UNIVERSIDAD MIGUEL HERNÁNDEZ DE ELCHE

FACULTAD DE MEDICINA

TRABAJO FIN DE GRADO

GRADO EN FISIOTERAPIA

Mechanisms of lower limb muscle injuries in Soccer analyzed through Video Analysis. Systematic Review.

AUTOR: Keller Bonet, Juan

TUTOR: Moreno Pérez, Víctor

Departamento: Patología y Cirugía

Curso académico 2023-2024.

Convocatoria de 14 de Junio 2024

CONTENTS INDEX

ABSTRACT

Objective: The main objective of this Systematic Review was to observe the literature in search of lower limb muscle injuries in soccer that have been studied through Video Analysis.

Methods: the search began December 1st, 2023, a PEO search strategy was elaborated, and search equations were created for each of the 5 databases used (PubMed, SPORTDiscuss, Embase, WebOfScience and Cochrane), the QA-SIVAS scale was used to evaluate the selected articles' quality and following the 2020 PRISMA declaration recommendations.

Results: A total of 5 articles were included in the review, most of the articles contained a European sample (83%). Kicking actions were the predominant cause of quadriceps injuries (72.4%), with a position that involved hip extension and knee flexion, for the hamstring it was sprinting (42.1%) while in positions of maximum hip flexion and knee extension, the acceleration phase represented the highest action at injury for the calf (58.8%), and lastly kicks (31.2%) or reaching actions (37.5%) for the adductor, where the leg was abducted and externally rotated in different hip angles, it was found that most injuries occurred during a defensive action (53.7%).

Conclusion: The muscles that were injured mostly were the hamstring, quadriceps, adductors, and calf. There was a variety of actions that lead to injury identified for each muscle at study, but a predominant biomechanical posture and action for each one of them was observed.

Keywords: football, visual analysis, muscle rupture, muscle tear, injury etiology.

RESUMEN

Objetivo: El objetivo de esta revisión sistemática es de observar la literatura en busca de lesiones musculares de miembro inferior en futbol que hayan sido estudiadas por medio del Video Análisis.

Método: La búsqueda comenzó el 1 de Diciembre del 2023, se elaboró una estrategia de búsqueda PEO y se crearon ecuaciones de búsqueda para cada una de las 5 bases de datos usadas (PubMed, SPORTDiscuss, Embase, WebOfScience and Cochrane), se empleó la escala QA-SIVAS para evaluar la calidad de los artículos seleccionados, y siguiendo las recomendaciones de la declaración PRISMA 2020.

Resultados: Un total de 5 artículos fueron incluidos en la revisión la mayoría de los artículos contienen una muestra Europea (83%), las acciones de golpeo fueron la causa predominante de lesiones en el cuádriceps (72.4%), con una posición que involucra una extensión de cadera y flexión de rodilla, para los isquiosurales fue el sprint (72.4%), mientras se realizaba una posición de flexión de cadera y extensión de rodilla máximas, la fase de aceleración representó la acción lesiva más alta para el tríceps sural (58.8%), y los golpeos (31.2%) o las acciones de alcance (37.5%) para el aductor, donde la pierna se encontraba abducida en rotación externa y en diferentes ángulos de flexión de cadera, se encontró que la mayoría de lesiones ocurren durante una acción defensiva (53.7%).

Conclusión: Los músculos mayoritariamente lesionados son isquiosurales, cuádriceps, aductores y gemelos. Existe variedad en la acción lesional de cada músculo, pero se observa una biomecánica y acción predominante para cada uno.

Palabras clave: fútbol, análisis visual, rotura muscular, muscular, etiología de la lesión.

1. INTRODUCTION

Soccer is one of the most popular sports in the world, it's practiced by a high number of people ranging from all ages and genders. It is not only extremely popular, but at the professional level it is a very demanding sport (1). The players suffer high amounts of internal and external load, as well as psychologically demanding situations, it involves a handful of different movements: linear acceleration, side to side movements, with high levels of muscle fatigue and high demand on the cardio-respiratory system (1). Due to the sport's demands, previous studies have shown an important injury incidence. In this sense, injuries in soccer are estimated to be around 8.1 per 1000 hours of exposure, as shown in (2) and lower limb muscle injuries have the highest incidence, specifically muscle and tendinous injuries which lead the podium, representing from 31% (3) up to 41% of total injuries (4).

