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Injury risk profile for soccer players: identification of the risk factors for soccer-related injuries – an umbrella review

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ABSTRACT

This review aimed to identify risk factors for soccer injuries and provide researchers the needed elements to build a soccer-player's injury risk profile. An umbrella review was conducted following the PRIOR criteria (OSF registration link: https://osf.io/jr7xe/). A literature search was run to identify studies investigating soccer-related injury risk factors. We included systematic reviews published between 2013 and 2023 related to soccer and analysed the identified risk factors to classify these in intrinsic and extrinsic, group in categories and identify relationships between risk factors and injury location. Among 240 risk factors, 181 (75.4%) were classified as intrinsic and 59 (24.6%) as extrinsic. We grouped risk factors in 14 categories. Finally, we found relationships between risk factors and injury locations for 159 factors, with the knee representing the body area most affected by risk factors ($N = 101$), followed by the ankle ($N = 65$) and the thigh ($N = 65$).

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Soccer; risk profile; injuries, complex systems

Introduction

Sports participation entails a considerable risk of injury for both elite and recreational athletes (Bahr & Krosshaug, 2005) and injury prevention is an important goal for clinicians, researchers, athletes, and the active population (Meeuwisse et al., 2007).

Despite there is no screening test available to predict sports injuries with adequate test properties (Bahr, 2016), profiling athletes is an important procedure to identify risk factors and understand athletes' risks to sustain injuries. Injury risk profiles procedures have been inspired by aetiology models. An interesting injury risk profile procedure has been presented by Joyce and Lewindon (Joyce & Lewindon, 2016), which proposed a seven-step process for the development of a screening tool to profile athletes in sports. In this procedure, practitioners should start from the creation of a generic warning index to identify sport-specific and team-specific risks, which can be obtained both studying the sport-related

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epidemiology or conducting injury surveillance procedures. Practitioners should then individualize the warning index to identify athlete-specific risks, know the risk factors for sport-specific injuries, select appropriate assessments and analyse the results to understand how to address any of the identified risk factors. Finally, to keep the process dynamic, practitioners should consistently review the process and modify it when required.

According to models presented by researchers on injury aetiology (Meeuwisse, 1994; van Mechelen et al., 1992), the profiling of athletes requires the identification of the risk factors predisposing and making athletes susceptible to sustain injuries when exposed to inciting events. This Umbrella Review tries specifically to answer to this step of the injury profiling process and to know risk factors for soccer-specific musculoskeletal injuries.

In the most recent model on injury aetiology, authors suggested that the predisposition to sustain an injury depends on the interactions between risk factors rather than on their individual analysis and that a multifactorial assessment of causation would be needed (Bittencourt et al., 2016). Since the causes of injuries are multifactorial, forecasting injuries ignoring known risk factors as well as applying a reductionistic approach that only considers linear relationships represent a restricted analysis of the injury phenomenon. Recently, the use of complex systems approach has been promoted by researchers (Bittencourt et al., 2016; Hulme & Finch, 2015; Hulme et al., 2019) who recognised sports injury as an emergent phenomenon resulting from the complex interactions among different risk factors suggesting the need to not only identify risk factors through athletes' profiling but also consider the relationship into the network of risk factors. The model proposed by Bittencourt et al. in 2016 (Bittencourt et al., 2016) called "the web of determinant" explain the need to consider a complex approach clearly.

One of the main objectives of sports medicine researchers and practitioners is to reduce activity-related injuries. Despite several authors investigated this issue, a practical procedure to build an injury risk profile in soccer has not been clarified. Our goal is to take the next steps in the direction indicated by the latest research starting with the identification of which the risk factors in soccer are. To achieve this goal, the first step is to identify which the soccer-related injury risk factors are and we performed this umbrella review of the literature among soccer-related injury risk systematic reviews. The next steps will be the development of a soccer-specific screening tool to identify risk factors and the development of a complex injury risk profile of soccer players by integrating risk factors into a complex system framework.

Materials and methods

We conducted an Umbrella Review on the issue of risk factors for injury in soccer, following the preferred reporting items for overviews of reviews (PRIOR) statement. The protocol was registered on OSF (https://osf.io/jr7xe/). Data on intrinsic and extrinsic risk factors for soccer-specific injuries were extrapolated and analysed. We then performed on our dataset two sub-analyses aiming to explore where risk factors were located within the body and to investigate which body areas have a theoretical higher risk to sustain injuries based on the relationships between risk factors and body areas stated in the articles included in our umbrella review.

Eligibility criteria and exclusion criteria

We only included systematic reviews with or without meta-analysis published between 2013 and 2023.

We decided to limit the research to this period as most of the studies that theorize complex models for athlete profiling have been only published in the recent years. Also, we decided to limit the research to this period because analysing systematic reviews which include primary studies from the previous years, we would anyway dispose of risk factors studied and reported several years earlier.

All the systematic reviews and meta-analyses not related to soccer or not containing at least one article on this topic were excluded by our study. We also excluded papers not stating risk factors for soccer-related injuries or solely focused on medical issues as illnesses or other non-musculoskeletal conditions. Despite some studies referred to a different sport in the title, since they reported interesting data on soccer in the main text or in the meta-analysis, they have been included in this umbrella review. Finally, we excluded articles not written in English language.

Literature search

We developed and performed comprehensive research for systematic reviews with or without metanalysis. On date 23 February 2023, two authors (MT and SN) performed the search strategy and ran the search in the following electronic databases: Pubmed, Embase and Cochrane Library, using the following key words: “injury”, “risk factor”, and “soccer”. The present study was carried out following the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines (M. J. Page et al., 2021) summarized in the flowchart in Figure 1.

Data selection

Based on the selection criteria, two review authors (SN and MT) independently screened all titles, abstracts and full texts for inclusion and appropriateness. The full text of each potentially relevant systematic review screened on title and abstract was then read by two reviewers who independently applied the inclusion and exclusion criteria. A discussion with a third review author (FG) resolved any disagreement, obtaining a final consensus.

Data extraction

Three researchers (MT, SN and EP) independently extracted data from the included articles. The data we extrapolated involved the first author of the article, the year of publication, the name of the risk factors reported by the systematic review and the potentially injured body areas when those risk factors were present.

