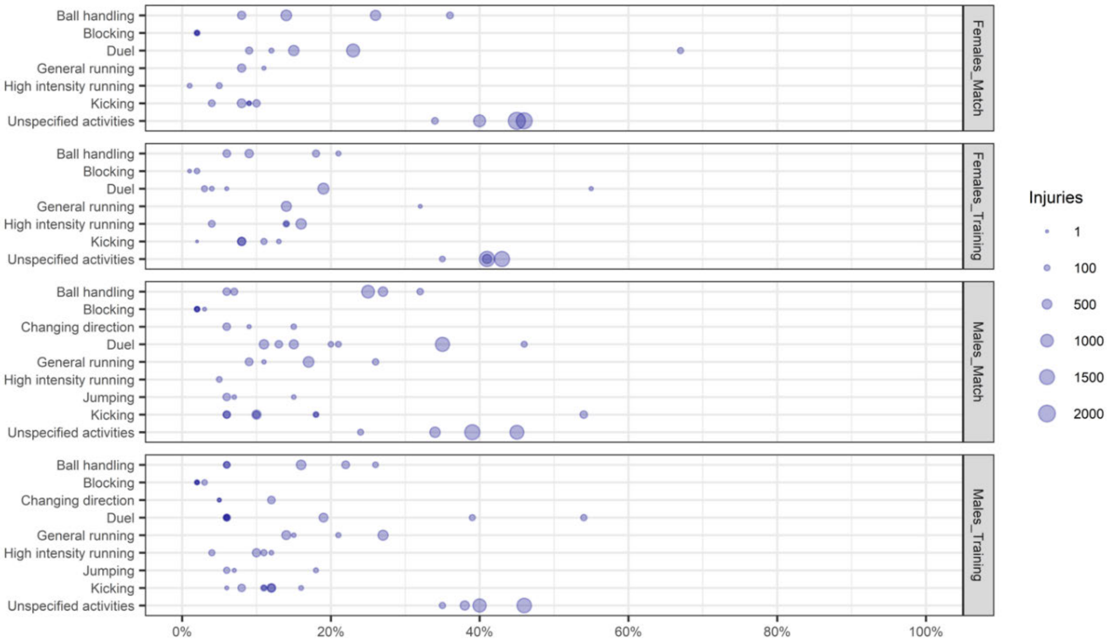

Figure 3.5. Percentage of injuries that occurred during specific inciting activities by sex and session type reported separately for females and males, with division of match and training injuries for both. Size of the dot represents the number of injuries. Number of injuries reported: Females-match = 11457, Females-training = 8937, Males-match = 13589, Males-training= 9979

3.3.4 Inciting circumstances leading to specific injuries

Inciting circumstances leading to hip (3, 5%), thigh (6, 9%), knee (17, 27%), and ankle and foot (5, 8%) injuries were reported by 29 studies (some studies reported injuries that occurred to multiple locations) which allows the analysis of the inciting circumstances leading to injuries by injury location. Twelve studies reported inciting circumstances of 1613 ACL injuries. A small percentage of injuries occurred during general and high intensity running, while results for other categories were heterogeneous (Figure 3.6). With reference to the inciting activities reported by the studies (presented in Table 3.5) changing direction, pressing, tackling, twisting/turning, landing, and being tackled were reported as the most frequent inciting activities of ACL injuries in males. Most of the studies reported that such injuries occurred during the defensive phase but information regarding pitch position was reported inconsistently (Table 3.5). In females, tackling, pressing, defending, chasing a loose ball, cutting, and stopping were among the most frequent inciting activities of ACL injuries. Kaneko et al. (2017) and Lucarno et al. (2021) reported that ACL injuries occurred more frequently during the defensive phase. Five studies (Brophy et al., 2015; De Carli et al., 2021; Grassi et al., 2017; Lucarno et al., 2021; Waldén et al., 2015) analysed the inciting activities leading to ACL injuries using video-analysis. Duel activity is the most prevalent category, while general running and jumping are the least prevalent (Figure 3.3). Considering the inciting activities reported by the studies, tackling, recovering the ball and pressing were reported as the most frequent inciting activities of ACL injuries in males.

Four studies reported inciting circumstances of 353 other knee injuries and duel, kicking, and jumping were the most reported inciting activities. Two studies

(Buckthorpe et al., 2021; Krutsch et al., 2021) analysed the inciting circumstances leading to knee injuries using video-analysis. Duel was the most prevalent category, while falling, being tackled, pressing, and tackling were the most prevalent inciting activities reported by the studies.

Six studies reported inciting circumstances of 3040 hamstring and thigh injuries. These injuries occurred predominantly during running and kicking activities (Figure 3.5). Two studies (Gronwald et al., 2021; Klein et al., 2020) analysed the inciting circumstances leading to thigh injuries using video-analysis. High intensity and general running were the most prevalent categories, while sprinting, lunging, and accelerating were the most prevalent inciting activities reported by the studies. Cross et al. (2018) reported minor differences in the inciting activities of first and recurrent thigh injuries. Four studies reported inciting circumstances of 947 hip/groin and adductor injuries. Circa 10% of all the injuries occurred during duels, while the percentage was slightly higher for kicking and changes of direction. Results for other inciting activities were inconsistent. Serner et al. (2019) analysed the inciting circumstances of adductor longus injuries using video analysis and reported that such injuries mainly occurred during changing direction or kicking activities in the defensive and midfield thirds of the pitch. Finally, five studies reported inciting circumstances of 500 ankle and foot injuries, with duels being the most common. Three studies (Andersen et al., 2004a; Kofotolis et al., 2007; Krutsch et al., 2021) analysed the inciting circumstances leading to ankle injuries using video-analysis. Duel was the most prevalent category, while being kicked and contact with another player were the most prevalent inciting activities reported by the studies. Additionally, Giza et al. (2003) reported that most ankle and foot injuries occurred when the tackler was on his feet and tackled from the side (Table 3.6). The inciting activities reported by all the studies can be explored using the online dashboard available at the following link:

https://public.tableau.com/views/SystematicReviewofInjuryIncitingActivitiesinFootball/Story1?:language=en-GB&:display_count=n&:origin=viz_share_link.

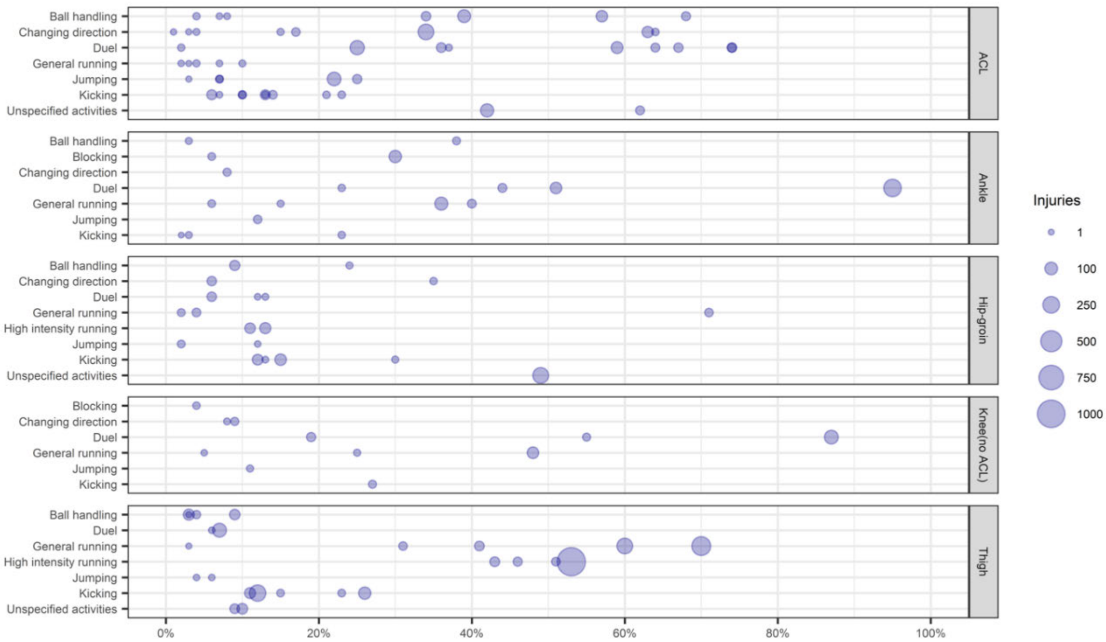

Figure 3.6. Percentage of injuries that occurred during specific inciting activities by injury type. Size of the dot represents the number of injuries. Knee injuries represent all non-ACL knee injuries. Number of injuries reported: ACL = 1716, Ankle = 593, Hip-groin = 947, Knee (no ACL) = 353, Thigh = 3040

3.3.5 Assessment of Risk of Bias

On average, the RoB was deemed as high or medium in 50% of all the items included in the checklist. Most of the studies showed low external validity, with 76% of the items scored as medium or high RoB, and medium internal validity, with 36% of the items scored as medium or high RoB (Fig. 6). The study population was considered a good representation of the target population in only 17 studies, and only 28 studies provided all the details of the study sample deemed necessary. Almost all the studies showed a medium or high RoB for the management of missing data. Most of the studies either did not report whether there were missing data or simply reported that there were some, without reporting the number of missing data. The few studies that reported such information did not analyse eventual differences among cases and participants with and without missing data.

With respect to internal validity, low RoB was mostly observed regarding sources of data. Indeed, 52 studies collected data directly from the participants, while 12 obtained the data from databases or other sources. Similarly, low RoB was observed for homogeneity of data collection methods and for the minimum length of the prevalence period, with only two studies demonstrating high RoB for these domains. However, high RoB was observed in the case definition and in methods for classification and measurement of inciting circumstances. Only three studies analysed inciting circumstances with both video analysis and classified them using a standardised system, while the remaining studies reported them using arbitrary classifications and/or collected such data through interview, questionnaires, or reports without providing further details on how data were collected. Additionally, only 13 studies implemented an appropriate injury definition supported by an appropriate reference, while 13 studies did not report the injury definition at all.

The studies which analysed ACL injuries showed a higher RoB than the others (Figure 3.8) with only one study clearly defining the study sample. Furthermore, all the studies which analysed ACL injuries showed high RoB for injury definition and systems implemented to measure inciting circumstances. After harmonisation, there was almost perfect agreement (K = 0.87) between the reviewers for the scoring of RoB.

Assessment of risk of bias for each included study is reported in Appendix D.

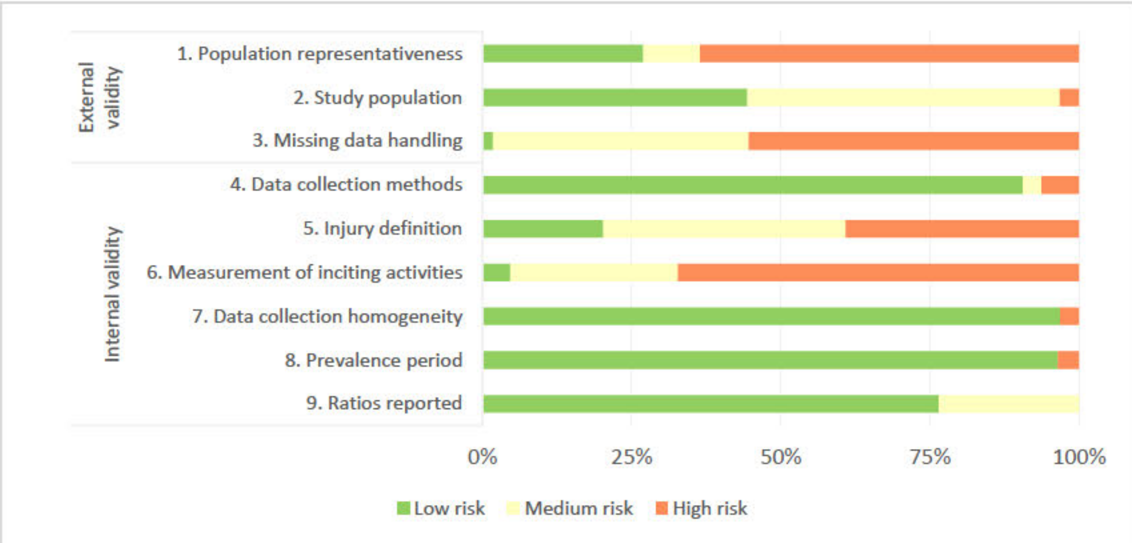

Figure 3.7. Assessment of RoB of the included studies

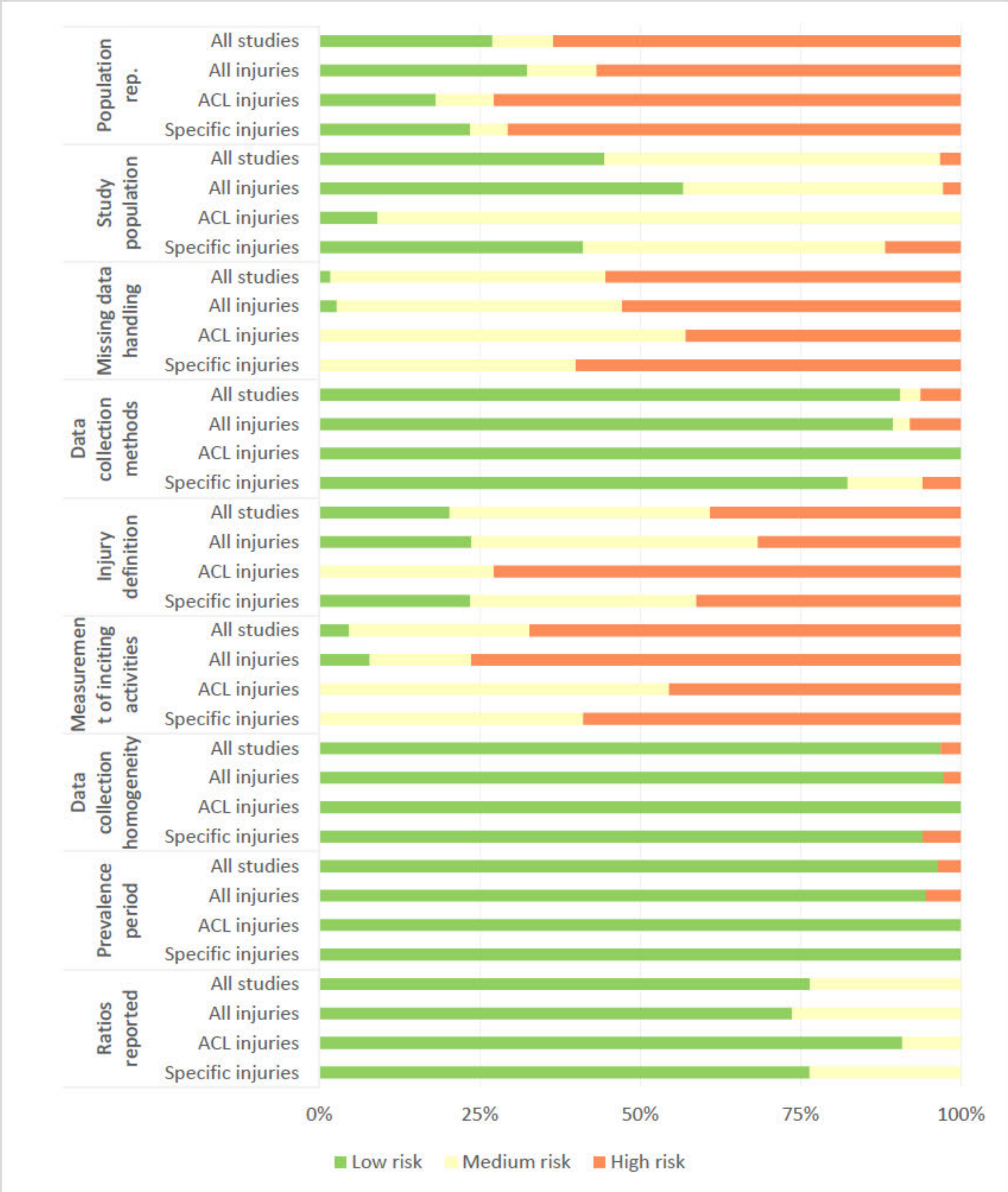

Figure 3.8. Percentage of studies showing low RoB for each item, according to type of injuries analysed

3.4 Discussion

Understanding the inciting circumstances of injury in football is important for the development of injury prevention strategies. However, due to methodological heterogeneity of the studies included using the criteria outlined above, summarising the available literature to provide information about the prevalence of inciting circumstances is challenging. Furthermore, few of the selected studies reported whether the injuries were incurred during contact, indirect contact, or were non-contact in nature which would support the ability to determine how preventable or otherwise these could be. Therefore, the following discussion provides a summary and qualitative comparison among studies of the inciting circumstances.

3.4.1 Inciting circumstances leading to injuries

Duels and unspecified activities appeared to represent higher risk activities, in both males and females (Figure 3.2). It seems that, in the included studies, all reported running related activities may have contributed to a higher percentage of injuries in males than in females. These differences in inciting activities between sexes could be expected due to differences in physiological and physical performance aspects. Indeed, male football players seem to cover more high-speed running distance than females (Bradley et al., 2014), which has been reported as one of the most high risk activities in football (Huygaerts et al., 2020; Mendiguchia et al., 2013). Therefore, a lower exposure to high intensity running in females might lead to a lower prevalence of running injuries. At the same time, the percentage of injuries caused by duels seems to be higher in females than in males. This may be partially explained by physical differences between males and females. Indeed, females show lower bone mineral density and free fat mass than males (Abe et al., 2003; Baker et al., 2020) which might make them less resilient against this type of activity. However, comparisons between sexes are currently difficult due to the limited literature available on inciting activities in female football. Small differences appear when considering only the studies which analysed the inciting activities through video-analysis. Duels clearly represent the riskiest activity and results of ball handling and blocking activities seem more consistent than the ones reported by studies which analysed the inciting activities with other methods. However, results with reference to general and high intensity running remain heterogeneous.

Due to inconsistencies in reporting and to the limited number of studies reporting inciting activities for training and match play separately, data should be interpreted carefully. From the studies included, the prevalence of injuries occurring during high intensity activities was higher in training than in matches. This may look inconsistent with the usually reported higher incidence rate in match vs training (Jones et al., 2019; Lopez-Valenciano et al., 2019), where greater high intensity running is expected during matches (Coutinho et al., 2015; Martín-García et al., 2018), however prevalence and incidence rate are two different measures of frequency with prevalence being just a crude proportion while incidence rate is normalised by time at risk (Rothman, 2013). Therefore, although the evidence is limited, it may be hypothesised that injuries in training and matches differ not only for incidence, with injury incidence being around seven times higher in matches than in training, but also for related inciting activities.

Eight studies reported some information regarding playing phases in which injuries occurred. Such studies reported that injuries in males occurred more frequently during the attacking phase than during the defensive phase. This difference may be due to a link between playing phases and physical activity. For example, it could be plausible that activities with high risk of injury occur more frequently during the attacking phase while activities which seem to account for small percentages of injuries occur more frequently during the defensive phase (Lorenzo-Martinez et al., 2020). Specifically, if future studies find high prevalence of injury occurring while being tackled and sprinting, and such activities are found to be more frequent during the attacking phase, this could explain why injuries are more frequent during the attacking phase. Other psychosocial factors such as player-coach relationship and players' personality and may contribute to higher injury prevalence in the attacking phase (Ivarsson et al., 2017; Pensgaard et al., 2018). However, information about playing phase during which injuries occur has been reported only in a few studies and usually in a generic way, therefore further investigation is required.

3.4.2 Inciting circumstances leading to specific injuries

Twelve studies (n=6 for male, n=3 for female, n=3 for both) analysed the inciting circumstances of ACL injuries but the results were heterogeneous both when considering categories used to classify inciting circumstances, and when considering the original activities reported by the studies. Results appear slightly more consistent when considering only studies which analysed the inciting circumstances using video-analysis. Duel clearly appears as the activity during which most ACL injuries occur followed by kicking. Considering the activities originally reported by the included studies, four studies (Della Villa et al., 2020; Grassi et al., 2017; Lucarno et al., 2021; Waldén et al., 2015) reported pressing as the riskiest inciting activity, followed by regaining balance after kicking, being tackled, and dribbling. The remaining studies which analysed the inciting circumstances through video-analysis (Brophy et al., 2015; De Carli et al., 2021) did not report any injury occurring during pressing or regaining balance after kicking, but reported other activities as the most prevalent ones. As discussed in Chapter 2.3, It has been largely reported in the literature that the load at which the ACL is exposed to increases when the knee is in a valgus, intra-rotated and extended position, which could occur when a player performs a tackle or during activities such as decelerations, changings of direction, and landings. Therefore, it could be reasonable to expect that these inciting activities contribute to a high percentage of ACL injuries, but this was not always the case. Some studies reported that duel activities, changing direction, and jumping activities contributed to a high percentage of injuries, while other studies reported that such activities accounted for a small percentages of injuries. This may be caused by the different classifications used to report the inciting activities. Therefore, even if changing direction, landing, and tackling are expected to be among the main inciting activities of ACL injuries, results currently available for male and female players are inconsistent and cannot confirm this hypothesis, which therefore needs to be further investigated.

Six studies reported the inciting circumstances of thigh (4) and specifically hamstring injuries (2). Since the four studies which reported inciting circumstances of thigh injuries did not report further details on the location it was not possible to understand if they were referring to anterior (i.e., rectus femoris) or posterior thigh (i.e., hamstring), hence it was supposed that they included injuries to both sides. Therefore, the data from the six studies were reported and discussed together. Running activities were the most reported inciting activities of thigh injuries, accounting for more than half of total injuries. Secondly, kicking activities seem to be the second main inciting activities of thigh injuries. These results partially align with the ones reported by two studies which used video-analysis to evaluate the inciting circumstances of thigh [60] and specifically hamstring injuries [59], reporting that general and high intensity running are the most prevalent activities leading to thigh injuries. For the activities originally reported by the included studies, sprinting and running were the most prevalent activities leading to thigh injuries while lunging and accelerating were the most prevalent activities leading to hamstring injuries. These results are partially in accordance with what has previously been hypothesised for football injuries and reported in other sports for hamstring and rectus femoris injuries, as discussed in Chapter 2.3. Running activities are believed to be the main cause of hamstring injuries followed by kicking activities (Huygaerts et al., 2020). However, Gronwald et al. (2021) reported that lunging was the most prevalent activity leading to hamstring injury followed by accelerating, high-speed running, and kicking. With reference to the rectus femoris, it has been hypothesised that kicking and high-intensity activities such as accelerating, decelerating, and running at high speed may put the rectus femoris at risk of injury (Mendiguchia et al., 2013). This is partly supported by the results reported by Klein et al. (2020), which suggested that sprinting, running, and lunging are the most prevalent activities leading to thigh injuries, although they did not report the specific injury location (e.g., rectus femoris, hamstring).

Even if the results of this review partially confirm the hypotheses on the inciting activities leading to thigh and ACL injuries in football, they should be interpreted carefully given several limitations of the included studies. While Cross et al. (2013) and Gronwald et al. (2021) clearly defined the location of injuries analysed (i.e., hamstring), the remaining studies reported inciting activities of thigh injuries in general, which could include different muscle groups (e.g., hamstring, quadriceps), therefore it is not clear which injuries occurred during the reported inciting activities . Furthermore, the number of studies which analysed such injuries is limited and they only reported generic descriptions of their inciting activities (e.g., running, kicking), which provide limited information. For example, it would be useful to analyse and report on the running phase and the running speed at which injuries occur. In runners, it has been reported that hamstring injuries occur while the athletes are running near their maximal speed (Askling et al., 2007), but such information within football has been reported by only four studies (Drummond et al., 2021; Gronwald et al., 2021; Klein et al., 2020; Ueblacker et al., 2015) reporting high intensity running without specifying the running speed. Furthermore, there is debate on whether running injuries occur during the early stance or the swing phase of running (Huygaerts et al., 2020; Liu et al., 2017). Reporting such detailed information would be helpful for football practitioners who could use them to plan training sessions and to develop injury prevention strategies (McCall et al., 2020b), although as will be discussed in Chapter 5, gathering this information could be difficult.

Similarly, only generic information was reported for injuries which occurred during kicking activities. Indeed, only the activities performed were reported (e.g., shooting, passing), but no details were reported on the kicking phase in which injuries occurred. These details may be important to achieve a more complete understanding of the injury inciting activities because, as discussed by Mendiguchia et al. (2013), rectus femoris injuries may occur during one of the three phases of kicking (i.e., swing phase, ball contact phase, ground contact phase). Reporting such detailed information would be helpful for football practitioners who could use them to plan training sessions and to develop injury prevention strategies (McCall et al., 2020b), although it is recognised that gathering this information with high levels of confidence could be difficult especially for muscle injuries.

In the studies included in this review four described inciting circumstances leading to hip/groin injuries. As reported for thigh injuries, only one study (Serner et al., 2019) specified the location of injuries analysed (i.e., adductor longus), while the other studies reported more generic injury locations such as hip/groin and groin/thigh. These injuries have been categorised and considered as hip/groin injuries to facilitate the analysis. High intensity running, kicking, and duel activities were reported as the inciting activities for 15% of each of hip/groin injuries, while results of the other inciting activities were unclear. One study (Serner et al., 2019) analysed the inciting circumstances leading to adductor longus injuries through video-analysis and reported that changing direction and kicking were the most prevalent activities leading to injury. These results are partially consistent with the available literature on the biomechanics of adductor injuries. Indeed, as discussed in Chapter 2.3 the adductor longus, which is reported as having a higher injury incidence when compared to the magnus and the brevis, achieves its peak eccentric activation when the hip is close to maximal extension, which is thought to put the adductor longus at high risk of injury. Considering that this position is achieved during kicking and running activities, they are expected to be the most common inciting activities of hip/groin injuries.

In addition to kicking and running at high intensity, it is believed that changing direction may be another inciting activity leading to hip/groin injuries. Indeed, these injuries seem to be more common in sports involving accelerations, decelerations, and changes of direction. Furthermore, it is thought to be linked to the adductor muscle group experiencing high eccentric load when the leg is abducted and externally rotated, as seen during execution of changes of direction (Crockett et al., 2015; Franklyn-Miller et al., 2017). However, the results of the studies included in the current review were inconsistent. Serner et al. (2019) reported that 35% of adductor injuries occurred during changing direction, but this was the reported inciting activity in only 6% of the injuries in the study conducted by Lundgårdh et al. (2019) and was not reported for any other study involving hip/groin injuries (Nielsen & Yde, 1989; Ralston et al., 2020). These differences could be due to different injury locations analysed by the included studies, however further investigations are needed. Furthermore, evaluating whether the risk of incurring in groin injuries differs according to running speed could provide practitioners with useful information.

Regarding other specific injuries five studies reported the inciting circumstances leading to ankle and foot injuries, but the reported inciting activities were mainly inconsistent, although the risk of incurring this type of injury seems to be slightly higher in duel activities. Three studies analysed ankle injuries using video-analysis and they all reported duel activities (i.e., contact with another player, being tackled, and tackling) as the activities leading to more than half of the injuries analysed (Andersen et al., 2004a; Kofotolis et al., 2007; Krutsch et al., 2021). These results seem to be in contrast with the literature available for ankle injuries in other sports. Indeed, within a systematic review, it has been reported that these injuries occur mainly during non-contact activities (Doherty et al., 2014). Specifically, as discussed in Chapter 2.3 studies suggests that ankle sprains, which constitute the majority of ankle injuries, occur with the foot in plantar flexion commonly occurring during activities such as landing and changing direction. Indeed, in basketball such injuries seem to occur mainly during landing (45%) and changing direction (30%), while only 10% of these injuries occur in contact activities (McKay et al., 2001). Therefore, further analyses are needed to understand which activities may lead to ankle injuries in football.

3.4.3 Methodological considerations on the selected studies

Several methodological limitations were observed in the studies included in this review, indeed respectively 76% and 36% of the items that evaluated external and internal validity were scored as having a medium or high RoB. The external validity was mainly influenced by the fact that 76% of studies did not clearly and explicitly specify the target population (i.e., population to which the researchers would like to apply the results) and hence it is difficult to understand whether the study population was a close representation of the target population (or acceptable for scientific inference and hence for generalization). Furthermore, 55% of studies did not clearly report information such as age, country of competition, competitive level and number of teams and participants included in the study. This makes it difficult to understand which population the results could be applied to. For example, it has been reported that physical performance changes according to age (Kobal et al., 2016; Loturco et al., 2019; Loturco et al., 2018) and competitive level (Slimani & Nikolaidis, 2019), therefore the prevalence of the inciting activities may change according to such player characteristics.

The internal validity of the studies was mainly influenced by methods for collecting and reporting injury data. Firstly, 45% of the included studies which analysed ACL injuries, 24% of studies which analysed other specific injuries, and 11% of studies which analysed general injuries collected data from databases or online platforms and had limited or no access to reliable medical information directly provided by the medical staff, which, except for severe injuries (e.g., ACL) for which this method seems reliable, may limit the validity of the results (Hoenig et al., 2022; Krosshaug et al., 2005; Krutsch et al., 2020). Recently, this approach is being increasingly used, however this method shows clear limitations. Indeed, Krosshaug et al. (2005) reported that studies which analysed injuries through video-analysis only, may have missed up to 70% of the non-contact injuries and up to half of the total injuries occurred. This may happen because some injuries, especially non-contact injuries, may occur far from the ball and therefore may not be captured by the footage, or because players keep playing for some time before reporting the injury to the medical staff and therefore locating the inciting activity is difficult. Furthermore, Krutsch et al. (2020) suggested that non-severe injury data reported online have low validity and recommended to use these data only after verification. This may partially explain the discrepancies between the inciting activities that are believed to be dangerous for ankle injuries and the ones reported in the studies. Further, there is an increased likelihood of these injuries being reported from match play where readily available video footage is more likely than that obtained from regular training practice.

Secondly, most of the studies included in the review did not implement an appropriate definition of injury and/or a validated or standardised classification system for the inciting circumstances. As reported by other systematic reviews (Alahmad et al., 2020; Diemer et al., 2021; Jones et al., 2019; Lopez-Valenciano et al., 2019; Pfirrmann et al., 2016), many studies that analyse football injuries do not follow the guidelines on injury definition in football provided by consensus statements such as Fuller et al. (2006). These guidelines are not necessarily the best way to classify injuries, but the heterogeneity of injury classification could substantially influence the total number of injuries reported and therefore the number of injuries reported to have occurred during each inciting activity. For example, the number of injuries that occur during activities that lead mainly to minimal and mild injuries (i.e., lasting less than seven days) may change significantly according to the injury definition implemented, as these injuries may not be considered in studies which consider players injured only if they miss a single match (Meyers, 2013). However, the main limitation observed in the included studies was the use of non-standardised systems to classify the inciting circumstances. This led the researchers to classify and report such data using arbitrary classifications, which is among the main causes of the heterogeneous results making the comparisons difficult between studies. Indeed, more than 100 different inciting activities have been reported, with some being used only by a few studies.

Additionally, some of the inciting activities reported, such as general play and contact with another player, are quite generic and provide limited information. To reduce such heterogeneity and compare the results of the studies, it was necessary to (arbitrarily) group inciting activities in categories, which limited the level of detail of the analysis. Thirdly, the included studies did not specify whether the injured players were performing more than one activity when the injuries occurred. For example, kicking injuries can occur with the players running at high speed (e.g., player kicking the ball with the first touch after a long pass) or in a more static situation (e.g., penalty or corner kick). It is unclear how the injuries occurred during mixed activities (e.g., kicking while running at high speed) were reported, however it would be appropriate to report all the activities performed at the time of injury as the combination of different activities may help to better understand why the injury occurred.

Finally, most of the studies did not specify how many injuries occurred during contact and non-contact circumstances, which is another important limitation. The few studies that reported such information, did not identify the nature of the contact (i.e., direct or indirect contact). These limitations could have led to a misclassification of the injuries and could have influenced the analysis of prevalence (Bahr et al., 2020).

3.4.4 Terminology

Using appropriate terminology is very important in any research field. A standardised terminology ensures that the readers do not misinterpret the meaning of the definitions. Using the term *injury mechanism* as an example, if this is not clearly defined it may be interpreted in different ways such as the mechanical forces which cause the tissue lesion, as the joint angles during which the injury occurred, or as the activities performed at the time of injury occurrence. This can occur because the way concepts and definitions are interpreted depends on several aspects such as language, education, work position and other cultural factors (van Mil & Henman, 2016).

In fields like football, where every team is independent from the others and uses its own data collection procedures (e.g., different databases, different technologies, data collected by different working figures), standardising terminology may be even more important than in other fields both to assist internal operations and to make the data suitable for research purposes to help support future practice in injury prevention. Indeed, elite football clubs can have tens of people working in sport-related departments (i.e., performance, medical, technical, and analysis departments) with high turnover, therefore implementing standardised terminology ensures that data are interpreted consistently by everyone and that when the staff changes this consistency is maintained. Secondly, to conduct research using data collected by different football clubs such as the UEFA Injury study (Ekstrand, 2019) it is crucial that the involved clubs use the same terminology, classification systems, and definitions. Being able to use data collected by several clubs is very important when conducting research on football injuries because, given the low number of players competing in each team and the incidence of injuries, this allows appropriate analysis of specific injuries to be performed.

The terminology proposed in Chapter 2.1.3.1 could be implemented in future research when analysing injury mechanisms, inciting activities, and inciting circumstances. Similarly, Fuller et al. (2006) proposed guidelines to report and define football injuries. Although these guidelines may be perfectible, they should be implemented regularly to limit the issues caused by inconsistent definitions described in this chapter and if the results of such guidelines are difficult to follow or are not shared by the research and football communities, they should be updated. This is part of the scientific process.

3.4.5 Recommendations for future research

Future research on inciting circumstances should try to avoid the limitations mentioned above. First of all, it is paramount that studies implement standardised injury definitions and standardised systems with consistent terminology to classify the inciting circumstances in order to have consistent data that can be compared among studies. Fuller et al. (2006) provided guidelines for injury definitions to implement in football. With reference to standardised systems to classify inciting circumstances, to the best of my knowledge, the only currently available system is the football incident analysis developed by Andersen et al. (2003) which has important limitations as discussed in Chapter 2. Therefore, it seems necessary to develop alternative methods for the classification of inciting circumstances in football as the uptake of this method has been extremely limited and there is no alternative currently available within the literature.

3.4.6 Limitations

Despite this review following the PRISMA 2020 guidelines as well as addressing the AMSTAR 2 domains, it is not exempt from limitations. Although a comprehensive research strategy was implemented, it is possible that some studies which reported inciting circumstances were not identified in this systematic review. This may be due to the fact that such information is usually reported in the full text as additional analysis, without being cited in the title or abstract. The exclusion of studies that were not written in English might be an additional cause. The inclusion of studies that analysed inciting circumstances without this being their main aim (i.e., as additional analysis) might be another limitation. However, it was believed that practitioners and researchers also use also additional analyses from scientific studies to inform their practice, therefore, it was deemed necessary to include such studies in the present review. Nevertheless, being a secondary outcome, the accuracy of these results may be inferior and this should be considered when interpreting the results. Despite attempts to group similar inciting activities, these categorisations remain arbitrary, and their interpretation could have been affected by the heterogeneity of the methods implemented by the included studies. The lack of standardised methods for the reporting of inciting circumstances and of studies on specific injuries did not allow a meta-analysis to be performed. For the same reasons, it was not possible to analyse the results according to age and playing level. Finally, the tool to assess the RoB in the studies had to be adapted from existing instruments, as there were none available that were suitable to address the domains deemed relevant.

3.5 Conclusions

The aim of this study was to review the literature around inciting circumstances in football. Duels and unspecified activities may put players at high risk of general injuries. High intensity running and kicking activities could be the main inciting activities of thigh and groin injuries, while duels might be the most common inciting activities of ankle injuries. Duel activities and pressing may be the most common inciting activities leading to ACL injuries, but there is not complete agreement within the literature. Despite the importance of such information for the development of injury prevention strategies and to guide further research on mechanisms of injury, the available evidence about this topic is limited, therefore making recommendations for practitioners and researchers is difficult.

These results need to be interpreted carefully, as the available evidence is limited and because most of the included studies implemented non-validated methods for the collection of injury data and for the analysis of the inciting circumstances, which led to heterogeneous results among studies. In turn, recommendations for injury prevention strategies based on inciting circumstances are difficult. Further studies should collect and analyse injury data using standardised methods and should report more details on the injuries and the circumstances leading to injuries. This would increase the consistency of data, allow a comparison among studies, and help the understanding of inciting circumstances within football. Given video-analysis and medical reports are, for the time being, the most practical methods for the analysis of the inciting events, it seems appropriate to develop a classification system which would allow researchers and practitioners to systematically report and analyse the inciting circumstances, which are crucial for the development of injury prevention strategies and to guide further research on mechanisms of injury. Furthermore, the development of a classification system which allows medical staff to easily record such information, while also giving the opportunity to perform a more detailed analysis, would evolve this area of applied research. Therefore, study two aims to develop such a system of reporting using a modified nominal group technique.

4 Development of a standardised system to classify injury inciting circumstances in football: the Football injury Inciting Circumstances Classification System

4.1 Introduction

As previously discussed, accurate and consistent recording and reporting of the outcomes is key to be able to combine, compare, and generalise findings across studies and then provide information to practitioners. Furthermore, clinical decisions are based on the effect of interventions on the outcomes, therefore measuring and reporting the outcomes appropriately is paramount (Clarke & Williamson, 2016). Unfortunately, outcome-reporting bias and outcome inconsistencies afflict the whole field of health care research and can lead to the implementation of inadequate interventions (Williamson et al., 2017). In football, imprecise reporting of risk factors and inciting circumstances may lead to the development and implementation of injury prevention strategies that do not target the correct aspects and could subsequently be ineffective. This may partially explain why, despite several injury prevention programmes having been proposed and implemented, injury burden has not changed in the past 18 years (Ekstrand et al., 2021) and why the rate of hamstring injuries has increased between 2001 and 2014 (Ekstrand et al., 2016)

If all researchers and practitioners collected and reported information on the inciting circumstances with standardised methods, the issues of outcome reporting could be limited (Hutton & Williamson, 2000). This could be achieved by developing a standardised core outcome set, which is a set of outcomes and information that should always be reported when conducting trials. Using a standardised core outcome set would allow the development of homogeneous and high-quality studies, but at the same time would leave researchers the option of reporting additional outcomes or information (i.e., optional outcome sets) if they wish to do so (Clarke, 2007; Williamson et al., 2017). As previously discussed in Chapter 2.1.3.2, a standardised system for the analysis and reporting of football inciting circumstances named "Football Incident Analysis" was developed by Andersen et al. (2003). The authors developed the system to evaluate the inciting circumstances combining medical information and video-analysis, including details on the inciting circumstances such as playing situation, player action, and duel situation in which the injuries occurred. However, despite a standardised system for the classification of inciting circumstances being developed almost 20 years ago, from the systematic review performed in Chapter 3 it has been used in only three studies (Andersen et al., 2003; Andersen et al., 2004b; Arnason et al., 2004), while the remaining studies implemented alternative but inconsistent classification systems.