Statistically the mainly injured muscle groups in soccer are hamstrings (37%), adductors (23%), quadriceps (19%) and the calf muscles (13%) (3). We now also understand that the number of injuries not only augmented during matches, but also during training, on top of that, previous studies have observed that one fifth of injuries were recurrent injuries (3,4). Apart from the high incidence of muscle injuries, in the last 21 years there's been an increase of up to two times as many hamstring muscles injuries and two times as many absence days caused by said injuries (5). This rise in the incidence of lower limb muscle injuries shows us that there is a need for better ways of understanding muscle injuries.

Regard to the etiology of injuries, it is often that the perceived severity of the injury for the player is not translated into the conclusions or diagnosis of the professional in charge of registering the injury (6), having that in mind, if we really want to go in depth and truly understand the injury, it's evident that we need the most objective method possible, one that sheds light into the multifactorial sphere of the injury one that allows us to understand the precise action that lead to the event, and all what surrounds that specific moment. Several methods have been used nowadays, previous studies showed the currently used methods such as: clinical trials, laboratory motion analysis, cadaver studies, athlete interviews (6).

With such variety there´s multiple perspectives on how to study the injury, and one of the newest methods is called Video Analysis.

There is limited information in the literature about the exact biomechanics and precise moment at the time of injury (7), as mentioned before, Video Analysis seems to be the tool to study those precise variables. Video Analysis is a method of describing injury mechanisms and the circumstances surrounding them, it originated from match analysis methods, and it summarizes variables observed in video, like the player's position, action leading to injury, biomechanics (8). The inter- and intra-observer results show Video Analysis to be a good method to study muscle injuries (8), but there´s still few evidence around the mainly injured muscle groups, riskiest actions at injury and biomechanics studied through Video Analysis.

1.1 Objectives

For the purpose of this Systematic Review the objectives are the following: the main objective is to observe the existing scientific evidence on lower-limb muscle injuries in soccer which have been studied through Video Analysis; from which the secondary objectives emerge: to describe the sample's characteristics, the main actions at injury and biomechanics for each muscle group injured and the playing circumstances (offensive/ defensive) behind the injury.

2. MATERIALS AND METHOD

2.1 Study Design

Preliminary findings were searched based on the initial interest: systematic video analyzed muscle injuries. A single search algorithm was created for each database: PubMed, SPORTDiscuss, Embase, WebOfScience and Cochrane. The quality of a systematic review depends on the extent to which the methods minimize the risk of error and bias (9).

2.2 Data Bases

The search for articles began December first 2023 and ended February 20, 2024. PubMed, SPORTDiscuss, Embase, WebOfScience and Cochrane were searched, this review was approved by the OIR, TFG COIR: TFG.GFI.VMP.JKB.240220.

2.3 PEO Strategy and article search strategy

The PEO (Population/Exposure/Outcome) strategy was used, instead of PICO, since this review aligns with an etiology perspective (9).

- Population: male* football (soccer) players.
- Exposure of interest: mechanism/context inciting lower limb muscle injuries.
- Outcome. video-based analysis.

Based on the PEO strategy, and through preliminary research these were the keywords used for the search, the items were put into four main categories (Table 1). The PRISMA 2020 (10) declaration was used as a tool to guide this research, it consists of a list of 27 items that should be present for a thorough systematic review.

Table 1. Items used in the search equation				
Injury Related		Video Related	Sport Related	Muscle Related
Wound	injury activities	Video	Soccer	Muscle
Wounds	injury characteristics	video-analysis	Football	muscle strain
injury mechanism	injury context	visual analysis		muscle strains
injury mechanisms	injury contexts	video inspection		muscle tear
injury event	injury pattern	videotape		muscle tears
injury events	injury patterns	videotaping		muscle rupture
injury situation	etiology situational			muscle ruptures
injury situations	situational patterns			muscle injury
injury circumstance				muscle injuries
injury circumstances				
injury occasion				
injury occasions				
injury activity				

The use of the items above and the correct use of the bolean operators “AND” and “OR”, was used for the search equations, “OR” was used to include all possible variables at study, and “AND” was used to ensure the articles included all the interests of the PEO strategy, the use of ”*” is for including all the derivations of the item. Therefore, the search strategy was based on the following equations (Table 2).