Assessment of methodological quality

Two investigators (MT and CC) independently assessed the quality of the methods reported in the included systematic reviews. This qualitative assessment was performed

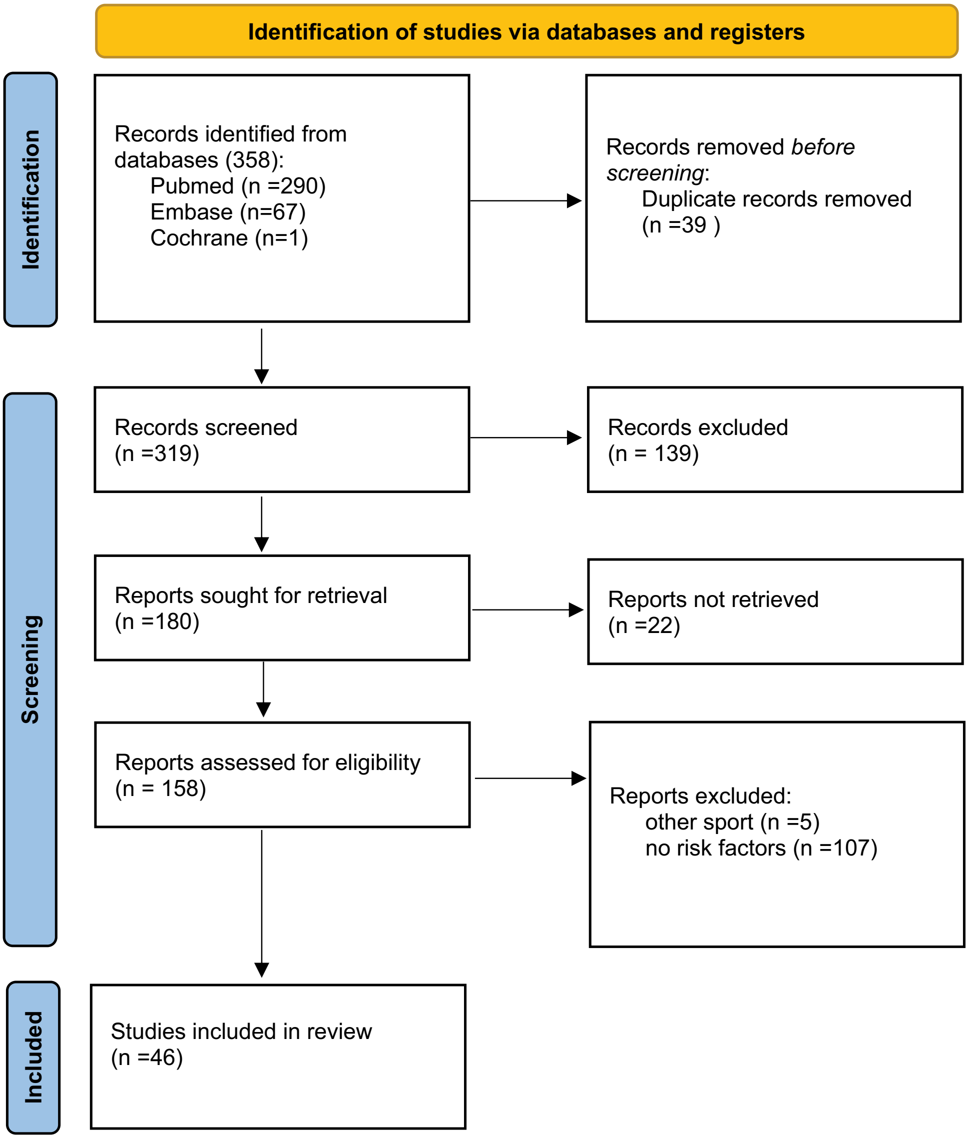

Figure 1. PRISMA flow chart of the studies' selection.

using a 16-criteria checklist included in AMSTAR 2 (Shea et al., 2017). AMSTAR 2 represents a fundamental revision of the original instrument of AMSTAR which was advised to evaluate systematic reviews that included randomized controlled studies. Discrepancies between the AMSTARS 2 scores for the articles were resolved by discussion between the two investigators.

Risk factors analysis

We extrapolated the relevant risk factors stated in the included systematic reviews. Risk factors that clearly referred to the same parameter, even if named in distinct ways by different systematic reviews, in our analysis have been unified under the same name (e.g. “hip ROM” and “hip ROM restriction” has been unified under the name “hip ROM restriction”). Since a unified nomenclature for risk factors does not exist, as expected we found different names for the same risk factors in different papers; the names of the risk factors that we listed in our results table have been chosen by the authors of this Umbrella Review as the name that in our opinion best described those considered factor. We removed all the risk factors that we found more than one time in our dataset, and we classified risk factors in intrinsic and extrinsic categories based on the definitions found in the literature (Saragiotto et al., 2014). Finally, we grouped risk factors into distinct categories to dispose of a better overview of the risk factors for soccer-related injuries.

Sub-analysis

We performed two sub-analyses on our dataset of risk factors. The first sub-analysis included all the identified risk factors and aimed to explore which areas of the body would be more prone to sustain an injury when a specific risk factor is present. This sub-analysis was based on the relationship between risk factors and injured body areas described in the articles included in our umbrella review. We indiscriminately considered all the relationships between risk factors and injured body areas clearly stated in the articles while we excluded from this sub-analysis those risk factors for which no body areas were mentioned as a location for a potential injury when those risk factors were present. The second sub-analysis that we performed has been ran only on the intrinsic risk factors and aimed to explore their location within the body to potentially understand which body areas would require a more detailed investigation and specific assessments in soccer players. Since relationships between risk factors and injured body areas were not standardised in the included articles and sometimes referred to specific anatomical parts (e.g. “Anterior cruciate ligament (ACL)”) while other times referred to more generic or body areas (e.g. “knee”), to homogenize our analysis we considered the recommended categories of body areas for injuries as suggested by IOC consensus and described in the two leading international codes for the classification of sports injuries, the Orchard Sport Injuries and Illnesses Classification System (OSIICS) (Orchard & Genovesi, 2022) and the Sport Medicine Diagnostic Coding System (SMCSC) (Meeuwisse et al., 2007). These sport injuries coding systems used the classification of the body in 18 body areas (without considering right/left side for the limbs); the body areas are: head, neck, shoulder, upper arm, elbow, forearm, wrist, hand, chest, thoracic spine, lumbosacral, abdomen, hip/groin, thigh, knee, lower leg, ankle, foot. Using this classification of the body in generic body areas, when we found relationships between risk factors and injury describing specific anatomical parts, we considered the body area to which that named anatomical part belongs (e.g. “anterior cruciate ligament” belongs to the “knee” body area).

Results

Umbrella review analysis

The research led to the identification of 358 articles. After removing duplicates, we included 319 articles for title and abstract reading, from whom 161 were excluded, for a total of 158 articles assessed for full text eligibility. After reading full texts, 112 articles were excluded because did not meet the inclusion criteria, for a result of 46 articles included in the umbrella review.