It is not clear why the Football Incident Analysis has been used rarely in football research. One may hypothesise that this may be in part due to the time and resources needed to report all the information included in this classification system or to other limitations discussed in Chapter 2.1.3.2. Therefore, given the importance of limiting reporting bias, the limitations of the Football Incidence Analysis and its scarce usage, it seems important to develop a core outcome set involving relevant stakeholders and following scientific guidelines.

Working with relevant stakeholders in the development of a core outcome set is necessary to achieve consensus on what should be included, how each domain should be defined, and how they should be measured (Williamson et al., 2017). Making these decisions as a group rather than individually has several advantages. Firstly, groups ensure that a wide range of knowledge and experience are included in the decision making. Secondly, interaction between members with different knowledge and experience encourages the whole group to consider different opinions. Finally, a decision made by a group may be more scientifically robust than one made by an individual (Black, 2006; Murphy et al., 1998). Using formal approaches to decision making supports the implementation of transparent methods and increases scientific credibility (Black, 2006). Core outcome sets are developed through consensus methods, but there are no clear guidelines around which method is the best, therefore various approaches have been used with the most common being the Delphi technique (Delphi) and the nominal group technique (NGT) (for a review see Williamson et al. (2017)).

Delphi and NGT methods are similar, although different in some respects. The Delphi is a technique that aims to achieve consensus through a series of surveys (named rounds) completed by the panel comprised of a group of stakeholders (usually named panellists or participants) deemed experts of their field. The panellists provide answers using Likert scales, then the responses of each survey are summarised and sent back to the panellists. This process is usually repeated for two or three rounds or until consensus is reached or is deemed impossible to reach (Black, 2006; Hasson et al., 2000; McPherson et al., 2018). The main advantage of Delphi is that there is no limit to the number of participants since everything is handled with online surveys, therefore a wide and geographically spread sample can be included. On the other hand, this technique is not without limitations. Since the process involves only online surveys, the panellists do not have the opportunity to discuss any divergencies and their initial ratings are changed only on the basis of the responses of other panellists. This could impact the level and the robustness of consensus reached (Black, 2006; Hutchings et al., 2006).

As with a Delphi approach, the NGT aims to achieve consensus among a group of stakeholders deemed experts of their field. The NGT usually comprises three phases: 1) panellists are required to express their opinion and generate ideas on the topic of interest; 2) panellists' opinions and ideas are used to produce a survey and panellists are required to rate their agreement with each point of the survey; 3) panellists' answers are analysed and reported back to them who then discuss eventual disagreements in a meeting facilitated by an expert who is not member of the panel. Once the meeting is complete, panellists rate the new level of agreement which is analysed to evaluate whether their views have changed after the meeting and to evaluate whether consensus has been reached. The main advantage of NGT is that panellists have the chance to meet, interact, and discuss divergent views. This could lead the group to consider different options, which is one of the main advantages of consensus methods. However, in order for the meeting to take place, the number of panellists should range between 6 and 14. NGTs conducted with smaller panels may produce results which have limited reliability, while in NGTs with bigger groups the discussion would be difficult to manage (Black, 2006; McMillan et al., 2016; Richardson, 1972).

Both NGT and Delphi can be modified depending on the context in which they are implemented and the panellists' availability (Black, 2006; Hasson et al., 2000; McMillan et al., 2016). In NGT, variations are usually applied to phase one (idea generation) and to the ranking process. For example, instead of asking participants to generate ideas, these can be obtained through a review of the literature (McMillan et al., 2016). This could reduce the time required by panellists and increase the possibility of finding experts who agree to be part of the panel. Indeed, both NGT and Delphi require the involvement of experts of the topic, who are usually busy and have limited availability. When selecting panellists, it is key to ensure that all the relevant stakeholders are included. This could increase the possibility that the decisions will have an impact on policies or practices (Black, 2006).

For the topic of analysis of inciting circumstances in football, the relevant figures may be doctors, physiotherapists, sport scientists, strength and conditioning (S&C) coaches, and injury-focussed researchers. Indeed, sport doctors and physiotherapists have, among others, the scope to prevent, diagnose, and treat sport injuries and to help athletes to return to sport (Schwellnus, 2009). On the other hand, S&C coaches and sport scientists play an important role for injury prevention and return to play after injury (Talpey & Siesmaa, 2017). Finally, injury-focussed researchers are the ones who need to analyse the injury data, therefore their involvement in the development of classification systems is paramount.

As discussed in 2, the STROBE-SIIS guidelines for reporting of injuries in sport suggest that sport-specific guidelines are reported for the classification of inciting circumstances (Bahr et al., 2020). So far, a sport-specific system to classify inciting circumstances does not appear to have been implemented in football clubs. Since injuries are commonly reported through report forms such the ones developed by Fuller et al. (2006), developing an additional form to report the inciting circumstances may be appropriate and may facilitate its implementation. Forms to report on the injuries are already implemented in football environment. Usually, these forms are filled out by the medical staff that sometimes interview the injured players (Krosshaug et al., 2005). However, as discussed in Chapter 2.2, reporting the inciting circumstances relying only on information reported by the injured player and the medical staff may not be optimal because medical staff may have limited view of the inciting circumstances and the reliability of information provided by players may be limited. Therefore, when reporting on inciting circumstances it would be appropriate to combine medical information with video-analysis when video clips of the inciting circumstances are available. However, this may not always be possible due to time and/or resources limitations. As a consequence, it is important to develop a system which can be implemented with and without video-analysis.

Therefore, the aim of this study is to develop a standardised classification system that can be implemented in football and research environments to classify inciting circumstances of injuries. The objectives are to develop a system that is quick, easy to use, and can be used to classify the inciting circumstances both with and without the use of video clips. To increase the usability of the system, it will be developed together with football practitioners and injury researchers and will be split into two sections: a core set and an optional information set. The objective is to develop a core set that is short and easy to use, that is not time-demanding and can be completed even without a video recording of the Injury. On the other hand, the optional set would be longer, more detailed and would need a video recording of the injury to be completed. Once developed, this standardised system could be implemented in football and research environments to collect and report data on the inciting circumstances. Using a standardised classification system would allow the reduction in the risk of reporting bias and the collation of reliable data that can be used to develop a better understanding of the circumstances that lead to injury in football players.

4.2 Methods

The study was conducted following the Core Outcome Measures in Effectiveness Trials (COMET) guidelines (Williamson et al., 2017). Ethical approval was granted by Edinburgh Napier University's School of Applied Sciences Research Integrity Committee (SAS/2773451) and participants provided electronic consent prior to participation.

To develop the Football Injury Inciting Circumstances Classification System (FIICCS), a standardised system for the classification of inciting circumstances in football, a simplified model for NGT was implemented. NGT models can be modified and adapted depending on the context in which are implemented and the participants' time (Black, 2006; McMillan et al., 2016).

The model implemented in this study consisted of six phases, summarised as follows:

1) Idea generation: the steering committee formed by four authors (myself, Dr. Brown, Dr. McCall, and Prof. Impellizzeri) reviewed the literature and generated a draft of the FIICCS. This follows the modified NGT model proposed by McMillan et al. (2016), which was implemented as panellists were either experienced football practitioners and / or researchers and had limited time.
2) First ranking: the draft of the FIICCS developed by the steering committee was delivered to the panellists, who were required to express their opinion and to suggest improvements on the FIICCS using closed-ended and open-ended questions.
3) Pre-meeting survey: the results of phase two were circulated to panellists, who were then asked to rate their agreement with the improvements suggested in the open-ended questions.
4) Panel discussion: panel's answers provided in phase three were analysed and circulated to panellists. Subsequently, an online meeting was held to allow panellists to discuss the disagreements that arose from phases two and three.
5) Confirmation: after the end of the discussion, the FIICCS was updated and then circulated to the panellists, who were asked to confirm their level of agreement with the final version.
6) Alignment with FIFA Football Language and Football injury surveillance methodology consensus: the terminology of the FIICCS was aligned with FIFA Football Language (FIFA, 2022) and with the football extension of the IOC consensus on methods for recording and reporting of epidemiological data on

injury and illness in sport. Following this alignment, the panellists were asked to further confirm their agreement.

All the phases of the study were conducted trying to limit as much as possible the burden on panellists in order to facilitate their participation and to reduce the risk of non-response (i.e., attrition).

4.2.1 Phase one: idea generation

During phase one, the steering committee developed the first draft of the FIICCS. This was done through a systematic review of the literature. Details of the systematic search are reported in Table 3.1. A list of the activities which lead to injury reported in the literature was obtained from the studies included in the systematic review (Table 3.5 and) and were organised into domains and sub-domains to build the draft of the FIICCS which was discussed within the steering committee for three months (between 10 February and 20 May 2022) until agreement was achieved. The first draft of the FIICCS included six domains: contact type, physical activity, ball situation, playing position, session detail, and contextual information. Each domain was structured in order to include all activities reported in the literature. Therefore, the domains of the FIICCS were split into two sections: core set and optional information set. To improve the clarity, the FIICCS was piloted by two sport scientists who were not part of the steering committee and had experience of working in professional football, who were asked to look at the structure of the FIICCS (provided in form of flow chart) and to test it using seven video clips provided by the steering committee. The clips showed injuries that occurred during football practice and allowed them to consider all the parts of the system. After the injuries were classified, they were asked to provide feedback on the clarity of the system, the clarity of the guidelines, on how the system was being tested, and on recommendations to improve it. The sport scientists who piloted the system were highly qualified and had experience in collecting data and conducting research on football injuries (highest level of education: PhD = 2; nationality: Italian = 1, Scottish = 1; years of experience working in professional football: 5 and 22). No changes were required to the system after pilot testing, while the guidelines for testing the system were updated to make the panellists aware that they could need to revisit the clips for further review of the injuries more than once. The practitioners included in the pilot group were not included in the subsequent expert panel.

4.2.2 Phase two: first ranking

The FIICCS was circulated to the panel group which was composed of all the stakeholders deemed relevant (i.e., sport doctors, physiotherapists, sport scientists, S&C coaches, and injury researchers). The members of the panel group were recruited through purposive sampling (Hasson et al., 2000) from the authors' network and knowledge of practitioners working in injury research and professional football. In order to be included, the experts had to be fluent English speakers, have at least five years of conducting research on football injuries or five years of experience working in professional football with duties concerning diagnosis or prevention of injuries or return to play protocols after injury (Table 4.1). No geographical limitations were put in place, on the contrary, I tried to include people from different regions and backgrounds. In total, 21 football practitioners and researchers were invited to take part in the study (males = 13, females = 8; doctors = 7, physiotherapists = 4, injury researchers = 2, S&C coaches = 3, sport scientists = 5), 15 of who agreed to participate (males = 11, females = 4; doctors = 6, physiotherapists = 4, injury researchers = 2, S&C coaches = 2, sport scientists = 1). Two weeks were given to potential participants to decide whether to take part in the study.

Table 4.1 Inclusion criteria for members of the panel group

Position	**Experience**	**Duties (at least one)**
Doctors, Physiotherapists, S&C Coaches, and Sport Scientists	Possess at least five years of experience working in professional football	Responsible for injury surveillance programmes **AND/OR** Experience with manually inputting injury data into surveillance systems **AND/OR** Experience on development and/or implementation of injury prevention programmes **AND/OR** Experience on management of return to play programmes **AND/OR** Experience of diagnosing injuries
Researchers	Possess at least five years of experience conducting research on injuries in football	Research on injury prevention strategies **AND/OR** Research on mechanisms of injury **AND/OR** Research on injury reporting standards/guidelines **AND/OR** Research on factors associated to injury occurrence

The panellists were provided with the FIICCS in the form of a flow chart and in the form of an online survey. Panellists were requested to look at the structure of the system and to test it using seven video clips provided by the steering committee. The clips showed injuries that occurred during football practice and allowed the panellists to view all parts of the FIICCS. After the panellists tested the system, they were asked to answer an online survey to rate their agreement with the content and the organisation of each domain, the importance of reporting on each domain, the clarity of each domain, and the difficulty of reporting on each domain in professional football and research environments.

The survey included five closed-ended and seven open-ended questions and was built to examine the content validity of the system and to ask panellists to provide recommendations on how to improve the system. The Likert scales included in the closed-ended questions were developed using the anchors proposed by Olaoluwa (2016). The aim was to keep the duration of this phase (i.e., testing the system and answering the survey) under 40 minutes due to the limited availability of the panellists. To do so, the closed-ended questions were administered for the core set and the optional set of each domain (i.e., core set of physical activity, optional information of physical activity, and so on). Panellists could specify which part they did not agree with and suggest improvements using the open-ended questions (Table 4.2) and were free to not answer questions if they did not want to. The survey was administered using the online platform Novi Survey 8.7 (https://novisurvey.net/). The panellists were given two months (from 19 July 2021 to 19 September 2021) to answer the survey. Three remainder emails were sent to panellists over the 2-month period, after which participants were considered withdrawn.

Table 4.2 Questions included in phase two survey

Question Number	Question	Answers
1	Please rate how much you agree with the content and the organisation of the following sections of the system: 1) Main structure - Core set; 2) Contact type - Core set; 3) Physical activity - Core set; 4) Ball situation - Core set; 5) Session detail - Core set; 6) Main structure -Optional information; 7) Contact type -Optional information 8) Physical activity -Optional information; 9) Ball situation -Optional information; 10) Session detail -Optional information; 11) Contextual information -Optional information	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree; NA = Prefer not to say
2	Do you have further feedback on the content and the organisation of the sections? Would you add/exclude some from the core set or the whole structure?	Open-ended question
3	Do you have any feedback on the items of each section (e.g., jumping, running, kicking)? Would you add/exclude some or change how they are structured within the sections?	Open-ended question
4	How important is including the following information when reporting injury mechanisms in football? 1) Contact type - Core set; 2) Physical activity - Core set; 3) Ball situation - Core set; 4) Session detail - Core set; 5) Contact type -Optional information; 6) Physical activity -Optional information; 7) Ball situation -Optional information; 8) Session detail -Optional information; 9) Contextual information -Optional information	1 = Not at all; 2 = Slight; 3 = Neutral; 4 = Moderately; 5 = Extremely; NA = Prefer not to say
5	Do you have further feedback on the importance of each section?	Open-ended question
6	Please rate the clarity of each section:	1 = Poor;

	1) Main structure - Core set; 2) Contact type - Core set; 3) Physical activity - Core set; 4) Ball situation - Core set; 5) Session detail - Core set; 6) Main structure - Optional information; 7) Contact type - Optional information 8) Physical activity - Optional information; 9) Ball situation - Optional information; 10) Session detail - Optional information; 11) Contextual information - Optional information	2 = Fair; 3 = Good; 4 = Very good; 5 = Excellent; NA = Prefer not to say
7	Which parts of the sections need to be revised to improve clarity?	Open-ended question
8	How difficult would it be to collect information on each section in football environment? 1) Contact type - Core set; 2) Physical activity - Core set; 3) Ball situation - Core set; 4) Session detail - Core set; 5) Contact type -Optional information; 6) Physical activity -Optional information; 7) Ball situation -Optional information; 8) Session detail -Optional information; 9) Contextual information -Optional information	1 = Very difficult; 2 = Difficult; 3 = Neutral; 4 = Easy; 5 = Very easy; NA = Prefer not to say
9	Do you have further feedback on how the system could be improved to make it easier to implement in football environment?	Open-ended question
10	How difficult would implementing the system in research environment be? 1) Contact type - Core set; 2) Physical activity - Core set; 3) Ball situation - Core set; 4) Session detail - Core set; 5) Contact type -Optional information; 6) Physical activity -Optional information; 7) Ball situation -Optional information; 8) Session detail -Optional information; 9) Contextual information -Optional information	1 = Very difficult; 2 = Difficult; 3 = Neutral; 4 = Easy; 5 = Very easy; NA = Prefer not to say
11	Do you have further feedback on how the system could be improved to make it easier to implement in research environment?	Open-ended question
12	Do you have further feedback or recommendation to improve the classification system?	Open-ended question

4.2.3 Phase three: pre-meeting survey

After the completion of phase two, panellists were provided with the results of the survey and were asked to rate their agreement with the improvements suggested in the previous phase. The aim of this survey was to identify the improvements on which panellists agreed and therefore did not need to be discussed during the meeting. This reduced the number of topics to discuss and helped shorten the time required for the meeting. The survey included 30 closed-ended questions (Table 4.3) and was administered using the software and Likert scales described in phase two. Panellists were given four weeks (from 7th October 2021 to 4th November 2021) to answer the survey. Two reminder e-mails were sent to panellists over the 4-week period, after which they were considered withdrawn.

Table 4.3 Questions included in the pre-meeting survey

Question N.	Question
1	Reduce the number of questions included in the core set (i.e., reduce the number of mandatory questions.
2	Remove optional information set and make all information belong to the core set (i.e., everything will be mandatory).
3	In question “How were injury information collected?” add the option “reported by medical staff who witnessed the injury”.
4	If question “How were injury information collected?” is answered with “reported by medical staff” then add a question to ask how many days after the injury the form was filled out.
5	In question “What is the main mechanism of injury?” rephrase “acute” and “overuse” with “sudden onset” and “gradual onset”.
6	In question “Contact type” include the option “unclear”.
7	In question “Type of contact” include collision (i.e., when two players run into each other unintentionally).
8	Restructure the answers to question “Tackle direction”.
9	In question “Physical activity – running activity” include the option “curved run”.
10	Remove question “Ball control - controlling phase” removed as it is difficult to distinguish and non-relevant.
11	In question “Ball situation” add “ball being contested for”.
12	Remove question “Pitch condition” as it is difficult to evaluate.

13	Include question “Pitch condition“ in the core set.
14	Include options for injured player who gets the sanction question “referee decision”.
15	Remove question “Player attention” because it is difficult to answer.
16	Remove question “Where was the player when the injury occurred?”.
17	Restructure the answer to question “Playing position” as follows: if the position in which the player was playing in the match/training he got injured is known, this will be reported. If it is not known, the position in which the player usually plays will be reported.
18	Include in all the questions an option “Not possible to determine/unclear”.
19	Include a guideline/user manual embedded in the classification system.
20	Add question for change of direction to indicate the side injured (i.e., towards/away from the side of the injured leg).
21	Running intensity is difficult to quantify and should be discussed during the meeting for alternatives.
22	In question “Ball situation” include a question for all activities indicating whether the player movement during which the injury occurred was caused by a player error (e.g., player poor touch may result in the injury mechanism such as a lunge for the ball or placing the player into a dangerous position for contact).
23	In question “Ball situation - kicking - player activity” add a question to specify ball impact (e.g., side-foot kick, instep kick, volley, etc).
24	In question “playing sub-phase” include sub-phases for goalkeepers.
25	In question “playing sub-phase” include “other” option with the possibility to include situations not covered by the options.
26	Include the question “Own team’s current ranking in championship / league championship ranking”.
27	Include the question “Opponent teams ranking in championship / league”.
28	Include the question “Phase of season”.
29	Include the question “Time of match/training during which injury occurred”.
30	Include the question “Specify how many minutes the injured player played”.

4.2.4 Phase four: panel discussion

After the completion of the pre-meeting survey, panellists were invited to an online meeting to discuss the topics around which consensus had not been reached. Panellists’ availabilities were collected and the meeting took place on the 18th

November 2021 on Microsoft Teams. One week before the meeting, panellists were provided with the results of the pre-meeting survey and with the list of the topics that were going to be discussed. Twelve aspects on which consensus was not previously reached were discussed during the meeting (Table 4.4). The aspects were sorted in order of importance to ensure that there was enough time to discuss the most important topics.

Table 4.4 Aspects discussed during the online meeting

Question N.	Question
1	What is the best length of the core set?
2	After the changes made, what is the clarity of the section ball situation – optional set?
3	How should running intensity be reported?
4	When injuries occur during changes of direction, should we indicate if the injured leg was the one used to change direction?
5	Shall we include a question to indicate whether the injury occurred after a player error?
6	When injuries occur during kicking, shall we specify the type of kick performed (e.g., volley, sidekick)?
7	Shall we remove the question to report pitch condition?
8	Shall we remove the question to report player position on pitch at time of injury?
9	How shall we report playing position of the injured player?
10	Shall we indicate own and opponent teams ranking position?
11	Shall we indicate the phase of season at time of injury?
12	Shall we include further option to report goalkeeper-specific activities?

On the day of the meeting, panellists were required to fill in the consent form. The meeting was facilitated by myself and Prof. Impellizzeri who has extensive experience on conducting and participating in consensus studies. At the start of the meeting, it was explained to the panellists that they were free to express their opinion and that they were not obliged to change their opinion just to reach consensus. Panellists were asked to listen and consider others' opinions openly and respectfully. To ensure all panellists felt comfortable and free to express their opinion the meeting was not recorded and hand notes were taken during the meeting by myself. Before beginning the discussion, panellists were asked to briefly introduce themselves. Subsequently, the first topic was introduced and panellists were requested to discuss. No time limits were given for the discussion of each topic, albeit to account for the limited time of the panellists it was agreed that the meeting would last no more than two hours. At the end of each discussion, the panel was asked to express their agreement with the group decision through an anonymous survey performed on Microsoft Teams. The scales for clarity and agreement were the ones implemented in previous phases (Table 4.2) however, to try to reach consensus the neutral options "neither agree nor disagree" and "good" were removed, but participants were allowed not to respond if they preferred.

Two panellists could not make the online meeting due to last-minute commitments with their respective football teams. This is common in the football environment, where the team schedule is very flexible and needs to change according to several factors. However, since the FIICCS was being developed to be used also by football teams it was deemed important to involve people working in such a setting and therefore panellists unavailability was a reality to deal with. Therefore, the two panellists who could not make the online meeting were not excluded from the study but were provided with an anonymous summary of the panel discussion (based on the facilitator notes) and were invited to respond to a survey to express their agreement with the group decisions.

4.2.5 Phase five: confirmation

Following the panel discussion, the FIICCS was updated, and the panel was asked to confirm their agreement with the final version. The final version was sent to the panel together with a report of the discussion including the results of the anonymous polls and the panel was asked to confirm their agreement with the system and to inform of any objections. This phase took place between 13th December 2021 and 6th January 2022.

4.2.6 Phase six: alignment with FIFA Football Language and Football injury surveillance methodology consensus

Following the initial confirmation from panellists, one panellist suggested to align the system with the FIFA Football Language which defines each player actions within a football match and can be used to analyse player's and team's actions (FIFA, 2022) and with the football extension of the IOC consensus on methods for recording and reporting of epidemiological data on injury and illness in sport. These projects were under development during the time of this study, but insights into this development were shared by FIFA so the included activities and their descriptions in recommended classifications could be aligned. The updated version was sent to the panellists who were asked if they had any objections to the amendments. This phase took place between 15th January and 10th June 2022 and was facilitated by a FIFA member.

4.2.7 Data analysis

A similar approach implemented by other studies for data analysis was used because there are no explicit guidelines for analysing consensus data (McPherson et al., 2018;

Williamson et al., 2017). Raw data were exported and analysed in RStudio 1.3.1056 using the packages *beeswarm, cowplot,* and *ggplot2* (Eklund & Trimble, 2021; RStudio Team, 2020; Wickham, 2016; Wilke, 2020). Consensus was deemed achieved when ≥ 70% of responders reported agreement or disagreement. This cut-off was arbitrarily selected a priori by the research team following methods implemented in other similar studies (Bateman et al., 2022; McCall et al., 2020b; van der Horst et al., 2017; Zambaldi et al., 2017) as guidelines for selection of consensus thresholds do not exist (see Hasson et al. (2000) and McPherson et al. (2018) for a review). Since participants could avoid answering any question for ethical reasons, the percentage for consensus was calculated on the total answers received. For example, if only 10 answers were received for a certain question, of which 7 (70%) were in agreement and 3 (70%) were in disagreement, consensus was deemed reached. Items on which agreement was reached were excluded from subsequent rounds. I recognise that this approach has some limitations (i.e., panellists could not re-score the items considering the scores of other members and it was not possible to compare agreement pre and post discussion), however I deemed it to be the most appropriate as it limited the time burden on panellists and reduced the risk of attrition (Williamson et al., 2017). Furthermore, panellists could provide further feedback after having considered other members' view during the online meeting and in phases five and six.

Open ended questions were analysed following the guidelines provided by Côté et al. (1993). All the answers were associated with a code which reflected the topic of the answer. Afterwards, answers with the same code (i.e., addressing the same topic) were grouped and merged in questions which were included in subsequent phases.

Finally, to examine the risk of attrition bias, the average scores of each round were calculated for each panellist and plotted as described in the COMET handbook (Williamson et al., 2017). Where the results of members who did not participate in subsequent phases were similar to those completing all the phases, attrition bias was deemed as unlikely to influence the results. Following the Supreme Court model proposed by Shrier (2021), the proportion of panellists who agreed and disagreed during each phase and the disagreement expressed during the study were summarised and reported. The system was subsequently uploaded in the Open Science Framework to provide a communication channel to those not involved in the development of the system.

4.3 Results

4.3.1 Participants

Twelve of the fifteen experts who agreed to be included in the panel completed the first phase (females n = 4; males = 8). Eleven panellists were working in football in different leagues: English Premier League (n = 2), English Women's Super League (n = 1), Qatar Stars League (n = 1), Spanish Primera Iberdrola (n = 1), Austrian BundesLiga (n = 1), Spanish La Liga (n = 1), European National Team (n = 1), Asian National Team (n = 2), South American National Team (n = 1). One panellist was working as researcher only. The panellists had nine different nationalities: Australian (n = 3), British (n = 2), Brazilian, Danish, Dutch/Brazilian, French, Italian, Japanese, Spanish (n = 1). One panellist held a Bachelor’s Degree, two panellists held a Master’s Degree and nine panellists held a PhD. Panellists had experience working as an injury researcher (n = 3) or in professional football as a doctor (n = 4), physiotherapist (n = 5), S&C coach (n = 2), and sport scientist (n = 3). On average, panellists conducted research on injuries for 9.4 years (range 7-15) and worked in professional football for 12.6 years (range 7-30) (Figure 4.1 Panellists' experience). All the duties included in the inclusion criteria described in Table 4.1 were fulfilled by at least 4 panellists (Figure 4.2)

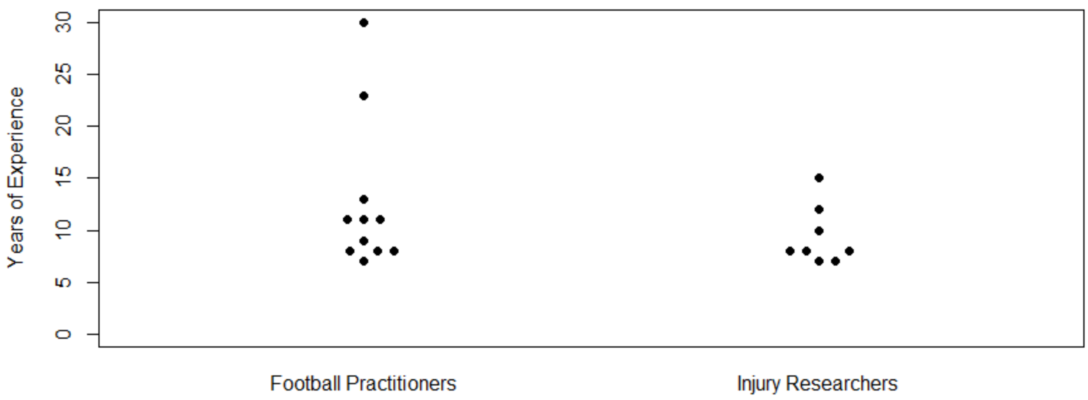

Figure 4.1 Panellists' experience

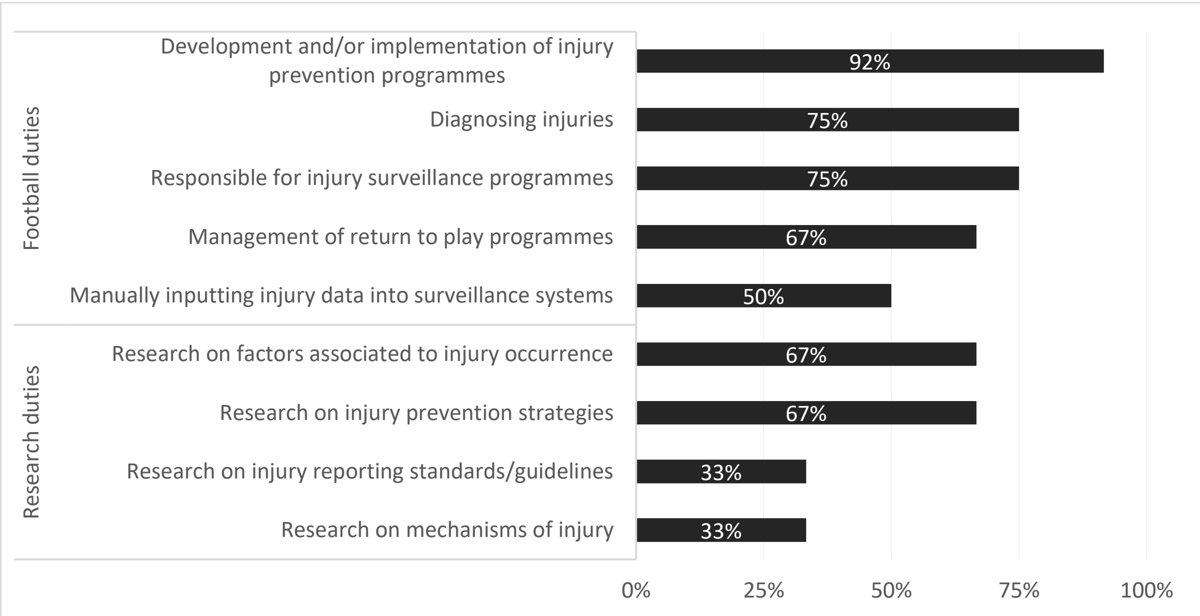

Figure 4.2 Panellists duties (expressed as a percentage of all panellists)

4.3.2 Phase one: idea generation

A list of the circumstances which lead to injury reported in the literature was obtained from the studies included in the systematic review (Table 3.4) and were grouped into six domains: Contact type, Physical activity, Ball situation, Playing position, Session detail, and Contextual Information. Each domain was structured in order to include all the circumstances reported in the literature. Therefore, the domains of the FIICCS were split into two sections: core set and optional information set. The core set constitutes the minimum information that should be included when reporting on the inciting circumstances in football, while the optional information set includes the details that would help the understanding of the inciting circumstances but are not deemed essential. When developing the core set, the steering committee tried to find the right compromise between the amount of information required and the length of the core set in order to increase its usability. Specifically, it was believed that with a short core set, the chances of obtaining the buy in from the practitioners would be higher. Furthermore, a simple core set would be usable even when video recordings of the injuries are not available. Therefore, both the main structure and the domains which compose the structure were split into core set and optional information set as described in Figure 4.3 to Figure 4.8.