Table 2.	Search equation for the identification of reports sought for retrieval.
PubMed	(“muscle*” OR “muscle strain*” OR “muscle tear*” OR “muscle rupture*” OR “muscle injury*” OR “adductor*” OR “hamstring*” OR “quadriceps” OR “gastrocnemius” OR “rectus” OR “calf*” OR “soleus” OR “lower leg*” OR “lower limb*”) AND (“video*” OR “video-analysis” OR “video inspection*” OR “videotape*”) AND (“soccer” OR “football”) AND (“wound*” OR “injury mechanism*” OR “injury event*” OR “injury situation*” OR “injury circumstance*” OR “injury occasion*” OR “injury activit*” OR “injury characteristic*” OR “injury context*” OR “injury pattern*” OR “etiology” OR “situational pattern*”)
Embase	(“muscle” OR “muscle strain*” OR “muscle tear*” OR “muscle rupture*” OR “muscle injury*” OR “adductor” OR “hamstring” OR “quadriceps” OR “gastrocnemius”) AND (“video” OR “video-analysis” OR “visual analysis” OR “video inspection” OR “videotape*”) AND (“soccer” OR “football”) AND (“wound*” OR “injury mechanism*” OR “injury event*” OR “injury situation*” OR “injury circumstance*” OR “injury occasion*” OR “injury activit*” OR “injury characteristic*” OR “injury context” OR “injury pattern*” OR “etiology” OR “situational pattern*”)
SPORT Discus	(“muscle” OR “muscle strain*” OR “muscle tear*” OR “muscle rupture*” OR “muscle injury*” OR “adductor” OR “hamstring” OR “quadriceps” OR “gastrocnemius”)AND (“video” OR “video-analysis” OR “visual analysis” OR “video inspection” OR “videotape*”) AND (“soccer” OR “football”) AND (“wound*” OR “injury mechanism*” OR “injury event*” OR “injury situation*” OR “injury circumstance*” OR “injury occasion*” OR “injury activity*” OR “injury characteristic*” OR “injury context” OR “injury pattern*” OR “etiology” OR “situational pattern*”)
Cochrane (CENTRAL)	(“muscle” OR “muscle strain” OR “muscle strains” OR “muscle tear” OR “muscle tears” OR “muscle rupture” OR “muscle ruptures” OR “muscle injury” OR “muscle injuries”)AND (“video” OR “video-analysis” OR “visual analysis” OR “video inspection” OR “videotape” OR “videotaping”) AND (“soccer” OR “football”) AND (“wound” OR “wounds” OR “injury mechanism” OR “injury mechanisms” OR “injury event” OR “injury events” OR “injury situation” OR “injury situations” OR “injury circumstance” OR “injury circumstances” OR “injury occasion” OR “injury occasions” OR “injury activity” OR “injury activities” OR “injury characteristic” OR “injury characteristics” OR “injury context” OR “injury contexts” OR “injury pattern” OR “injury patterns” OR “etiology” OR “situational pattern” OR “situational patterns”)
Web Of Science	(“muscle” OR “muscle strain*” OR “muscle tear*” OR “muscle rupture*” OR “muscle injury*” OR “adductor” OR “hamstring” OR “quadriceps” OR “gastrocnemius”)AND (“video” OR “video-analysis” OR “visual analysis” OR “video inspection” OR “videotape*”) AND (“soccer” OR “football”) AND (“wound*” OR “injury mechanism*” OR “injury event*” OR “injury situation*” OR “injury circumstance*” OR “injury occasion*” OR “injury activity*” OR “injury characteristic*” OR “injury context” OR “injury pattern*” OR “etiology” OR “situational pattern*”)

2.4 Eligibility Criteria

Based on the PEO strategy, inclusion criteria will be as follows:

- Population: male football (soccer) players.
- Exposure of interest: mechanism/context inciting lower limb muscle injuries.
- Outcome. video-based analysis.

Exclusion criteria:

- Articles were excluded if they didn't use video analysis for the investigation.
- Articles were excluded if they analyzed another injury instead of lower limb muscle injuries
- Articles were excluded if the population at study isn't male* football (soccer) players.

2.5 Filters

No filters were added to the databases, the earliest included article in this review dates to February 2019. Almost all articles found in "reports sought for retrieval" were male, the gender disparity will be discussed ahead in the article, and "male-based articles" was turned into an inclusion criterion for the review.

2.6 Data extraction

One article from the included in the review wasn't available on open access (11) so the article was requested to the investigator via email. The rest of the articles could be accessed either through open access sources or using the UMH Digital Library access. The variables sought for in this review are sample size, study type, action at injury, offensive/defensive action and biomechanics.

2.7 Article quality evaluation

The QA-SIVAS scale (12) was used; it consists of an 18-item checklist addressing the study design, data source, conduct, report, and discussion of video analysis studies in sports injury research. After the evaluation, one article (13) was excluded, fitting moderate quality standards (60-70% items). The items in the scale and the articles' score are shown in (Anexus 1).