The analysis of the 46 systematic reviews led to the identification of a total of 525 risk factors. After unifying risk factors with similar names under a same common name and removing the duplicates, we obtained 240 risk factors. Results of our umbrella review related to the 240 risk factors are summasized in Table 1 alongside the name of the first author of the systematic review that mentioned those risk factors, the year of publication and the potentially injured body areas or anatomical parts related to those risk factors. Among the 240 risk factors, 181 were intrinsic risk factors and 59 were extrinsic risk factors. We finally classified the 240 risk factors in distinct categories which names have been chosen by the authors. We classified the intrinsic risk factors in nine distinct categories: personal features (e.g. age and gender) ($N = 13$), medical history (e.g. previous injury) ($N = 10$), anatomical and biomechanical (e.g. range of motion) ($N = 42$), neuromuscular (e.g. strength imbalances) ($N = 50$), anthropometrics (e.g. weight) ($N = 18$), psychological (e.g. stress) ($N = 23$), physiological (e.g. blood lactate concentration) ($N = 11$), related to fitness (e.g. endurance) ($N = 5$), related to fatigue and effort (e.g. RPE) ($N = 9$). We classified the extrinsic risk factors in five distinct categories: External workload (e.g. amount of distance covered) ($N = 16$), environmental and opponent (e.g. weather, surface and opponent) ($N = 22$), equipment (e.g. cleats) ($N = 3$), calendar and schedule (e.g. busy schedule) ($N = 6$), human factors (e.g. incorrect rehabilitation) ($N = 12$). The classification in intrinsic and extrinsic alongside the classification into the 14 distinct categories are summarised in Figure 2.

Risk factors sub-analysis

The sub-analysis that we performed on the relationships between risk factors and injury location showed that a relationship with one or more body areas was described for 159 risk factors, while for the remaining 81 risk factors we only found a description of their capability to increase the risk to sustain an injury wherever in the body without adding information on specific body areas or anatomical parts where the injury may happen. Among the 159 risk factors for which these relationships were clearly stated in the included articles, as expected, the knee represented the body area potentially more affected by risk factors ($N = 101$), followed by the ankle ($N = 65$), the thigh ($N = 65$), the hip and groin ($N = 45$), the lower leg ($N = 27$), the foot ($N = 16$), and the areas of head and neck ($N = 4$). Unexpectedly, we did not find risk factors potentially impacting the lumbo-sacral body area. We did not find contradiction in the relationships between risk factors and potentially injured body areas in different papers. Results of this sub-analysis are showed in the Figure 3.

The second sub-analysis that we performed, aiming to explore the localization of the intrinsic risk factors within the body showed that among the 180 intrinsic risk factors identified by our umbrella review only 58 could be localised in specific body areas: also in this analysis, as expected most of the risk factors ($N = 18$) were localised in the knee, 13 in the hip and groin of which 11 in the hip and 2 in the groin, 12 in the thigh of which 6 in the hamstring, 7 in the ankle, 3 in the trunk, 3 in the foot, and 2 in the lower leg. Results of this sub-analysis are showed in the directed acyclic graph (DAG) in Figure 4: the blue circles

Table 1. Risk factors for soccer-related injuries.

Author	Publication's year	Risk factors	Potentially injured body-areas
Verschueren et al.	2019	• Balance • Fatigue • H/Q ratio • Hamstring strength • Proprioception • Weaker quadriceps peak torque	• Ankle • Knee • Posterior thigh
Xiao et al.	2022	• Cleat pattern • Climatic playing conditions • Hormonal fluctuations • Intercondilar notch width • Joint laxity • Landing mechanics • Muscle strength imbalances • Playing surface • Season • Workload	• Knee
Walden et al.	2015	• Abdominal wall weakness/sportman's hernia • External workload • Force development • Muscle strength deficits • Pelvic anatomy • Playing intensity • Training load	• Groin
Verstappen et al.	2021	• External workload • Fatigue • Fitness • General well-being • Perceived fitness • Personal accomplishment • Physical complaints • Recovery (time between matches) • Self-efficacy • Self-regulation • Sleep quality • Stress • Success	• Injury in general
Thron et al.	2022	• External workload	• Injury in general
Thomson et al.	2015	• Climatic playing conditions • Player's footwear • Playing surface	• Ankle • Knee
Sniffen et al.	2022	• ACWR (Acute to Chronic Workload Ratio) • Amount of distance covered • Busy calendar • Fatigue • High speed distance • Number of Accelerations • Session RPE • Training hours per week during training season/competition season • Workload	• Injury in general
Page et al.	2022	• Busy calendar • External workload • Fatigue • Flexibility • Lower limb muscle activation • Muscle strength deficits • Muscle strength imbalances • Playing at night • Recovery (time between matches) • Reductions in eccentric knee flexor strength • Travelling	• Lower limbs

(*Continued*)

Table 1. (Continued).

Author	Publication's year	Risk factors	Potentially injured body-areas
Mc Call et al.	2015	• Ankle biomechanical alterations • Knee biomechanical alterations • Hip biomechanical alterations • Trunk biomechanical alterations • Fatigue • Muscle strength deficits • Muscle strength imbalances • Neuromuscular control • Presence of scar tissue • Previous injuries • Tightness	• Injury in general
Pulici et al.	2023	• Age • Busy calendar • Career duration • Geographic region • Number of games played • Previous injuries • Specific physical demands of each league	• Knee • Thigh • Hip • Groin • Ankle
Jones et al.	2019	• Age • Fatigue • Maturity timing (PHV) • Playing matches • Playing surface • Preparation periods too short • Rapid growth stage • Recovery (time between matches) • Regional differences in climate • Sport specialization before puberty • Training load • Younger players "playing up"	• Ankle • Hip • Groin • Knee • Thigh
Crossley et al.	2019	• External workload • Gender • Landing mechanics • Muscle strength deficits • Previous injuries	• Knee • Ankle • Posterior thigh • Hip • Groin
Al Attar et al.	2017	• External workload • Fatigue • Previous hamstring injury • Workload	• Posterior thigh
Volpi et al.	2017	• Age • Climatic playing conditions • Experience • External workload • Gender • Genetic risk factors • H/Q (Hamstring/Quadriceps) ratio • Joint laxity • Landing mechanics • Limb dominance • Low postural sway of the legs • Player's footwear • Playing games • Playing position • Playing surface • Posterior tibial slope • Previous ACL i(Anterior Cruciate Ligament) njury	• Knee

(*Continued*)

Table 1. (Continued).