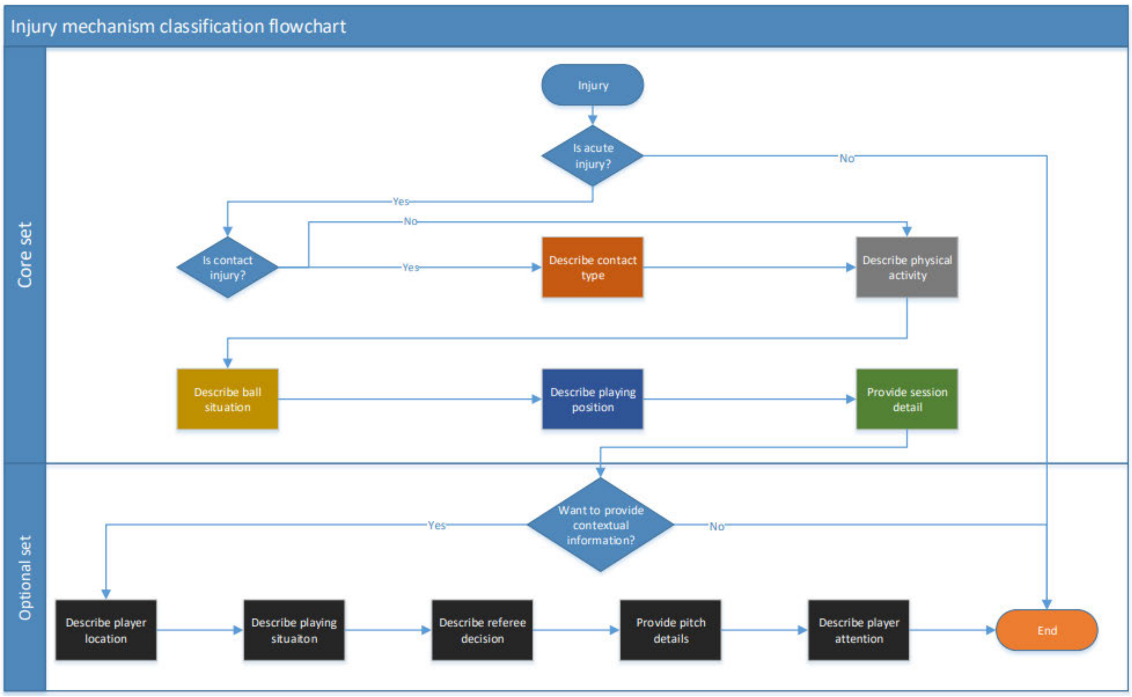

Figure 4.3 Draft of the structure of the injury FIICCS

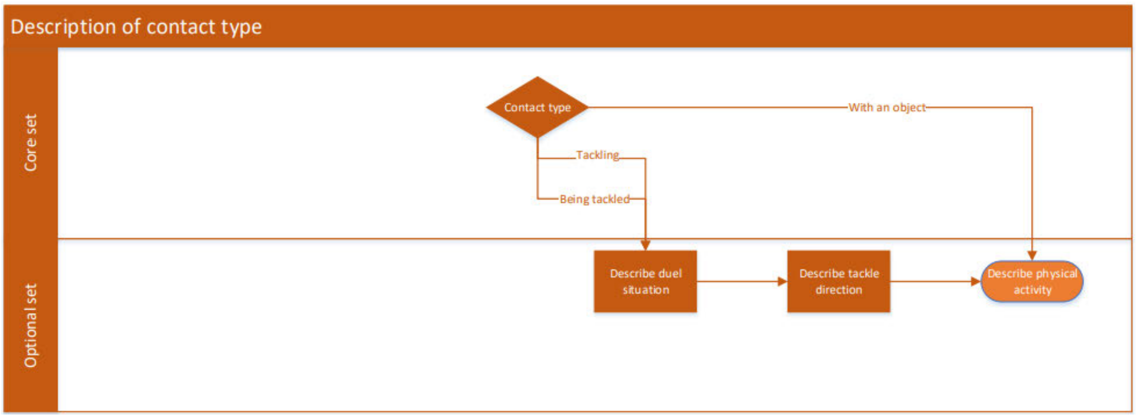

Figure 4.4 FIICCS draft, Contact Type

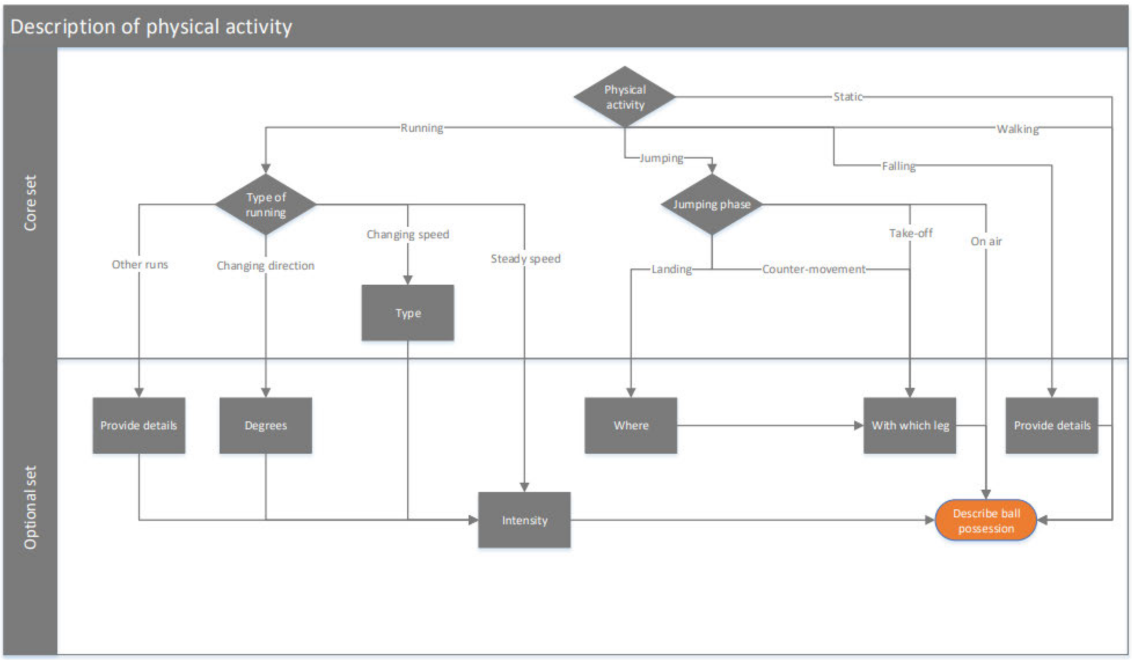

Figure 4.5 FIICCS draft, Physical Activity

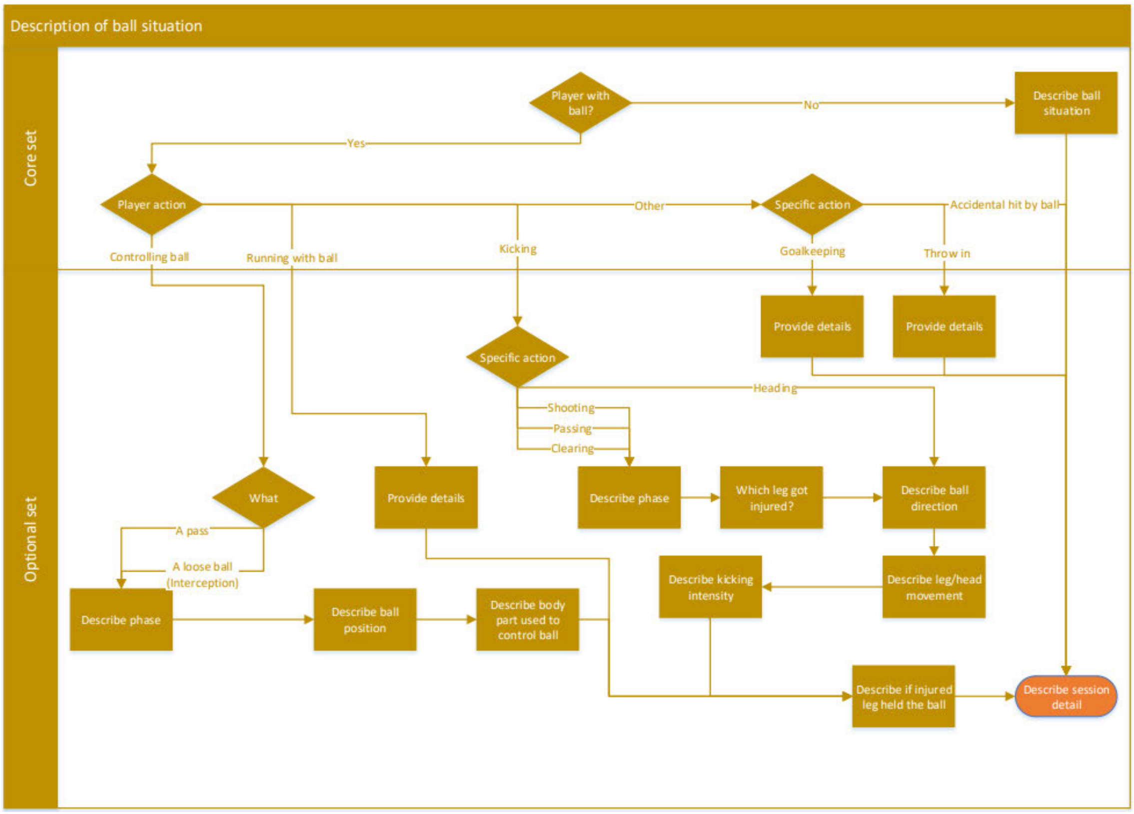

Figure 4.6 FIICCS draft, Ball Situation

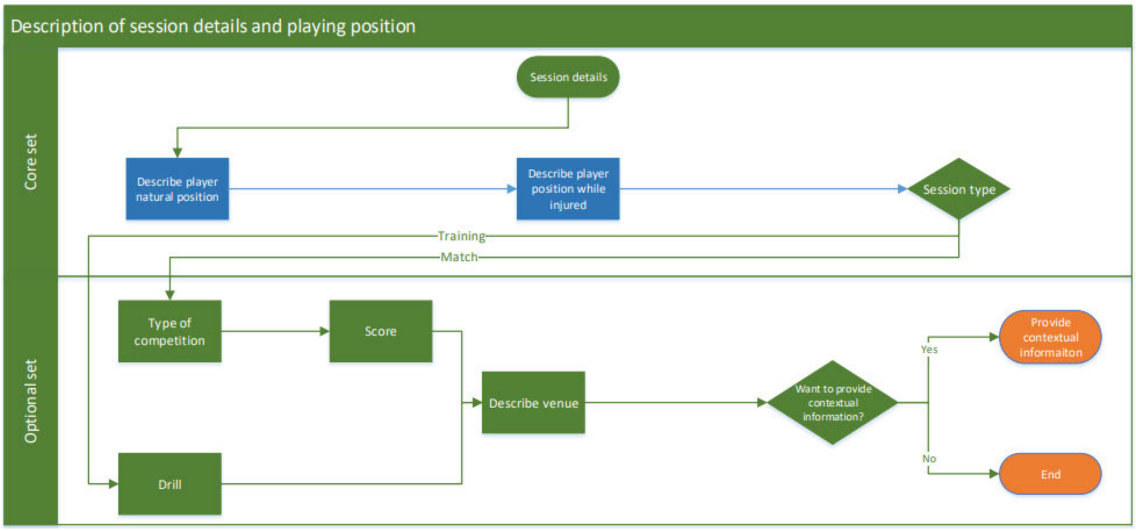

Figure 4.7 FIICCS draft, Session Details and Playing Position

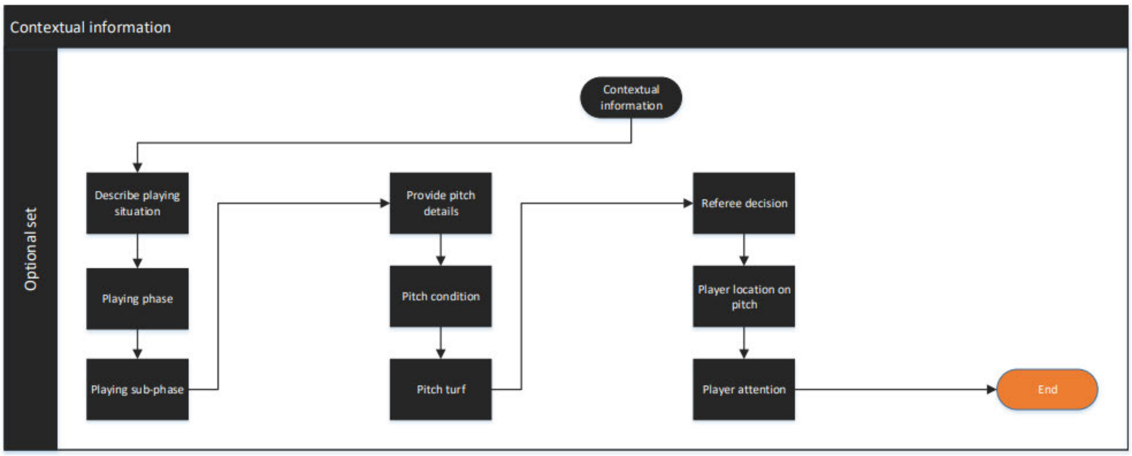

Figure 4.8 FIICCS draft, Optional information

4.3.3 Phase two: first ranking

In total, 12 panellists were asked to express their agreement through 49 unique questions (Table 4.2) with a total of 588 questions. In total, 511 answers (87% of total questions) were recorded (1 = 2 answers (<1%), 2 = 10 answers (2%), 3 = 50 answers (10%), 4 = 214 answers (42%), 5 = 235 answers (46%)) and 77 questions (13% of the total questions) were not answered. All the questions were answered by at least 8 panellists. In all questions, at least 60% of responders gave a response of 4 or 5.

Consensus was reached in 48 questions (98%), while was not reached in one question (2%): clarity of the domain concerning the optional set of ball situation.

For the structure and organisation of the system, there was consensus around how the system is structured and organised. Indeed, more than 75% of responders rated as "Agree" or "Strongly agree" about the structure and organisation of each domain (Figure 4.9 and Table 4.5).

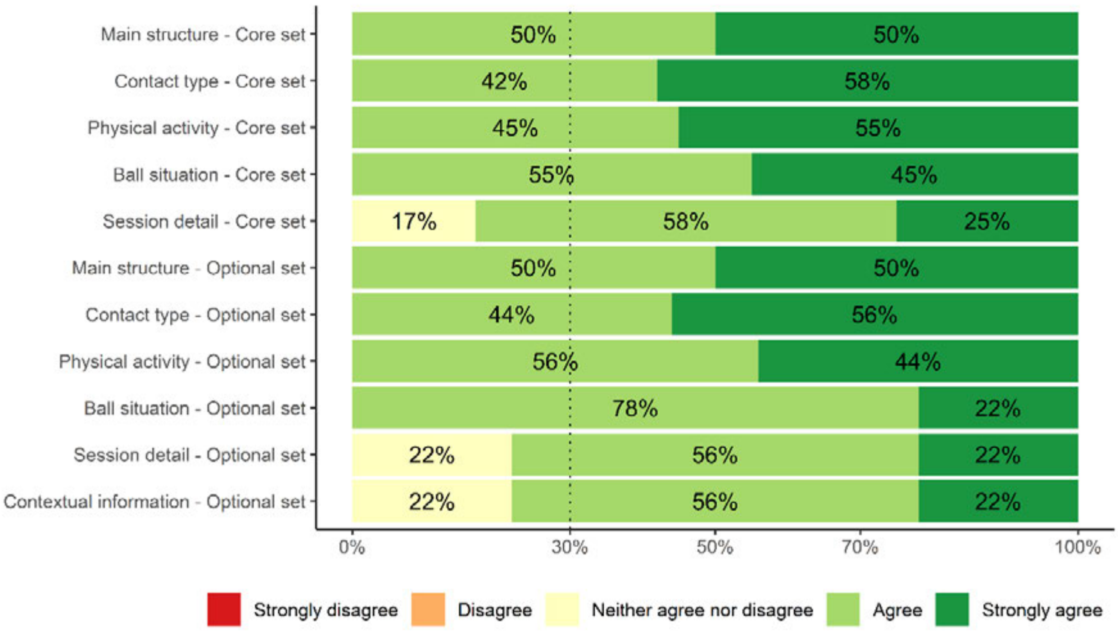

Figure 4.9 Agreement with content and organisation of the domains

Table 4.5 Answers on the agreement with content and organisation of the domains

Domain	1	2	3	4	5	Total
Main structure - Core set	0	0	0	6	6	12
Contact type - Core set	0	0	0	5	7	12
Physical activity - Core set	0	0	0	5	6	11
Ball situation - Core set	0	0	0	6	5	11
Session detail - Core set	0	0	2	7	3	12
Main structure - Optional set	0	0	0	4	4	8
Contact type - Optional set	0	0	0	4	5	9
Physical activity - Optional set	0	0	0	5	4	9
Ball situation - Optional set	0	0	0	7	2	9
Session detail - Optional set	0	0	2	5	2	9
Contextual information - Optional set	0	0	2	5	2	9

Considering the importance of reporting each domain, there was consensus around the importance of reporting all the domains included in the FIICCS (Figure 4.10 and Table 4.6). At least 80% of responders considered moderately or extremely important reporting information on all remaining domains.

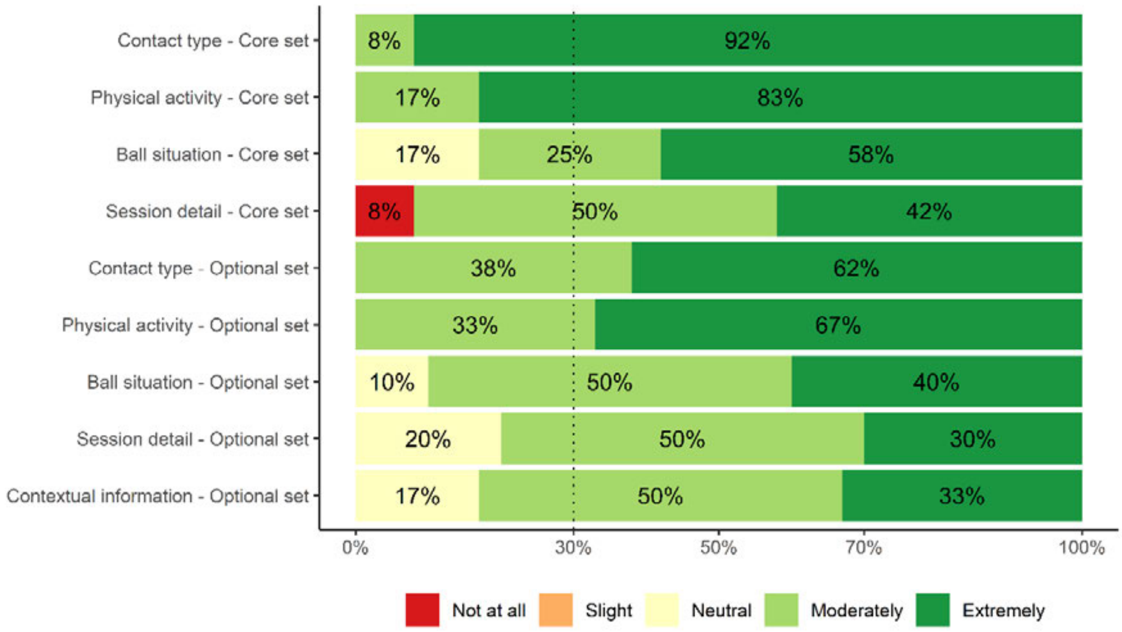

Figure 4.10 Consensus around the importance of reporting the domains

Table 4.6 Answers on the Importance of reporting each domain

Domain	**1**	**2**	**3**	**4**	**5**	**Total**
Contact type - Core set	0	0	0	1	11	12
Physical activity - Core set	0	0	0	2	10	12
Ball situation - Core set	0	0	2	3	7	12
Session detail - Core set	1	0	0	6	5	12
Contact type - Optional set	0	0	0	3	5	8
Physical activity - Optional set	0	0	0	3	6	9
Ball situation - Optional set	0	0	1	5	4	10
Session detail - Optional set	0	0	2	5	3	10
Contextual information - Optional set	0	0	2	6	4	12

Consensus was reached around the level of clarity of all the domains of the system except the domain of ball situation – optional set (Figure 4.11 and Table 4.7). Indeed, only six responders rated the clarity of this domains as very good or excellent, while three responders rated the clarity as good, and one rated the clarity of this domain as poor. Two panellists did not rate this section.

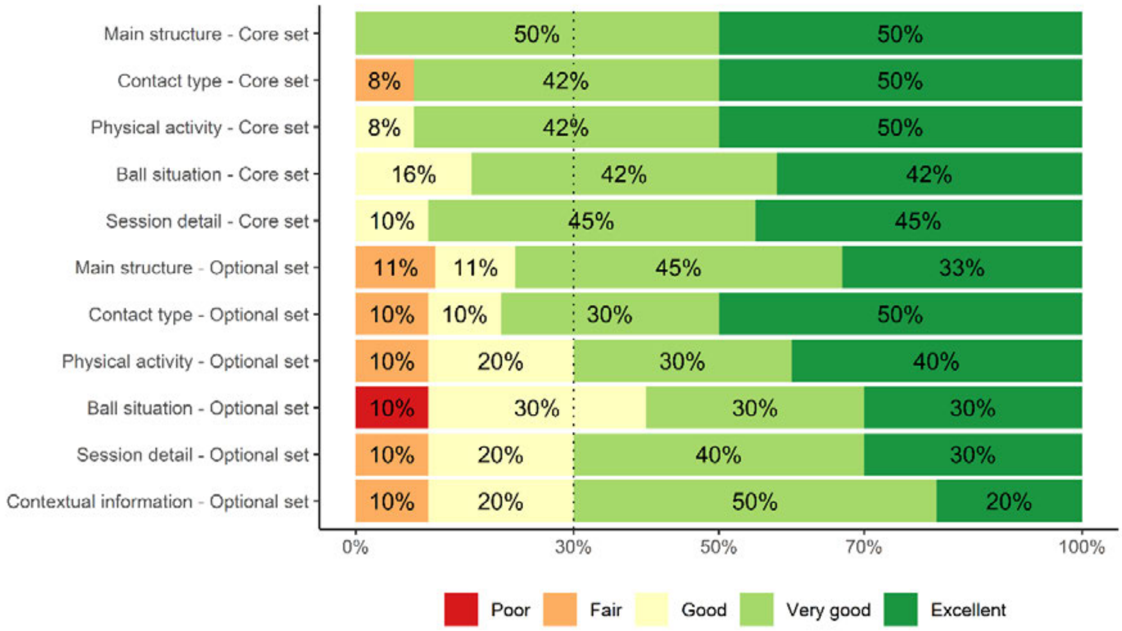

Figure 4.11 Consensus around the clarity of the domains

Table 4.7 Answers on the clarity of the domains

Domain	**1**	**2**	**3**	**4**	**5**	**Total**
Main structure - Core set	0	0	0	6	6	12
Contact type - Core set	0	1	0	5	6	12
Physical activity - Core set	0	0	1	5	6	12
Ball situation - Core set	0	0	2	5	5	12
Session detail - Core set	0	0	1	5	5	11
Main structure - Optional set	0	1	1	4	3	9
Contact type - Optional set	0	1	1	3	5	10
Physical activity - Optional set	0	1	2	3	4	10
Ball situation - Optional set	1	0	3	3	3	10
Session detail - Optional set	0	1	2	4	3	10
Contextual information - Optional set	0	1	2	5	2	10

Finally, all panellists agreed that the system is easy to use both in professional football (Figure 4.12) and in research environment (Figure 4.13), although consensus on the usability of the system in research environment was slightly wider. Considering a football environment, 70% of responders rated the collection of optional information on ball situation and contextual information as easy or very easy, while for the other domains these answers were provided by more than 80% of responders. Considering a research environment, more than 70% of responders consider the collection of information on session details and contextual information as easy or very easy, while for the other domains these answers were provided by more than 85% of responders. Details of answers provided on usability of the system in football and research environment are reported in and Table 4.8 and Table 4.9, respectively.

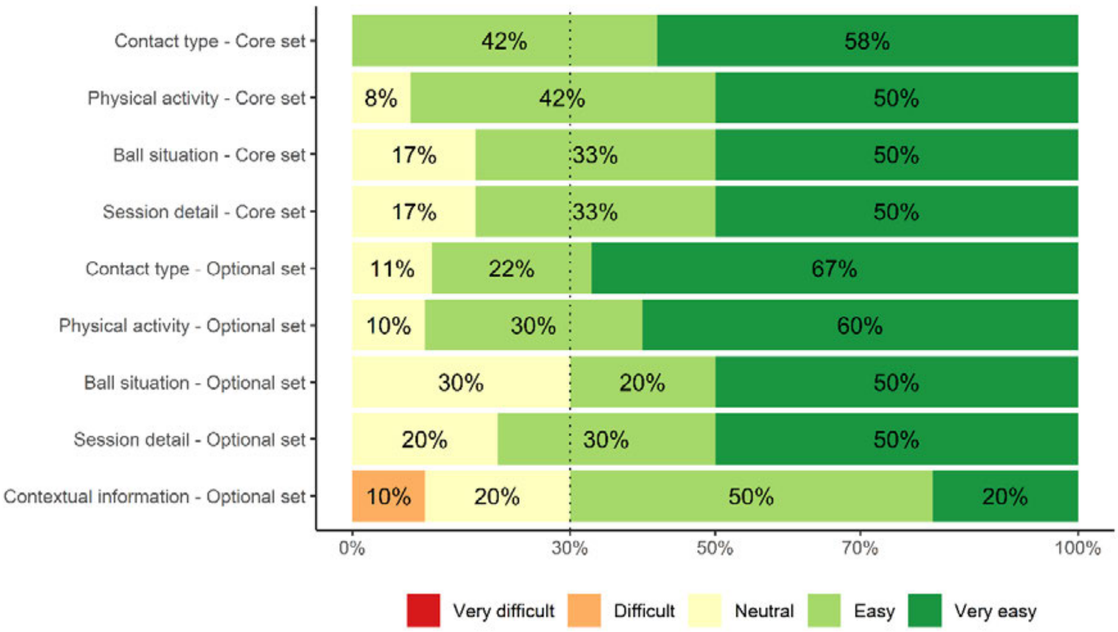

Figure 4.12 Consensus around the usability of the FIICCS in a football environment

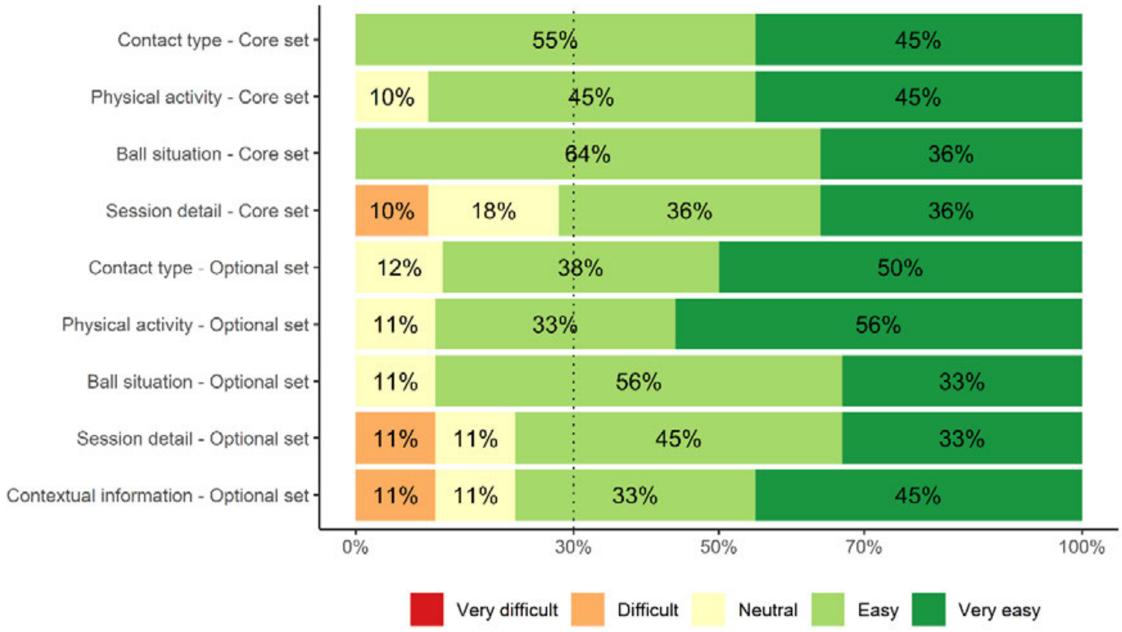

Figure 4.13 Consensus around the usability of the FIICCS in a research environment

Table 4.8 Answers on the usability of the FIICCS in a football environment

Domain	1	2	3	4	5	Total
Contact type - Core set	0	0	0	5	7	12
Physical activity - Core set	0	0	1	5	6	12
Ball situation - Core set	0	0	2	4	6	12
Session detail - Core set	0	0	2	4	6	12
Contact type - Optional set	0	0	1	2	6	9
Physical activity - Optional set	0	0	1	3	6	10
Ball situation - Optional set	0	0	3	2	5	10
Session detail - Optional set	0	0	2	3	5	10
Contextual information - Optional set	0	1	2	5	2	10

Table 4.9 Answers on the usability of the FIICCS in a research environment

Domain	1	2	3	4	5	Total
Contact type - Core set	0	0	0	6	5	11
Physical activity - Core set	0	0	1	5	5	11
Ball situation - Core set	0	0	0	7	4	11
Session detail - Core set	0	1	2	4	4	11
Contact type - Optional set	0	0	1	3	4	8
Physical activity - Optional set	0	0	1	3	5	9
Ball situation - Optional set	0	0	1	5	3	9
Session detail - Optional set	0	1	1	4	3	9
Contextual information - Optional set	0	1	1	3	4	9

Finally, the changes proposed by the panellists in the open-ended questions were collated into 30 questions (Table 4.3), which were included into the pre-meeting survey.

4.3.4 Phase three: pre-meeting survey

Panellists were asked to rate their agreement on the improvements suggested during the first survey. Of the 12 panellists who completed the first survey, 11 answered the pre-meeting survey while one panellist (doctor = 1) could not continue the study due to limited availability.

In total 11 panellists expressed their agreement through 30 questions (Table 4.3) with a total of 330 answers (i.e., all the panellists answered all the questions). Consensus was reached on 13 items and the remaining 17 items were included during the online meeting (Table 4.10 and Figure 4.14).

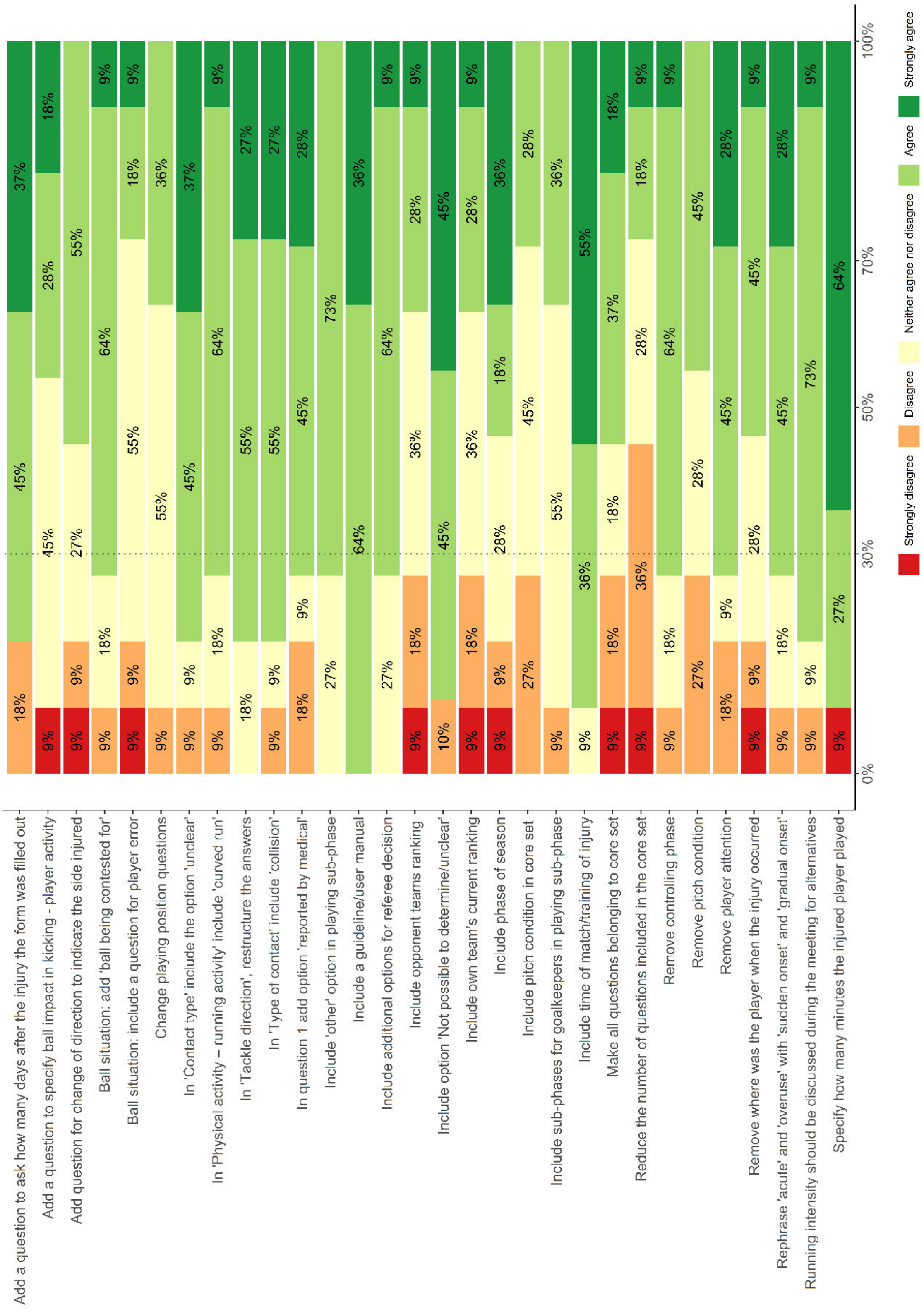

Figure 4.14 Agreement with changes proposed during the first survey

Table 4.10 Answers from pre-meeting survey

Question	1	2	3	4	5	Total
Reduce the number of questions included in the core set	1	4	3	2	1	11
Make all questions belonging to core set	1	2	2	4	2	11
In question 1 add one more option (reported by medical)	0	2	1	5	3	11
Add a question to ask how many days after the injury the form was filled out	0	2	0	5	4	11
Rephrase “acute” and “overuse” with “sudden onset” and “gradual onset”	0	1	2	5	3	11
In “Contact type” include the option "unclear"	0	1	1	5	4	11
In “Type of contact” include "collision"	0	1	1	6	3	11
In “Tackle direction”, restructure the answers	0	0	3	6	3	11
In “Physical activity – running activity” include “curved run”	0	1	2	7	1	11
Remove controlling phase	0	1	1	7	1	11
Ball situation: add “ball being contested for”	0	1	2	7	1	11
Remove pitch condition	0	3	3	5	0	11
Include pitch condition in core set	0	3	5	3	0	11
Include additional options for referee decision	0	0	3	7	1	11
Remove player attention	0	2	1	5	3	11
Remove where was the player when the injury occurred	1	1	3	5	1	11
Change playing position questions	0	1	6	4	0	11
Include option “Not possible to determine/unclear”	0	1	0	5	5	11
Include a guideline/user manual	0	0	0	7	4	11
Add question for change of direction to indicate the side injured	1	1	3	6	0	11
Running intensity should be discussed during the meeting for alternatives	0	1	1	8	1	11
Ball situation: include a question for player error	1	1	6	2	1	11
Add a question to specify ball impact in kicking - player activity	1	0	5	3	2	11

Include sub-phases for goalkeepers in playing sub-phase	0	1	6	4	0	11
Include “other” option in playing sub-phase	0	0	3	8	0	11
Include own team’s current ranking	1	2	4	3	1	11
Include opponent teams ranking	1	2	4	3	1	11
Include phase of season	1	1	3	2	4	11
Include time of match/training of injury	0	0	1	4	6	11
Specify how many minutes the injured player played	1	0	0	3	7	11

4.3.5 Phase four: panel discussion

Nine panellists participated at the online meeting while two (S&C coach = 1, doctor = 1) could not attend it due to last-minute commitments with their football team.

The meeting lasted 90 minutes and all the 12 questions on which consensus was not achieved in the previous phases were discussed. Consensus was reached on 11 questions, and it was not achieved around whether further details in the description of goalkeeper-specific activities should be included (Figure 4.15 and Table 4.11).

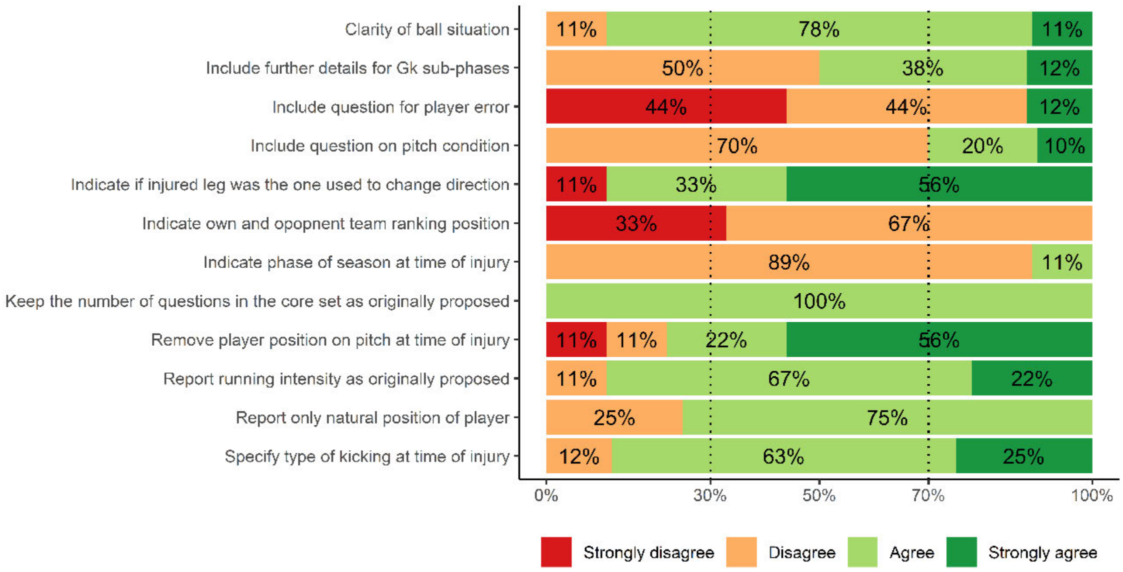

Figure 4.15 Panel answers after online discussion

Table 4.11 Answers following meeting discussion

Question	**1**	**2**	**4**	**5**	**Prefer not to say**	**Total**
Keep the number of questions in the core set as originally proposed			9		1	10
After the changes made, what is the clarity of section "ball situation"?		1	7	1	1	10
Running intensity should be reported as originally proposed		1	6	2	1	10
Include a question to indicate which leg had contact with the ground when the injury occurred during a change of direction	1		3	5	1	10
Include a question to indicate whether the injury occurred after a player error	4	4		1	1	10
Add a question to specify the type of kick during which injury occurred		1	5	2	2	10
Include question on "pitch condition" in the classification system		7	2	1		10
Remove question on "player position on pitch at time of injury"	1	1	2	5	1	10
Report only natural position of player and exclude "actual" playing position		2	6		2	10
Include a question for own teams and opponent team ranking position	3	6			1	10
Include a question to indicate the phase of season during which the injury occurred		8	1		1	10
Include question to further specify goalkeeper sub-phases		4	3	1	2	10

When discussing the length of the core set, the panel appreciated that time demand is a concern when collecting information in the practical setting but argued that the current length of the core set does not pose an excessive burden on practitioners and that a shorter core set would not allow the collection of enough information. One panellist suggested extending the length of the core set, but the panel finally agreed to keep the length of the core set as originally proposed. Following the changes proposed in phase two and accepted in phase three, the panel deemed the optional set of ball situation section to be clear.

With reference to the definition of running intensity, the panel agreed that this is an important aspect to evaluate (as discussed in Chapter 2.3.3) but that it must be acknowledged that not all teams can collect this information objectively. To do so, it would be necessary to monitor player activities through instruments such as Global Positioning Systems (GPS) or optical video-tracking systems and when an injury occurs, the inciting event needs to be localised in the tracking data, which requires accurate data collection as will be discussed in the next chapter. Therefore, the panel agreed that although the classification of running intensity originally proposed is not ideal, it seems the best way to collect such information as it gives the possibility of reporting it either using objective instruments or using the reported categories (i.e., high intensity, medium intensity, low intensity) which are explained to standardise their interpretation. The panel agreed that if the inter-rater reliability (which will need to be tested in further studies) results are high, this classification is reasonable, otherwise alternatives will need to be considered.

With reference to whether a question to indicate if the injured leg was the one used to perform the change of direction should be included, it was discussed that this information could be useful especially for ankle, adductor, and ligament injuries, hence should be included. With respect to whether a question to indicate whether the injury occurred after a player error should be included, some panellists argued that it may be relevant because a player error (e.g., bad touch, wrong pass, or wrong tactical behaviour) may lead the player to perform sudden and unusual movements, while others argued that this information may not be relevant because it cannot be used to develop prevention strategies. However, there was large consensus that determining whether a player made an error is very subjective and there could be several different opinions of the same injury even when coaches are included in the decision, therefore the panel agreed not to add this aspect into the FIICCS.

With reference to whether a description on the type of kick performed at the time of injury should be included, the panel agreed that this information is easy to collect and is relevant because each type of kick (e.g., inside kick, outside kick, back heel) involves different movements. The panel argued that information could be used both to understand the mechanism of injury and to inform the development of rehabilitation protocols. With regard to whether pitch condition should be reported, some panellists argued that this information is important because pitch quality may vary significatively even in professional settings and may influence player load and the risk of some injuries such as ankle and knee injuries. On the other hand, other panellists argued that the quality of the pitch may not be homogeneous (i.e., some area of the pitch may be of good quality and other areas may be of bad quality) and that reporting it may not be relevant because this information cannot be used for the development of prevention strategies. Regardless of the importance of reporting this information, there was consensus that evaluating pitch condition can be difficult because it is subjective and can change in different areas of the pitch, therefore the panel agreed to exclude this question from the FIICCS.

With reference to player location on pitch at the time of injury, the panel agreed to remove this question because it was deemed to be not important and that it cannot provide relevant information for the development of prevention strategies. With respect to reporting playing position, it was argued that people who report injury circumstances may not know the position the player was playing when the injury occurred because players change position very frequently during football games, therefore it is difficult to collect and report the information accurately. Therefore, the panel agreed to report only the natural playing position (i.e., the position in which the player usually plays in). The panel agreed not to collect information on teams ranking position and phase of season at the time of injury respectively because it was deemed to be not worth collecting and because the information can be extrapolated from the date of injury.

Finally, the panel discussed whether more information on the goalkeeper-specific activity should be reported. It was discussed that the FIICCS allows the reporting of the most important inciting circumstances (e.g., landing, kicking, diving) therefore it may not be relevant to include further information. However, consensus was not reached because only 50% of the panellists agreed not to include further information. Therefore, since the reporting of goalkeeper-specific inciting activities is included in the optional set, no further information was included in the domain, but further details can be collected if the researchers or practitioners deem this to be necessary.

One of the panellists who could not make the online meeting (Doctor) agreed to answer the survey, while the other panellist (S&C Coach) did not and was therefore excluded from further phases.

4.3.6 Phase five and six: alignment with FIFA Football Language and football extension of IOC Consensus, and final confirmation

The FIICCS was updated following panel comments, the publication of the FIFA Football Language and the football extension of the IOC consensus on methods for recording and reporting of epidemiological data on injury and illness in sport, and was finally sent to the panellists for final approval. All the panellists confirmed they agreed with the final version and did not have any further comment.

4.3.7 Final classification system

The FIICCS was updated following the changes agreed in the previous phases. Since the description of goalkeeper-specific action is included in the optional set and that consensus on whether changing it or not was not achieved, it was left as originally proposed and further descriptions can be included by the researchers according to their objectives.

Overall, the following changes were applied to the system developed in phase one:

- An additional question was included to specify the number of days that pass between the injury occurrence and the form being filled out
- An additional option was included to report whether the ball is being contested for at the time of injury

- An additional option was included to report whether the type of contact is unclear
- An additional option was included to report whether the injury occurred during a curved run
- The domain “tackle direction” was restructured
- An additional option was included to report whether the injury occurred during a collision
- An additional option was included to report whom the injured player collided with
- An additional option was included to report whether the injury occurred during an aerial duel
- An additional option was included to report whether the injury is reported by medical staff who diagnosed the injury
- An additional option was included to allow the use of open-ended answers to report on the playing sub phase at the time of injury
- Additional options were included to report referee decisions
- An additional option was included to report whether information requested by the subdomains cannot be clearly reported due to the inciting circumstance
- An additional question was included to report the minute during which the injury occurred and how many minutes the player had played before the injury occurred
- The subdomains “controlling phase”, “player attention”, “player position”, and “pitch condition” were removed

- The options for the domain “Onset of injury” were rephrased from acute and overuse to sudden onset and gradual onset
- An additional question was included to report whether the injured leg was the one used to change direction at the time of injury
- An additional question was included to report own and opponent team ranking position
- An additional question was included to report type of kicking performed at the time of injury
- The subdomain “playing position” was restructured to report only the players’ natural position
- The subdomain “controlling ball” was rephrased to “receiving ball”
- “Blocking” was added in “receiving ball” to distinguish between receiving the ball with intention to retain possession (interception) and without intention to retain possession (blocking)
- “Running type” in the core set of physical activity was restructured to include both the type of running (i.e., linear run, curved run, changing direction) and the speed (i.e., accelerating, decelerating, steady speed)
- The subdomain “conducting ball” was rephrased to “dribbling”

The final version of the of the FIICCS is available at the following link (https://osf.io/jqtse/) and its structure is described in Figure 4.16 to Figure 4.21. The user guidelines with the definition of the domains and sub domains of the core and optional sets have been developed by the Steering Committee, revised by the panellists, further revised by the steering committee and one panellist as part of the development of the medical coding of the FIFA Football Language, and finally approved by the panel.