3. RESULTS

For the processing of results, all variables mentioned previously were sought for in the articles, an Excel (V. 2402) sheet was used for the better processing of the information. PRISMA 2020 flow diagram was used for identification of studies, and Mendeley Reference Manager v2.107.0, for article processing and duplicate elimination.

3.1 Article identification

A total of 1782 articles were found on the preliminary findings (PubMed: 363; Embase: 417; Sport Discuss: 514; Cochrane: 106 and WebofScience: 382). Which were used for the identification of search items and later for the confection of the final search equations. With the results of said aquations, 113 articles showed up. Using Mendeley, duplicate records were removed, which left 98 records to be screened, after reading the title and abstract, 40 articles were sought for retrieval, after the review based on inclusion and exclusion criteria and article quality evaluation process, 5 articles were included in this research (11,14-17). This procedure is shown in (Figure 1). From the five articles included in this review, three of them were cross-sectional studies (12,14, 17), and two of them, descriptive case series studies (15,16).

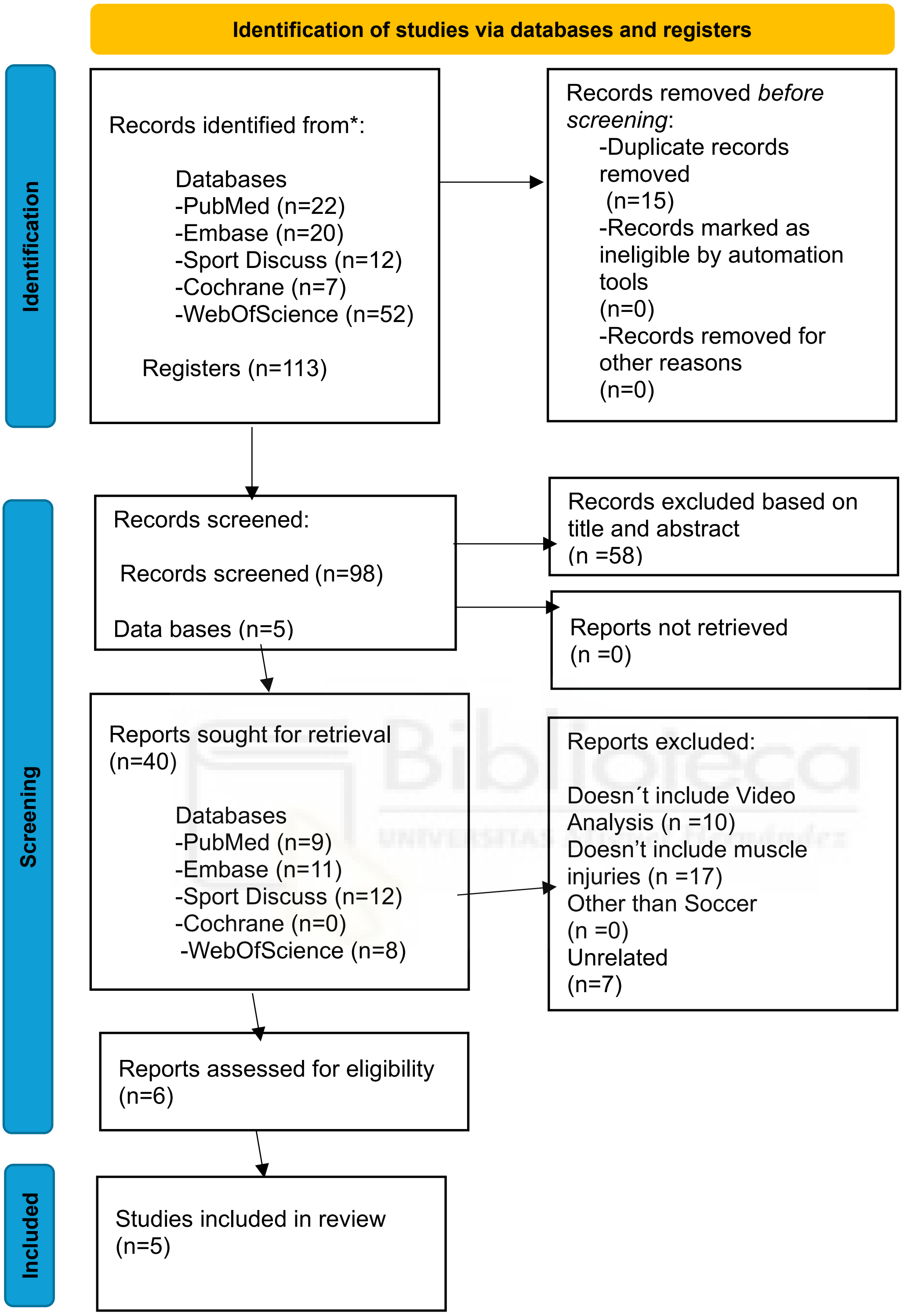


Figure1. Flow diagram for the identification of studies, following PRISMA 2020.