Author	Publication's year	Risk factors	Potentially injured body-areas
Pfirrmann et al.	2016	• Age • Busy calendar • Competition level • Concealment of injury • Fatigue • Inadequate rehabilitation • Maturity timing (PHV) • Mental burnout • Motivation • Playing position • Pressure • Previous injuries • Reinjury • Season • Speed of the game • The end of each half of play • Workload	• Ankle • Knee • Upper leg
Jabalera et al.	2021	• Ankle biomechanical alterations • Knee biomechanical alterations • H/Q (Hamstring/Quadriceps) ratio • Hip range of motion • Knee valgus • Lower limb muscle activation • Neuromuscular deficit antagonist-agonist relationships • Neuromuscular deficit decreased co-contraction • Neuromuscular deficit decreased proprioception • Trunk biomechanical alterations	• Knee
Freiberg et al.	2021	• External workload	• Knee
Cronstrom et al.	2021	• BMI • Family history • Gender • Greater knee joint laxity • Intercondilar notch width • Joint laxity • Kinematics and kinetics • Knee biomechanics alterations • Lower limb muscle activation • Menstrual cycle • Muscle strength deficits • Posterior tibial slope • Proprioception • Trunk biomechanical alterations • Use of contraceptives	• Knee
Bram et al.	2020	• Competitive gameplay • Greater anterior tibial laxity • Hamstring strength • Intercondilar notch width • Knee valgus	• Knee
Mayhew et al.	2021	• Busy calendar • Climatic playing conditions • External workload • Fatigue • Physical demands	• Knee • Thigh • Ankle

(*Continued*)

Table 1. (Continued).

Author	Publication's year	Risk factors	Potentially injured body-areas
Caldemeyer et al.	2020	• Ankle laxity • Greater range of motion • History of ankle sprain • Hormonal fluctuations • Posture	• Ankle
Orchard et al.	2015	• Amount of distance covered • External workload • Pitch size • Player position	• Groin • Hip
Farrel et al.	2023	• Adductor muscle weakness • Previous acute groin injury • Previous injuries • Reduced rotational hip range of motion	• Groin
Vatovec et al.	2019	• Age • Ethnicity • Fatigue • Flexibility • Muscle strength imbalances • Previous injuries	• Posterior thigh
Cuthbert et al.	2019	• Age • Decrease in fascicle length • Ethnicity • Fatigue • Flexibility • High speed distance • Muscle architecture • Muscle strength deficits • Previous hamstring injury	• Posterior thigh
Al Attar et al.	2022	• Balance • Decreased ankle plantar flexion • Excessive ankle range of motion	• Ankle
De Noronha et al.	2019	• Balance • Body mass • Fatigue • Functional instability • Height • History of ankle sprain • Joint laxity • Playing surface	• Ankle
Marinho et al.	2022	• Busy calendar • Equipment • Fatigue • Fitness • Flexibility • Inadequate rehabilitation • Improper exercise • Lower levels of perceived injury risk • Muscle strength deficits • Overtraining • Player position • Playing surface • Previous injuries • Sleep	• Injury in general

(*Continued*)

Table 1. (Continued).

Author	Publication's year	Risk factors	Potentially injured body-areas
Mandorino et al. (part I)	2023	• Absolute leg stiffness • Adductor muscle weakness • Age • Anxiety • BMI (Body Mass Index) • Body mass • Decreased Hip adduction ROM • Decreased Hip external rotation ROM • Decreased muscle activation of rectus femoris • Decreased muscle activation of semimembranosus • Decreased muscle activation of vastus medialis • Difference Squat Jump and Countermovement Jump Height • Equipment • External workload • Familiar disposition ACL injury • Fatigue • Frontal plane knee projection angle (FPKPA) during the single-leg squat • Hamstring strength • Height • High Acute Training Load • High Chronic Training Load • Hip abduction muscle force • Hip range of motion (ROM) • Increased Hip abduction ROM • Increased Hip internal rotation ROM • Knee Isokinetic strength • Isometric hip strength • Knee valgus • Leg stiffness • Life events • Limited ankle dorsiflexion • Lower limb mobility • Maturity timing (PHV) • Monotony • Motivation • Normalized knee separation during drop jump (NKS) • Peak vertical landing forces (pVGRF) • Perceived pain on isometric • Perception of success • Player position • Playing surface • Posterior chain hip muscle forces • Previous injuries • Previous spine injuries • Reactive strength index (RSI) • Recovery-stress state (REST-Q) • Reduced anterior thigh flexibility • Relative leg stiffness • Reporting of Knee complaints • Season • Session RPE • Side asymmetry-single-leg hop for distance • SLCMJ (Single Leg Counter Movement Jump) peak landing vertical ground reaction force asymmetry	• Injury in general

(*Continued*)

Table 1. (Continued).

Author	Publication's year	Risk factors	Potentially injured body-areas
		• SLCMJ (Single Leg Counter Movement Jump) peak landing vertical ground reaction force relative to body weight • Sport specialization • Strain • Trunk biomechanical alterations • Years of organized soccer play	
Mandorino et al. (part II)	2023	• Age • Body composition • Body size • Flexibility • Gender • Hormonal fluctuations • Muscle strength deficits • Neuromuscular control • Playing surface • Previous injuries • Rules • Shape • Training load	• Ankle • Foot • Thigh • Knee
Green et al.	2017	• Age • Anthropometry • Balance • Body mass • Busy calendar • External workload • Foot posture (pronation) • Height • Knee biomechanical alterations • Knee laxity • Leg strength • Match characteristics • Playing position • Previous calf muscle injury • Previous injuries • Previous knee injury • Recovery (time between matches) • Training and match exposure time	• Leg
Christopher et al.	2021	• Age • Body mass • Career duration • Functional movement competencies • H/Q ratio • Landing mechanics • Soccer injury movement screening (SIMS) • Tuck jump assessment	• Knee • Injury in general
Alahmad et al.	2020	• Age • Anxiety • BMI • Competition level • Decreased concentration in the latter stages of games • Equipment • Excessive ankle range of motion • Fatigue • H/Q (Hamstring/Quadriceps) ratio • Landing mechanics • Player position • Pre-menstrual symptoms • Previous injuries • Stress • Use of contraceptives	• Ankle • Knee • Anterior thigh

(*Continued*)

Table 1. (Continued).

Author	Publication's year	Risk factors	Potentially injured body-areas
Almeida et al.	2013	• Adductor muscle weakness • External workload • Greater hip abductor to adductor muscle strength ratio • Hip range of motion • Muscle imbalances between the abdominal musculature and the hip adductor muscles • Workload	• Groin
Balazs et al.	2014	• Climatic playing conditions • Opponent • Period in the game • Player position • Player's footwear • Playing surface • Precipitation • Timing of game within the season • Type of play	• Knee
Dos Santos et al.	2019	• Gender • High GRFs (Ground Reaction Forces) • Knee valgus • Limb dominance • Player's footwear • Trunk biomechanical alterations	• Knee
Driban et al.	2017	• Age • Competition level • Gender • Genetic risk factors • Previous joint injury	• Knee
Esteve et al.	2015	• Hip adduction muscle force • Previous acute groin injury	• Groin
Faude et al.	2017	• Age • Balance • Gender • Knee internal rotation • Knee valgus • Leg alignment • Leg power • Leg strength • Skills • Task biomechanics	• Injury in general
Hanlon et al.	2020	• Absolute leg stiffness • Age • Anatomical alignment issues • Anxiety • Balance • Body size • Competition level • Coordination • Endurance • Equipment • Flexibility • Foot morphology • Gender • General well-being • Motivation • Muscle performance • Muscle strength deficits • Pain • Perceived ability • Perceived risk • Player's footwear • Playing surface • Previous injuries • Sensory deficits • Skills	• Injury in general

(*Continued*)

Table 1. (Continued).