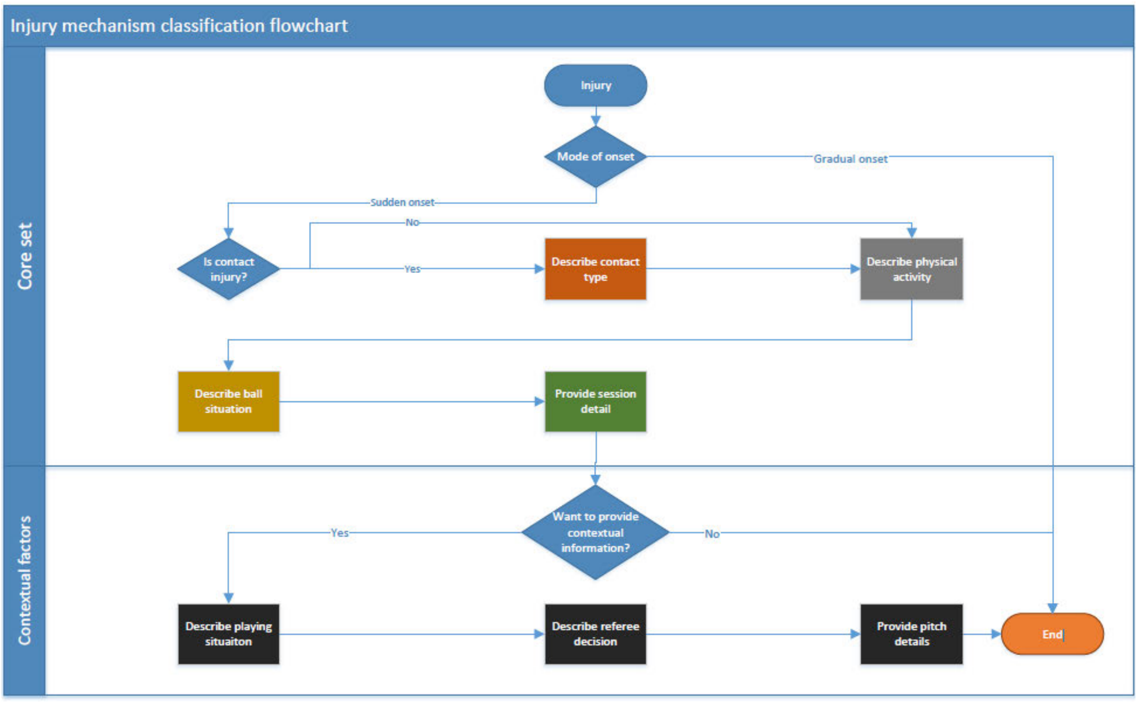

Figure 4.16 Final structure of the injury FIICCS

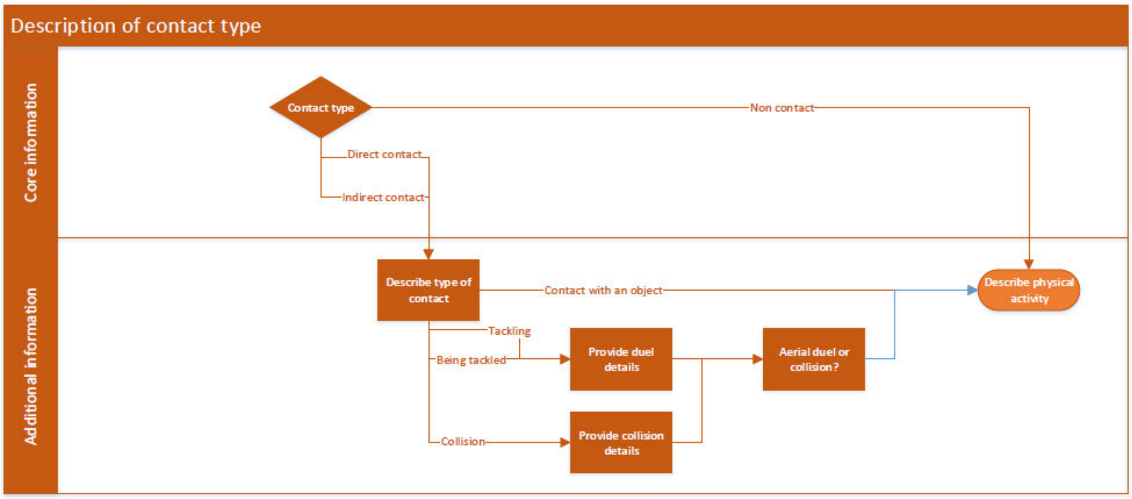

Figure 4.17 Final FIICCS, Contact Type

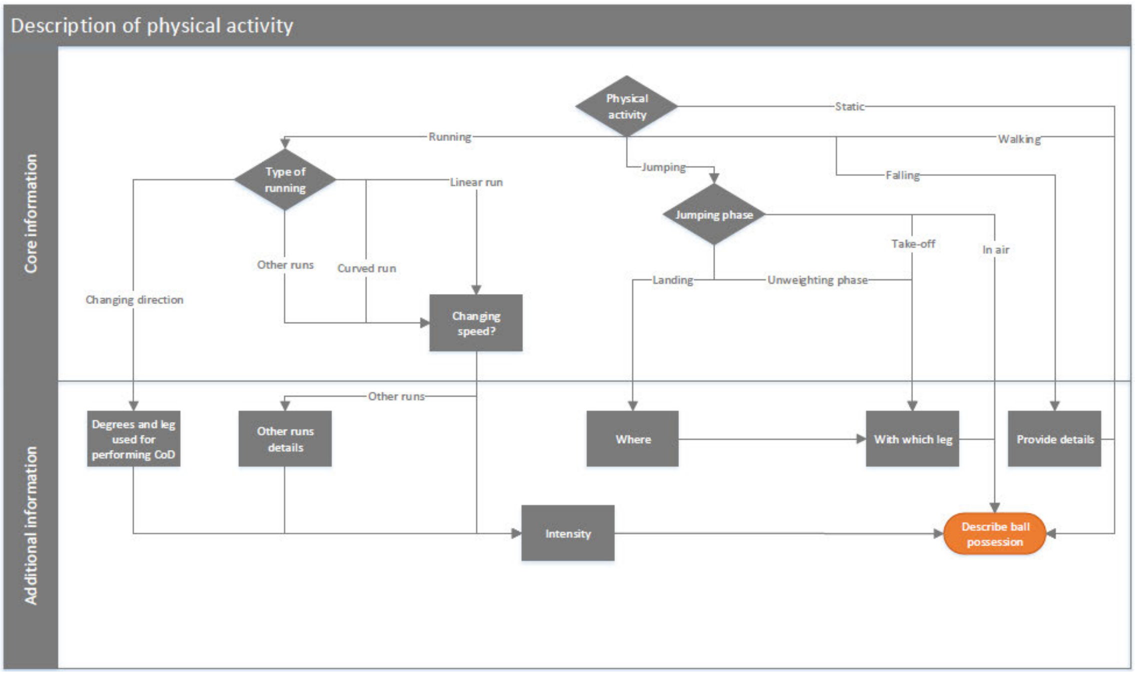

Figure 4.18 Final FIICCS, Physical Activity

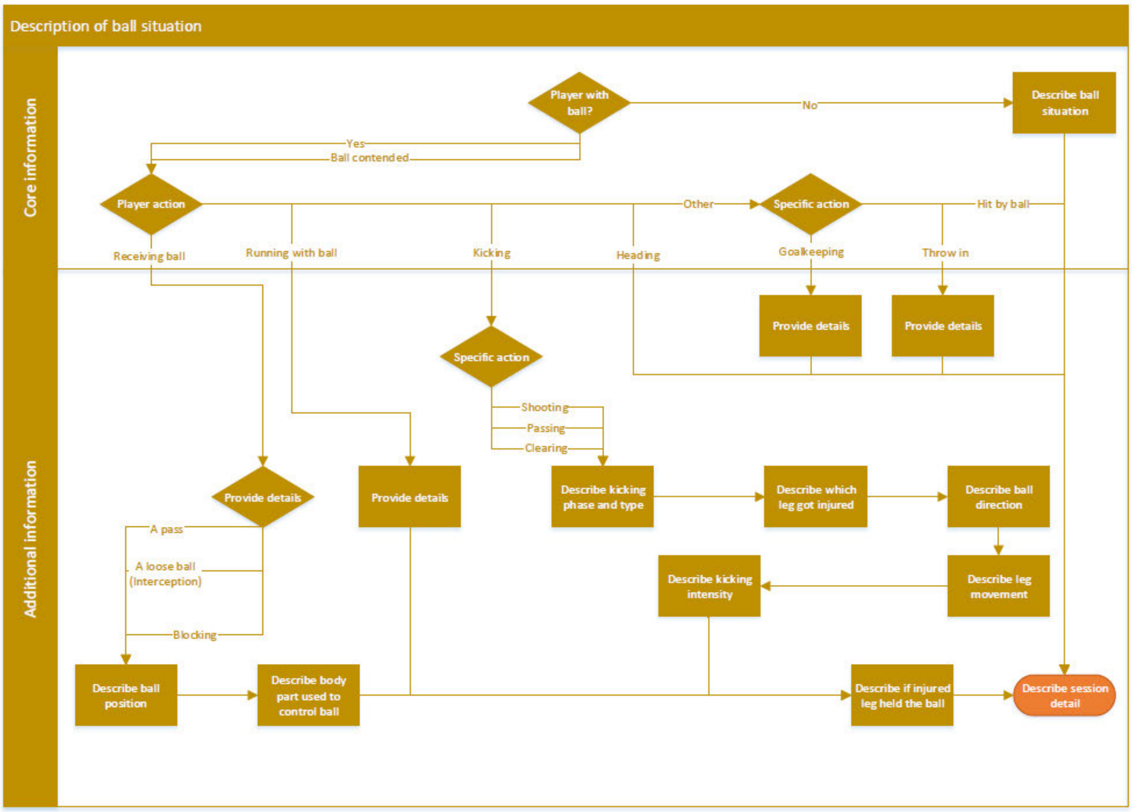

Figure 4.19 Final FIICCS, Ball Situation

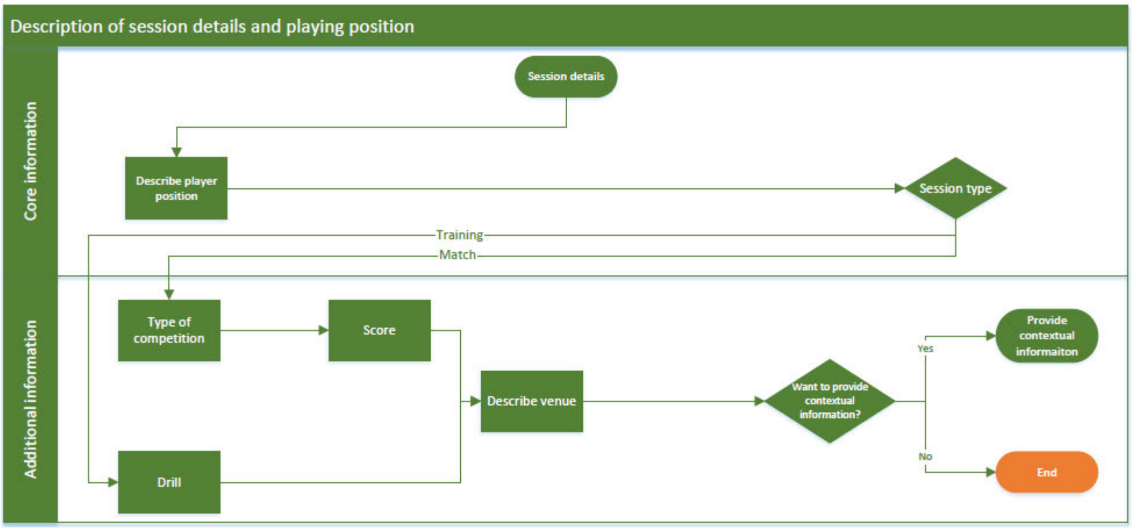

Figure 4.20 Final FIICCS, Session Details

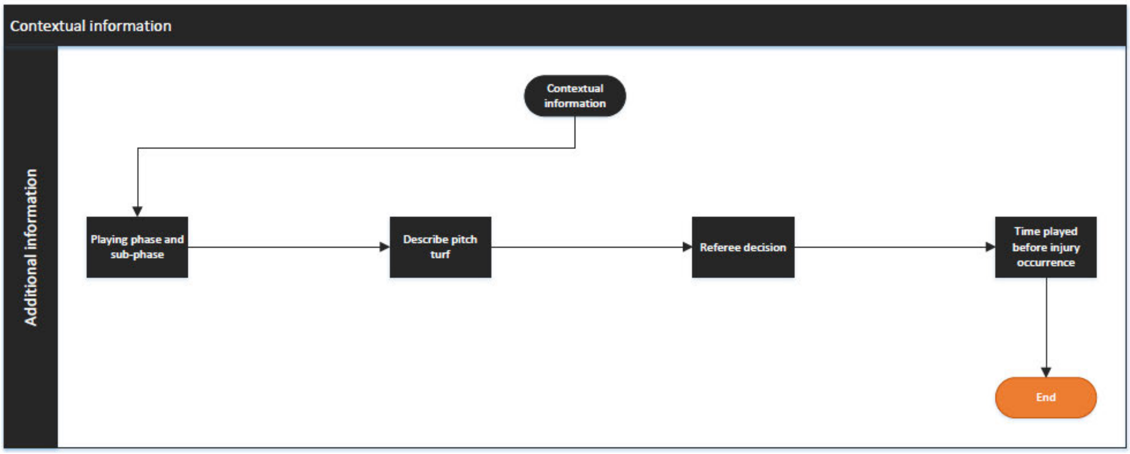

Figure 4.21 Final FIICCS, contextual information

4.3.8 Attrition

Twelve panellists originally agreed to participate in the study and completed the second phase. One panellist (doctor) left the study after the second phase and another (S&C coach) left the study after the third phase. Both panellists declared that they could not continue the study due to their limited availability to be able to meet the necessary time commitment. To evaluate whether attrition in phase 3 and 4 introduced bias, the average score of the answers provided by panellists who left the study were compared with the average score of the answers provided by the panellists who completed all the phases. The average score of those who did not complete phase three or phase four did not differ from the average score of the panellists who completed the study (Fig. 5), which suggests that attrition was unlikely to introduce bias.

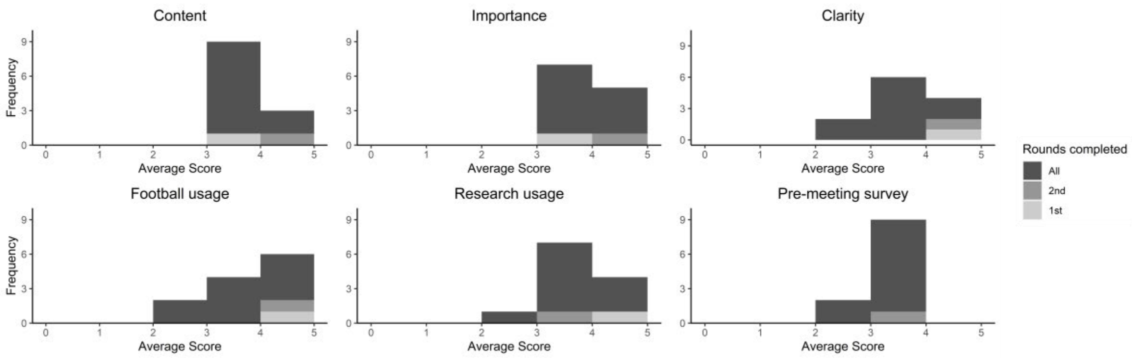

Figure 4.22 Average scores in phase two by question category and in phase three. All are panellists who completed the study, second is the panellist who completed phase two and three but did not attend the panel discussion, first is the panellist who completed only phase two

4.4 Discussion

Measuring and reporting the inciting circumstances consistently is key to combine, compare, and generalise findings across studies, provide information to practitioners, and to develop effective injury prevention strategies. The high reporting inconsistency observed in the available literature and discussed in previous chapters could lead to the development and implementation of inadequate prevention strategies. Using a standardised classification system would allow a decrease in the risk of reporting bias and the gathering of reliable data that can be used to develop a better understanding of the inciting circumstances. Therefore, the aim of this study was to develop a standardised classification system which can be used by practitioners and researchers to systematically report inciting circumstances within football training and match play.

The study was conducted following the COMET guidelines for the development of core outcome sets (Williamson et al., 2017). To involve all the stakeholders deemed relevant, which is crucial for the development of core outcome sets, a modified NGT protocol was implemented. This was justified by the need to limit the time burden on the panellists to limit the risk of attrition (McMillan et al., 2016). Professional football practitioners have a very tight schedule which changes very frequently, therefore limiting as much as possible the time demand was paramount to ensure their involvement. Indeed, the two panellists who decided to drop out did so due to limited time availability. The panel was comprised of ten members including doctors, physiotherapists, S&C coaches, sports scientists, and injury researchers who had more than five years of experience in working in professional football and conducting research on injuries. The panel tested the first version of the FIICCS developed by the steering committee and gave feedback on possible improvements which were discussed in the following phases. The FIICCS was updated following panel feedback and aligned with the FIFA Football Language, with FIFA associated medical coding of inciting circumstances, and with FIFA football extension of the STROBE- SIIS. Finally, the panellists confirmed their agreement with the final version of the system.

The FIICCS comprises two sets and five domains. The two sets are the core set and the optional set, and the five domains are Contact Type, Running Activity, Ball Situation, Session Details, and Contextual Information. The domain Contextual Information is included in the optional set, while the other domains are in part included in the core set and in part included in the optional set. The core set allows the reporting of information deemed necessary at a minimum level to evaluate the inciting circumstances and means that this information should always be reported. It was deemed to be easy to use and not excessively time demanding by the panellists. The optional set is longer and allows the reporting of more in-depth detail on the inciting circumstances. It was deemed to be easy to use in professional and research settings but to report the information requested viewing of a relevant video clip of the inciting circumstances is required. The optional set can be also adapted by the researchers or practitioners who wish to collect different or additional information on the inciting circumstances and depends on the research question or the question posed in the practical setting. The core set, which on the contrary should not be modified, will encourage sufficient reporting consistency and addresses the issues of inconsistent reporting observed in the literature and discussed in Chapter 3.4.3.

The FIICCS can be used as a method deemed appropriate and easy to use by football experts and injury researchers to collect and report inciting circumstances, but it is recommended to use it with caution until the system is evaluated further for validity and reliability of reporting. Practitioners and researchers working with football clubs may easily include the core set in the report forms they routinely use to collect injury data. This increases the chances that the core set will be implemented because it is not time demanding and can be incorporated into injury monitoring procedures already in place. The optional set has been deemed easy to implement in football environments by the panel, however since it is more time demanding, its implementation may encounter some barriers. On the other hand, both the core set and the optional set can be easily implemented within research settings. Indeed, researchers could be interested in performing detailed analyses of the inciting circumstances and in some cases could decide to change the optional set according to their purposes. For example, if the study aims to evaluate the biomechanics of ACL injuries or to report in detail the tactical circumstances at the time of injury, appropriate optional sets would need to be implemented. It is recognised that following its implementation it is possible that further improvements will arise and the system will need to be updated, but this is a normal part of the scientific process. Additionally, it will be necessary to evaluate the reliability of the system which might be reduced in some situations such as when evaluating running intensity without appropriate instrumentation as will be further discussed in Chapter 5.1. Given the extent of reporting inconsistency of inciting circumstances discussed in previous chapters, the system could be implemented to reduce this issue while further studies evaluate its reliability. Doing so will allow findings across studies to be combined, compared, and generalised, which could subsequently allow the identification of possible mechanisms of injury, to inform practitioners, and to develop injury prevention strategies that can be tested.

The completion of the core set requires less than two minutes and the completion of the optional set requires less than three minutes. Therefore, the system can be implemented in football practice and in future research studies to report the inciting circumstances, but has limited efficacy in interpreting the available literature because the inciting circumstances have been reported without providing a qualitative description or a definition of the reported inciting circumstances. Taking running activities as example, without knowing how the authors defined running it is not possible to classify these activities using the FIICCS because the authors might or might not have included in “running” several inciting activities (e.g., accelerating, changing direction). On the other hand, it is possible for the authors of such studies to reclassify the inciting circumstances. Some authors of studies which collected data on inciting circumstances might have qualitative descriptions in their notes and might be able to reclassify them following the FIICCS. In studies that used video-analysis such as Tscholl et al. (2007) and Serner et al. (2019), reclassifying the inciting circumstances would be easier. Indeed, given that medical information has already been collected and video clips have already been located, the authors could easily watch the clip and reclassify the injuries. This would sensibly improve the quality of the studies and provide consistent information to researchers and practitioners. The same reclassification could also be performed by authors of studies that analysed clips of the inciting circumstances obtained through online platforms. This would improve the consistency of the reported inciting circumstances, but the quality of these information sets would remain questionable given the limitations on injury definition and the reliability of information provided by online platforms discussed in Chapter 3.4.3.

4.4.1 Limitations

Despite following the COMET guidelines this study is not without limitations. The study protocol had to be modified to meet the limited availability of the panellists, whose involvement was crucial for the development of the FIICCS. Furthermore, there is significant uncertainty on methods to develop core outcome sets (Williamson et al., 2017). As a consequence, some decisions (e.g., the cut-off value to deem consensus reached, the exclusion of the neutral answer in phase four) were taken on the basis of the experience of the steering committee and following the methodology implemented in similar studies.

Further limitations concern how the panel was recruited, how much time was given to them to complete each phase, and the risk of attrition bias. Recruiting panellists from the network of the steering committee might have led the panel to be formed by experts whose opinions are similar to the steering committee's. Using purposive sampling was necessary due to the difficulties in recruiting practitioners working in professional football as reported in other consensus studies (McCall et al., 2020b; Zambaldi et al., 2017). It could have been possible to invite experts outside the network of the steering committee, for example by contacting experts who have published and/or work in the field. This could have reduced the risk of confirmation bias. However, considering that experts who work in the field are extremely busy and were even busier during the period in which this study was conducted due to the pandemic, it was expected that the majority of the experts that would have been invited would have not agreed to participate in the study. As a consequence, considering the time limitation of this project, it was deemed appropriate to invite only practitioners within the network of the steering committee. To give panellists enough time to complete the surveys, while keeping the phases close to each other to maintain high the interest and participation, the study was originally planned to last two and a half months but ended up taking nine months. Extending the duration of the study was necessary because panellists were extremely busy in the first phases and because it was necessary to align the FIICCS with the FIFA football language and the FIFA football extension of the STROBE-SIIS. Phase two took place in July and August

2021 which coincided with the pre-season phase of most European football clubs, the Olympics, and the Paralympic Games, while phase three took place in October 2021 which coincided with the FIFA World Cup qualification matches. Furthermore, three panellists (one of whom did not complete the full study) changed their job during the study. With reference to alignment to FIFA projects, the FIFA football language was published in November 2021 and was reported to the steering committee in January 2022, while the consensus meeting for the development football extension of the STROBE-SIIS took place in March 2022. Therefore, to try and limit attrition as much as possible and align the system with FIFA guidelines which is an important step in ensuring widespread use of the FIICCS, it was deemed necessary to extend the duration of the phases. Despite efforts put in place to reduce attrition (e.g., extra time to complete the phases was conceded, personalised follow ups were sent) 2/12 (17%) of panellists did not complete the study. The risk of attrition bias was low but the opinions of the panellists who did not complete the study might have led to different decisions. Another limitation is that panellists had to be fluent English speakers which limits the representativeness of those who do not speak English. Finally, I acknowledge that classifying injuries as non-contact, direct and indirect contact as per STROBE-SIIS guidelines (Bahr et al., 2020) may be challenging as suggested by Shrier (2021) and that this will deserve further consideration which was beyond the scope of this study.

4.5 Conclusions

The aim of this study was to develop a standardised system that allows practitioners and researchers to systematically report inciting circumstances leading to injury in football. Following robust consensus methods 10 football and research experts from four continents were involved in the development of a core outcome set and an optional information set. The core set is short, can be easily used in research and practice environments, and can be included in the injury reporting routines already in place in football, while the optional set can be implemented both in football and research environments but requires video-analysis. This study constitutes a first attempt to create a standardised classification system involving stakeholders and is not without limitations: 1) the selection of the panel may have introduced bias 2) the system needs to be evaluated for validity and reliability of reporting 3) following its implementation it is possible that further improvements will arise and the system will need to be updated. However, given the extent of reporting inconsistency of inciting circumstances in the available literature, future studies should use this system to classify the inciting circumstances while further studies evaluate its reliability. Following recommendations from Shrier (2021), the disagreements that arose within the panel are reported in detail and the FIICCS has been uploaded on Open Science Framework to provide a communication channel to those not involved in its development.

Now that a standard classification system to report the inciting circumstances has been developed, it should be easier to evaluate the injury inciting circumstances in football. Ideally, the FIICCS will be included into the medical data collection routine already in place within football clubs. However, even if the FIICCS has been included into FIFA projects, there is no guarantee that it will be implemented within all football clubs. Furthermore, even if the FIICCS gets implemented, more time will be needed to collect a sufficient number of injury data to understand the inciting circumstances. On the other hand, at present it could be possible to retrospectively analyse injuries that occurred in the past and classify them using the FIICCS. This would allow an immediate analysis of the inciting circumstances. Therefore, study three aims to develop and test a protocol to perform a retrospective analysis of inciting circumstances using data previously collected within elite football clubs.

5 Analysis of inciting circumstances in elite football players: a video and GPS based approach

5.1 Introduction

As discussed in the literature review, to analyse the circumstances of injuries it is recommended to use both medical information and video analysis in order to limit missing data and perform accurate and detailed analyses (Krosshaug et al., 2005). Indeed, certain details (e.g., type of kicking performed at the type of injury, the height of the ball which was being controlled by the injured player) may be difficult to evaluate only on the basis of what has been witnessed by the medical staff reporting the injury or of what is remembered by the injured player. Therefore, report forms allow the collection of only basic information about the inciting circumstances (i.e., the ones included in the core set of the FIICCS), while video analysis allows the collection of additional information which may support the research on injury mechanisms and the development of prevention strategies. However, video analysis may not be enough to obtain all relevant and important information concerning the physical activity. Indeed, even using video-analysis and injury reporting to analyse inciting circumstances, it is not possible to objectively report themeasures of player physical activities. This is the reason that led the panellists who contributed to the development of the classification system to question the reliability of the reporting of speed at which the player is running at the time of injury (Chapter 4.3.5).

In football, physical activities performed by the players during matches and training sessions are commonly monitored using Global Positioning Systems (GPS). Such systems are used by all elite football teams to monitor external load, support training programming, and try to reduce injury risk (Buchheit & Simpson, 2017). In recent years their usage has become widespread in all professional football teams also thanks to the availability of low-cost systems (Schulze et al., 2021).

Despite the limitations of the technology (Bataller-Cervero et al., 2019; Beato et al., 2018; Lacome et al., 2019), GPSs can provide detailed information on aspects of players' physical performance and remain the most used Electronic Performance Tracking Systems in professional football. These systems allow the analysis of variables of interest associated with physical performance, while technical and tactical performance is commonly analysed using match analysis. Match analysis is used to evaluate the performance of their own teams and competitors' technical and tactical performance. This can be done by analysing the video (e.g., opponent teams offensive tactics, individual players behaviour in certain football circumstances) and, at a deeper level, by implementing big data and machine learning technologies to analyse tactical behaviour. A detailed review of match analysis methods is beyond the scope of this study and can be found in the literature (Filetti et al., 2017; Low et al., 2020a; Low et al., 2020b; Mackenzie & Cushion, 2013; Sarmento et al., 2018; Sarmento et al., 2014), however it is clear that video and tracking data are routinely collected and are becoming more and more utilised in professional football to monitor and improve player performance and to try to reduce the risk of injury.

Considering the issues observed in the literature about how data concerning inciting circumstances are collected and reported, a standard classification system has been developed. To ensure that such a system was appropriate and usable in research and professional environments, consensus guidelines were followed and all the stakeholder roles deemed relevant were involved in its development. To support the usability of the system it was deemed important to limit the time burden on practitioners, hence it would be useful to use data collection processes already put in place in football clubs. Report forms are already used within football clubs to collect medical data, although they seem to allow the reporting of only a brief description of the inciting circumstances. Video analysis allows the reporting of more detailed and accurate information on the inciting circumstances and, since it is already used to support technical staff, such videos can be used to analyse the inciting circumstances without adding further burden on practitioners. Similarly, since video analysis does not allow the analysis in detail of players' physical activity at the time of injury, and since football players are commonly monitored with GPSs, these systems can be included in the analysis of inciting circumstances to obtain detailed information on the physical activity performed by the players at the time of injury.

Therefore, the inciting circumstances could be analysed using video clips, GPS, and medical data that are routinely collected by professional football teams to monitor players' health and improve their performance,without the need to implement further data collection procedures. Now that a standardised system to report the inciting circumstances has been developed, they may be analysed in professional football teams. Consequently, the aims of this study are to evaluate whether and how these data can be used , and to determine the best method for doing so (pilot, part one) and then to use the FIICCS to retrospectively analyse the inciting circumstances in elite football players (part two). The objectives are 1) to evaluate whether the data routinely collected by professional football clubs can also be used to investigate the inciting circumstances of injuries, 2) to identify the inciting circumstances that may put football players at greater risk of incurring specific injuries and 3) to make a preliminary evaluation of whether injury occurrence is linked with players' running intensity as discussed in the literature review. In the first part of the study procedures for data collection and analysis will be piloted and refined, because to the best of my knowledge video-analysis, GPS and report forms have never been combined before to analyse inciting circumstances. Therefore, the procedure developed in the first part will be used in the second part to investigate the injury circumstances.

5.2 Pilot

5.2.1 Methods

5.2.1.1 Participants and equipment

Fifty-eight male professional football players competing with the U18 and U23 teams of one English elite football club in two seasons (2018 – 2019 and 2019 – 2020) were included in this study. Medical data from previous seasons were available but due to unavailability of GPS and video clips they could not be analysed. Physical data were routinely collected by the sport science department during all training sessions and matches through STATSports Apex GPS (STATSports, Northern Ireland) which shows good reliability and has been certified by FIFA (Beato et al., 2018; Crang et al., 2021; FIFA Resource Hub). The pods used a Global Navigation Satellite System and included 952 Hz accelerometer, 952 Hz gyroscope, 10 Hz magnetometer and 18 Hz GPS. Raw data were exported into Sonra 3.3.136 (STATSports, Northern Ireland). Training sessions and matches were routinely video recorded by the football analysis department through a 1080p HD, 30 fps video camera (iPad 6th generation, Apple Inc., Cupertino, CA, USA), exported into mp4 format, and viewed in VLC 3.0.16 (VideoLAN non-profit organization, France). An injury was defined as "any injury that results in a player being unable to take a full part in future football training or match play" (time loss injury) (Fuller et al., 2006). Medical data were routinely collected into Microsoft Excel (Microsoft, Redmond, WA, USA) by the sport medicine department using the standard injury form proposed by Fuller et al. (2006). Ethical approval was granted by Edinburgh Napier University's School of Applied Sciences Research Integrity Committee (SAS/2786536).

5.2.1.2 Data collection

Data were collected by the above-mentioned departments and stored within club's databases.

To obtain and analyse the data the following procedures were put in place:

1) Data sharing agreement was discussed with the legal and IT teams of the football club to ensure to comply with GDPR, and the club's and university's data policies;
2) Medical data were requested and transferred by the Medical department in excel format and shared through Microsoft OneDrive (Redmond, Washington, U.S.);
3) GPS data of sessions in which acute injuries occurred were requested and transferred by the Sport Science department through Sonra in order to allow a cut for the periods of interest (i.e., the periods during which injuries occurred) without modifying the session used by the club for performance analysis. The

size of the raw data of each player-session (i.e., the session of the injured player) ranged between 1 GB and 3 GB;

4) Video clips of sessions in which sudden onset injuries occurred were requested and transferred by the Football Analysis department through the club's internal servers due to the size of the file which ranged between 1 GB and 10 GB.

5.2.1.3 Data analysis

Medical data were filtered and injuries classified as overuse were excluded since by definition they occurred outwith an identifiable inciting event. For injuries classified as sudden onset, the GPS data of the session during which the injuries occurred was inspected to identify the time of injury occurrence which was supposed to be close to the moment the player suspended the activity (i.e., either interrupted a training session or requested a substitution during a match) (Figure 5.1). Once the time of injury occurrence was identified, the video clip was explored and cut between one minute prior to the inciting event up to when the player suspended hiss activity. When it was not possible to identify the time of injury occurrence through the GPS track, the entire video was watched and possible inciting events were noted if a player showed sign of pain or discomfort (e.g., the player touched the thigh which was reported to be injured in the injury report form) or was involved in a situation which might have led to injury (e.g., the player was involved in a head – to – head situation which might have led to the concussion reported in the injury report form).

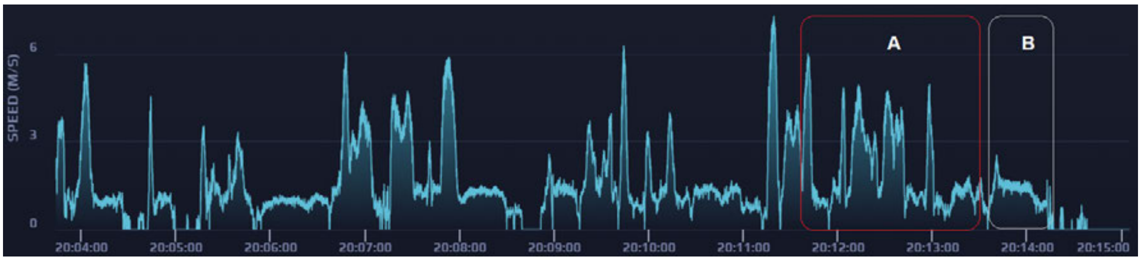

Figure 5.1 Examples of identification of time of injury occurrence. A: Potential time of injury occurrence; B: player suspends football activity

Once the inciting events were identified on video they were analysed using the FIICCS. Video and GPS times were synchronized manually by visual inspection. The time at which the player interrupted the activity was used as reference because it was the easiest moment to identify both on video and on the GPS data. From there the video and GPS tracks were moved backward and the physical activity of the inciting events were analysed. The physical activities performed at the time of injury were analysed as follows:

- T0: Defined as the activity during which injury occurred
- T-1: Defined as the 5 seconds before T0
- T-2: Defined as the activity preceding T0
- T-3: Defined as the 60 seconds before the begin of T0

T0 and T-3 were always applicable, while T-2 was applicable only when a clear activity was identifiable from the video (e.g., the injured player performed a change of direction (T-2) followed by a high-speed run which leads to injury (T0)), and T-1 was applicable only when T-2 was not applicable. This approach was chosen to allow the analysis of the inciting circumstance (T0), the activity which preceded the inciting circumstance (T-1 or T-2) and to have a general overview of the physical effort performed before the inciting circumstance (T-3). A description of the analysis is reported in Figure 5.2.

Figure 5.2 Description of method used for the analysis of physical activities during which injuries occurred. T0: activity during which injury occurred; T-1: 5 seconds before T0; T-2: activity preceding T0; T-3: 60 seconds before the begin of T0.

5.2.2 Results

One hundred and twenty-four injuries occurred between July 2018 and March 2020, after which English competitions were suspended due to the COVID-19 pandemic. Thirty-seven injuries were classified as gradual onset, while 87 injuries were classified as sudden onset. Sixty-three injuries occurred during training and 61 injuries occurred during official matches (Appendix E).

5.2.2.1 Data collection

The GPS data and video clips of the sessions during which the 87 sudden onsetinjuries occurred were requested from the Sport Science and Football Analysis departments. The Sport Science department was unable to locate the data referring to season 2018 – 2019, therefore injuries that occurred in this season needed to be excluded, leaving 40 acute injuries for analysis (Appendix E).

It was possible to locate video and GPS data of 21 injuries, while for 15 injuries the injury date did not coincide with any match or training sessions recorded on video and

GPS, and four injuries had a session recorded by GPS but did not have any video footage. As a consequence, players' attendance to training and match sessions was checked and the last session which preceded a gap in training attendance was investigated to evaluate whether the injury occurred during that session. For example, if an injury was reported to occur on 5th February 2020 but there was no video available for that day, player attendance was checked and if his last attendance was on 4th February that session was analysed to identify the inciting event. Therefore, 19 further video clips were requested from the Football Analysis department, which was able to locate only 15 of them. It is possible that the four sessions which were not located but where player attendance was recorded are sessions during which players trained with the first team. These sessions would have been recorded by a different department and were not accessible for this study. From the analysis of the 36 video clips, the inciting events of eight injuries could be identified. Data collected through GPS had already been requested and obtained for four cases, while data of the remaining four cases had to be requested because the session date did not coincide with the ones recorded in the medical data. The GPS data of the remaining four sessions were requested but were not obtained. The injuries whose GPS data were not obtained were three contact injuries and one non-contact calf injury. A clear description of the data collection process is available in Figure 5.3.