3.2 Sample characteristics

Regarding the selected articles, the general sample was European (83%) composed mainly by Spain, Finland, England, Germany (11,14-16), while only 17% from Asia (Qatar) (17). Concerning the average age of the sample in the different articles, it was 25 years, with a range of 18-38 years (11,14-17). When looking at the player position, a total of 6.71% goalkeepers, 39.5% defenders, 28.4% midfielders and 25.4% forwards were included in this review. A total of 200 injuries were analyzed representing 60.5% in hamstring, 16.5% in adductors 14.5% for quadriceps and 8.5% for the calf (11,14-17).

3.3 Action at injury

From the total of selected articles, 60% included the hamstring (11,14,16), 40% for both the adductors (14,17) and quadriceps (14,15), and 20% included the calf (14).

For the hamstring (11,14,16), running injuries were identified as the highest-risk action at injury 42.1% (n=51) in which acceleration injuries 12.4% (n=15) are included , followed by reaching or stretching 37.1% (n=28) in which stopping or lunging injuries 14.0% (n=17) are included, kicking injuries 14.9% (n=18),change of direction 3.3% (n=4), landing 2.5% (n=3) and shielding 0.8 % (n=1).

For the quadriceps (14,15), kicking injuries were identified as the highest-risk action at injury 72.4% (n=21), followed by reaching or stretching 13.8% (n=4), change of direction 13.8% (n=4) and lastly running 10.3% (n=3).

For the adductors (14,17), reaching and stretching injuries were identified as the highest-risk action at injury 37.5% (n=12), followed by kicking in 31.2 % (n=10) cases, change of direction in 18.7% (n=6) and lastly jumping 12.5% (n=4). While the adductor injuries were classified into the running injuries category.

Regarding the calf (14), running injuries were identified as the highest-risk action at injury in 58.8% (n=10) of the cases, closely followed by reaching and stretching injuries which represent 41.1% (n=7). For the calf, only two actions at injury were found.

Concerning the action at injury four main actions were found to be the most occurring: running, kicking, reaching/stretching and change of direction (Figure 2).

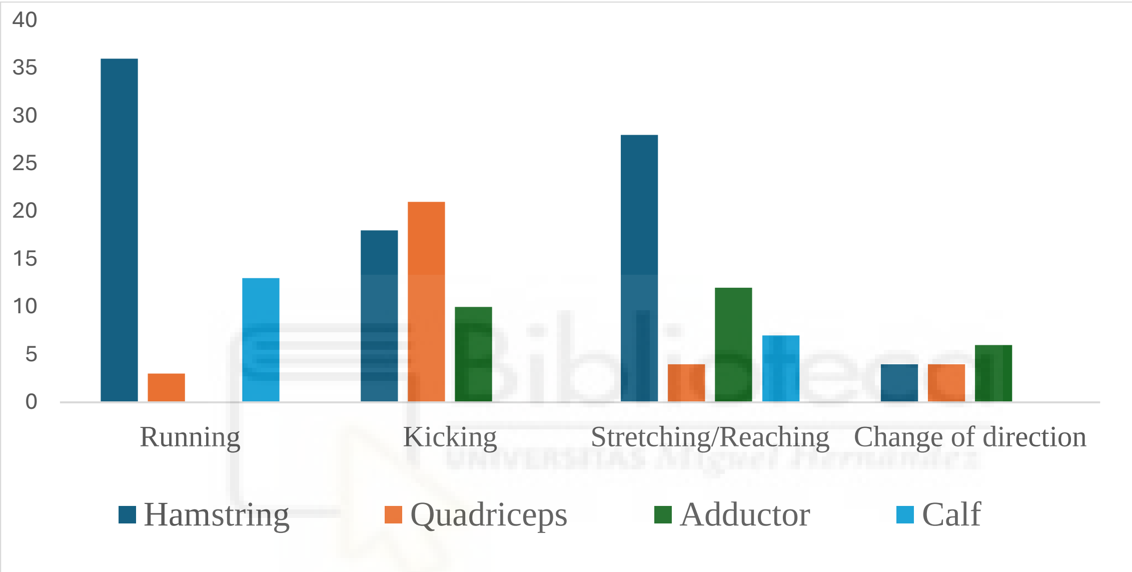


Figure 2. Representation of most occurring actions at injury in the four mainly injured muscle groups.