Author	Publication's year	Risk factors	Potentially injured body-areas
Hughes et al.	2017	• Age • Ankle isokinetic strength • Balance • BMI • Body composition • Body mass • Climatic playing conditions • CMJ • Decrease in fascicle length • Fascicle length relative to BFLH length • Flexibility • Functional knee strength ratio • Functional movement competencies • Height • Hip abduction muscle force • Knee isokinetic strength • Knee joint stability • Knee valgus • Lean mass • Leg press • Limb dominance • Limited ankle dorsiflexion • Lower limb length • Match venue/type • Maximal average squat power • Mid thigh girth • Muscle thickness • MVIC fascicle length imbalance • MVIC length • MVIC muscle thickness • Period in season • Playing position • Previous injuries • Recovery • Seasons at elite level • Tibia length • Training load	• Injury in general
Jiang et al.	2022	• Age • Amount of distance covered • Busy calendar • Competition load • External workload • Fatigue • Gender • High speed distance • Number of accelerations • Number of decelerations • Sprint distance • Workload	• Injury in general
Kupperman et al.	2020	• ACWR (Acute to Chronic Workload Ratio) • Amount of distance covered • Flexibility • High speed distance • Muscle strength deficits • Number of accelerations • Number of Decelerations • Previous injuries	• Injury in general

(*Continued*)

Table 1. (Continued).

Author	Publication's year	Risk factors	Potentially injured body-areas
Lopez-Valenciano et al.	2020	• Altered muscle architecture • Biomechanical alterations • Busy calendar • Coach compliance to the injury prevention program • Eccentric strength deficits • Flexibility • Hydration • Neuromuscular control • Nutrition • Players adherence to the injury prevention program • The stability of the club in terms of coaching, medical staff and management • Workload	• Injury in general
Noriega et al.	2022	• Age • Biomechanical abnormalities of the foot • Climatic playing conditions • Environment • Gender • Improper exercise • Limited ankle dorsiflexion • Obesity • Overtraining • Player's footwear • Playing surface • Prolonged standing • Recovery-stress state (REST-Q) • Sedentary lifestyle • Skills • The mode of exercise	• Foot
Slimani et al.	2018	• Anxiety • Fatigue • Life events • Perceived mastery climate • Poor visual and verbal memory • Previous injuries • Recovery-stress state (REST-Q) • Stress	• Injury in general
Van Beijsterbeldt et al.	2013	• Absolute leg stiffness • Age • Hamstring flexibility • Inadequate warm-up • Pain • Playing surface • Previous injury • Quality of life • Strength imbalances • Tightness • Training load	• Posterior thigh

show the number of intrinsic risk factors for which we found a location in a specific body area, the green circles show the body areas potentially injured by those intrinsic risk factors, or rather those body areas that have been named by the included articles as the body areas that may suffer an injury if that risk factor was present. Finally, the black lines show the relationships between risk factor location and potentially injured body areas.

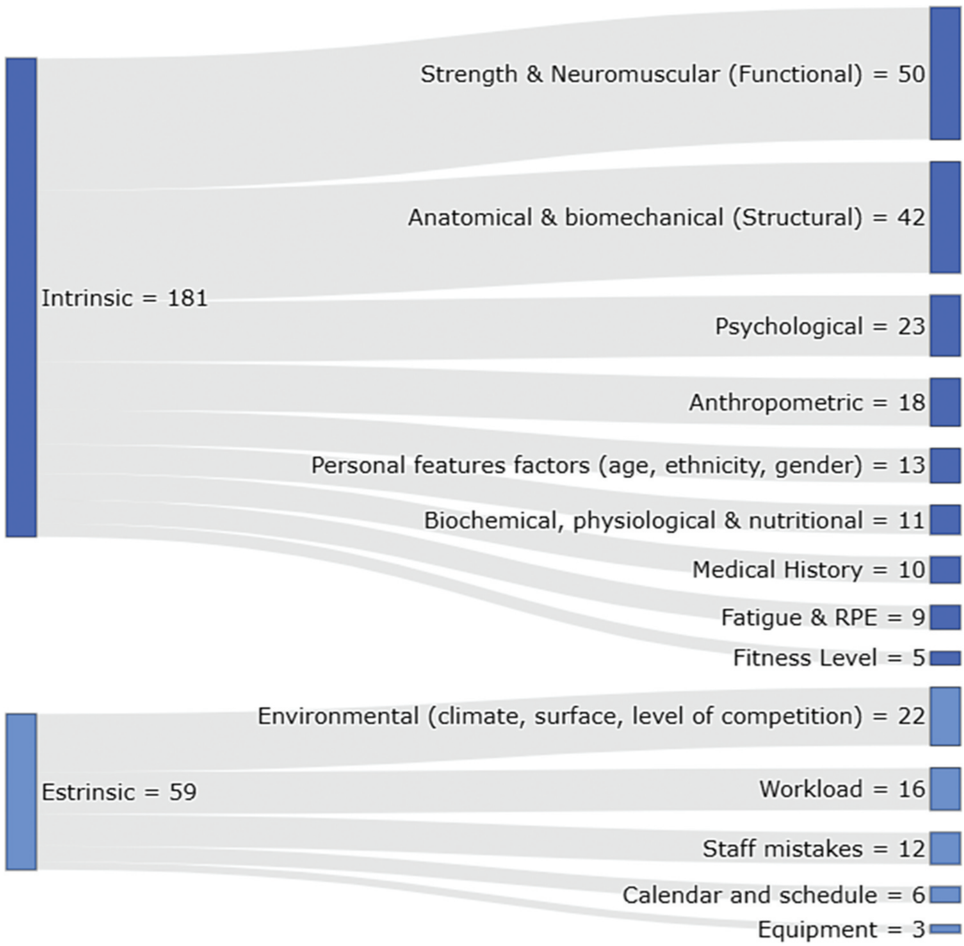

Figure 2. Classification of the intrinsic and extrinsic risk factors in distinct categories.