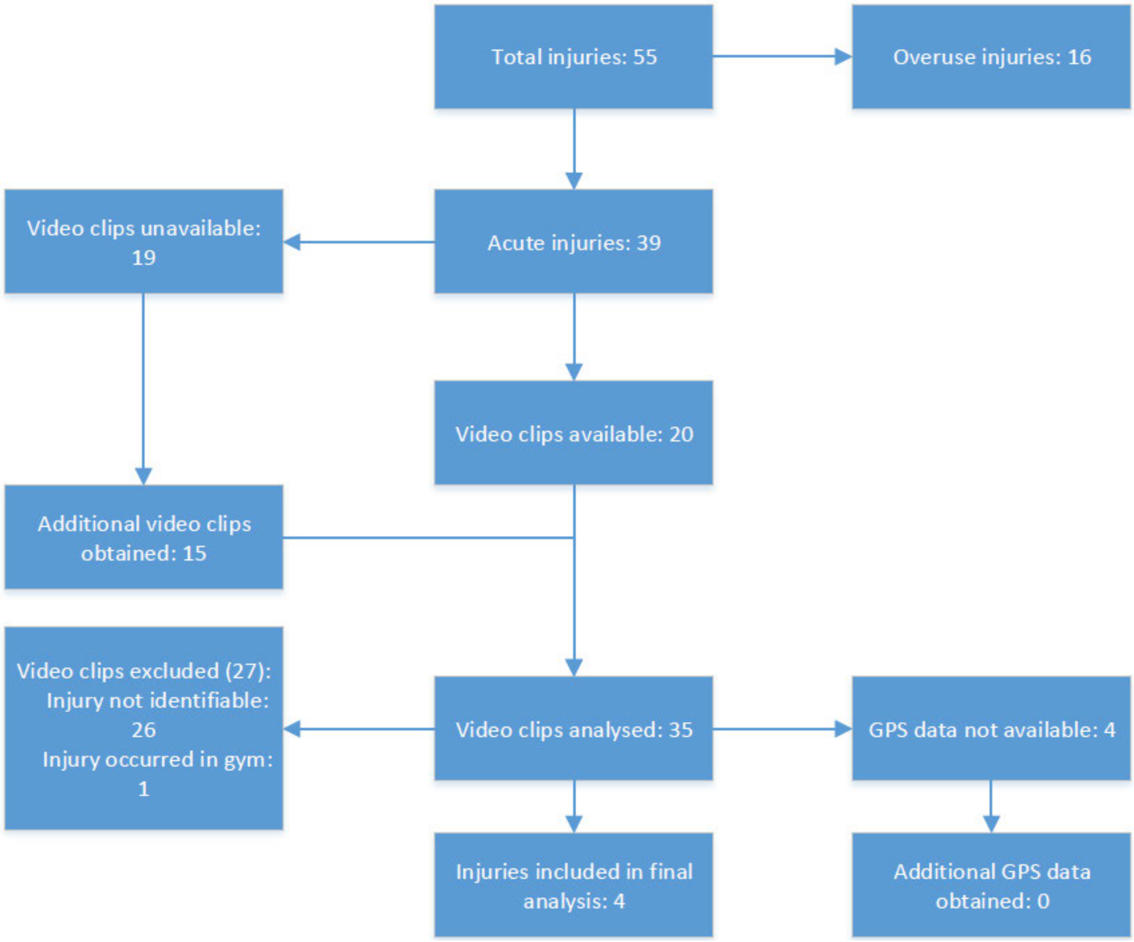

Figure 5.3 Data collection flowchart

Twenty-one percent of sudden onset (8/39) were identified on video of which seven occurred during matches (28% of total match injuries) and one occurred during training (7%). Approximately 20% of total joint and ligament injuries and around 30 % of muscle, tendon, and concussion injuries were identified, while none of the eight contusion, haematoma, fractures, and bone injuries were identified. The percentage of injuries identified varied according to the location of injury. A breakdown of the number of acute injuries identified is reported in Appendix F.

5.2.2.2 Inciting circumstances

Video and GPS data of four injuries were located and analysed. Two injuries occurred to the ankle and two injuries occurred to the hamstring. Both ankle injuries occurred during indirect contact circumstances and both hamstring injuries occurred during non-contact circumstances. The first ankle injury (ID 92) occurred during a small-sided game while the player was accelerating to tackle a direct opponent with the ball. At T0, the peak speed measured 19.5 Km/h and the peak acceleration measured 4.3 m/s^2. The second ankle injury (ID 120) occurred during an official match while the player was landing after a jump performed to head the ball during which he collided with an opponent. At T0, the peak speed was 14.8 Km/h and the peak acceleration was 2.2 m/s^2. Both hamstring injuries occurred during a non-contact acceleration performed in a match between the 11th and 20th minute of game. The first hamstring injury (ID 73) occurred with the player running with the ball and achieving during T0 a peak speed of 30.5 Km/h, a peak acceleration of 2.9 m/s^2, and a peak deceleration of 1.2 m/s^2. The second hamstring injury (ID 116) occurred with the player running without the ball and achieving during T0 a peak speed of 30 Km/h, a peak acceleration of 2.0 m/s^2, and a peak deceleration of 2.2 m/s^2. All the details of the injury circumstances are reported in table 5.1 and the activity graphs of T0 for the hamstring injuries are reported in Figure 5.4 and Figure 5.5.

Table 5.1 Injury circumstances

		Medical information			**Contact type**	
ID	**Side**	**Injury description**	**Severity**	**Days missed**	**Onset**	**Contact type**
73	Left	Left hamstring strain	Moderate	13	Sudden	Non - contact

92	Left	Ankle ATFL sprain	Mild	6	Sudden	Indirect contact – While tackling – 1v1 – To front from side/diagonal
116	Left	Hamstring strain 2c	Severe	45	Sudden	Non - contact
120	Left	Ankle deltoid ligament sprain	Moderate	14	Sudden	Indirect contact – Collision – To front from side/diagonal

Table 5.1 Injury circumstances (continue)

	Physical activity	**Running intensity**						
ID	**Physical activity**	**Time of injury**	**Tot. Dist. (m)**	**Avg. Speed (Km/h)**	**Max Speed (Km/h)**	**Max Acc. (m/s²)**	**Max Dec. (m/s²)**
73	Running – Changing speed – Accelerating	T-3	147	2.4	17.1	2.1	3.2
		T-1	12	2.4	11.0	1.4	1.2
		T0	39	6.3	30.5	2.9	1.2
92	Running – Changing speed – Accelerating	T-3	29	0.5	21.0	6.6	5.1
		T-1	6	1.2	8.8	3.5	5.1
		T0	9	3.0	19.5	4.3	1.2
116	Running – Changing speed – Accelerating	T-3	101	1.7	23.7	2.8	1.6
		T-2	40	5.2	23.7	2.8	0
		T0	37	5.2	30.0	2.0	2.2
120	Jumping – Upon landing – On pitch – With injured leg	T-3	79	1.3	15.6	2.6	5.3
		T-1	1	0.2	3.5	1.3	1.1
		T0	45	1.7	14.8	2.2	1.6

Table 5.1 Injury circumstances (continue)

ID	**Ball situation**	**Player position**	**Session type**	**Session venue**	**Competition**	**Drill**
73	Injured player with ball – running with the ball - conducting	RW	Match	Away	Friendly match	
92	Injured player without ball - Direct opponent with the ball	CB	Training	Home		Small-sided game
116	Injured player without ball - Other	LB	Match	Away	Domestic league	

	opponent with the ball				
120	Injured player with ball - Kicking - Heading - Strong heading - Frontal movement - Ball toward the air	RB	Match	Home	Domestic league

Table 5.1 Injury circumstances (continue)

	Contextual information				
ID	**Playing phase**	**Playing sub-phase**	**Pitch turf**	**Referee decision**	**Which minute of match or training did the injury occur?**
73	Offensive	Attacking play	Natural grass	No foul	11
92	Defensive	Defending	Natural grass	No foul	27
116	Defensive	Defending	Natural grass	No foul	20
120	Offensive	Attacking play	Natural grass	No foul	49

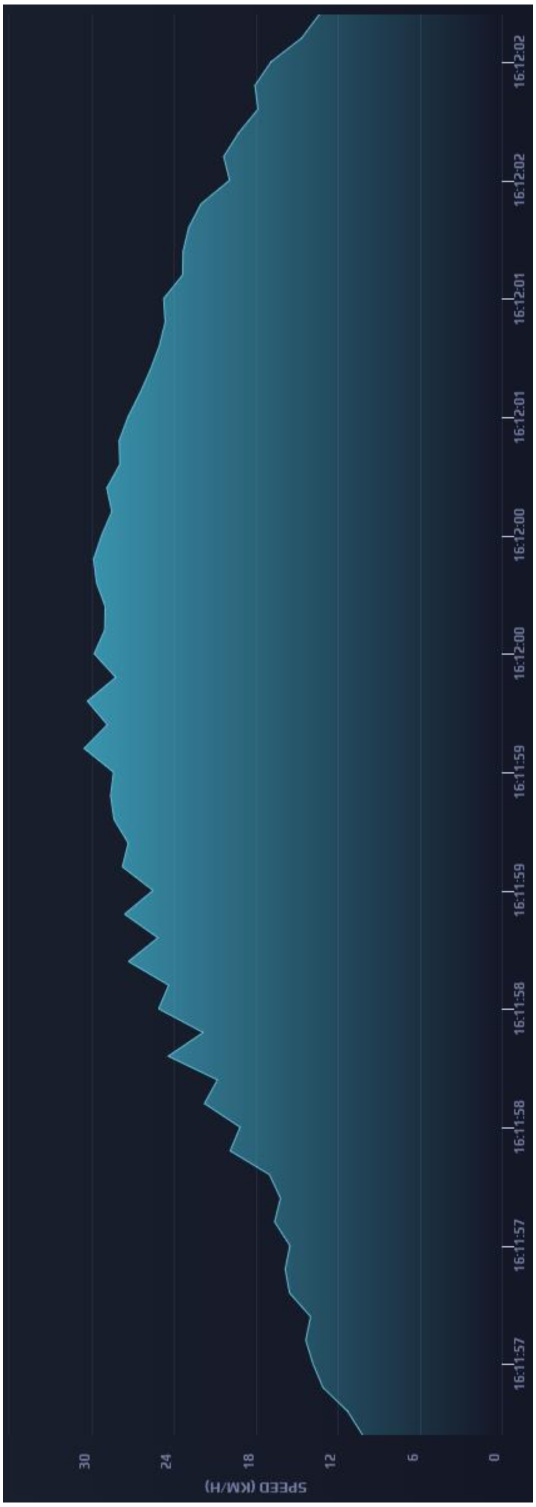

Figure 5.4 *Activity graph of injury ID73*

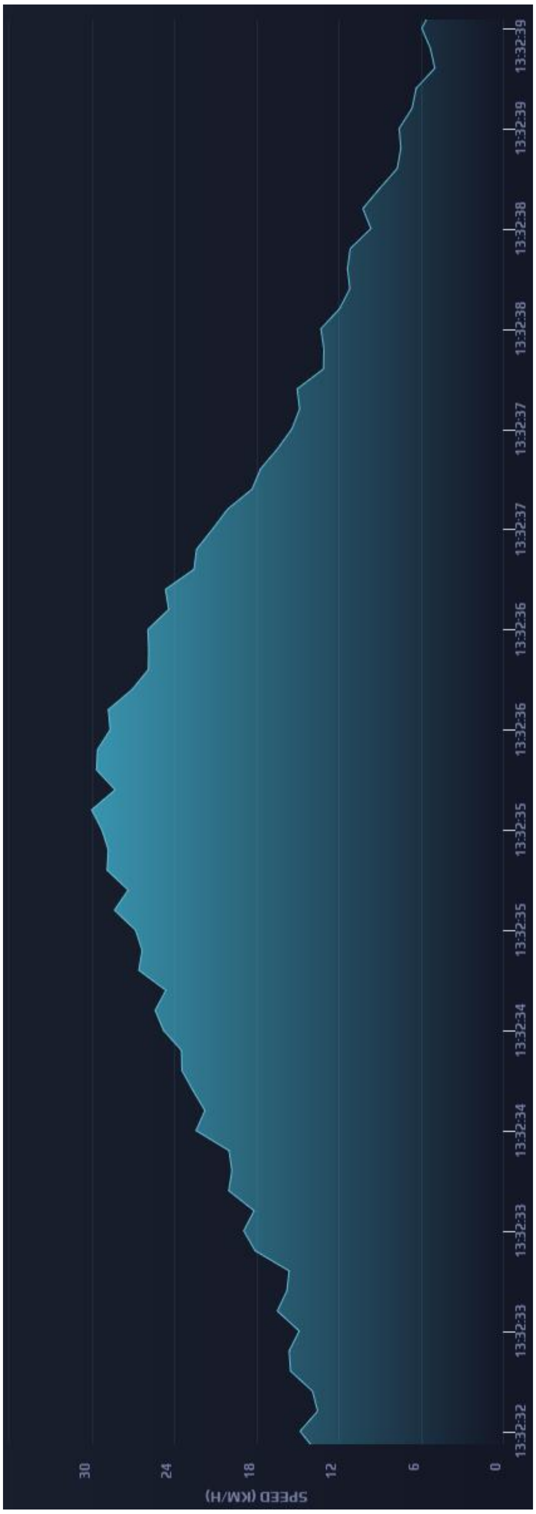

Figure 5.5 Activity graph of injury ID116

5.2.3 Discussion

The aim of this pilot was to evaluate how the data routinely collected by professional football clubs can be used to investigate the inciting circumstances. The main problems were identified in locating and transferring the data from the various department of the football club and in identifying the inciting events on video. Due to limitations put in place by the club during the COVID-19 pandemic only essential staff could access training facilities for a very limited period of time. For this reason, it was necessary to ask the staff to locate and transfer the data, which added further workload on the staff during a complicated period. As a consequence of these problems only 10% (4 out of 39) of the total acute injuries occurred could be analysed.

5.2.3.1 Data location

Locating the data was the factor that most limited the number of injuries analysed. Indeed, while locating medical data was simple since they were stored in Microsoft Excel format which were easy to find and to transfer thanks to the small size of the file, the location of video clips and GPS data was difficult and time demanding. With the exception for the injuries which occurred while the players were training with the first team, which could not be included in the analysis due to the data protection policy of the club, locating the files of the video clips per se was simple because the files were stored in external hard drives. The difficulty came from the inaccuracy of the reporting of the date of injury, which then made it difficult to locate the video clips needed. Indeed, 48% of the injuries (19 out of 39) had an injury date which differed from the actual date of the session during which the injury seemed to have occurred. Furthermore, it is likely that it was not possible to locate on video some of the injuries because the wrong session was being watched. Indeed, if an injury occurred on the 8th of October but was reported to have occurred on the 6th of October, the video clip of the 6th of October was initially requested and analysed. However, it is not possible to tell whether the injury actually occurred the 6th of October and was not identifiable on video or if it occurred on the 8th October and, having had access to the that video, it would have been identifiable. To evaluate this possibility it would have been necessary to analyse the video clip of the sessions close to the sessions which were originally reported as the ones during which the injury occurred (i.e., if the injury was reported to have occurred the 8th of October it would have been necessary to watch the session of the 7th and of the 9th of October), however this was not possible due to the time needed to locate and transfer these files.

With reference to GPS data, locating the data was very difficult and has been an important limiting factor to the number of injuries analysed. Indeed, the medical data were available from the season 2011 – 2012 onwards and the club video recorded all match and training sessions from the season 2015 – 2016 onwards, therefore if GPS data were available, it would have been possible to analyse data from five seasons (from 2015 – 2016 to 2019 – 2020). This was prevented by the impossibility of locating the laptops in which the raw data had been exported. Therefore, after preliminary discussion with the sport science department, it was initially decided to include only the two most recent seasons (i.e., 2018 – 2019 and 2019 – 2020) in the analysis. Subsequently, it was necessary to exclude one season (2018 – 2019) due to the impossibility of locating the raw data. However, even if it was possible to locate the data of the seasons between 2015 and 2019, their analysis would have been difficult because in these five seasons two different types of GPS pods and four different software packages were used, therefore the reliability of the data would have been questionable (Buchheit & Simpson, 2017).

5.2.3.2 Data transfer

Defining data transfer protocols has been complex and time demanding because three departments (club's legal department, club's IT department, and Edinburgh Napier University data protection department) from two institutions with two different data protection policies were involved and because of the nature of the data. Indeed, the extended size of the video files made it necessary to use the club's internal server for data transfer and the GPS raw data could be transferred only through STATSports software. The need to use these methods to transfer the data has impacted the extent of collaborations received from the departments. With reference to the video, uploading them on the internal server was time demanding. With reference to the GPS sessions, it was not possible to export all the sessions needed and transfer them at once, therefore the sport science department had to locate and transfer each session one by one. The process of locating and sharing one session lasted between two and five minutes, depending on the number of sessions recorded for that date and on the size of the file, however the process was inefficient because it was not possible to use the software while the session was being transferred. These were the main factors which limited the possibility of effectively identifying and retrieving the appropriate data.

5.2.3.3 Data analysis

The most difficult part of the analysis consisted of the identification of the injuries on video. Indeed, 78% (29/37) of the reported injuries where the video was available could not be identified on video. As discussed previously, it is not possible to tell whether the injuries could not be identified on video because the wrong video was being watched, because the injury occurred outside of camera view, or because the players continued the training or the game and reported the injury the after the end of the activity. It is plausible that a certain number of injuries fall into the last description and hence could not be identified on video. Krosshaug et al. (2005) suggested that around 50% of all injuries in football may not be identifiable on video. The authors hypothesised that the injuries unidentifiable may be the non-contact ones (e.g., the ones occurring while sprinting or changing direction), which occur far from the ball and may not be included in the camera view, but this may not be the case. Indeed, in most cases when the players are far from the ball and hence out of camera view, they perform very low intensity activities such as walking or jogging, therefore it is unlikely that half of all the injuries occur when players are far from the ball. An alternative hypothesis may be that in some cases players suffer a trauma but keep playing and then start to feel pain and report the injury after the end of the session. To the best of my knowledge the proportion of injuries reported after the end of activity has never been analysed, but this situation is not uncommon in football.

With reference to the evaluation of the inciting circumstances, the analysis has been quick and easy overall. As reported by the practitioners who piloted the classification system (Chapter 4.3.3), to fill out all the sections of the core and optional sets it was necessary to watch the video more than once, but the classification of each injury required only a few minutes. Few difficulties were encountered in the identification of the type of contact (i.e., direct contact, indirect contact, non-contact) and in the identification of the time at which the injures occurred. Considering the type of contact, this was easy to identify in three injuries which were clearly non-contact (ID73 and ID 116) or indirect contact (ID120) but it was unclear in one injury (ID92). In this case the player got injured while tackling, but it was not possible to identify the nature of contact from the video even when played at low speed. This case strengthens the importance of using reliable medical data when performing these analyses and justifies the concerns around studies which analyse inciting circumstances without medical data. Indeed, the type of contact is commonly included in the medical reports and is easily assessed by the medical staff when talking with the players during the diagnosis. On the other hand, the identification of time of injury was more difficult for non-contact injuries. Taking the two hamstring injuries as an example, identifying the inciting events on clips was easy but identifying the exact moment of injury occurrence was not possible, therefore the entire activity needed to be analysed (i.e., T0). Another slight difficulty arose when GPS data needed to be synchronised with the video. Indeed, in some cases synchronising the GPS with the video waschallenging because it was difficult to find a moment on video which could clearly be located in the GPS track. The synchronisation could have been easier and more accurate if the video had included information about the time of recording. This information is usually collected automatically by video cameras as metadata but was not available in the files used for analysis, probably because they were not the files originally obtained from the video camera. Had this information been available, it would have been possible to synchronise easily and accurately the video with the GPS data using the Coordinated Universal Time.

The difficulties described above may impact the identification of the running activity performed at the time of injury. Indeed, since it was not possible to accurately recognise the time of injury it was necessary to analyse the entire activity (i.e., T0), but as reported for the hamstring injuries both high peak velocities and high peak accelerations were observed and it was not possible to say whether the injury occurred while running at steady speed or if it occurred in the acceleration phase. When a player suffers a time loss injury they are not able to continue their performance (Bahr et al., 2020), therefore it can probably be assumed that after an injury occurs during a running activity the player would need to reduce their running speed and interrupt their performance, or at least would not be able to accelerate or to run at high speed. For this reason, it can be hypothesised that the injury occurred around the time the player achieved peak speed.

5.2.3.4 Applications for part 2 (lessons learned)

The pilot of this novel approach highlighted the aspects to improve in order to perform an accurate analysis of the circumstances which lead to injury in professional football using data routinely collected in football teams. The points that need improvement are listed below and possible solutions are discussed:

- Time required to define data management policies
- Time required for data transfer
- Data quality
- Difficulties in identifying the time of injury occurrence
- Difficulties in synchronising video and GPS data
- Availability and accuracy of old GPS data

The length of time required to define data management policies has been a result of a collaboration between two institutions. Institutions must have data protection and management policies in place to align with the GDPR, therefore this process can be simplified by asking the data controller (i.e., the football club) to analyse the data and share them with the research team once anonymised. Alternatively, the research project can be performed within a single institution or with institutions which have data management agreements already in place. The time required for data transfer has been a result of the exceptional circumstances dictated by the COVID-19 regulations. In normal circumstances the video files stored on external hard drives would have been transferred by cable, which would reduce the time needed for data transfer and eliminate the time burden on the football analysis department. With reference to GPS data, in normal circumstances these could have been analysed on the laptop where they were originally stored, thus eliminating the data transfer issue and the time burden on the sport science department. In retrospective studies, very little can be done to address the issue of inaccuracy of medical data collected months or years before the conduction of the study. This issue in retrospective studies can only be prevented by increasing the awareness of practitioners working within medical and sport science departments of the importance of collecting data accurately and consistently. To address the difficulties in identifying the period during which the injury occurred, comparing the GPS track of the injured player to the track of another player could help to identify differences in activity that may be caused by the inciting event. If this is not possible, the only option is to watch the entire session to try and identify the inciting event. The precise moment during which the injury occurred (which would be useful for evaluation of to the running intensity and the running phase with greater precision) cannot be identified in retrospective studies. The only method that might allow the identification of the time of injury with precision is by involving the player in the review of the inciting event, but this can be done only in prospective studies or if the players are still with the club at the time of analysis.

Even if the precise moment of injury was detected, the physical activity at that time could not be analysed unless video and GPS data were fully synchronised. This can be done only if both video and GPS data include the Coordinated Universal Time. As per the accuracy of the medical data, the only way to prevent this issue is to make medical and sport science staff aware of the importance of these procedures. The issue of the accuracy of old GPS data and the appropriateness of comparing them with newer data is well known (Buchheit & Simpson, 2017). Assuming that a comparison among old and new data is not feasible due to time demand and low interest from the football clubs, the only way to limit this issue without lessening the number of injuries analysed is to reduce the number of seasons involved in the analysis and to involve more teams within the same club (e.g., 1st team, U23 team, and U18 team). In addition or as an alternative, more clubs could be involved in the analysis, but this would create additional difficulties due to the fact that the clubs may use different GPS systems which would make the comparability of data questionable and the difficulties that involving more clubs could create with respect to data management agreement and/or coordinating the work with multiple practitioners who, as observed in this study, could have other priorities. Finally, if football clubs do not collect information on players' peak speed and peak acceleration, little can be done to normalise the running speed achieved at the time of injury by players' physical capacities. Indeed, these physical capacities are usually tested by measuring the time spent to cover 30 or 40 meters placing timing gates at certain split distances (e.g., 10, 20, and 30 meters) (Kobal et al., 2016; Loturco et al., 2019; Loturco et al., 2018). However, this protocol measures the average speed of the player during the test and during each split distance but does not provide information about the peak speed and the peak acceleration. Peak speed could be measured using GPS during the speed test if performed in open space or taking the peak speed achieved by the players over a certain time while playing.

The solutions discussed above to improve the feasibility of the analysis of the circumstances which lead to injury in professional football using data routinely collected in football teams can be summarised as follow:

- Ask the data controller to perform the analysis or work on research projects with a single institution or with multiple institutions which already have data management agreements in place;
- If the data controller does not want to perform the analysis, collect the data in person to reduce time burden on staff;
- Reiterate importance of data collection and storage to sport science and medicine staff;
- Limit the number of clubs involved and include multiple teams within the same club

Following these guidelines would improve the quality of the analysis, however the difficulties concerning medical data accuracy, identification of time of injury, synchronisation of video and GPS data, GPS data localisation, and normalisation of physical data may remain, depending on how football clubs collect and store GPS, video, and medical data.

5.3 Part 2

In the first part of this study, the aim was to pilot procedures for data collection and data analysis. Given the limited amount of data available in the first part, the aims of the second part will be to further pilot and refine data analysis procedures accounting for the lessons learned from part one and to use this method to provide preliminary information about injury circumstances.

5.3.1 Methods

5.3.1.1 Participants and equipment

Following from the pilot described above, the following methodology was implemented. A retrospective study was conducted using data collected from 46 elite football players from one Italian football club competing in Italian Serie A. All players trained on a full-time basis and played competitive fixtures within the Serie A and European Competitions during three seasons (2019 – 2020, 2020 – 2021, 2021 – 2022). The number of players and players characteristics are reported in table Table 5.2. Physical data were routinely collected by the sport science department during all training sessions and matches through Catapult Vector S7 devices (Catapult Sports, Melbourne, Australia) which includes Global Navigation Satellite System and Local Position System technologies. These have been reported to have good inter-device reliability for the measurement of peak velocity and average acceleration and have been certified by FIFA for use both in training and in matches (Crang et al., 2021; FIFA Resource Hub). The pods included 100-Hz accelerometer, magnetometer, and gyroscope and a 10 Hz GPS. Raw data were exported and analysed with the custom software OpenField 3.4.0 (Catapult Sports, Melbourne, Australia). Training sessions were routinely video recorded by the football analysis department and viewed using the club's internal database. An injury was defined as "any injury that results in a player being unable to take a full part in future football training or match play" (time loss injury). Medical data were routinely collected into Microsoft Excel (Microsoft, Redmond, WA, USA) by the sport medicine department using the standard injury form and injury definitions proposed by Fuller et al. (2006). Specifically, the following details of the injuries were reported: side, body area, classification, pathology, session type, nature of contact, date of injury, and number of days missed.

Table 5.2 Characteristics of players included in the study

Season	N. of players	Age (years)	Height (m)	Max speed (km/h)
2019 – 2020	30	25.03 ± 4.69	1.84 ± 0.07	33.16 ± 2.08
2020 – 2021	25	25.60 ± 4.73	1.85 ± 0.07	33.43 ± 1.74
2021 – 2022	23	24.43 ± 3.80	1.82 ± 0.06	33.62 ± 2.11

5.3.1.2 Data collection

The same procedures described in Chapter 5.2.3.1 were followed, but video and GPS data were not transferred from the club. To comply with club's data policy, the data stayed within the club databases and were analysed by myself and the first team assistant sport scientist as described in the next section.

5.3.1.3 Data analysis

Medical data were filtered and injuries classified as gradual onset were excluded since by definition they occurred outwith an identifiable inciting event. Similarly, contact injuries were excluded from the analysis. This decision was taken due to time limitations. Indeed, as discussed in the pilot, the localisation of the inciting events on video was time demanding and there was limited time availability. Therefore, it was decided to focus on the analysis of inciting circumstances of non-contact injuries. Therefore, the assistant sport scientist and myself located the inciting events on video and analysed them as previously described in the pilot. However, on the basis of the results of the pilot and of discussion held with the club's assistant sport scientist and head of sport science, physical activities performed at the time of injury were analysed as follows

- T0 defined as the peak speed at which the injury occurred
- T-1 defined as the activity which leads to T0
- T-2 defined as the activity which precedes T-1

If the injury occurred during acceleration or peak speed, it was analysed as described in Figure 5.6. With this being a retrospective study, it was not possible to conduct interviews to understand the exact time of injury occurrence. It was hypothesised that after the injury occurred the players were not able to accelerate or maintain high running speed, therefore the time at which players achieved the peak velocity was used as time of injury occurrence. Peak speeds were obtained from T0 and total distances were calculated as the sum of T-1 and T0. If the injury occurred during a deceleration, it was analysed as described in Figure 5.7. Peak speeds were obtained from T-1 to give an indication of the speed the players were decelerating from and the total distances were obtained from T0. Percentages of max speed were automatically calculated by the software using the highest speed recorded for each player. The software did not report acceleration data from short time periods, therefore these were obtained by calculating the mean acceleration or deceleration as follows, with t being the time elapsed between the start and end of the activity and v being the speed difference between the start and end of the activity:

$$\Delta v \div \Delta t$$

In the case of acceleration injury, the mean acceleration was calculated between the start of T-1 and the peak speed achieved at T0. In the case of deceleration, the mean deceleration was calculated between the start and end of T0. Data reported in figures include injuries occurring during all activities and are described as median and IQRs.

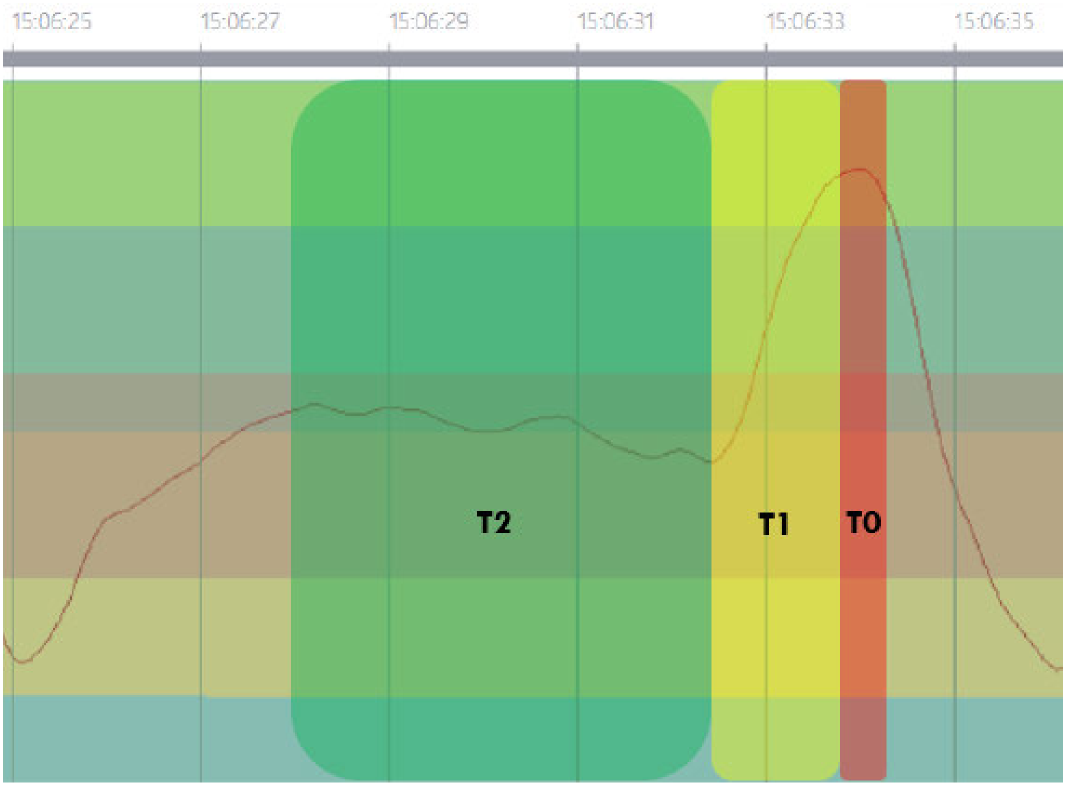

Figure 5.6 Description of method used for the analysis of physical activities during which injuries occurred in case of injuries occurred during acceleration phase. T0: time of injury occurrence; T-1: activity preceding T0; T-2: activity preceding T-1

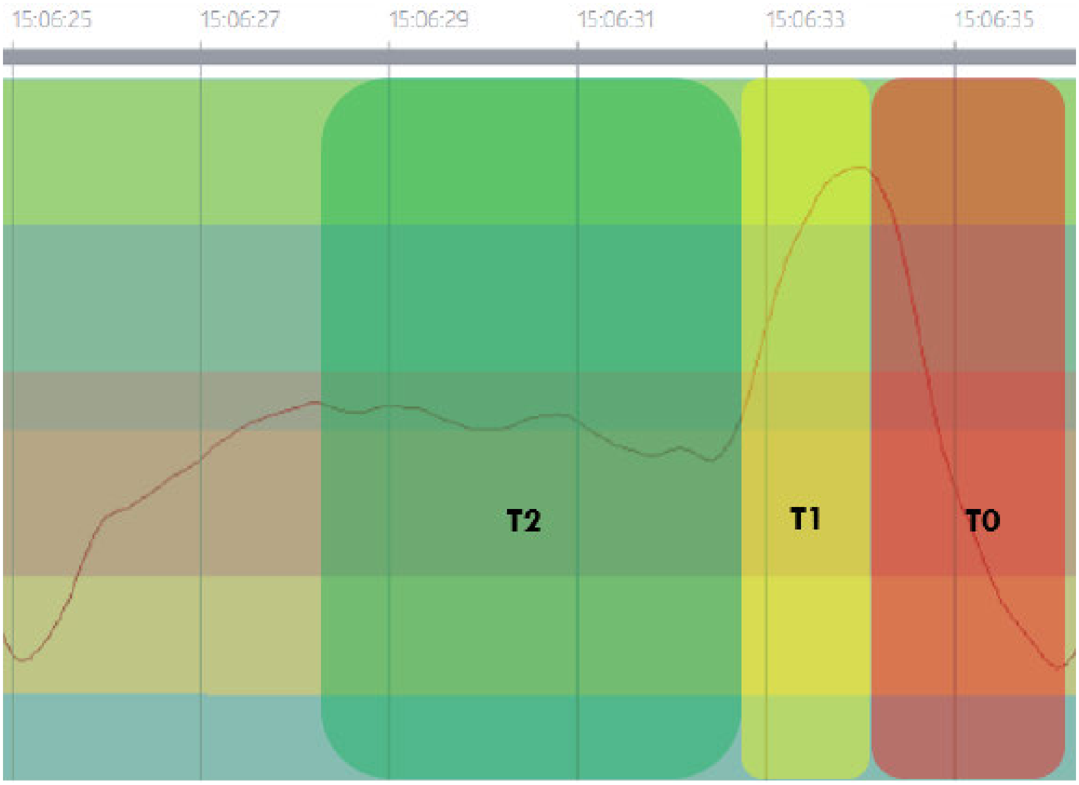

Figure 5.7 Description of method used for the analysis of physical activities during which injuries occurred in case of injuries occurred during deceleration phase. T0: time of injury occurrence; T-1: activity preceding T0; T-2: activity preceding T-1

5.3.2 Results

5.3.2.1 Data collection

In total 103 injuries occurred in the three seasons analysed of which 80 were originally classified as non-contact injuries. Circa 37.5% (30/80) of non-contact injuries could not be analysed because video and/or GPS data were not available. Of the 80 non-contact injuries, 30 could not be analysed due to missing data. Of the remaining 50 injuries, 16 were excluded because they could not be identified on video. In twelve cases it was possible to talk with the players who reported that there was no specific inciting event (i.e., it was a gradual onset injury), in one case the player did not remember the onset of injury, and in three cases it was not possible to talk with the players because they had left the team (Figure 5.8). Finally, 34 non-contact injuries were analysed. Six injuries occurred during training and 28 injuries occurred during official matches (Table 5.3). With reference to injury type, 53% (25/47) and 25% (2/8) of muscular and ligament non-contact injuries were analysed, respectively. Considering location of non-contact injuries, 75% (6/8) of adductor injuries, 61% (17/28) of hamstring injuries, 33% (2/6) of quadriceps injuries, 33% (1/3) of ACL injuries, and 40% (4/10) of calf injuries were analysed.

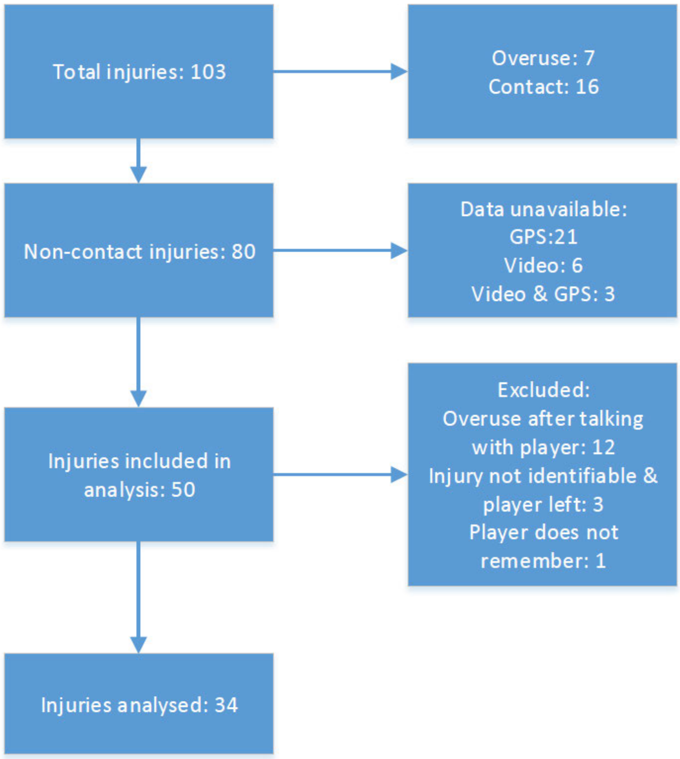

Figure 5.8 Data collection flowchart

Table 5.3 Number of injuries identified by injury details

	NON-CONTACT ANALYSED	NON-CONTACT NOT ANALYSED	CONTACT / OVERUSE	TOTAL
Session				
Training	6	22 (1)*	9	37
Match	28	12 (3)*	26	66
Type				
Bruising/haematoma	0	0	1	1
Dislocation	0	0	1	1
Fracture	1	1	4	6
Instability	0	0	1	1
Ligament	2	6	7	15
Muscle strain/spasm	25	22 (4)*	15	62
Osteochondral	1	0	1	2
Other Pain/ unspecified	2	2	1	5
Synovitis/ impingement/bursitis	0	2	1	3
Tendon	3	1	3	7
Severity				
Minimal	0	1	1	2
Mild	0	4	4	8
Moderate	22	18 (3)*	20	60
Severe	12	11 (1)*	10	33
Location				
Head/neck				
Face	0	0	2	2
Upper limb				
Shoulder	0	1	0	1
Upper body				
Lower back	0	1	1	2
Lower limb				
Hip/groin	0	3	1	4
Adductors	6	2	6	14
Hamstring	17	11 (3)*	8	36
Quadriceps	2	4	2	8
Knee	1	1	3	5
ACL	1	2	0	3
MCL	0	0	4	4
LCL	1	0	0	1
Meniscus	1	0	1	2
Calf	4	6 (1)*	1	11
Lower leg	0	0	1	1
Ankle	0	1	2	3
Foot	1	2	3	6

* Numbers in brackets correspond to injuries which were neither identifiable on video nor identifiable by players

5.3.2.2 Inciting circumstances

Of the 17 hamstring injuries analysed, 15 occurred while players were performing a linear run, one occurred while the player was performing a curved run and one while the player was in the air after a jump. Three injuries occurred while players were accelerating without the ball (n=2), and while receiving the ball (n=1) (Table 5.4). Four injuries occurred while players were decelerating without the ball (n=3) or while running with the ball (n=1). Nine injuries occurred while players were running at steady speed without the ball (n=7) or with the ball (n=2). One injury occurred while the player was receiving the ball at upper body height while in air following a jump, with the hip of the injured limb flexed and the knee extended (Appendix G). Considering only the injuries occurred during running activities, players run for 16.75 m (8.42 – 26.65 m) (Figure 5.9), achieved a peak speed of 29.28 km/h (26.61 – 31.13 k,/h) which corresponded to 87.55% of players' maximal speed (78.5% - 89.75%) (Figure 5.10). All hamstring running injuries occurred with the players achieving a peak speed > 25 km/h. Players were performing a deceleration > 2 m/s^2 and < 2 m/s^2 in four and one cases respectively (median deceleration: 2.41 m/s^2, IQR 2.44 – 2.07 m/s^2). Players were performing an acceleration < 2 m/s^2 and > 2 m/s^2 in eight and three cases respectively (median acceleration: 1.74 m/s^2, IQR 1.51 – 2.07 m/s^2) (Figure 5.11). Considering only the injuries which occurred while players were accelerating (both below and above 2 m/s^2), players ran for 23.9 m (16.75 – 35.5 m) and achieved a peak speed of 27.6 km/h (25.66 – 31.4 km/h) which corresponded to 83% of their maximal speed (74 – 91%). Considering only the injuries that occurred while players were decelerating (both below and above 2 m/s^2), players ran for 7.7 m (6 – 8.2 m) and were decelerating from 30.69 km/h (30.27 – 30.83 km/h) which corresponded to 88% of their maximal speed (87 – 89%).