3.4 Biomechanics

In 76 cases the exact Biomechanical posture at time of injury was determined, 43.4% for the hamstring (11, 14) in 34.2% for the quadriceps (14,15) and 22.3% for the adductors (14,17) (Table 3, 4 and 5).

Table 3. Quadriceps Injury Biomechanis				
MUSCLE	**OPEN/CLOSED CHAIN**	**HIP**	**KNEE**	**ANKLE**
Quadriceps (n=26)	Open Chain Kicking 19/26 (73.1%)	Extension to Flexion 19/19 (%)	Flexion to extension 19/19 (%)	-------------------
	Closed chain Kicking (Injured leg is fix) 4/26 (15.1%)	Flexion to extension 4/4 (%)	Extension to Flexion 4/4 (%)	-------------------
	Closed Chain Change of Direction 1/26 (3.8%)	Flexion to extension 1/1 (%)	Extension to flexion 1/1 (%)	-------------------

Table 4. Hamstring Injury Biomechanics				
MUSCLE	**OPEN/CLOSED CHAIN**	**HIP**	**KNEE**	**ANKLE**
Hamstring (n=33)	Open chain Stretch related injuries 30/33 (90.9%)	Extension to Flexion 23/30 (76.6%)	Flexion to extension 25/30 (83.3%)	-------------------
		Flexion to extension 7/30 (23.3%)	Extension to Flexion 5/30 (16.6%)	-------------------
	Open chain Sprint related injuries 3/33 (9.1%)	Extension to flexion 3/3 (%)	Flexion to extension 3/3(%)	-------------------

Table 5. **Adductors Injury Biomechanics**				
MUSCLE	**OPEN/CLOSED CHAIN**	**TRUNK**	**HIP**	**KNEE**
Adductors (n=17)	-------------------	Neutral 8/17 (47.1%) Extension 4/17 (23.5%) Flexion 2/17 (11.8%)	<u>Sagittal Plane:</u> Extension 9/17 (52.9%) Flexion 5/17 (29.4%) Neutral 1/17 (5.9%) <u>Frontal plane:</u> Abduction 12/17 (70.6%) Neutral 2/17 (11.8%) <u>Transverse plane:</u> External 7/17 (41.2%) Neutral 4/17 (23.5%) Internal 2/17 (11.8%)	Flexion <45 degrees 10/17 (58.8%) Flexion between 45-90 degrees 5/17 (29.4%) Flexion >90 degrees 1/17 (5.9%)

For the calf, no information regarding biomechanics of calf injuries were found in the reviewed articles.

3.5 Offensive or defensive action

For the main muscle groups at study in this review, each one was classified into a defensive or offensive context at injury (12,15). Offensive actions constituted 46.3% of the injuries while defensive actions 53.7%. Calf (58.8% (n=10)) and quadriceps (88.9 % (n=8) were the muscles which mostly injured during an offensive situation, while the hamstring during defensive actions (73% (n=27)). In the case of the adductors, half of the actions were offensive and the other half defensive.

4. DISCUSSION

In the results section, the sample's characteristics, the main actions at injury and biomechanics for each muscle group injured and the playing circumstances (offensive/ defensive) behind the injury were described, these findings will be discussed in context of the existing scientific evidence in the following section.