The size of the circles expresses the number of risk factors located in each body area (blue circles) and the higher chance of a body area to sustain an injury (green circles) when the related risk factors are present. The thickness of the black lines expresses the number of relationships between risk factors' location and impacted body areas. Right/Left side should not be considered in the figure.

Methodological qualitative analysis

The results of the AMSTAR2 assessment are reported in Table 2. Our findings show that the main weaknesses of the analysed papers were the absence of a list indicating the excluded studies and the reason why those studies have been excluded (93%), the lack of explanation of the reason why authors chosen those studies designs (87%) and the lack of sources of funding's report (87%).

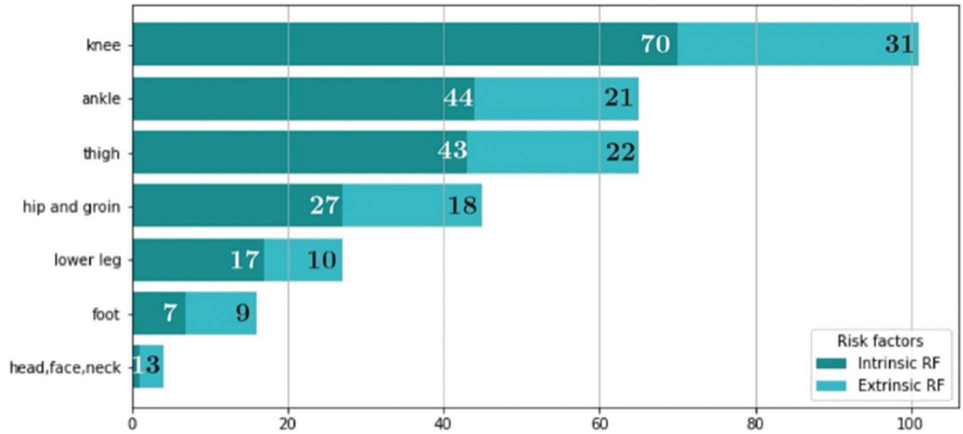

Figure 3. Distribution of the 159 risk factors identified by our umbrella review potentially impacting different body areas. Risk factors for each body area are divided in intrinsic (dark area of the bars) and extrinsic (light area of the bars) risk factors.

Discussion

Since higher players availability is well-related to team success in professional soccer (Hagglund et al., 2013), one of the main goals of researchers is to find the way to reduce the occurrence of injuries. To achieve this goal, alongside the daily monitoring of players external and internal workload, as suggested by IOC and other authors for sports in general (Bourdon et al., 2017; Halson, 2014; Soligard et al., 2016) and by some authors more specifically for soccer (Impellizzeri et al., 2020; Rossi et al., 2018), is necessary to screen players to build appropriate athletes' injury risk profile. Since the knowledge of risk factors is essential to build an injury risk profile, we conducted an umbrella review aiming to detect the risk factors for injury in soccer. We identified 240 risk factors which we classified in 181 intrinsic and 59 extrinsic based on definitions found in the literature. According to these definitions, we considered a risk factor as intrinsic when associated with the athletes' individual characteristics and as extrinsic when related to the environment, climate, equipment and training (Saragiotto et al., 2014). Despite we did not classify risk factors in modifiable and not-modifiable in our analysis, we suggest clinicians to clearly distinguish these two categories when building players' injury risk profiles: since the injury risk profile aims to address risk factors to implement preventive strategies as described in the second and third steps of the "sequence of prevention" of injuries proposed by van Mechelen in 1987 (van Mechelen et al., 1992), the modifiable risk factors, being modifiable, represent the main targets of appropriate intervention strategies. Among the identified risk factors, the factors "previous injuries" was the one reported the most in the articles included in our umbrella review, suggesting the importance to carefully investigate all the previous injuries sustained by the players using appropriate inventories, and to record appropriately the ongoing injuries using validated injury codes as the Orchard Sport Injuries and Illnesses Classification System (OSIICS) (Orchard & Genovesi, 2022) or the Sport Medicine Diagnostic Coding System (SMCSC) (Meeuwisse et al., 2007). Most of the intrinsic risk factors that we have identified were related to neuromuscular features as neuromuscular control, strength deficits or strength

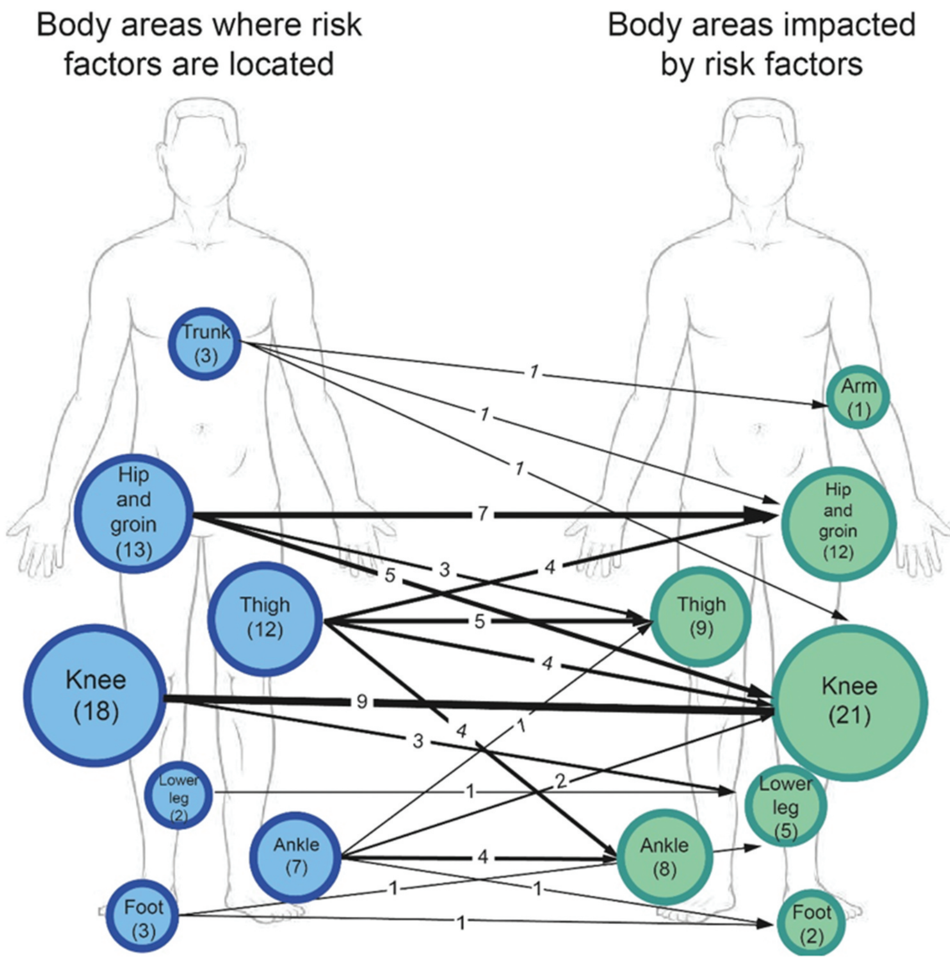

Figure 4. Distribution of the location of the 58 localizable intrinsic risk factors within body areas (blue circles), and relative relationships (black lines) with the body areas potentially impacted by those localizable risk factors (green circles). The size of the circles as well as the thickness of the lines indicate a higher number of risk factors and relationship respectively.