Three adductor injuries occurred while players were running at steady speed and receiving the ball at upper body level (n=1), running with the ball and dribbling an opponent (n=1), and performing an instep kick (n=1) (Table 5.4). One adductor injury occurred while the player was decelerating without the ball, one injury occurred while the player was performing an acceleration and controlling the ball at knee level, and one injury occurred while the player was performing an instep kick without running. Considering only the injuries that occurred during running activities, players ran for 8 m (6.1 – 11.9. m), and achieved a peak speed of 21.39 km/h (19.75 – 21.98), which corresponded to 66% of players' maximal speed (0.55% – 0.69%). In two cases players were performing a deceleration (2.39 and 1.25 m/s^2) and in three cases players were performing an acceleration (1.53, 1.97, 2.8 m/s^2) (Figure 5.11). Considering the three injuries that occurred while players were accelerating (both below and above 2 m/s^2), players ran for 8, 11.0, and 13.1 m and achieved a peak speed of 21.39, 18.25, and 19.75 km/h which corresponded to 66%, 52% and 55% of their maximal speed respectively. Considering the two injuries that occurred while players were decelerating, players ran for 1.5 and 6.1 m and were decelerating from 21.98 and 24.88 km/h which corresponded to 69% and 77% of their maximal speed.

Two calf injuries occurred while the players were accelerating without the ball (n=1, acceleration: 2.99 m/s^2, distance covered: 5.5 m, peak speed achieved: 16.54 km/h, 46% of the player's maximal speed) and decelerating while kicking the ball (n=1, deceleration: 2.1 m/s^2, distance covered: 8.2 m, peak speed achieved: 19.29, 58% of the player's maximal speed). One injury occurred while the player was landing after a jump to head the ball and one injury occurred while the player was walking and receiving the ball.

Both quadriceps injuries occurred while players were kicking (Table 5.4). In one case the player was kicking the ball while walking, in the other case the player was kicking the ball while running (total distance covered: 9.3 m, acceleration: 1.3 m/s^2, peak speed achieved: 18.71 km/h which corresponded to 59% of player's maximal speed).

All injuries but one occurred to players who had played for the entire match or training (i.e., did not come in from the bench). The number of hamstring injuries increased over time with the exception of the last period (Figure 5.12). Analysis for other injuries was not possible due to the limited number of cases. Fifteen injuries occurred during home training or matches and 19 injuries occurred during away matches. With reference to match injuries, 10 injuries occurred while the team was winning, five while the team was losing, and 13 while the score tied. Considering the injuries that occurred during matches or small sided games, 15 injuries occurred during the defensive phase and 18 injuries occurred during the offensive phase. Details of injury circumstances per injury are reported in Appendix G.

Table 5.4 Summary of physical activity and ball situation at the time of injury

Location	Physical activity	Injured player without ball	Receiving ball	Running with ball	Kicking	Heading
Hamstring	Accelerating	2	1	0	0	0
	Decelerating	3	1	0	0	0
	Running at steady speed	7	0	2	0	0
	Jumping – in air	0	1	0	0	0
Quadriceps	Running at steady speed	0	0	0	1	0
	Walking	0	0	0	1	0
Adductor	Accelerating	0	1	0	0	0
	Decelerating	1	0	0	0	0
	Running at steady speed	0	1	1	1	0
	Static	0	0	0	1	0
Calf	Accelerating	1	0	0	0	0
	Decelerating	0	0	0	1	0
	Upon landing from jump	0	0	0	0	1
	Walking	0	1	0	0	0
Meniscus	Running at steady speed	1	0	0	0	0
Foot	Running at steady speed	0	0	1	0	0
Knee	Running at steady speed	1	0	0	0	0
LCL	Running at steady speed	0	1	0	0	0
ACL	Changing direction	0	0	1	0	0

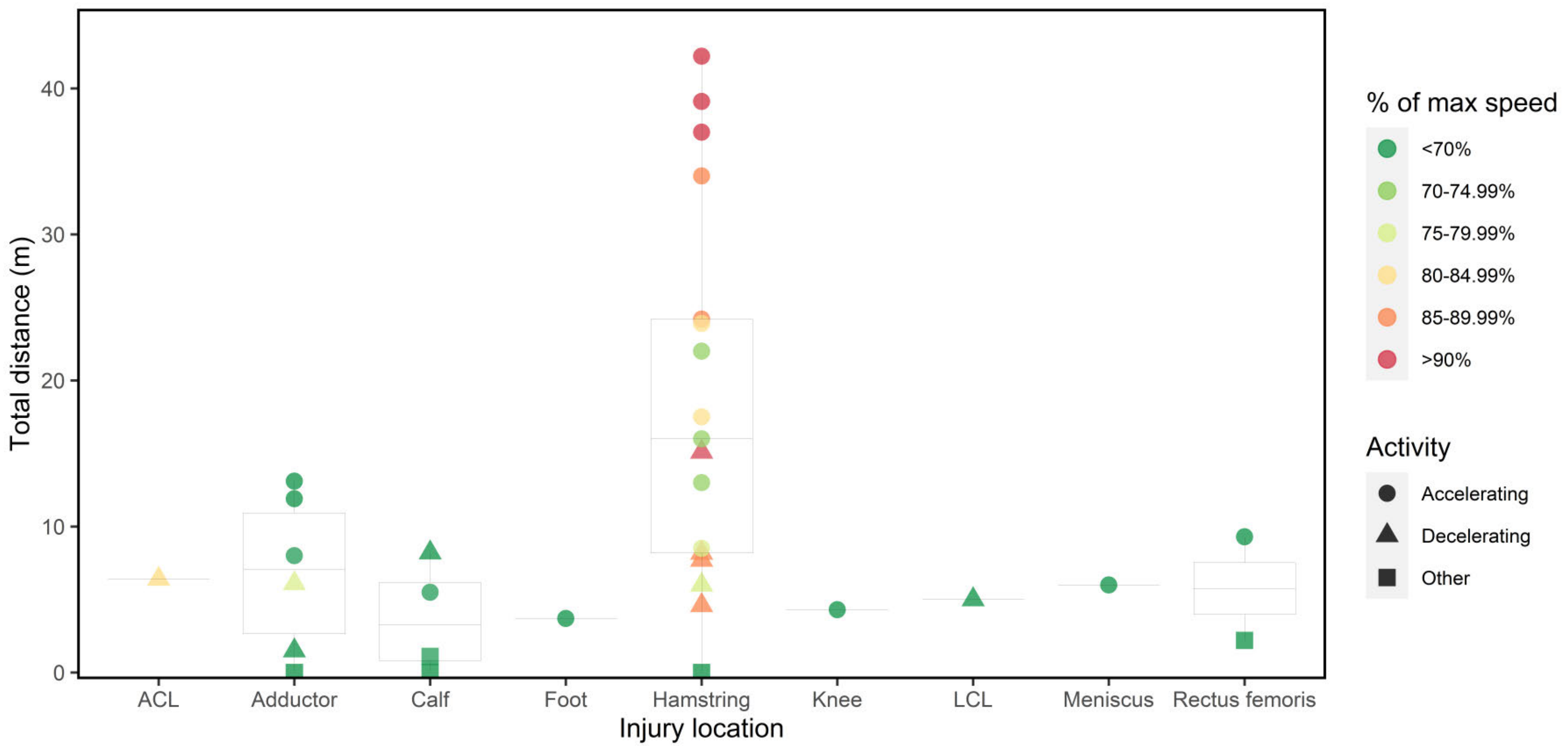

Figure 5.9 Distance covered during the inciting activity by injury location and players' activities. Accelerating and decelerating include actions both above and below 2 m/s^2.

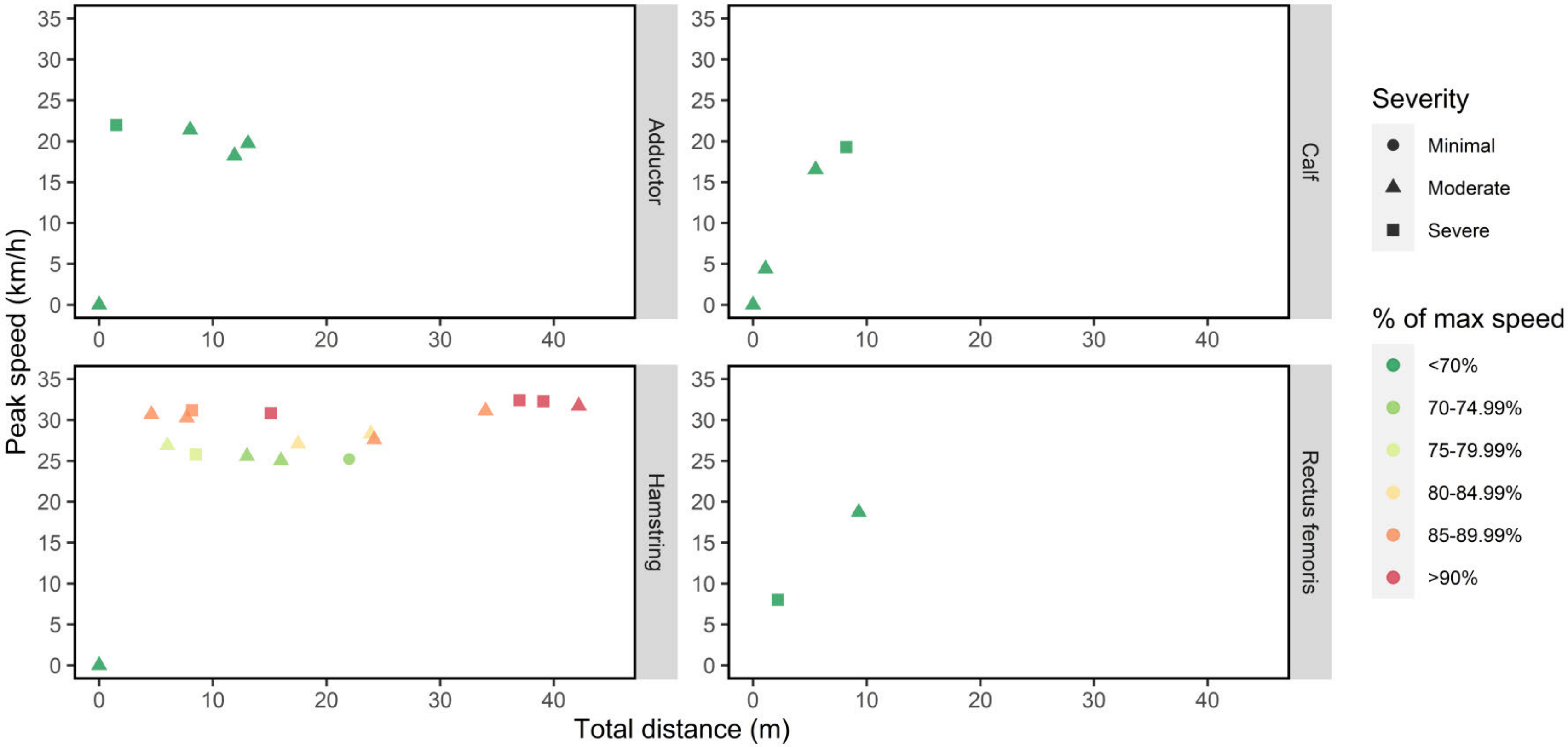

Figure 5.10 Distance covered and peak speed achieved during the inciting activity of muscle injuries by injury location. Injuries reported with speed = 0 are injuries occurred while the player was static or jumping

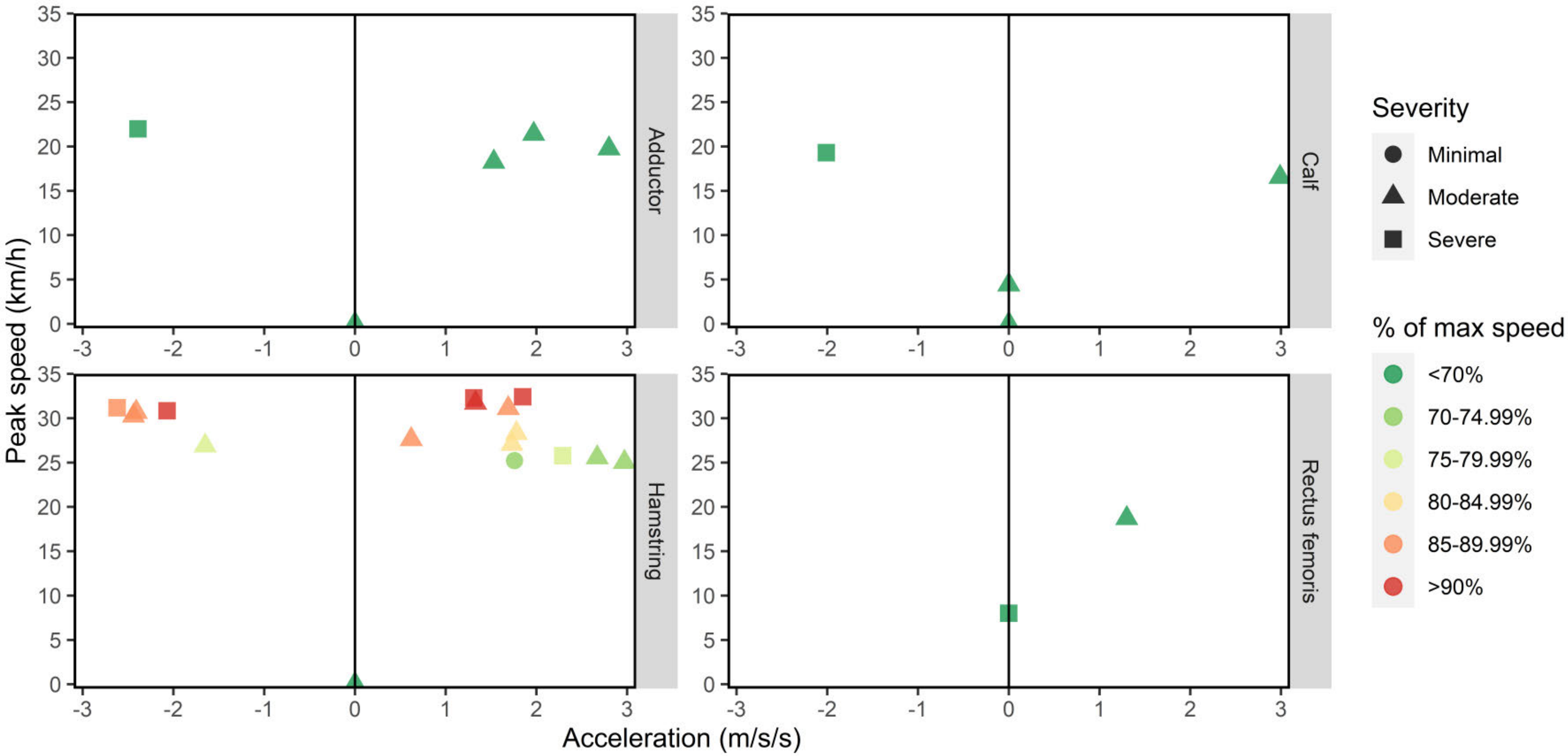

Figure 5.11 Peak acceleration and peak speed achieved during the inciting activity of muscle injuries by injury location. When acceleration is positive the peak speed corresponds to the maximal speed achieved by the player during that activity, when acceleration is negative the peak speed corresponds to the speed from which the player was decelerating. Injuries reported with speed = 0 are injuries occurred while the player was static or jumping

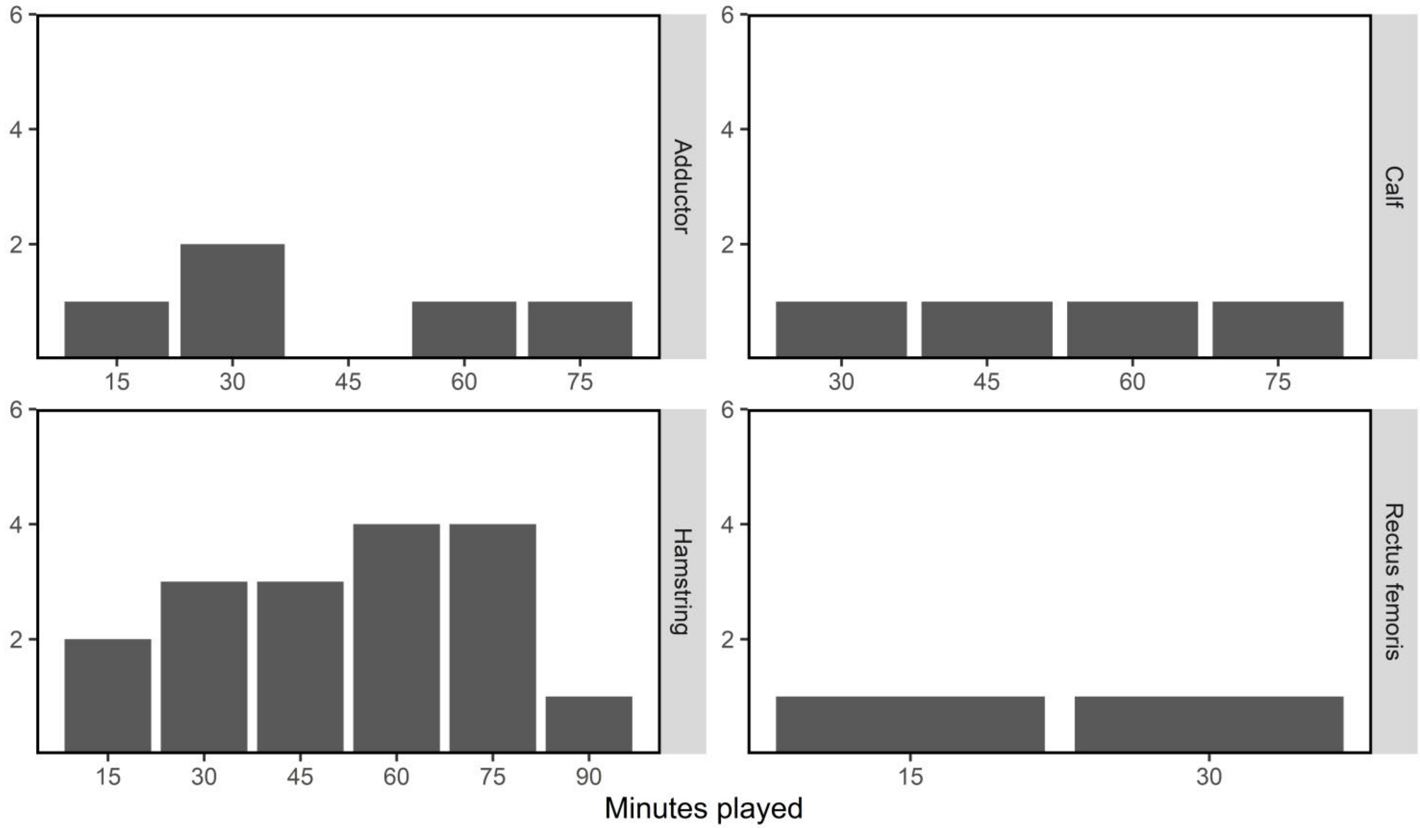

Figure 5.12 Time of injury occurrence by injury location. Time refers to the actual time played by the players

5.3.3 Discussion

5.3.3.1 Data location

The club collected injury data using different databases over the three seasons. However, no problems arose for the location of such data and, unlike the pilot, there was perfect accuracy between the date of injury reported and the actual injury date. The video clips of training and matches were stored within the club's online databases and were easily accessible by the sport scientist who supported the analysis, although in nine cases video clips of the session were not available. With reference to GPS data, locating the data was straightforward thanks to the support of the sport scientist. However, in 24 cases GPS data were not available because in seven cases the data had been collected with different systems and were not accessible, while in 17 cases the players were not wearing the pod in the session during which the injury occurred. This reiterates the issues of data collection procedures implemented in football which have been previously discussed.

5.3.3.2 Data transfer

Only medical data have been transferred and the process was straightforward. To align with data protection policies of the club, video and GPS data were kept within the club's databases and were viewed and analysed in collaboration with a member of staff who accessed the data (i.e., video and GPS), shared the screen remotely and supported the analysis. On one hand, this process facilitated the analysis because it prevented the need to transfer a large amount of data, and the development of the data management plan was much easier in comparison with what was experienced in the pilot. Furthermore, conducting the analysis with a member of staff has strengthened the reliability of the analysis as will be described in the next section. On the other hand, this procedure imposed a significant time burden on the sport scientists who supported the analysis and led to the decision to only analyse non-contact injuries.

5.3.3.3 Data analysis

As reported in the pilot phase, the identification of the injury on video has been the most difficult and time demanding part of the analysis. The time of injury was not included in the medical report, therefore the injury had to be identified using the GPS data and then by watching the video. The time required to analyse an injury was not monitored, but in some cases more than 5 minutes were needed to identify the moment of injury on video. However, once the injuries were identified the tags T0, T-1, and T-2 were created on the GPS software in a few seconds, while filling out the FIICCS required approximately one or two minutes depending on the type of inciting circumstance. Interestingly, one injury occurred while the study was being conducted therefore it was possible to evaluate the time needed to perform this analysis prospectively. As expected, the prospective analysis required much less time. The sport scientist noted the time of injury during the session in which the injury occurred and so the injury was located on video and on the GPS track in a few seconds, and in total the analysis required less than five minutes.

Unlike the pilot phase, during which I analysed the injuries on my own, in phase two I collaborated with the club's sport scientists which has sensibly improved the quality of the analysis for several reasons. Firstly, having a member of staff actively involved in the analysis has helped in situations in which data needed to be retrieved from old hard drives or where further video footage was needed to be required from the video analysis department. Secondly, when it was difficult to identify the time of injury, the sport scientist could ask for further information from the injured players or speak to other members of staff who witnessed the injury and had talked with the players. This was useful when it was unclear whether the injuries had occurred when players were running at high speed or when players decelerated from high-speed runs. Finally, since the reliability of the FIICCS has not been tested yet, performing the analysis of inciting circumstances with another expert has strengthened the reliability of the data herein. Indeed, there was complete agreement for all 34 injuries analysed, which seems promising with reference to the reliability of the FIICCS.

5.3.3.4 Injury inciting circumstances

As previously discussed in the literature review, the great majority (16/17) of hamstring injuries occurred while the players were accelerating up to or decelerating from a speed > 25 km/h, which is sometimes reported in football as high-speed running, very high-speed running, or sprinting (Teixeira et al., 2021). Furthermore, 11 injuries occurred when players were running above 80% of their maximal running speed which, as previously discussed in the literature review, could be linked to the higher hamstring activation recorded at high speed. Therefore, if these data are confirmed preparing players to withstand running at and decelerating from high speeds (i.e., > 25 km/h and > 80% of their maximal running speed) may contribute to a reduction ine hamstring injuries. In elite football the most common strategies to do so include exposing players to high-speed running and eccentric exercises (McCall et al., 2020b) although there is limited evidence supporting their effectiveness (Fanchini et al., 2020). The only hamstring injury which did not occur during running activities occurred while the player was receiving the ball with the foot at upper body height. All hamstring injuries analysed occurred while players were in a position of hip flexion and knee extension, which supports the available literature on the mechanisms of hamstring injuries (Danielsson et al., 2020). Similar results have been previously reported in rugby where the majority of hamstring injuries were reported to occur while players were in a position of hip flexion and knee extension (Kerin et al., 2022). Gronwald et al. (2021) reported that about 50% of the hamstring injuries analysed occurred with hip flexion <45° while all injuries occurred with knee flexion <45°. To the best of my knowledge the study conducted by Gronwald et al. (2021) is the first to report with this level of detail the mechanisms of hamstring injuries in football, therefore further studies should be conducted to further investigate these aspects. As discussed in Chapter 2.3, there is debate on whether hamstring injuries that occur during running activities occur during the late swing phase (high eccentric work combined with great musculotendon length) or the early stance phase (high eccentric work due to ground reaction forces) of the running cycle (for a review see Kenneally-Dabrowski et al. (2019) and Liu et al. (2017)). It was not possible to investigate this aspect in the current study, but I believe that it might be possible to answer this question by combining player interviews and prospective video analysis. During the current study in 26 cases the times of injury were not clearly identifiable on video, therefore we reviewed the video with the players and asked them whether they remembered the time of injury. Four cases could not be analysed because players had left the club, but in 18 cases players declared that they remembered a gradual onset (which explains why the injuries were not identifiable on video), while in four cases players could identify the time of injury on video despite the injuries having occurred several months earlier. Therefore, it is possible that if the video clips are reviewed with the injured players shortly after the injury occurred, players might be able to identify the running phase during which the injuries occurred. This approach has previously been implemented by Serner et al. (2019) and may allow the analysis of the inciting circumstances in detail and with greater accuracy. This applies not only to the analysis of the running phase, but also to other aspects such as the running speed and the kicking phase. However, given that these activities occur at very high speeds, it's unclear whether players would be able to identify the exact time of injury (e.g., injury occurred during late swing or early stance).

The inciting activities for adductor injuries are similar to the ones reported by Serner et al. (2019) which to the best of my knowledge are the only research group that analysed adductor injuries through video analysis. The authors reported kicking as high-risk activity, which is confirmed by our results. The adductor longus achieves its peak activation and stretch immediately before the kicking leg achieves peak hip extension during the swing phase (Charnock et al., 2009). However, Serner et al. (2019) reported changing direction, reaching, and jumping as other high-risk activities, which is slightly different from the results of this study. It is possible that the inciting activity "receiving the ball" was reported by Serner et al. (2019) as "reaching for the ball", because their study was conducted before the development of the FIICCS. In this study two adductor injuries occurred while the players were receiving the ball at knee and upper body heights with the injured leg while running at high speed, supporting the hypothesis that the adductors are at risk of injury during rapid transitions from hip extension to hip flexion (Charnock et al., 2009). No injuries in the present study occurred during changes of direction and only one injury occurred while decelerating, while changing direction was reported as the most prevalent inciting activity by Serner et al. (2019). As discussed in the literature review, muscle injuries occur usually during eccentric actions, therefore it is plausible that adductor injuries occur during decelerations and changes of direction, both activities which require high eccentric actions (Chaudhari et al., 2014). It might be that in the study conducted by Serner et al. (2019) the injuries occurred during the deceleration phase of the change of direction, however given that the ground contact time during changes of direction lasts less than 0.5 seconds (Nimphius et al., 2016) this is difficult to evaluate. Alternatively, it may be that no adductor injuries occurred during changes of direction were observed in the current study due to the small number of injuries analysed or because only non-contact injuries were analysed, which may also explain the different proportion of injuries that occurred during changes of direction and deceleration.

Three of the four calf injuries occurred during running and landing activities, which have been reported to be frequent inciting activities in other football codes (Green et al., 2020b). It has been hypothesised that calves are under great stress during running, which explains why most injuries occur during such activity.

Both quadriceps injuries occurred while players were kicking either while walking or while running, which supports the hypothesis discussed in Chapter 2.3. on how rectus femoris injuries may occur during different phases of kicking (i.e., ground contact of the non-kicking leg, swing phase of kicking, or contact with ball). It was not possible to evaluate the phase of kick during which the injury occurred, but since both injuries occurred to the kicking leg the first phase can be excluded. Additionally, given that muscle injuries tend to occur during eccentric actions it may be that quadricep injuries occur during the swing phase, but this still needs to be investigated. In one case the player was kicking while walking, while in the other the player was running at 18.71 km/h. It is difficult to say whether one situation may be riskier than the other and to the best of my knowledge the biomechanics of kicking from different walking and running speeds has never been investigated.

Since only one case was recorded for other injuries (e.g., ACL, LCL, foot) it is difficult to compare data obtained from the present study with the available literature. Given the low incidence of such injuries, multicentric studies are needed to evaluate the inciting circumstances.

5.3.3.5 Strengths and limitations

This study constitutes the first attempt to incorporate GPS and video analysis to evaluate inciting circumstances. Using a standard classification system for inciting circumstances and objective equipment to evaluate players' speed improved the perceived reliability of the data, although some limitations remain. The scientific reliability of the FIICCS has not been evaluated yet therefore data should be considered carefully, although two authors analysed the video simultaneously and no disagreement arose. Furthermore, the choice to assume that injuries occurred at peak speed may not always stand and constitutes a further limitation. When the injury was not identifiable on video I asked staff and players to identify the time of injury, but since some injuries had occurred several months earlier and that players' ability to recognise the exact time of injury is uncertain, I decided not to ask them to identify the specific time of injury, because this would have increased the burden on staff and may have jeopardised the completion of the study. The number of missing data constitutes another limitation of this study. When injuries were not clearly identifiable on video, they were identified by asking staff members or players when needed. Doing so allowed me to analyse all injuries but one for which data were available. Video or GPS data were not available for 37% (30/80) of cases originally reported as non-contact injuries. It can be assumed that there is no association between injury circumstances and missing data (i.e., data are missing completely at random), and as a consequence it is likely that no bias has been introduced by the missing data (Rothman, 2013). Despite this, the large number of missing data observed in datasets belonging to two elite football clubs strengthens the need to improve procedures for collection and storage of not only medical data (as discussed throughout this thesis) but also of GPS and video. Hence, it seems very important that football clubs improve such procedures in order to increase the quality of the datasets which are used to guide decision making processes. Therefore, considering the limitations of this study and the limited number of injuries analysed, further studies are needed to evaluate the inciting circumstances leading to injuries in football.

5.3.3.6 Considerations for further studies

Future studies should be conducted in collaboration with a member of staff. This would reduce the need for data management requirements and facilitate the analysis of the data. Furthermore, it would be interesting to implement this approach and analyse injuries as they occur instead of analysing them all together at the end of the observation period. This would facilitate the processes of data location and identification of the inciting event on video and would allow the determination of whether players are able to identify the specific time of injury, which could lead to more detailed analysis of inciting activities and mechanisms of injury. It is important to consider that it may be difficult to implement this method in the analysis of injuries with low incidence. To find enough cases of injuries such as ACL and LCL injuries, multicentric and/or multi-year studies are needed. Indeed, inciting circumstances of ACL injuries have been previously analysed using either online databases (e.g., Transfermarkt.com and Youtube.com) or national databases. However, these studies have only used medical reports or video-analysis without using GPS data, which are more difficult to store and share than video or report files. This means that this approach might not be feasible to conduct research on rare injuries unless multiple clubs agree to share video, GPS, and medical data.

5.4 Conclusions

The first aim of this study was to develop and test a new approach for the analysis of the inciting circumstances in football using data collection procedures already in place within football clubs. Difficulties were observed in retrospectively locating and transferring data from football clubs and in identifying the time of injury on video. Difficulties for data location and transfer were solved when a member of staff was involved in the process, while the identification of injury remained time demanding. On the other hand, the data analysis process was simple and swift. From the current study it seems that players can recall the time of injury with precision even several months after the injury occurred, however this aspect was not evaluated in the current study hence needs to be further investigated. That said, retrospective studies could be time consuming and could result in a greater percentage of missing data.

Although conducting research on rare injuries might be difficult with this approach, it remains valid for conducting research on the remaining injuries, and practitioners may still decide to use it to analyse all injuries (both rare and frequent). For example, this information may be used by practitioners to tailor return to play protocols according to the inciting circumstance (e.g., the return to play protocol after a hamstring injury might differ if the injury occurred while player was running at 90% of their peak speed rather than if the injury occurred while the player was kicking). Exposing players to the inciting circumstance during the return to play process may also be useful to increase players' confidence and reduce fear of re-injury, which are important criteria for return to play (Dunlop et al., 2020; Zambaldi et al., 2017). Furthermore, such information can be used to develop prevention strategies and training programmes as previously discussed in the literature review.

The second aim of the study was to analyse the inciting circumstances of injuries in football. All but one hamstring injury occurred when the players were running at more than 25 km/h either with or without the ball and in 65% of cases players were running at more than 80% of their maximal running speed. Adductor injuries occurred while the players were kicking, receiving the ball or decelerating. Calf injuries occurred during running and landing activities, and quadriceps injuries occurred while players were kicking either from static position or while running. This study constitutes a first attempt to use this new approach for the analysis of inciting circumstances. It is recommended that further studies use a similar methodology, ideally analysing the data prospectively and involving players in the identification of the time of injury.

6 General Discussion

6.1 Chapter outline

The aim of this chapter is to discuss the results of the studies with regard to the overall aim of the thesis which was to develop a system to analyse the circumstances leading to injury in elite football players. The findings of the individual studies have been discussed in detail in the respective chapters, therefore this chapter provides a summary of those findings and a discussion of their contribution and application to practice and research. Specifically, an overview of the thesis will be provided in section 6.2 of this chapter. In section 6.3 the results of the studies conducted on the inciting circumstances (study one and study three) will be summarised and their practical applications will be discussed. In section 6.4 the methodology for the analysis of inciting circumstances proposed and tested in this thesis will be discussed. Strengths and limitations of the studies will also be discussed.

6.2 Overview of the Thesis

This thesis provided a summary of the available literature on inciting circumstances in football and methodological guidelines for conducting prospective and retrospective studies using data routinely collected by football clubs.

The aims of the thesis were:

6.2.1 Aims

1) To examine the available literature on circumstances leading to injury in professional football players.
2) To develop methodological guidance and standard terminology for further studies investigating this topic.

3) To evaluate whether such guidance can be used to analyse data routinely collected in football.

These aims were achieved through the following studies:

6.2.2 Studies

1) Injury inciting circumstances in male and female football players: a systematic review
2) Development of a standardised system to classify injury inciting circumstances in football: the Football Injury Inciting Circumstances Classification System (FIICCS)
3) A retrospective analysis of injury inciting circumstances in elite European football players

The literature review explored these areas:

1) The limitations of the guidelines implemented for injury recording;
2) Definition of the terminology used in research on injury inciting circumstances;
3) Methodology used to analyse inciting circumstances in football;
4) Current knowledge on circumstances leading to the most important injuries in football;
5) How research is used to guide practitioners.

Considering that accurate and consistent recording and reporting of outcomes is key to combine, compare, and generalise findings across studies and then provide robust information which can be used by practitioners to make decisions (Clarke & Williamson, 2016), in the literature review the aspects of injury reporting guidelines which show some limitations were discussed. Time-loss injuries, which are defined as health problems that impedes the player to complete the current and/or subsequent match or training session (Bahr et al., 2020), reduce players' availability hence cause performance and financial loss (Carling et al., 2015; Hagglund et al., 2013; Marsh JLT Specialty, 2019), therefore most research focuses on time-loss injuries. However, although clear guidelines have been provided to define injuries and specifically time-loss injuries, they are not always followed in research. Indeed, numerous authors use different injury definitions such as 24-hour loss and one-match loss, which evidently impact the evaluation of injury extent and the analysis of risk factors, injury inciting circumstances, and prevention strategies.

A second limitation of the guidelines for injury reporting is the definition of the injured body region. Since inciting circumstances and risk factors are likely to differ according to body area, it seems clear that reporting such information is crucial to try to prevent injuries. However, current injury reporting guidelines recommend reporting the injured body area incompletely. For example, it is recommended to report all thigh injuries together (Bahr et al., 2020), but since quadriceps and hamstring injuries seem to have different incidence, risk factors and mechanisms (Ekstrand et al., 2011; Huygaerts et al., 2020; Mendiguchia et al., 2013) it seems more appropriate to report such injuries separately.

A third limitation of the injury reporting guidelines concerns the reporting of inciting circumstances. In the literature review the term "injury mechanism" was discussed and it was explained why different terminology (i.e., "inciting circumstances" and "inciting activities") may be more appropriate to describe environmental factors and sport-specific activities performed at the time of injury, while the term "injury mechanisms" seems to be more appropriate to describe the mechanical aspects of the inciting event. Subsequently, the methods used to analyse the inciting circumstances were presented and their strengths and limitations discussed. Report forms are the methods most used in football to collect injury data (including the ones that refer to inciting circumstances), however, while standard guidelines have been provided to collect such data (e.g., incidence, severity, type, location) for all sports and specifically for football (Bahr et al., 2020; Fuller et al., 2006), no such guidelines have been reported for the collection of data pertaining to inciting circumstances and the guidelines for injury data collection and reporting provided by the International Olympic Committee recommend the development of sport-specific classification systems for injury mechanisms (referred herein as injury inciting circumstances) (Bahr et al., 2020). As a consequence, the reliability of data collected and reported with report forms is questionable.

Another method used to analyse the inciting circumstances is video analysis. This method allows a more detailed analysis of the inciting circumstances to be conducted than that possible only through report forms. Andersen et al. (2003) proposed a checklist for reporting inciting circumstances during video analysis, but the methodology used to develop such a checklist did not seem to be very robust and furthermore this checklist has been used only three times since its development in 2003. In the last five years numerous studies have used video-analysis to analyse the inciting circumstances but given that injuries were analysed without access to reliable medical data and were reported using arbitrary classifications, the reliability of results is questionable. A final method used to collect information on inciting circumstances is through questionnaires which are usually used when it is not possible to use either report forms or video analysis. This method shows similar limitations to those for report forms with the addition of the risk of recall bias.

In the third section of the literature review the literature on inciting circumstances was discussed which led to a systematic review being conducted on this topic, and so the current literature will be discussed further in a subsequent section of this general discussion (Chapter 6.3). In the final section of the literature review the process of how practitioners inform their practice was discussed. Practitioners rely on intuition and experience when they need to take immediate decisions but when possible they try to use information obtained in the literature and through conferences and informal conversation to implement evidence-based practices (Coutts, 2016). However, the literature on injury prevention strategies has been shown to be inconsistent (Al Attar et al., 2017; Impellizzeri et al., 2020a; Impellizzeri et al., 2020b; Impellizzeri et al., 2020; Lolli et al., 2019a; Lolli et al., 2019b; McCall et al., 2020a; van Dyk et al., 2019; Wang et al., 2020), which could explain the failure in reducing injuries (Ekstrand et al., 2021; Ekstrand et al., 2016) and could lead practitioners to lose their trust in research (Ardern et al., 2019). As a consequence, it was clear that more robust information is needed to develop better injury prevention strategies.