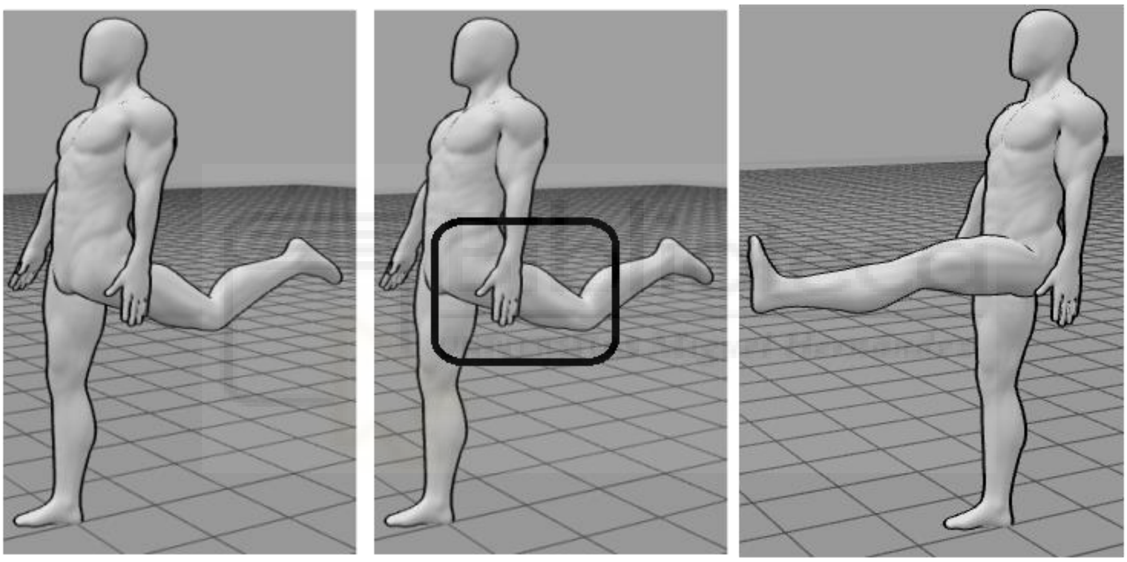
4.1 Sample characteristics discussion

Regarding the selected articles, the general sample was European 83% while only 17% from Asia (Qatar). Many of the selected articles were based on a European sample, this could be attributed to the fact that historically, most of the earlier soccer related articles were published in northern and central European countries (18), as well as the efforts of European Football/ Soccer Leagues and organizations to invest in sports science and research, an example being the UEFA using prospective studies on teams (19). While few examples existing in non-European teams and leagues (20).

On the other hand, another explanation could be due to the injury epidemiology. Injury incidence tends to be higher in non- European countries, and there is various explanations in the existing evidence, some authors propose that the methods used in their studies were more reliable (21), while other authors propose that the incidence is higher due to a lower conditioning in Asian players, thus resulting in a higher amount of injuries (22). What does not appear to change between European players and non-European is the injury patterns (21). Apart from the earlier, cultural events such as the Ramadan have been thought to influence injury incidence (23, 24).

4.2 Action at injury and biomechanics discussion

The main findings showed that for the quadriceps kicking actions were identified as the highest leading action to injury (72.4%) while running, stretching or change of direction actions represent the rest of the injuries observed, similar to observed in previous reports (25). The results suggest that the biomechanical pattern behind kicking injuries was based on a rapid movement from hip extension to hip flexion, with the knee moving from flexion to extension, in an open chain movement (Table 3). The kicking action involves the muscle being stretched in the early phases, with the muscle generating an eccentric force until the momentum change, where the swing phase of the kick will happen (26), at that moment the injury occurs, the mechanism is represented in (Figure 3).



*All representations were created with public free to use software (PoseMyArt).

Figure 3. Representation of quadriceps kicking injuries (eccentric stretch in the early stages of the kick.).

In the hamstring muscle injuries, a variety of injury actions were observed, although running was identified as the highest leading action to injury, representing 42.1% of the cases, especially while high speed running, closely followed by stretching, reaching for a ball and kicking. High speed running has been previously attributed as a high-risk action for injury, where the subject is more prone to injury when running more than 25 km/h and above 80% of their maximum speed (27). The biomechanics of the injury were mostly studied in stretch related injuries, where the main injury mechanism involves the hip going from extension to flexion and the knee passing from a flexed position to an extended one, while there wasn't a significant difference in trunk position, just a slight tendency to trunk flexion. These joint positions remained the same in sprint related injuries. This position where the hip is fully flexed and the knee is fully extended seems to be a weak anatomical position for the hamstring, which is supported by previous investigation on the topic, where, the time of injury for sprint related injuries corresponds to the late swing stage where the knee is fully extended (28) (Figure 4).