imbalances followed by anatomical and biomechanical factors as range of motion restrictions, joint laxity or hypermobility. These finding underline the importance to assess strength and ROM at the beginning of the season and periodically during the season to keep those factors monitored by clinicians and practitioners working with soccer players. Regarding the extrinsic risk factors, the external workload was the category represented the most underlining the importance to monitor players' external workload on daily basis by sport scientists and fitness coaches. The factor "External workload" was followed by factors related to schedule and calendar: busy calendar, season schedule and playing matches close one each other seem to represent a risk factor for musculoskeletal injuries in soccer. This finding may suggest the need to organise and plan match schedules in an appropriate way by sport organisations and leagues to avoid short recovery time between matches.

Table 2. AMSTAR 2 quality assessment score. PY= Partial Yes; NM=Non Meta-Analysis.

Study	Question & inclusion	Protocol	Study design	Search strategy	Study selection	Data extraction	Exclusion reasons	Inclusion details	Assess risk of bias	Funding source	Analysis method	Risk of bias on analysis	Risk of bias	Discuss heterogeneity	Publication bias	Conflict of interest
Alahmad et al. (2020)	Yes	No	No	PY	No	No	No	Yes	No	No	NM	NM	No	Yes	NM	Yes
Al Attar et al. (2017)	Yes	Yes	No	PY	Yes	Yes	No	Yes	No	No	Yes	No	No	No	Yes	Yes
Al Attar et al. (2022)	Yes	Yes	No	PY	Yes	Yes	No	Yes	Yes	No	No	No	No	No	Yes	Yes
Almeida et al. (2013)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Balazs et al. (2015)	Yes	Yes	Yes	PY	Yes	Yes	No	Yes	No	No	NM	NM	No	No	NM	Yes
Bram et al. (2021)	Yes	No	No	PY	No	No	No	Yes	No	No	No	No	No	No	No	Yes
Caldemeyer et al. (2020)	Yes	No	No	PY	No	No	No	Yes	No	No	NM	NM	No	No	NM	Yes
Christopher et al. (2021)	Yes	Yes	No	PY	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes
Cronstrom et al. (2021)	Yes	Yes	No	PY	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Crossley et al. (2019)	Yes	Yes	No	Yes	Yes	Yes	No	PY	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Cuthbert et al. (2020)	Yes	No	No	PY	No	No	No	PY	PY	No	Yes	Yes	Yes	Yes	Yes	Yes
de Norohna et al. (2019)	No	Yes	No	PY	Yes	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No
Dos'santos et al. (2019)	Yes	PY	No	PY	Yes	No	No	PY	No	No	NM	NM	No	No	NM	Yes
Driban et al. (2017)	Yes	No	No	Yes	No	No	No	PY	No	No	NM	NM	No	No	NM	No
Esteve et al. (2015)	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes
Gonzalez Farrell et al. (2023)	No	Yes	No	Yes	Yes	No	No	Yes	No	No	NM	NM	No	No	NM	Yes
Faude et al. (2017)	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No
Freiberg et al. (2021)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Green and Pizzari (2017)	No	No	No	Yes	Yes	Yes	No	PY	Yes	No	NM	NM	Yes	Yes	NM	Yes
Hanlon et al. (2020)	Yes	PY	No	PY	No	No	No	PY	No	No	NM	NM	No	No	NM	No
Hughes et al. (2017)	Yes	PY	Yes	PY	No	No	No	PY	Yes	No	NM	NM	Yes	Yes	NM	No
Olivares-Jabalera et al. (2021)	Yes	Yes	No	PY	Yes	No	No	Yes	Yes	No	NM	NM	Yes	Yes	NM	Yes
Jiang et al. (2022)	Yes	PY	No	PY	Yes	No	No	PY	Yes	No	NM	NM	No	No	NM	Yes
Jones et al. (2019)	Yes	PY	No	PY	No	No	No	PY	No	No	Yes	No	No	Yes	No	Yes
Kupperman and Hertel (2020)	No	No	No	PY	No	No	No	PY	No	No	No	No	No	No	No	No
Lòpez-Valenciano et al. (2020)	Yes	PY	No	PY	Yes	Yes	No	PY	Yes	No	Yes	Yes	Yes	Yes	No	No
Mandorino et al. (2023a) part I	Yes	PY	No	PY	Yes	No	No	PY	No	No	NM	NM	No	No	NM	Yes
Mandorino et al. (2023b) part II	Yes	PY	No	PY	Yes	No	No	PY	No	No	NM	NM	No	No	NM	Yes
Cardoso-Marinho et al. (2022)	Yes	Yes	No	PY	Yes	Yes	No	Yes	Yes	No	NM	NM	Yes	No	NM	Yes
Mayhew et al. (2021)	Yes	PY	No	PY	Yes	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes
McCall et al. (2015)	Yes	PY	No	PY	Yes	No	No	PY	Yes	No	NM	NM	No	No	NM	Yes
Noriega et al. (2022)	Yes	PY	No	PY	No	No	No	No	No	No	NM	NM	No	No	NM	Yes
Orchard 2015	Yes	PY	No	PY	No	No	No	PY	No	No	NM	NM	No	Yes	NM	Yes
R. M. Page et al. (2023)	No	Yes	No	PY	No	No	No	Yes	Yes	No	NM	NM	Yes	Yes	NM	Yes
Pfirrmann et al. (2016)	Yes	No	No	PY	No	No	No	Yes	No	No	NM	NM	No	No	NM	Yes
Pulici et al. (2022)	Yes	Yes	Yes	Yes	Yes	Yes	No	PY	Yes	No	Yes	Yes	Yes	Yes	No	Yes
Slimani et al. (2018)	Yes	PY	No	PY	No	Yes	No	Yes	Yes	No	No	No	No	No	Yes	Yes
Sniffen et al. (2022)	Yes	PY	No	PY	Yes	No	No	Yes	Yes	No	NM	NM	Yes	No	NM	Yes
Thomson et al. (2015)	Yes	PY	No	PY	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes
Thron et al. (2022)	Yes	PY	No	PY	No	No	No	Yes	Yes	No	NM	NM	No	No	NM	Yes

(Continued)

Table 2. (Continued).