Despite the limitations observed with reference to all the factors which guide the development of injury prevention strategies (i.e., injury extent, risk factors, and inciting circumstances), it was decided to focus this project on the analysis of inciting circumstances in football. This decision was taken considering the time and resource limitations and that information on inciting circumstances (environmental factors and inciting activities) can be used to develop prevention strategies and to guide research on injury mechanisms and risk factors which are in turn important for the development of such prevention strategies.

6.3 Inciting circumstances leading to injury by body area

After discussing the limitations of the collection of injury data and how providing inaccurate information may negatively impact practitioners' trust in research, the results on the inciting circumstances leading to specific injuries obtained from the systematic review (Study 1) and the retrospective analysis of inciting circumstances (Study 3) will be discussed. Subsequently, it will be discussed how such information could be used to guide further research on risk factors, injury mechanisms, and prevention strategies, while considering the limitations of the studies and the small number of injuries that were analysed which limit the reliability of the results and their transferability.

6.3.1 ACL

Only one ACL injury was analysed in study three (which occurred during a non-contact change of direction performed at high-speed), therefore a comparison with the literature is not appropriate. From the literature review and the systematic review there seems to be strong evidence to suggest that most ACL injuries occur during non-contact and indirect contact circumstances. However, more detailed descriptions of inciting activities are difficult due to the different classifications used by the studies. Some studies which used video-analysis reported pressing and regaining balance after kicking as the most prevalent inciting activities, but other studies did not report any injury occurring during such activities. This is probably due to the arbitrary classifications used by the studies included. Since these studies used video analysis, it would be interesting to repeat the analysis using the FIICCS. Doing so during this project was not possible due to time limitations, but it is hoped that the authors of the original study do so. Following the experience from study 3 the most challenging and time-consuming activities of this type of analysis are data collection (e.g., identifying date of injury, locating video), data transfer (i.e., transferring the video) and injury location (i.e., identifying the injuries on video) all of which have already been performed during the original studies. Therefore, it is expected that repeating the analysis of the injuries using the FIICCS would be time efficient and would provide more consistent detail on the inciting activities of ACL injuries.

Despite the literature on inciting circumstances leading to ACL injuries not providing consistent results, prevention strategies for ACL injuries have been developed on the basis of the knowledge about the mechanisms of ACL injuries. Indeed, as discussed in Chapter 2, there is strong consensus in the literature about the mechanisms of ACL injuries (e.g., dynamic knee valgus and intra rotation, hyperextension) in several sports including football (Alentorn-Geli et al., 2009b; Della Villa et al., 2020; Grassi et al., 2017; Lucarno et al., 2021; Waldén et al., 2015; Yu & Garrett, 2007). Therefore prevention strategies have been developed to limit such movements, or to improve the capability of the relevant tissues to cope with the higher demands known to increase load on ACL (e.g., knee dynamic valgus during landing or change of direction) and seem to be effectively reducing the rate of ACL injuries (Dai et al., 2014; Donnelly et al., 2012; Silvers-Granelli et al., 2017). Further knowledge on inciting circumstances specific for football players may help to develop football-specific prevention strategies which focuses more on the circumstances most common in football and improves the effectiveness of the prevention strategies.

6.3.2 Hamstring

Sixteen of the seventeen sudden onset injuries analysed in study three occurred while players were running and achieved a peak speed > 25 km/h. In five cases the injuries occurred while players were decelerating at various intensities and in 11 cases the injuries occurred while the players were accelerating at various intensities. This partially confirms the findings from the systematic review. Indeed, running activities were reported to be the most common inciting activity for hamstring injuries. However, results from study three appear to be different when compared with those reported by Gronwald et al. (2021) which is the only study included in the systematic review which conducted a video-analysis of hamstring injuries. Gronwald et al. (2021) reported that all non-contact running injuries occurred during accelerations or high-speed running and explicitly reported that no injuries occurred during decelerations. Secondly, circa 35% of the non-contact injuries were reported to have occurred due to stretch-related mechanisms and circa 20% of non-contact injuries were reported to have occurred during kicking, while in study three only one injury occurred during stretch-related mechanisms. Finally, about 50% of hamstring injuries were reported to have occurred at hip flexion <45° while all hamstring injuries analysed in study three occurred when players were in a position of great hip flexion and knee extension.

These differences are probably due to the different methodologies implemented by the studies. Firstly, Gronwald et al. (2021) only analysed injuries of duration > 7 days which occurred during matches. Secondly, they did not have contact either with the players or with the staff, therefore it is not clear how they dealt with cases in which players kept playing for some time before reporting the injury. Finally, they used a different classification system and did not use Electronic Performance & Tracking

Systems such as GPS or optical tracking to evaluate physical performances, therefore it is not clear how acceleration and high-speed running were differentiated or measured. These methodological differences probably explain the differences observed in the number of injuries occurring during acceleration and deceleration, however it is difficult to understand the reasons behind the extensive difference between the two studies on the number of injuries occurring during stretch-related mechanisms and with different hip positions. Considering also the studies included in the systematic review which analysed hamstring injuries without video analysis and the ones which analysed thigh injuries (i.e., without differentiating between muscles), kicking has been reported as the second most frequent inciting activity. Therefore, although in study three all hamstring injuries occurred during running activities, it is plausible that kicking is another activity which leads to hamstring injuries. This aspect should be further investigated in future studies (the methodology will be discussed in Chapter 6.4).

In retrospect, in study three hamstring injuries for which GPS data were not available could have been analysed only with the video. This would have allowed the analysis of more injuries and a more robust evaluation of the prevalence of stretch-type and sprint-type mechanisms. However, on the basis of the difficulties encountered with data transfer and with staff buy-in in the pilot study, it was decided to give priority to evaluating the usability of this approach (i.e., GPS and video analysis). Therefore, injuries for which GPS data were not available were excluded in order to limit the burden on the team staff as much as possible and to increase the chances of completion of the study.

Despite the literature and the limitations to the results from study three, it seems plausible that most running injuries occur during high-speed running activities. Prevention strategies should be developed (and tested) using this information. Recent studies (Mendiguchia et al., 2021; Mendiguchia et al., 2020) have investigated the effectiveness of training protocols to reduce the anterior pelvic tilt which may in turn reduce the tension of the hamstring during running and as a consequence reduce the risk of hamstring injuries. Others have proposed that since the level of activation achieved by the hamstrings during sprints cannot be achieved by other activities or exercises (van den Tillaar et al., 2017), (progressive and planned) exposure to high-speed running may help to prevent hamstring injuries (Butler, 2019; Edouard et al., 2020). Previous studies have proposed that being exposed to 95% of maximal speed 10 to 15 times within a week (Malone et al., 2017b) or being exposed to 85% of maximal speed five to eight times in a 4-week period (Colby et al., 2018) may reduce the risk of hamstring injuries. Therefore, future research could investigate how to increase the ability of the hamstrings to resist load during high-speed running activities, and whether particular exposure to high-speed running and the reduction of anterior pelvic tilt could be part of the solution help to reduce hamstring injuries. However, it is important to keep in mind that one single factor (pelvic tilt, exposure to high-speed running, or others) is just one piece of the complex system which may lead to injuries. Indeed, as discussed in previous chapters even when one factor of the system has been identified, it is important to consider that injuries are not likely to be caused by that factor only but also by other factors of the system (e.g., inciting event, psychosocial factors) which can occur at different points in time.

With reference to stretch-type injuries (e.g., kicking, controlling the ball), the evidence about the prevalence of such injuries is contrasting and the literature focused on exercises to increase hamstring eccentric strength does not allow conclusive recommendations. However, since injuries occur when the load exceeds the tissue's load tolerance (McIntosh, 2005) and that muscle injuries seem to occur during eccentric actions (Garrett, 1990) it seems sensible to try to increase the hamstrings' ability to tolerate eccentric load. Therefore, until more information is available and research is able to give recommendations based on robust findings, practitioners can use the current recommendations to try and prevent hamstring injuries. However, as described in Chapter 2.4 it is important to make practitioners aware that there is no certainty about the effectiveness of such strategies. This would allow practitioners to make informed decisions and should these strategies prove not to work in the future this should not harm practitioners' trust in research.

6.3.3 Quadriceps injuries

None of the studies included in the systematic review specifically reported inciting circumstances leading to quadriceps injuries. Since most thigh injuries occur to the hamstring (Ekstrand et al., 2011) it does not seem appropriate to use inciting circumstances reported for thigh injuries in the systematic review to discuss quadriceps injuries. Only two quadriceps injuries were analysed in study three and both occurred when players were kicking (either while walking or while running at 18.7 km/h). This is in accordance with the hypothesis formulated by Mendiguchia et al. (2013) that running at high speed and kicking may put the rectus femoris at risk of injury. This hypothesis is also supported by a study published in July 2022 (Geiss Santos et al., 2022) which was not included in the systematic review because the last search was run in December 2021. In this study kicking was reported as the most frequent inciting activity (54%) followed by sprinting (30%). Further studies should confirm these results but in the meantime this information could be used to develop prevention strategies specific for rectus femoris injuries, the literature around which seems to be scarce (Ishøi et al., 2020; Mendiguchia et al., 2013).

6.3.4 Hip-groin injuries

From the systematic review, high intensity running, kicking, and duel activities were reported as the inciting activities leading to 15% of hip/groin injuries, while Serner et al. (2019) who specifically analysed adductor injuries through medical reports and video-analysis reported that adductor injuries occurred while players were changing direction, kicking, and reaching for the ball. Results from study three partially confirm what was reported in the systematic review, indeed kicking and reaching for the ball (reported in study three as "controlling the ball" following the development of the FIICCS) have been reported as inciting activities leading to adductor injuries. However, no injuries were observed to have occurred during changes of direction, which is believed to be one of the main inciting activities leading to adductor injuries as reported by Serner et al. (2019), although other studies included in the systematic review reported a lower prevalence of injuries occurred during this activity. Therefore, changing direction, decelerating, kicking, and controlling the ball seem to be the most common inciting activities leading to adductor injuries, although such data need to be interpreted carefully due to the small number of injuries included in study three. Further studies should confirm the prevalence of such inciting activities analysing a larger number of injuries with robust methods as will be discussed in the next section.

In the meantime, practitioners can use this information to inform their practice and try to prevent adductor injuries. For example, since around 70% of groin injuries in football concern the adductors (Werner et al., 2009) and that most of these injuries seem to occur during eccentric actions, focussing on these muscles might help to reduce injuries (Harøy et al., 2019).

6.3.5 Calf injuries

As discussed in Chapter 2.3.6, the literature on calf injuries is scarce. Indeed, none of the studies included in the systematic review specifically analysed calf injuries. Data from study three (four injuries) suggest that running and landing might be activities leading to calf injuries, as similarly reported in Australian Football (Green et al., 2020b). Clearly, such a small number of injuries does not allow a robust evaluation of the activities which lead to calf injuries and therefore requires further investigation. Similarly, the literature on prevention strategies for calf injuries is very limited and to the best of my knowledge no RCTs have been performed to investigate prevention strategies for these injuries. This may be due to the low incidence and burden of calf injuries in football (Ekstrand et al., 2011), which may lead research on these injuries to be perceived as less important.

6.3.6 Ankle injuries

No ankle injuries were analysed in study three, but from the systematic review it appears that contact activities such as being tackled and tackling are the most common activities leading to ankle injuries in football. As discussed in the literature review, from the information concerning mechanisms of ankle injuries and inciting activities in other sports it could be expected to see ankle injuries occurring predominantly during activities in which the foot is in plantar flexion such as landing and changing direction (Doherty et al., 2014; McKay et al., 2001), but this doesn't seem to be the case in football, although further studies are needed due to the limitations observed in the available literature.

In other sports (e.g., basketball, volleyball) balance and proprioception training and external supports seem to effectively reduce the risk of ankle injuries (Chen et al., 2019; Taylor et al., 2015). Therefore, practitioners may use similar strategies to try and reduce ankle injuries, however if further studies confirm that the inciting circumstances differ importantly between football and these sports, the effectiveness of these strategies may be limited and the development of alternative strategies may be needed. If it is confirmed that more than half of ankle injuries occur during contact situations it may be that exercise-based prevention strategies can only partially help to reduce ankle injuries.

6.4 Methods for the analysis of inciting circumstances

During the systematic review it appeared evident that the methodological limitations of the studies currently available in the literature made it very difficult to clearly identifying the inciting circumstances which lead to injury in football, hence the subsequent difficulty in providing guidelines to researchers and practitioners. As described in the literature review, providing reliable information on the inciting circumstances is important both to guide the research specifically on injury mechanisms and risk factors and to guide the development of prevention strategies. Inaccurate information could lead to a waste of time and resources for researchers and in the development of ineffective prevention strategies which would fail to reduce injuries and could harm practitioners' trust in research.

Given the methodological limitations observed during the systematic review and the importance of providing accurate information on the inciting circumstances, it was decided to try to develop robust and standardised guidelines to collect and report information concerning the inciting circumstances. As discussed in the literature review and reported in the systematic review, report forms are currently far more widely used than video-analysis and questionnaires to collect and report inciting circumstances, although video-analysis allows the performance of a more detailed and accurate analysis (if time of injury is precisely identified). Therefore, it was decided to develop a classification system that would allow the collection of data using both methods. Given the fast-paced environment in which football practitioners work, limiting the time burden on practitioners and ensuring a good level of usability was deemed to be crucial to increase the chances of the system being implemented.

To increase the usability of the system several actions were put in place. Firstly, since involving the end-user is the best way to ensure good reception to the system (Williamson et al., 2017), practitioners with extensive experience of working in elite football environments were involved in the development of the FIICCS. This constituted both a strength and a limitation. Indeed, recruiting experts is very difficult and one usually needs to rely on a personal network which might introduce bias because experts in the personal network may have similar beliefs to the beliefs of the recruiters (Hasson et al., 2000). Another limitation is that to allow the project to be manageable only a small number of experts could be included. Managing the project with 12 experts has been very time demanding and has required a great amount of administrative work (e.g., reminders, personalised e-mails, meeting organisation), therefore a larger group may have extended the duration of the project which could have resulted in an increased number of experts leaving the project with consequent increased risk of attrition bias. Finally, the NGT protocol had to be adapted to limit time burden on the panel.

Secondly, to increase the usability of the FIICCS the system was split into two levels: a core set and an optional set. This was deemed to be very important to reduce the time burden on football practitioners when they need to fill out the form and, at the same time, to give standard guidelines for more detailed analysis. Interestingly during the online meeting for the development of the system, differences arose between researchers and practitioners. Indeed, practitioners agreed to have a short core-set to limit the time needed to fill the form, while researchers were keener to extend the length of the core set in order to have more information. This reiterates the importance of involving all the key stakeholders in the project. Finally, a report form freely accessible was developed in excel format and published on Open Science Framework. This will facilitate the implementation of the system because it can be easily included in report forms already used in football to report other injury data and could be included in Athlete Management Systems which are becoming more and more popular.

As previously discussed in Chapter 4.4, this project constituted a first attempt to develop a classification system and may need to be updated once it is implemented in the real world, as occurred for other classification systems (Clarsen et al., 2020; Finch & Cook, 2014). For example, while the system was used in study three it became clear that reporting only the acceleration intensity or the running speed may not be the best option because it is probably not possible to say with precision if the injury occurred while players were accelerating or decelerating (considering the 2 m/s^2 threshold) or not because it is very difficult to evaluate the exact time of injury. Therefore, it may be better to report both the peak speed and the peak acceleration recorded during the inciting circumstance, without trying to evaluate the speed at the exact time of injury unless future studies provide a method to allow the exact time of injury to be identified. Other observations may arise from a more extensive use of the system, hence why the report form was updated and is accessible on an online platform (Open Science Framework) which allows those not involved in the development of the FIICCS to provide feedback which can be used in a future update of the system.

Following the development of the system, three main questions arise about whether it will fulfil its aims or not. The first question concerns the reliability of the system which needs to be evaluated. The aim of the FIICCS was to standardise the reporting of inciting circumstances to allow the provision of information for the development of prevention strategies. But if it shows low reliability the aim will not be achieved. Preliminary implementations of the FIICCS are promising in term of reliability. During study three the system was used by two people and no disagreement arose, and during preliminary tests of the medical coding of the FIFA Football Language (which incorporates all the parts of the FIICCS) the analysts reported good reliability (inter-rater reliability >90%). Clearly these data are preliminary and more robust evaluations are needed.

The second question concerns whether football teams and researchers will use the system. Hopefully the involvement of practitioners with extensive experience in football, the involvement of the key figures in football injuries (i.e., medical doctors, injury researchers, physiotherapists, sport scientists, and S&C coaches) and the availability of the system in excel format will help the dissemination of the system. The inclusion of the system in the medical coding of the FIFA Football Language and in the football extension of the International Olympic Committee consensus on methods for recording and reporting of epidemiological data on injury and illness in sport, will probably further help the dissemination of the system, which is of course key to standardising the reporting of the injury inciting circumstances. Additionally, researchers are provided with the optional set to collect more information, and further sets can be developed according to study aims.

The third main question concerns the possibility of using the system to analyse rare injuries. Indeed, aside for hamstring (which have a relatively high incidence (Ekstrand et al., 2016)) and ACL injuries (which could be analysed without direct access to medical data (Hoenig et al., 2022; Krutsch et al., 2020)), the small incidence of the other injuries makes it difficult to analyse a large number of injuries using data from a single team. Collecting data during multiple seasons as done in study three may be an option although it's unclear whether this would work. Indeed, even if data collected during three seasons were analysed in study three, less than 15 injuries occurred to the adductors, calves, quadriceps, and ankles (considering both sudden and gradual onset injuries) and the only study that I am aware of which analysed a great number of rare injuries (i.e., quadriceps) required data collected over nine years (Geiss Santos et al., 2022). This clearly doesn't seem optimal, because in the meantime practitioners and researchers will have very limited information on the inciting circumstances to inform practice.

A possible solution to this difficulty could be to conduct multicentre studies involving multiple football teams. This requires clubs not only to use the same system to report injuries but also to share such data (after anonymisation). Some clubs may be reluctant to share their data therefore this may be difficult, however it could be feasible if such projects are conducted by governing bodies such as UEFA, FIFA, or national football federations. For example, the UEFA conducts periodic injury studies using data shared from some of the most influential football clubs in the world and FIFA has conducted injury surveillance studies over international tournaments (Ekstrand, 2019; Junge & Dvorak, 2013). Other multicentre studies have been conducted in the USA using national databases (Cross et al., 2013), which allowed the analysis of more than 500 hamstring injuries.

In my opinion, retrospective analyses as the one conducted in study three are not practical due to the time needed to organise data location, data transfer, and the identification of the inciting events on video. Multicentric studies of data collected prospectively could be a valid alternative and could allow the analysis of a sufficient number of injuries to obtain clear information about inciting circumstances. For example, this could be achieved with governing bodies asking clubs to collect data concerning the inciting circumstances using pre-determined report forms and then to share with the governing bodies, which would collate the information and produce periodic reports.

The inclusion of GPS data has been a novel approach in the analysis of inciting circumstances. All things considered, the results of the systematic review supported the hypothesis that hamstring injuries predominantly occur during high-speed activities. However, the description of “high-speed” for all injuries was subjective and quite generic, especially considering that some studies in the literature define any run performed above 15 km/h as high-speed running (Teixeira et al., 2021). Therefore, despite the conduction of a systematic review, providing clear information about the inciting activities of running injuries was still difficult. Providing this information seems particularly important given that in the past decade football coaches have been using small-sided games to stimulate physical adaptations in football which do not expose players to high peak velocities (Castagna et al., 2017; Clemente & Sarmento, 2021; Kyprianou et al., 2022). Therefore, knowing that injuries occur at high velocities could guide practitioners to adapt their training programmes. For example, if injuries occur during high-speed activities practitioners who use predominantly small-sided games during training could decide to include other running drills in order to increase players' exposure to high velocities (McCall et al., 2020a).

Given the importance of providing this information, the use of Electronic Performance & Tracking Systems such as GPS to evaluate the running activities seems important, although including these data in the analysis adds some difficulties. As seen in study three, including GPS data in the analysis may reduce the number of injuries analysed due to missing data. In study three GPS data were not available either because players had forgotten to wear the pods or because the data were collected using a different provider and were not accessible anymore by the club. To the best of my knowledge the issue of players not wearing GPS has not been investigated, but other studies have reported missing training load data (Bowen et al., 2020; Malone et al., 2017b; McCall et al., 2018). Given the growing interest in data analysis in sport (Fiscutean, 2021; Harper, 2021) it is likely that more attention will be paid to ensure that training data are constantly and appropriately collected and stored.

The issue of old GPS data not being accessible is well known in the field (Buchheit & Simpson, 2017) and the solution appears to be that clubs stick with their providers, but of course this cannot be guaranteed. However, if the analysis of inciting circumstances is performed within a few hours or days after the injuries occur, this will not be an issue anymore since clubs usually change provider at the end of the season.

The barriers which hamper the use of GPS for the analysis of inciting circumstances may be overcome, however the limitations of the tool must be considered when data are interpreted. Given the difficulties of identifying the exact time of injury, it is not possible to be completely confident in the evaluation of the exact activity (i.e., running speed, acceleration or deceleration intensity) which led to the injury, therefore peak or average values need to be used. This and the limitations about data accuracy discussed in Chapter 5.1 suggest that data collected with GPS must be interpreted carefully. Taking hamstring injuries as an example, in study three it was reported that all hamstring injuries occurred when players were running at or decelerating from a speed > 25 km/h. This must not be taken as a cut off (i.e., no hamstring injuries occur when running at < 25 km/h) but as a general indication that hamstring injuries seem to occur during activities where a velocity of around or above 25 km/h is achieved. This is particularly true when considering acceleration data. Indeed, acceleration data are calculated and filtered by the manufacturer software using different techniques (e.g., exponential filters, moving average, and median) which influence the derived data (Malone et al., 2017a). Therefore, including GPSs in the analysis of inciting circumstances can provide important information which needs to be interpreted considering the limitations of the tool.

A final consideration about the methods for the analysis of the inciting circumstance concerns the involvement of the injured players in the analysis of inciting circumstances. Players are usually involved in the diagnosis of the injury (e.g., location, injury onset), but to the best of my knowledge the practice of reviewing the video of the inciting event with the player is not implemented in football. This practice has been introduced in injury research by Serner et al. (2019) and in my opinion it may be interesting to integrate into football practice. Firstly, if players are able to identify with good precision the moment of injury, this method would provide additional detail on the inciting activity (e.g., running phase, kicking phase) which as discussed in the literature review would be very useful for the analysis of injury mechanisms and the development of prevention strategies. Secondly, such information might be considered when developing tailored return to play protocols. For example, if an injury occurred during kicking, specifically when the kicking leg contacts the ball, the practitioners responsible for the rehabilitation process might decide to focus part of the return to play protocol on that specific activity to increase players' confidence and reduce fear of re-injury, which are important criteria for return to play (Dunlop et al., 2020; Zambaldi et al., 2017). Since training and matches are routinely video recorded for technical/tactical purposes, including the review of the inciting event would not require additional data collection.

Despite this type of review of the inciting event with the players not requiring additional data collection, some other elements need to be considered. For example, reviewing the video of the injury might expose players to psychological stress, especially if the injury is severe or recurrent. To the best of my knowledge this has never been investigated, therefore it cannot be excluded. Furthermore, although data are already collected, this practice would require time (although very limited), which given the limited time practitioners have may discourage its use. Finally, clubs may be reluctant to involve players in non-essential activities. While study three was being planned it was proposed to conduct it prospectively and involve players in the video-analysis of the inciting event, as similarly done by Serner et al. (2019). This would have involved the injured players, a sports medicine practitioner as well as me as the researcher. However, the club was reluctant to involve players in this practice hence this idea was discarded. No reasons were given for this reluctancy, but it may be speculated that this is linked to the importance football players have within clubs. Indeed, players are the most important asset of clubs and more than 60% of football clubs' expenses are due to player salaries and investments in player transfers (Deloitte Sports Business Group, 2020; Ingle, 2019; Ozanian, 2019; Sporting Intelligence, 2019). Clearly, players play a key role in the success of the club, therefore great caution is taken when dealing with them. From the experience of study three, players seemed collaborative in giving information about the inciting event, although care was taken to approach them at the right moment (i.e., not after a match loss or during a stressful period). It is unknown whether players would be keen to participate in this analysis and if they'd be able to identify with precision the time of injury, but given the experience of Serner et al. (2019) and of study three this may be possible and in my opinion is something worth investigating.

6.5 Limitations of the Thesis

The main limitations of the thesis are connected with the design of the studies, the nature of the literature, and the adjustments made to deal with the circumstances of this project (e.g., collaborating with elite football clubs, involving expert practitioners, COVID-19 pandemic).

The systematic review was conducted following the most recent guidelines for systematic reviews (PRISMA 2020 and AMSTAR 2) and the research team included experts in conducting systematic reviews and in conducting research on inciting circumstances. The main limitation of the review consists in the arbitrary categorisation of the inciting activities reported by the studies included, which was necessary due to the high heterogeneity of reporting. The high risk of bias observed in the definition of injuries and the analysis and reporting of inciting activities likely influenced the results of the review. Another limitation is that information about the inciting circumstances is usually reported in the full text without being cited in the title or abstract. To deal with this problem a very comprehensive search strategy was implemented, but it is possible that some studies which reported inciting activities in football were not included in the review. However, it is very likely that the limitations observed in the included studies (i.e., heterogeneous reporting of inciting activities) would have been observed in other studies, therefore the exclusion of some studies likely did not influence significatively the quality of the systematic review.

The nominal group technique used for the development of the FIICCS followed the COMET guidelines, but some adaptations needed to be made to allow the involvement of practitioners working in elite football. The first draft of the system was developed by the steering committee following the results of the systematic review instead of being developed by the panel. For the same reason panellists needed to be recruited from the network of the steering committee, which might have introduced some bias. Given the small number of panellists involved in the development of the FIICCS, it might be that the inclusion of different experts may have led to a different system. However, this system does not intend to be definitive, but it is just a first attempt to standardise the analysis and reporting of the inciting circumstances and it is acknowledged that it may change following its implementation in the “real world”.

Due to time and resource limitations, the FIICCS was tested only on a small number of injuries, and players were not always included in the analysis. The results on the inciting circumstances obtained from study three need to be interpreted carefully due to the novelty of the method used and to the high number of missing data. Additionally, from a dynamic ecological perspective an injury in football can be seen as the result of a complex interaction between the player and the environment. Players' movement patterns and decisions are influenced by environmental factors such as other players in the field and the state of the game (Bittencourt et al., 2016; Bolt et al., 2021). However, the results reported in this thesis reflect only the inciting circumstances and do not consider the interaction of such factors with other factors of the complex system, which constitutes a further limitation.

6.6 Implications for future research

Future research should further evaluate whether the football medicine staff will use the FIICCS to report inciting circumstances and, if they do not, an evaluation of how its implementation can be supported is encouraged. Further studies should evaluate the reliability of the system. Following recommendations from Bahr et al. (2020), other sport-specific classification systems should be developed for the reporting of inciting circumstances and additional optional sets may be developed for specific injuries (e.g., ACL, adductors). Future studies which aim to investigate inciting circumstances in football can use the FIICCS as a guideline which will lead to standardised reporting and will make it easier to interpret the results and use them for the development of prevention strategies. Governing bodies may decide to include this system in their guidelines for reporting information on inciting circumstances and may conduct multicentric studies.

The use of Electronic Performance & Tracking Systems such as GPS seems feasible and gives extensive information on the inciting activities. Further studies should be performed using this methodology to evaluate the running speed at which certain injuries (e.g., hamstring, quadriceps) occur. This will provide important information for the development of prevention strategies and for the investigation of injury mechanisms and risk factors.

Despite the limitations of the available literature and of the studies presented in this thesis, the information concerning the inciting circumstances provided in this thesis can be used (with caution) to develop prevention strategies to test. It will be important to account for the limitations discussed in the thesis and be careful about the confidence and the communication of strategies developed on the basis of such information.

Last but not the least, this project highlighted once more the difficulties encountered by researchers when trying to summarise the literature on injury and to provide guidelines or recommendations to practitioners. The low quality of data concerning injuries in football has been reported several times (Alahmad et al., 2020; Diemer et al., 2021; Jones et al., 2019; Lopez-Valenciano et al., 2019; Pfirrmann et al., 2016), but to the best of my knowledge little has been done so far to improve the quality of data. Hopefully this project will contribute to improving the report of some aspects of injuries, but more work is still needed to improve the general reporting of injury data.

7 Conclusions

The findings of this thesis show that there are important limitations on how inciting circumstances leading to injury in football are analysed and reported. To overcome such limitations a standardised classification system was developed together with injury researchers and football practitioners. It seems that the system can be used in football to collect and report data on inciting circumstances which can be used to develop injury prevention strategies.

From this thesis it seems that ACL injuries occur during non-contact circumstances, but providing a more detailed description of the inciting circumstances is difficult with the literature currently available. Hamstring injuries seem to occur mostly during running activities during which players achieve a peak speed > 25 km/h. Kicking seems to be the most common activity leading to quadriceps injuries. Kicking may also lead to hip-groin injuries, together with controlling the ball, decelerating, and changing direction. Running and landing might be the most common inciting activities leading to calf injuries, while contact activities such as being tackled and tackling seem to be the most common inciting activities leading to ankle injuries.

These results must be interpreted carefully due to the limitations of the literature and the limited number of injuries analysed in this project. Further studies need to be conducted ideally involving multiple football clubs. Guidelines for doing so have been developed and discussed in this thesis.

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Appendix A: Tool to assess [redacted]

N.	Item description	Criteria	How the item can influence the results	Examples
			Internal validity	
4	Were data collected directly from the participants (as opposed to a proxy)?	Injury data must directly come from players or staff (i.e., not coming from databases or internet sources)	Data coming from databases or internet sources may come from untrustworthy sources and have been reported or collected with various and inappropriate methods. This may afflict data reliability and therefore study results.	• Data were collected by team doctor during team training and matches: Yes (Low Risk of Bias) • Data were collected from online databases: No (High Risk of Bias)
5	Was an acceptable case definition used in the study?	Injury definition must be acceptable, clearly stated and justified by a validation reference (e.g. Fuller 2006).	An unclear or inappropriate case definition may influence the number of cases and therefore the prevalence of each mechanism	• Following the guidelines reported by Fuller et al., (2006), injuries were defined as any physical complaint sustained by a player that resulted from a football game or training session and led to them being unable to take a full part in future football training or match play: Yes (Low Risk of Bias) • As previously done in other studies, injuries were defined as any physical complaint sustained by a player that resulted from a football game or training session: Partially (Medium Risk of Bias) • Injuries were defined as receiving medical treatment on the pitch: N (High Risk of Bias) • Injury definition is not reported: U (High Risk of Bias)
6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	Activities of injury must have been analysed through video analysis and classified using a standardised system (e.g., FIA)	The usage of non-validated methods to evaluate injury activities may limit validity of the results and afflict prevalence of mechanisms	• Injury activities were evaluated through video-analysis and classified using a standardised classification system: Yes (Low Risk of Bias) • Injury activities were evaluated through video-analysis: Partially (Medium Risk of Bias) • Injury activities were evaluated through report/questionnaires: No (High Risk of Bias)

7	Was the same mode of data collection used for all participants?	Data related to injuries must have been collected through the same mode for all the participants	The usage of different methods to collect injury data may alter injury prevalence	• Injury activities were evaluated through report only: Yes (Low Risk of Bias) • Injury activities were evaluated through video-analysis and report. Data obtained through each method are reported separately in table: Partially (Medium Risk of Bias) • Injury activities were evaluated through video-analysis and, when video clip were not available, data were obtained by medical reports: No (High Risk of Bias) • Injury activities were evaluated through report and video-analysis: Unclear (High Risk of Bias)
8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	At least 1 entire season or 1 entire tournament should have been analysed	An inappropriate length of prevalence/observation period may bias injury prevalence	• Data were collected during 2 seasons: Yes (Low Risk of Bias) • Data were collected during 10 matches: No (High Risk of Bias) • The study does not indicate the length of observation period: Unclear (High Risk of Bias)
9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Appropriate numerator (number of injuries for a given mechanism) and denominator (total number of injuries) should have been reported. If percentages are reported without reporting the numerator, score as "unclear".	An unclear reporting of numerators and denominators may limit the understanding of prevalence	• In total, 100 injuries occurred. 20 injuries occurred while running, 10 occurred while kicking, etc: Yes (Low Risk of Bias) • In total, 100 injuries occurred. 20 % of total injuries occurred while running, 10 % occurred while kicking, etc: Partially (Medium Risk of Bias) • The study does not indicate the length of observation period: Unclear (High Risk of Bias)

Appendix B: List of full texts excluded from the Systematic Review with reason (n = 142)

Title	Authors	Year	Reason of exclusion
A 15-year prospective epidemiological account of acute traumatic injuries during official professional soccer league matches in Japan	H. Aoki; N. O'Hata; T. Kohno; T. Morikawa; J. Seki	2012	Inciting activities not reported
A comparative analysis of injuries in handball, hockey, volleyball and soccer in kenya	M. Wekesa; W. W. Njororai; E. L. Madaga; J. M. Asembo	2001	Unable to access
A Decade of Hip Injuries in National Collegiate Athletic Association Football Players: An Epidemiologic Study Using National Collegiate Athletic Association Surveillance Data	J. L. Makovicka; A. Chhabra; K. A. Patel; S. V. Tummala; D. E. Hartigan	2019	Other sport
A four year prospective study of injuries in elite Ontario youth provincial and national soccer players during training and matchplay	M. Mohib; N. Moser; R. Kim; M. Thillai; R. Gringmuth	2014	Inciting activities not reported
A one year prospective study of soccer injuries in the 1992-1993 Kenyan national team	M. Wekesa	1995	Unable to access
Analysis of injury incidences in the Korea national men's soccer teams	K. Hwang-Bo; C. H. Joo	2019	Inciting activities not reported
Analysis of injury incidences in the Korea national men's soccer teams	K. Hwang-Bo; C. H. Joo	2019	Inciting activities not reported
Ankle injuries among United States high school sports athletes, 2005-2006	A. J. Nelson; C. L. Collins; E. E. Yard; S. K. Fields; R. D. Comstock	2007	Mixed population
Ankle injuries in football academies: a three-centre prospective study	D. J. Cloke; P. Ansell; P. Avery; D. Deehan	2011	Inciting activities not reported
Ankle sprain in athletes: retrospective study	M. F. Pedrini; F. Petraglia; O. Licari; C. Costantino	2013	Inciting activities not reported
Anterior cruciate ligament injury in elite football: a prospective three-cohort study	M. Walden; M. Hagglund; H. Magnusson; J. Ekstrand	2011	Inciting activities not reported
Anterior cruciate ligament injury in female athletes: Epidemiology	M. L. Ireland	1999	Review
Anterior cruciate ligament injury patterns and their relationship to fatigue and physical fitness levels - a cross-sectional study	S. F. Alsubaie; W. K. Abdelbasset; A. A. Alkathiry; W. M. Alshehri; M. M. Azyabi; B. B. Alanazi; A. A. Alomereni; F. Y. Asiri	2021	Population
Aspects on musculo-skeletal trauma incidence in competitive sportsmen. A comparative study of athletes and football players - part ii	M. Elena-Doina; M. Alexandra	2012	Other sport

Association between ball-handling versus defending actions and acute noncontact lower extremity injuries in high school basketball and soccer	S. M. Monfort; R. D. Comstock; C. L. Collins; J. A. Onate; T. M. Best; A. M. Chaudhari	2015	Inciting activities not reported
Avoidance of soccer injuries with preseason conditioning	R. S. Heidt, Jr.; L. M. Sweeterman; R. L. Carlonas; J. A. Traub; F. X. Tekulve	2000	Inciting activities not reported
Boys soccer league injuries: a community-based study of time-loss from sports participation and long-term sequelae	T. Timpka; O. Risto; M. Bjormsjo	2008	Inciting activities not reported
Changes in injury incidences and causes in Swiss amateur soccer between the years 2004 and 2015	A. Gebert; M. Gerber; U. Puhse; O. Faude; H. Stamm; M. Lamprecht	2018	Inciting activities not reported
Comparative sport injury epidemiological study on a Spanish sample of 25 different sports	C. Pujals; V. J. Rubio; M. O. Marquez; I. Sanchez; R. Ruiz-Barquin	2016	Inciting activities not reported
Descriptive epidemiology of collegiate men's soccer injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2002-2003	J. Agel; T. A. Evans; R. Dick; M. Putukian; S. W. Marshall	2007	Inciting activities not reported
Descriptive epidemiology of collegiate women's soccer injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2002-2003	R. Dick; M. Putukian; J. Agel; T. A. Evans; S. W. Marshall	2007	Inciting activities not reported
Descriptive Epidemiology of Soccer Injury During Elite International Competition in Africa	A. Nuhu; M. Kutz	2017	Inciting activities not reported
English Premiership Academy knee injuries: Lessons from a 5 year study	O. Moore; D. Cloke; P. Avery; I. Beasley; D. Deehan	2011	Inciting activities not reported
Epidemiologic study of young soccer player's injuries in U12 to U20	C. Tourny; S. Sangnier; T. Cotte; R. Langlois; J. Coquart	2014	Inciting activities not reported
Epidemiological Findings of Soccer Injuries During the 2017 Gold Cup	J. Chahla; B. Sherman; M. Cinque; A. Miranda; W. E. Garrett; G. Chiampas; H. O'Malley; M. B. Gerhardt; B. R. Mandelbaum	2018	Inciting activities not reported
Epidemiological Patterns of Ankle Sprains in Youth, High School, and College Football	D. R. Clifton; R. M. Koldenhoven; J. Hertel; J. A. Onate; T. P. Dompier; Z. Y. Kerr	2017	Other sport
Epidemiological profile of sports-related knee injuries in northern India: An observational study at a tertiary care centre	R. John; M. S. Dhillon; K. Syam; S. Prabhakar; P. Behera; H. Singh	2016	Inciting activities not reported
Epidemiology of 10,000 high school football injuries: patterns of injury by position played	M. A. Badgeley; N. M. McIlvain; E. E. Yard; S. K. Fields; R. D. Comstock	2013	Other sport
Epidemiology of anterior cruciate ligament injuries in soccer	J. M. Bjordal; F. Arnly; B. Hannestad; T. Strand	1997	Inciting activities not reported

Epidemiology of Anterior Cruciate Ligament Injury in Italian First Division Soccer Players	A. Grassi; L. Macchiarola; M. Filippini; G. A. Lucidi; F. Della Villa; S. Zaffagnini	2019	Inciting activities not reported
Epidemiology of Anterior Cruciate Ligament Injury in Italian First Division Soccer Players	A. Grassi; L. Macchiarola; M. Filippini; G. A. Lucidi; F. Della Villa; S. Zaffagnini	2020	Inciting activities not reported
Epidemiology of football injuries in Asia: a prospective study in Qatar	C. Eirale; A. Farooq; F. A. Smiley; J. L. Tol; H. Chalabi	2013	Inciting activities not reported
Epidemiology of Football Injuries in the National Collegiate Athletic Association, 2004-2005 to 2008-2009	Z. Y. Kerr; J. E. Simon; D. R. Grooms; K. G. Roos; R. P. Cohen; T. P. Dompier	2016	Other sport
Epidemiology of Hip and Groin Injuries in Collegiate Athletes in the United States	Y. E. Kerbel; C. M. Smith; J. P. Prodromo; M. I. Nzeogu; M. K. Mulcahey	2018	Inciting activities not reported
Epidemiology of injuries in First Division Spanish football	J. Noya Salces; P. M. Gómez-Carmona; L. Gracia-Marco; D. Moliner-Urdiales; M. Sillero-Quintana	2014	Inciting activities not reported
Epidemiology of Injuries in First Division Spanish Women's Soccer Players	R. Martín-San Agustín; F. Medina-Mirapeix; A. Esteban-Catalán; A. Escriche-Escuder; M. Sánchez-Barbadora; J. C. Benítez-Martínez	2021	Inciting activities not reported
Epidemiology of injury in English Professional Football players: A cohort study	A. Jones; G. Jones; N. Greig; P. Bower; J. Brown; K. Hind; P. Francis	2019	Inciting activities not reported
Epidemiology of meniscal injuries in US high school athletes between 2007 and 2013	J. Mitchell; W. Graham; T. Best; C. Collins; D. Currie; R. Comstock; D. Flanigan; T. M. Best; D. W. Currie; R. D. Comstock; D. C. Flanigan	2016	Inciting activities not reported
Epidemiology of Muscle Injuries in Professional Football (Soccer)	J. Ekstrand; M. Hägglund; M. Waldén	2011	Inciting activities not reported
Epidemiology of physical activity-related injuries in Chinese university students	W. Cai; L. Gao; L. Li; Y. Gao; C. Jia; W. Yang; S. Duan; H. Zhang	2019	Inciting activities not reported
Epidemiology of player--player contact injuries among US high school athletes, 2005-2009	Z. Y. Kerr; C. L. Collins; S. K. Fields; R. D. Comstock	2011	Inciting activities not reported
Epidemiology of Quadriceps Strains in National Collegiate Athletic Association Athletes, 2009-2010 Through 2014-2015	T. G. Eckard; Z. Y. Kerr; D. A. Padua; A. Djoko; T. P. Dompier	2017	Inciting activities not reported
Epidemiology of soccer players traumatic injuries during the 2015 America Cup	O. Pangrazio; F. Forriol	2016	Inciting activities not reported
Epidemiology of time loss groin injuries in a men's professional football league: a 2-year prospective study of 17 clubs and 606 players	A. B. Mosler; A. Weir; C. Eirale; A. Farooq; K. Thorborg; R. J. Whiteley; P. Hlmich; K. M. Crossley	2018	Inciting activities not reported

Evaluating the level of injury in English professional football using a risk based assessment process	S. Drawer; C. W. Fuller	2002	Data used in another study included
Evaluation of Muscle Injuries in Professional Football Players: Does Coach Replacement Affect the Injury Rate?	G. Donmez; S. Kudas; M. Yorubulut; M. Yildirim; N. Babayeva; S. S. Torgutalp	2018	Inciting activities not reported
Exposure to injury in major college football. A preliminary report of data collection to determine injury exposure rates and activity risk factors	B. R. Cahill; E. H. Griffith	1979	Other sport
Football injuries at Asian tournaments	Y. S. Yoon; M. Chai; D. W. Shin	2004	Inciting activities not reported
Football injuries during European Championships 2004-2005	M. Walden; M. Hagglund; J. Ekstrand	2007	Inciting activities not reported
Football injuries during the 2014 FIFA World Cup	A. Junge; J. Dvorak	2015	Inciting activities not reported
Football injuries during the World Cup 2002	A. Junge; J. Dvorak; T. Graf-Baumann	2004	Inciting activities not reported
Football injuries on synthetic turf fields	S. Akkaya; M. Serinken; N. Akkaya; I. Turkcuer; E. Uyanik	2011	Inciting activities not reported
Foul play is associated with injury incidence: an epidemiological study of three FIFA World Cups (2002-2010)	J. Ryynanen; A. Junge; J. Dvorak; L. Peterson; H. Kautiainen; J. Karlsson; M. Borjesson	2013	Inciting activities not reported
Gender differences in sport injury risk and types of inju-ries: a retrospective twelve-month study on cross-country skiers, swimmers, long-distance runners and soccer players	L. Ristolainen; A. Heinonen; B. Waller; U. M. Kujala; J. A. Kettunen	2009	Inciting activities not reported
Gender-specific differences in school sports injuries	J. Kelm; F. Ahlhelm; K. Anagnostakos; W. Pitsch; E. Schmitt; T. Regitz; D. Pape	2004	Mixed population
Gradual increase in the risk of match injury in Norwegian male professional football: A 6-year prospective study	J. Bjorneboe; R. Bahr; T. E. Andersen	2014	Inciting activities not reported
Harmful association of sprinting with muscle injury occurrence in professional soccer match-play: A two-season, league wide exploratory investigation from the Qatar Stars League	W. Gregson; V. Di Salvo; M. C. Varley; M. Modonutti; A. Belli; K. Chamari; M. Weston; L. Lolli; C. Eirale	2020	Inciting activities not reported
High school football injuries: field conditions and other factors	B. L. Andresen; M. D. Hoffman; L. W. Barton	1989	Unable to access
Illness and Injuries in Elite Football Players-A Prospective Cohort Study During the FIFA Confederations Cup 2009	N. Theron; M. Schwellnus; W. Derman; J. Drovak	2013	Inciting activities not reported

Impairment of Sprint Mechanical Properties in an Actual Soccer Match: A Pilot Study	R. Nagahara; J. B. Morin; M. Koido	2016	Did not analyse injury
Incidence and characteristics of injuries during the 2011 West Africa Football Union (WAFU) Nations' Cup	A. K. Akodu; O. B. Owoeye; M. Ajenifuja; S. R. Akinbo; F. Olatona; O. Ogunkunle	2012	Inciting activities not reported
Incidence and Descriptive Epidemiology of Injuries to College Ultimate Players	D. I. Swedler; J. M. Nuwer; A. Nazarov; S. C. Huo; L. Malevanchik	2015	Other sport
Incidence and factors associated with injuries among adolescent players in an amateur soccer tournament in Nigeria	A. Olumide; K. Ajide	2016	Inciting activities not reported
Incidence and Mechanisms of Collegiate Men's Soccer Match Injuries on Artificial Turf Versus Natural Grass	M. C. Meyers	2011	Duplicate
Incidence and risk factors for injuries to the anterior cruciate ligament in National Collegiate Athletic Association football: data from the 2004-2005 through 2008-2009 National Collegiate Athletic Association Injury Surveillance System	J. L. Dragoo; H. J. Braun; J. L. Durham; M. R. Chen; A. H. Harris	2012	Other sport
Incidence of Football and Futsal Injuries Among Youth in Malaysian Games 2018	A. H. Ahmad-Shushami; S. Abdul-Karim	2020	Inciting activities not reported
Incidence of football injuries in youth players - Comparison of players from two European regions	A. Junge; J. Chomiak; J. Dvorak	2000	Inciting activities not reported
Incidence of Popular Ball Game Injuries in Indian Pre and Post Adolescent Boys	J. Sen	2005	Mixed population
Injuries among spanish male amateur soccer players: a retrospective population study	H. Herrero; J. J. Salinero; J. Del Coso	2014	Inciting activities not reported
Injuries and illnesses of football players during the 2010 FIFA World Cup	J. Dvorak; A. Junge; W. Derman; M. Schwellnus	2011	Inciting activities not reported
Injuries in amateur soccer players on artificial turf: A one-season prospective study	P. Sousa; A. Rebelo; J. Brito	2013	Inciting activities not reported
Injuries in Austrian football players: Are they an issue?	F. Fischer; C. Hoser; C. Blank; W. Schobersberger; C. Hepperger; P. Gfoller; C. Fink	2019	Other sport
Injuries in elite youth football players: a prospective three-year study	M. Ergun; H. N. Denerel; M. S. Binnet; K. A. Ertat	2013	Inciting activities not reported
Injuries in elite-level women's football-a two-year prospective study in the Irish Women's National League	D. Horan; C. Blake; M. Hägglund; S. Kelly; M. Roe; E. Delahunt	2021	Inciting activities not reported
Injuries in female football players in top-level international tournaments	A. Junge; J. Dvorak	2007	Inciting activities not reported

Injuries in football: risk factors, injury mechanisms, team performance and prevention	A. Arnason	2004	Data used in another study included
Injuries in formal and informal non-professional soccer - an overview of injury context, causes, and characteristics	A. Gebert; M. Gerber; U. Puhse; P. Gassmann; H. Stamm; M. Lamprecht	2018	Recreational participants
Injuries in greek amateur soccer players	G. Tsiganos; D. Sotiropoulos; P. Baltopoulos	2007	Inciting activities not reported
Injuries in Japanese Junior Soccer Players During Games and Practices	K. Kenji; S. Masashi; U. Ryo	2017	Inciting activities not reported
Injuries in Portuguese Amateur Youth Football Players: A Six Month Prospective Descriptive Study	M. Nogueira; R. Laiginhas; J. Ramos; O. Costa	2017	Inciting activities not reported
Injuries in Portuguese Youth Soccer Players During Training and Match Play	J. Brito; R. M. Malina; A. Seabra; J. L. Massada; J. M. Soares; P. Krustrup; A. Rebelo	2012	Inciting activities not reported
Injuries in professional male football players in Kosovo: a descriptive epidemiological study	I. Shalaj; F. Tishukaj; N. Bachl; H. Tschan; B. Wessner; R. Csapo	2016	Inciting activities not reported
Injuries in soccer	W. C. McMaster; M. Walter	1978	Inciting activities not reported
Injuries in Spanish female soccer players	J. Del Coso; H. Herrero; J. J. Salinero	2018	Inciting activities not reported
Injuries of veteran football (soccer) players in Germany	D. Hammes; K. Aus Der Funten; S. Kaiser; E. Frisen; J. Dvorak; T. Meyer	2015	Inciting activities not reported
Injury characteristics in the German professional male soccer leagues after a shortened winter break	K. aus der Funten; O. Faude; J. Lensch; T. Meyer	2014	Inciting activities not reported
Injury epidemiology in a national football team of the Middle East	C. Eirale; B. Hamilton; G. Bisciotti; J. Grantham; H. Chalabi	2012	Inciting activities not reported
Injury evaluation of the Turkish national football team over six consecutive seasons	B. Bayraktar; C. Dinc; I. Yucesir; A. Evin	2011	Inciting activities not reported
Injury in elite women soccer and national women soccer in the lower extremity	E. Blasco; A. Paredes; C. Monleon; M. Martin; M. Fargueta; L. Elvira	2018	Inciting activities not reported
Injury incidence and injury patterns in professional football: the UEFA injury study	J. Ekstrand; M. Hagglund; M. Walden	2011	Inciting activities not reported
Injury incidence in a spanish sub-elite professional football team: a prospective study during four consecutive seasons	J. Mallo; P. Gonzalez; S. Veiga; E. Navarro	2011	Inciting activities not reported
Injury mechanisms in a Mexican soccer team	S. Echegoyen; C. Rodriguez	1998	Abstract only
Injury patterns in professional arena football	M. A. Herbenick; J. S. King; G. Altobelli; B. Nguyen; L. Podesta	2008	Other sport

Injury patterns in selected high school sports: a review of the 1995-1997 seasons	J. W. Powell; K. D. Barber-Foss	1999	Inciting activities not reported
Injury prevalence, types and anotomical localizations in elite football players	T. C. Akalin; M. Goktepe; M. Gumus; K. Gokdemir; M. E. Ciplak; B. Emektar	2020	Inciting activities not reported
Injury Prevalence, Types and Mechanisms in Football: A Media-based Approach	R. M. Musa; I. Hassan; M. R. Abdullah; M. N. L. Azmi; S. M. Mat-Rasid	2019	Inciting activities not reported
Injury Profile in a Brazilian First-Division Youth Soccer Team: A Prospective Study	L. G. Cezarino; B. L. da Silva Grüninger; R. S. Silva	2020	Inciting activities not reported
Injury Profile in a Brazilian First-Division Youth Soccer Team: A Prospective Study	L. G. Cezarino; B. L. D. Gruninger; R. S. Silva	2020	Inciting activities not reported
Injury Profile in Swedish Elite Floorball	U. Tranaeus; E. Gotesson; S. Werner	2016	Other sport
Injury Profile of Elite Male Young Soccer Players in a Spanish Professional Soccer Club: A Prospective Study During 4 Consecutive Seasons	J. Raya-Gonzalez; L. Suarez-Arrones; A. Navandar; C. Balsalobre-Fernandez; E. Saez de Villarreal	2019	Inciting activities not reported
Injury Profile of Elite Male Young Soccer Players in a Spanish Professional Soccer Club: A Prospective Study During 4 Consecutive Seasons	J. Raya-González; L. Suárez-Arrones; A. Navandar; C. Balsalobre-Fernández; E. Sáez de Villarreal	2020	Inciting activities not reported
Injury risk for goalkeepers in norwegian male professional football	E. Strand; T. Krosshaug; T. E. Andersen	2011	Abstract only
Injury surveillance during a 2-day national female youth football tournament in Kenya	M. Lislevand; T. E. Andersen; A. Junge; J. Dvorak; K. Steffen	2014	Inciting activities not reported
Injury surveillance during a national female youth football tournament in kenya	M. Lislevand; K. Steffen; A. Junge; J. Dvorak; T. E. Andersen	2011	Abstract only
Injury Surveillance in Major League Soccer: A 4-Year Comparison of Injury on Natural Grass Versus Artificial Turf Field	S. P. Calloway; D. M. Hardin; M. D. Crawford; J. M. Hardin; L. J. Lemak; E. Giza; B. Forsythe; Y. Lu; B. H. Patel; D. C. Osbahr; M. B. Gerhardt; B. R. Mandelbaum; W. W. Baldwin	2019	Inciting activities not reported
Injury surveillance in the World Football Tournaments 1998-2012	A. Junge; J. Dvorak	2013	Inciting activities not reported
Injury surveillance survey results from the First Annual Gulf Council Sports Medicine Conference, Abu Dhabi, UAE	J. A. Nyland; B. D. Stocker; D. N. M. Caborn; B. Adkisson; J. A. Brosky	1997	Mixed population
Le lesioni nel calcio. Epidemiologia e meccanismi. / The epidemiology and mechanisms of soccer injuries	F. Latella; G. Serni; P. Aglietti; G. Zaccherotti; P. De Biase	1992	Unable to access
Lunacy revisited - the myth of the full moon: are football injuries related to the lunar cycle?	N. Yousfi; R. N. Rekik; C. Eirale; R. Whiteley; A. Farooq; M. Tabben; S. Gillogly; R. Bahr; K. Chamari	2018	Inciting activities not reported

Mechanisms of injury of the anterior cruciate ligament in soccer players	A. J. Delfico; W. E. Garrett, Jr.	1998	Review
Moderate to severe injuries in football: a one-year prospective study of twenty-four female and male amateur teams	A. Lion; D. Theisen; T. Windal; L. Malisoux; C. Nuhrenborger; R. Huberty; A. Urhausen; R. Seil	2014	Inciting activities not reported
Muscle injuries in the academy of a Spanish professional football club: A one-year prospective study	J. Raya-Gonzalez; L. Suarez-Arrones; J. Larruskain; E. S. de Villarreal	2018	Inciting activities not reported
Natural and synthetic grass. A comparative study on the incidence of muscle injuries for senior athletes	M. Pietro	2019	Inciting activities not reported
Orthopaedics injuries in male professional football players in Brazil: a prospective comparison between two divisions	G. G. Arliani; P. H. S. Lara; D. C. Astur; A. Pedrinelli; J. R. Pagura; M. Cohen	2017	Inciting activities not reported
Orthopedic injuries in a formation of a soccer club	D. A. Carvalho	2013	Inciting activities not reported
Orthopedic injuries in men's professional soccer in brazil: prospective comparison of two consecutive seasons 2017/2016	E. R. de Moraes; G. G. Arliani; P. H. S. Lara; E. H. R. da Silva; J. R. Pagura; M. Cohen	2018	Inciting activities not reported
Physical fitness, injuries, and team performance in soccer	A. Arnason; S. B. Sigurdsson; A. Gudmundsson; I. Holme; L. Engebretsen; R. Bahr	2004	Inciting activities not reported
Predictors of moderate and severe injuries in Italian major leagues soccer teams: results from a cohort study	S. Raimonde; E. Taioli	2007	Inciting activities not reported
Pre-season Fitness Level and Injury Rate in Professional Soccer - A Prospective Study	E. Eliakim; O. Doron; Y. Meckel; D. Nemet; A. Eliakim	2018	Inciting activities not reported
Pre-season injuries in Scottish football: a prospective study	G. M. Mackay; W. S. Hillis	1996	Unable to access
Prospective Evaluation of Injuries occurred during the Brazilian Soccer Championship in 2016	D. C. Netto; G. G. Arliani; E. S. Thiele; M. N. L. Cat; M. Cohen; J. R. Pagura	2019	Written in other language
Prospective evaluation of injuries ocurred during a professional soccer championship in 2016 in sao paulo, brazil	G. G. Arliani; P. H. S. Lara; D. C. Astur; A. Pedrinelli; J. R. Pagura; M. Cohen	2017	Inciting activities not reported
Rapid Posterior Tibial Reduction After Noncontact Anterior Cruciate Ligament Rupture: Mechanism Description From a Video Analysis	A. Grassi; F. Tosarelli; P. Agostinone; L. Macchiarola; S. Zaffagnini; F. Della Villa	2020	Inciting activities not reported
Risk assessment in professional football: an examination of accidents and incidents in the 1994 World Cup finals	R. D. Hawkins; C. W. Fuller	1996	Inciting activities not reported
Risk factors for injuries in elite female soccer players	O. Faude; A. Junge; W. Kindermann; J. Dvorak	2006	Inciting activities not reported
Risk of injury on third-generation artificial turf in Norwegian professional football	J. Bjorneboe; R. Bahr; T. E. Andersen	2010	Inciting activities not reported

Safety of third-generation artificial turf in male elite professional soccer players in Italian major league	R. M. Lanzetti; A. Ciompi; D. Lupariello; M. Guzzini; A. De Carli; A. Ferretti	2017	Inciting activities not reported
Saudi Professional League: A Prospective Study of the Injuries and Illnesses Sustained by Professional Soccer Players During the 2015 - 2016 Season	Q. I. Muaidi	2019	Inciting activities not reported
Soccer Injuries and Recovery in Dutch Male Amateur Soccer Players: Results of a Prospective Cohort Study	A.-M. van Beijsterveldt; K. Steffen; J. H. Stubbe; J. E. Frederiks; I. G. L. van de Port; F. J. G. Backx	2014	Inciting activities not reported
Soccer injury in the lower extremities	P. Wong; Y. Hong	2005	Review
Sports injuries profile of a first division Brazilian soccer team: a descriptive cohort study	G. F. Reis; T. R. Santos; R. C. Lasmar; O. Oliveira Junior; R. F. Lopes; S. T. Fonseca	2015	Inciting activities not reported
Tackle mechanisms and match characteristics in women's elite football tournaments	P. Tscholl; D. O'Riordan; C. W. Fuller; J. Dvorak; A. Junge	2007	Did not analyse injury
Ten-Year Epidemiology of Ankle Injuries in Men's and Women's Collegiate Soccer Players	M. Gulbrandsen; D. E. Hartigan; K. A. Patel; J. L. Makovicka; S. V. Tummala; A. Chhabra	2019	Inciting activities not reported
The epidemiology of ankle injuries occurring in English Football Association academies	D. J. Cloke; S. Spencer; A. Hodson; D. Deehan	2009	Mixed population
The epidemiology of anterior cruciate ligament injury in football (soccer): a review of the literature from a gender-related perspective	M. Walden; M. Hagglund; J. Werner; J. Ekstrand	2011	Review
The Epidemiology of Injuries in Middle School Football, 2015-2017: The Advancing Healthcare Initiatives for Underserved Students Project	Z. Y. Kerr; N. Cortes; J. P. Ambegaonkar; A. M. Caswell; M. Prebble; K. Romm; S. V. Caswell	2019	Other sport
The incidence and nature of injuries sustained on grass and 3rd generation artificial turf: a pilot study in elite Saudi National Team footballers	M. Almutawa; M. Scott; K. P. George; B. Drust	2014	Inciting activities not reported
The influence of match frequency on the risk of injury in professional soccer	J. Vilamitjana; N. Lentini; E. Masabeu	2013	Inciting activities not reported
Time-trends and Inciting activities surrounding ankle injuries in men's professional football: an 11-year follow-up of the UEFA Champions League injury study	M. Walden; M. Hagglund; J. Ekstrand	2013	Inciting activities not reported
Training habits and injuries of masters' level football players: A preliminary report	R. Newsham-West; C. Button; P. D. Milburn; A. Mundermann; G. Sole; A. G. Schneiders; S. J. Sullivan	2009	Inciting activities not reported
UEFA injury study--an injury audit of European Championships 2006 to 2008	M. Hagglund; M. Walden; J. Ekstrand	2009	Inciting activities not reported
Video analysis of causes and mechanism of the ACL injuries in the Iranian professional soccer player	H. Tarmah; N. Rahnama; K. Khayyambashi	2010	Abstract only

Appendix C: PRISMA 2020 Checklist for Systematic Review

Section and Topic	Item #	Checklist item	Location where item is reported (page)
TITLE			
Title	1	Identify the report as a systematic review.	64
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	NA
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	6464
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	64
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	65
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	66
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	66
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they	68

Section and Topic	Item #	Checklist item	Location where item is reported (page)
		worked independently, and if applicable, details of automation tools used in the process.	
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	68
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	68
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	68
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	72
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	75
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	65
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	68
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	75
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	75
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	NA
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	NA
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	72
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	NA
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	76
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	302
Study characteristics	17	Cite each included study and present its characteristics.	77

Section and Topic	Item #	Checklist item	Location where item is reported (page)
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	314
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	104
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	314
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	NA
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	110
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	NA
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	110
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	NA
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	113
	23b	Discuss any limitations of the evidence included in the review.	122
	23c	Discuss any limitations of the review processes used.	127
	23d	Discuss implications of the results for practice, policy, and future research.	128
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	65
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	65
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	65
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	NA
Competing interests	26	Declare any competing interests of review authors.	68
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	NA

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71. For more information, visit: http://www.prisma-statement.org/

Appendix D: RoB assessment of the studies included in the Systematic Review

	N.	Item description	Andersen, 2003
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	NA
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	P
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	N
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	Y
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	P

	N.	Item description	Andersen, 2004
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	Y
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	P
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	Y
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	Y
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Andersen, 2004

External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	P
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	P
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Arnason, 1996

External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	Y
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	Y
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	P

	N.	Item description	Arnason, 2004
External validit	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U

	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	N
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	N
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	Y
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Azubuike, 2009
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P

	3	Were missing data addressed with appropriate methods?	P
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	U
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	N
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	P

	N.	Item description	Bastos, 2013
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	P
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	U

Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Bjørneboe, 2014
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	U
Intern al validit	4	Were data collected directly from the participants (as opposed to a proxy)?	N

	5	Was an acceptable case definition used in the study?	N
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	P
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Brophy, 2015
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	NA
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	U

	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	P
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	NA
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Buckthorpe, 2021
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	NA
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	N
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	P

	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Carli, 2021
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	Y
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	NA
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	N
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	P
	7	Was the same mode of data collection used for all participants?	Y

	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	**Item description**	**Carling, 2010**
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	P
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	P
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y

	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Chandran, 2021
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	Y
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Chandran, 2021
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	Y
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Cross, 2013
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	P

	N.	Item description	Cross, 2018
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	Y
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	P

	N.	Item description	de Freitas Guina Fachina, 2013

External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	P
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Della Villa, 2020
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U

	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	P
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	U
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	P
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	DiStefano, 2018
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	Y
	2	Was the study population clearly specified and defined?	Y

	3	Were missing data addressed with appropriate methods?	P
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Drummond, 2021
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	Y
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	P

Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	U
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Ekstrand, 1983
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	U
Intern al validit	4	Were data collected directly from the participants (as opposed to a proxy)?	Y

	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	P

	N.	Item description	Faude, 2005
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	P
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	Y

	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Faunø, 2006
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	P
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N

	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	NA
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Fitzharris, 2017
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	Y
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	P
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	Y
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y

	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	P

	N.	Item description	Gaulrapp, 2010
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	Y
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y

	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	P

	N.	Item description	Giza, 2003
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	N
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	P
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Grassi, 2017
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	NA
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	U
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	P
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	NA
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Gronwald, 2021
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	U
	3	Were missing data addressed with appropriate methods?	P
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	P
	5	Was an acceptable case definition used in the study?	N
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	P
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Gupta, 2020
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	Y
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	N
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	U
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	P

	N.	Item description	Hassabi, 2010

External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	P
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	N
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Hawkins, 1998
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U

	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	P
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	N
	5	Was an acceptable case definition used in the study?	N
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	P
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	P

	N.	Item description	Hawkins, 1999
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	Y

	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Hawkins, 2001
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	P
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	P

Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Ibikunle, 2019
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	Y
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	U
Intern al validit	4	Were data collected directly from the participants (as opposed to a proxy)?	Y

	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Jacobs, 2012
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	Y
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	Y
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	U

	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Kaneko, 2017
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	U
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N

	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	NA
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Kerr, 2018
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y

	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Khodaee, 2017
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	Y
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y

	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Kittipong, 2013
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	y
	5	Was an acceptable case definition used in the study?	U
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	P

	N.	Item description	Klein, 2020
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	U
	3	Were missing data addressed with appropriate methods?	P
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	P
	5	Was an acceptable case definition used in the study?	N
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	P
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Kofotolis, 2007
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	P
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Krutsch, 2021
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	NA
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	N
	5	Was an acceptable case definition used in the study?	N
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	P
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Lucarno, 2021

External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	NA
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	N
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	P
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Lundblad, 2020
Extern al validit	1	Was the study's target population a close representation of the national target in relation to relevant variables?	Y

	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	P
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	Y
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Lundgårdh, 2019
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	Y

	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	Y
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	P

	N.	**Item description**	**Meyers, 2013**
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	U

Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Meyers, 2017
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	U
Intern al validit	4	Were data collected directly from the participants (as opposed to a proxy)?	Y

	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Nielsen, 1989
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P

	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Nilsson, 2016
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	P
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	Y
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N

	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Rahnama, 2002
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	NA
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	N
	5	Was an acceptable case definition used in the study?	N
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	P
	7	Was the same mode of data collection used for all participants?	Y

	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	N
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Rahnama, 2009
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	U
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	U
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y

	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Ralston, 2020
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	Y
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	Y
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Rochcongar, 2009
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Sentsomedi, 2016
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	Y
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	P
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	U
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Serner, 2019
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	U
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	P
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Steffen, 2007

External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	Y
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Stubbe, 2015
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U

	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	P
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	Y
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Takahashi, 2019
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	P
	2	Was the study population clearly specified and defined?	P

	3	Were missing data addressed with appropriate methods?	P
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	U
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	NA
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Tscholl, 2007
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	P

Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	Y
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	P
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	P

	N.	Item description	Ueblacker, 2015
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	P
Intern al validit	4	Were data collected directly from the participants (as opposed to a proxy)?	Y

	5	Was an acceptable case definition used in the study?	Y
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	P

	N.	Item description	Waldén, 2015
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	P
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P

	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	P
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	NA
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Woods, 2002
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	Y
	3	Were missing data addressed with appropriate methods?	P
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N

	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

	N.	Item description	Yard, 2008
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	Y
	2	Was the study population clearly specified and defined?	P
	3	Were missing data addressed with appropriate methods?	U
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	P
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y

	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	Y
	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	P

	N.	Item description	Zeren, 2005
External validity	1	Was the study's target population a close representation of the national target in relation to relevant variables?	U
	2	Was the study population clearly specified and defined?	NA
	3	Were missing data addressed with appropriate methods?	NA
Internal validity	4	Were data collected directly from the participants (as opposed to a proxy)?	Y
	5	Was an acceptable case definition used in the study?	U
	6	Was the study instrument that measured the parameter of interest shown to have validity and reliability?	N
	7	Was the same mode of data collection used for all participants?	Y
	8	Was the length of the shortest prevalence period for the parameter of interest appropriate?	NA

	9	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Y

Appendix E: Number of injuries by season

	2018-2019	2019-2020	TOTAL
Session			
Training	38	25	63
Match	31	30	61
Type			
Concussion/nerve	1	3	4
Contusion/haematoma	8	4	12
Fractures and Bone stress	12	10	22
Joint and Ligament	23	15	38
Muscle and Tendon	24	23	47
Other	1	0	1
Severity			
Minimal	2	0	2
Mild	9	6	15
Moderate	27	25	52
Severe	31	24	55
Main mechanism			
Overuse	21	16	37
Trauma - Contact	20	19	39
Trauma - Non-Contact	28	20	48
Location			
Head/Neck	**1**	**3**	**4**
Head	1	3	4
Upper limb	**5**	**2**	**7**
Shoulder	1	2	3
Wrist	3	0	3
Hand	1	0	1
Upper body	**3**	**5**	**8**
Trunk	1	3	4
Lower back	2	2	4
Lower limb	**60**	**45**	**105**
Hip/adductors	13	7	20
Glute	1	0	1
Hamstring	11	8	19
Quadriceps	2	5	7
Knee	5	6	11
Calf	5	2	7
Lower leg	1	2	3
Ankle	12	8	20
Foot	10	7	17
Total	**69**	**55**	**124**

Appendix F: Number of injuries identified by injury detail

	IDENTIFIED	NOT IDENTIFIED	TOTAL
Session			
Training	1	13	14
Match	7	18	25
Type			
Concussion/nerve	1	2	3
Contusion/haematoma		4	4
Fractures and Bone stress		4	4
Joint and Ligament	3	12	15
Muscle and Tendon	4	9	13
Other			0
Severity			
Mild	2	4	6
Moderate	4	14	18
Severe	2	13	15
Contact type			
Trauma - Contact	4	15	19
Trauma - Non-Contact	4	16	20
Location			
Head/Neck	**1**	**2**	**3**
Head	1	2	3
Upper limb	**1**	**1**	**2**
Shoulder	1	1	2
Upper body		**1**	**1**
Trunk		1	1
Lower limb	**6**	**27**	**33**
Hip/adductors	1	5	6
Hamstring	2	5	7
Quadriceps		2	2
Knee		5	5
Calf	1	0	1
Ankle	2	6	8
Foot		4	4
Total	**8**	**31**	**39**

Appendix G: Details of injury circumstances of each injury

ID	Location	Physical activity summary	Ball situation summary	Session	Venue	Competition	Score	Drill	Playing phase	Match minute	Minutes played
215	Rectus femoris	Walking	Injured player with ball - Kicking - Passing - Medium intensity - Frontal movement - Ball toward air - Kicking phase unclear - Inside kick - Injured leg with ball	Match	Home	Domestic league	Tie		Off.	11	11
41	Rectus femoris	Running - Linear Run - Steady speed - 18.71 km/h, 1.3 m/s^2	Injured player with ball - Kicking - Shooting - Medium intensity - Frontal leg movement - Kicking phase unclear - Inside kick - Injured leg with ball	Training	Home			Medium-intensity technical drill	Off.	24	24

52	Meniscus	Running - Linear Run - Steady speed - 9.49 km/h, 0.85 m/s^2	Injured player without ball - Teammate with ball	Match	Home	Domestic league	Losing		Off.	28	28
90	LCL	Running - Linear Run - Steady speed - 8.9 km/h, - 0.19 m/s^2	Injured player with ball - Receiving ball - A loose ball - At ground height - With foot - Injured leg without ball	Training	Home			Small-sided game	Def.	56	56
86	Knee	Running - Linear Run - Steady speed - 11.21 km/h, 1.35 m/s^2	Injured player without ball - Other opponent with ball	Match	Home	Int. cup	Tie		Def.	25	25
225	Hamstring	Running - Linear Run - Steady speed - 31.71 km/h, 1.33 m/s^2	Injured player without ball - Loose ball	Match	Away	Int. cup	Winning		Off.	53	53
217	Hamstring	Running - Linear Run - Steady speed - 25.21 km/h, 1.76 m/s^2	Injured player with ball - Running with ball - Dribbling - Injured leg without ball	Match	Away	Domestic league	Losing		Off.	66	20

209	Hamstring	Running - Linear Run - Accelerating - 25.77 km/h, 2.29 m/s^2	Injured player with ball - Receiving ball - A loose ball - At upper body height - With foot - Injured leg with ball	Match	Home	Domestic league	Winning	Def.	86	86
206	Hamstring	Running - Linear Run - Steady speed - 27.07 km/h, 1.73 m/s^2	Injured player without ball - Loose ball	Match	Away	Friendly match	Winning	Def.	55	55
103	Hamstring	Running - Linear Run - Steady speed - 32.29 km/h, 1.31 m/s^2	Injured player without ball - Direct opponent with ball	Match	Away	Domestic league	Winning	Def.	60	60
102	Hamstring	Running - Linear Run - Steady speed - 26.89 km/h, - 1.65 m/s^2	Injured player with ball - Running with ball - Dribbling - Injured leg with ball	Match	Away	Int. cup	Tie	Off.	2	2
99	Hamstring	Running - Linear Run - Accelerating - 25.04 km/h, 2.97 m/s^2	Injured player without ball - Direct opponent with ball	Match	Away	Domestic league	Tie	Def.	25	25

97	Hamstring	Running - Linear Run - Steady speed - 31.12 km/h, 1.69 m/s^2	Injured player without ball - Loose ball	Match	Away	Domestic league	Tie	Off.	66	66
96	Hamstring	Running - Linear Run - Decelerating - 30.69 km/h, -2.41 m/s^2	Injured player without ball - Loose ball	Match	Away	Int. cup	Tie	Off.	25	25
88	Hamstring	Running - Linear Run - Decelerating - 30.83 km/h, -2.07 m/s^2	Injured player without ball - Loose ball	Match	Home	Domestic league	Tie	Def.	9	9
79	Hamstring	Running - Curved run - Steady speed - 27.6 km/h, 0.62 m/s^2	Injured player without ball - Direct opponent with ball	Match	Home	Domestic league	Winning	Def.	42	42
61	Hamstring	Running - Linear Run - Decelerating - 32.17 km/h, -2.62 m/s^2	Injured player with ball - Receiving ball - A loose ball - At ground height - With foot - Injured leg with ball	Match	Away	Domestic league	Tie	Def.	70	70

58	Hamstring	Running - Linear Run - Decelerating - 30.27 km/h, -2.4 m/s^2	Injured player without ball - Loose ball	Match	Away	Int. cup	Winning		Def.	53	53
57	Hamstring	Running - Linear Run - Steady speed - 28.3 km/h, 1.78 m/s^2	Injured player without ball - Direct opponent with ball	Match	Home	Domestic league	Tie		Def.	35	35
56	Hamstring	Running - Linear Run - Accelerating - 25.56 km/h, 2.67 m/s^2	Injured player without ball - Loose ball	Match	Away	Domestic league	Winning		Off.	73	73
55	Hamstring	Jumping - in air	Injured player with ball - Receiving ball - A pass - At upper body height - With foot - Injured leg with ball	Training	Home			Small-sided game	Off.	71	71
9	Hamstring	Running - Linear Run - Steady speed - 32.41 km/h, 1.85 m/s^2	Injured player without ball - Loose ball	Match	Away	Domestic league	Tie		Def.	32	32

80	Foot	Running - Linear Run - Steady speed - 13.18 km/h, 0.68 m/s^2	Injured player with ball - Running with ball - Dribbling past - Injured leg without ball - Injured leg with ball	Match	Away	Domestic league	Winning		Off.		67
221	Calf	Running - Linear Run - Accelerating - 16.54 km/h, 2.99 m/s^2	Injured player without ball - Direct opponent with ball	Training	Home			Small-sided game	Def.	75	75
216	Calf	Jumping - upon landing - on pitch - with injured leg	Injured player with ball - Heading	Match	Away	Domestic league	Losing		Off.	52	52
203	Calf	Walking	Injured player with ball - Receiving ball - A pass - At knee height - With foot - Injured leg with ball	Match	Away	Friendly match	Tie		Off.	35	35

69	Calf	Running - Linear Run - Decelerating - 19.29 km/h, -2.01 m/s^2	Injured player with ball - Kicking - Shooting - Medium intensity - Internal leg movement - Ball directed toward air - Kicking phase unclear - Instep kick - Injured leg with ball	Match	Away	Int. cup	Winning		Off.	30	30
213	Adductor	Running - Linear Run - Accelerating - 19.75 km/h, 2.8 m/s^2	Injured player with ball - Receiving ball - A loose ball - At knee height - With foot - Injured leg with ball	Training	Home			Small-sided game	Def.	53	53

91	Adductor	Static	Injured player with ball - Kicking - Passing - Medium intensity - Internal leg movement - Ball toward ground - Kicking phase unclear - Instep kick - Injured leg with ball	Match	Away	Domestic league	Tie		Off.	30	30
81	Adductor	Running - Linear Run - Steady speed - 18.25 km/h, 1.53 m/s^2	Injured player with ball - Kicking - Shooting - Strong intensity - Internal leg movement - Ball toward air - Kicking phase unclear - Instep kick - Injured leg with ball	Training	Home			High-intensity technical drill		25	25

53	Adductor	Running - Linear Run - Steady speed - 21.39 km/h, 1.97 m/s^2	Injured player with ball - Running with ball - Dribbling an opponent - Injured leg without ball	Match	Home	Int. cup	Winning	Off.	65	65
50	Adductor	Running - Linear Run - Steady speed - 24.88 km/h, -1.25 m/s^2	Injured player with ball - Receiving ball - A loos ball - At upper body height - With foot - Injured leg with ball	Match	Away	Int. cup	Losing	Def.	65	65
48	Adductor	Running - Linear Run - Decelerating - 21.98 km/h, -2.39 m/s^2	Ball contended	Match	Away	Domestic league	Tie	Off.	4	4
112	ACL	Running - changing direction - 0-45 degree - performing CoD with injured leg - 28.2 km/h, 0..81 m/s^2	Injured player with ball - Running with ball - Dribbling past - Injured leg with ball	Match	Home	Domestic league	Losing	Off.	35	35

Off. = offensive, Def. = defensive