Study	Question & inclusion	Protocol	Study design	Search strategy	Study selection	Data extraction	Exclusion reasons	Inclusion details	Assess risk of bias	Funding source	Analysis method	Risk of bias on analysis	Risk of bias	Discuss heterogeneity	Publication bias	Conflict of interest
van Beijsterveldt et al. (2013)	Yes	PY	Yes	PY	Yes	Yes	No	Yes	No	No	NM	NM	No	No	NM	Yes
Vatovec et al. (2020)	Yes	PY	No	PY	Yes	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Verstappen et al. (2021)	Yes	PY	No	PY	No	No	No	Yes	Yes	Yes	NM	NM	Yes	No	NM	Yes
Volpi et al. (2016)	Yes	PY	No	PY	Yes	No	No	Yes	No	No	NM	NM	No	No	NM	Yes
Waldén et al. (2015)	Yes	Yes	No	PY	Yes	No	No	PY	Yes	Yes	NM	NM	Yes	Yes	NM	Yes
Xiao et al. (2022)	Yes	Yes	No	PY	Yes	Yes	No	PY	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes

Our sub-analysis to explore the location of the intrinsic risk factors within the body showed that the hip and groin were the areas where the highest number of risk factors were localised, followed by the knee and the thigh, suggesting clinicians and practitioners that these body areas may require more detailed assessments and investigation during pre-season and in-season screening procedures. Nevertheless, complete assessments of each body area as well as holistic approaches studying the complexity of the human anatomy (Della Posta & Veltro, 2016) and of the movement system (Sahrmann, 2017) should be considered by clinicians and practitioners working with soccer players. In relation to the risk factor "previous injury", the DAG reporting the results of our sub-analysis (Figure 4) only considered that factor when clearly stated by the articles included in our umbrella review. However, when building the injury risk profile of a specific soccer player in practical, researchers and clinicians should consider each body area presenting a previous injury as a body area presenting that risk factor as well as a body area potentially impacted by that same risk factor "previous injury".

We finally explored which body areas would have a higher risk to sustain an injury based on the found relationships between risk factors and body areas. This sub-analysis showed that the knee joint represented the area impacted by risk factors the most, with ACL representing the most mentioned anatomical part. This finding may reflect the fact that severity and burden for knee injuries are high in soccer and led researchers to dedicate a lot of studies on this issue with the outcome of finding more risk factors potentially related with that body area. Also, considering the position of the knee in the middle of the lower limb, and considering its close biomechanical relationships both with the hip superiorly and with the ankle inferiorly, that body area may be potentially influenced by problems affecting those joints.

Our research presents some limitations. A first limitation is on the methodological choice to only include articles from systematic reviews published between 2013 and 2023. This represents a limitation because some risk factors may be present in primary studies not included in secondary studies. However, we assumed that all the main risk factors have been included in secondary studies. Also, we chosen to restrict our research to this period since most of the studies analysing risk factors considering complex models were published in the last few years. Another limitation on the methodology is related to the fact that we did not consider population specific biases, geographical differences, age differences and level of play. Since we decided to list all the relevant risk factors for the sport "soccer", we included in the results all the risk factors for soccer regardless players or league specific characteristics. However, in the building of the soccer players injury risk profile, researchers and clinicians should consider the specificity of the players and level of competition. Other limitations are related to our analysis and sub-analyses. A limitation of our main analysis regards the names we gave to risk factors: to avoid duplicating risk factors related to the same parameter but named differently in distinct papers, we unified those under the same name, but this name was under our judgement. This limitation may suggest the need to create a dictionary of risk factors in the future. Also, related to the same issue, some authors named risk factors using the name of the test to assess the risk factor itself (e.g. Mandorino et al. reported the REST-Q, a questionnaire to assess recovery, as a risk factor, probably referring to the risk factor "stress"). However, since it could be possible that a test assesses multiple factors, there may be a bias in their interpretation. This limitation may suggest the need to conduct future research on how to assess different risk factors that could also provide practical guidelines to practitioners. A limitation regards the relationships between risk factors and injured body areas described in the included articles: for some risk factors in fact, were described relationships with injuries in each of the lower limb anatomical areas. Nevertheless, from those papers it was not clear if those risk factors have been investigated for their potential impact on each of the mentioned body areas or if the authors named each body area of the lower limb just to express the ability of those risk factors to increase the injury risk in those body areas typically injured in soccer players. Another limitation is that in the same sub-analysis we included all the relationships between risk factors and injured body areas clearly stated in the articles without investigating the meaningfulness of those relationships. However, future studies should examinate the meaningfulness of the relationships to also assign a different relevance to each of those. A final limitation is that our analysis and sub-analyses have been conducted on data extrapolated by studies using a reductionistic approach on injuries, suggesting the need for future research to use models and machine learning approach to analyse risk factors through complex approaches and in live, ongoing and dynamic situations. Since an injury happen when a player presenting some intrinsic and extrinsic risk factors is exposed to certain inciting events, as suggested both in reductionistic and complex models, the advantage to use machine learning models based on complex system approaches is that the risk factors network would be analysed at each exposure to inciting events; furthermore the profiling procedure would be a dynamic analysis rather than static, that would lead to the understanding of which risk factors represent the main determinants and which is the structure of the risk factors network that is more dangerous and risky for each specific player.

Conclusion

Having identified the relevant risk factors emerging from the most recent systematic reviews in soccer, this article provides vital information for clinicians and researchers who want to profile soccer players for injury risk. Internal risk factors related to soccer players characteristics, as range of motion, strength or physiological features, should be carefully analysed alongside accurate monitoring of external risk factors related to the environment and training as the players' external workload, the matches schedule and the playing surfaces. When addressing risk factors within the body through clinical assessment, clinicians should look carefully at the body areas of the hip and groin, the knee and the thigh as the body areas potentially presenting more risk factors. However, all the body areas as well as full-body holistic assessments should be considered. Despite a reductionistic approach considering linear relationships between risk factors and injuries is easy to apply and understand, researchers should follow the direction indicated by the research. Since an injury represents a complex phenomenon emerging from the interactions between different risk factors, and between those and inciting events, to dispose of a holistic picture of the soccer players' risk profile and analyse players with more accuracy, researchers and clinicians should move to complex approaches and models. Future research should use the results of this Umbrella Review to put in practice the step towards complex approaches already suggested by the literature. The found risk factors may be used to fill machine learning models based on complex systems, such as the web of determinants of Bittencourt et al., and to create a dynamic injury risk profile for soccer players. Finally, considering the multifactorial nature of risk factors and their association to specific subjects, an interdisciplinary collaboration between different practitioners (as clinicians, sports scientists, physiotherapists, coaches, etc.) would be necessary to detect risk factors and apply these findings in the practice.

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