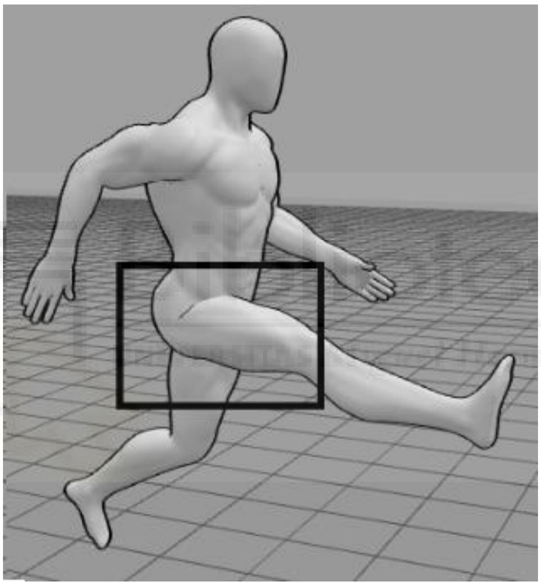


Figure 4. Late swing stage in sprint related injuries

For the adductor a variety of actions at injury were identified, no action at was significantly higher compared to the others. Reaching for the ball (37.5%), followed by kicking (31.2%) were identified as the two highest leading actions to injury, change of direction (18.7%) or jumping (12.5%) represent the rest of total injuries, cutting maneuvers and passing have been found to represent a high risk of injury for the adductors in previous studies (29), for their great solicitation of the adductor musculature. During the kicking actions the trunk remained neutral, the pelvis was rotated to posterior, the hip was extended, abducted and externally rotated, and the knee was mostly at an angle lower than

45 degrees of flexion, we see that this position correlates with the maximum muscle activation, maximum lengthening rate and maximum hip extension (30) (Figure 5). For reaching injuries the joint positions remained the same, except for the hip that stayed in a flexed position (Figure 6).

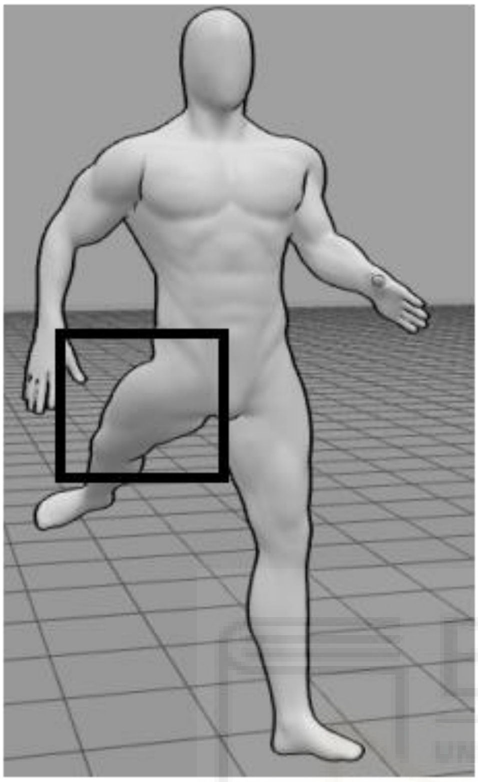


Figure 5. Adductor kicking injury in maximum adductor eccentric stretch.

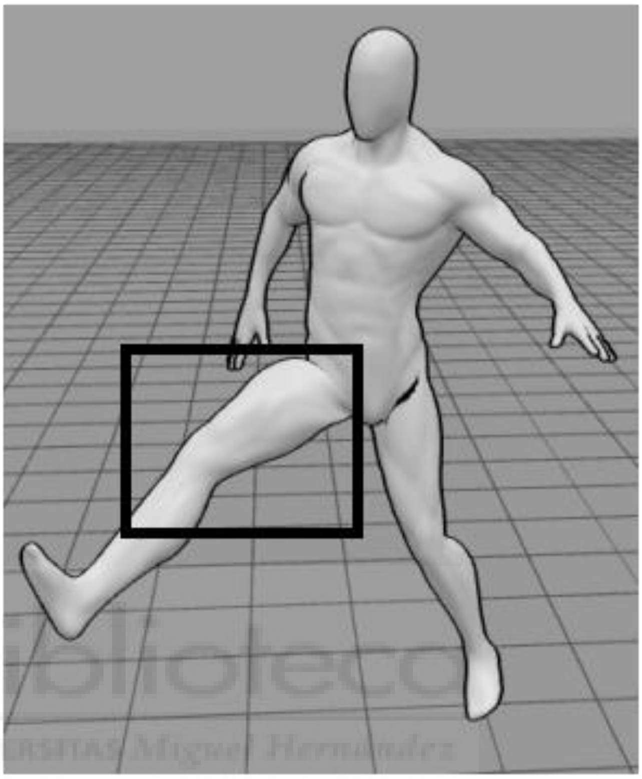


Figure 6. Adductor stretching/reaching injury.

The calf muscles were studied only for action at injury, running injuries were identified as the highest-risk action at injury in 58,8% of the cases, with a high incidence during the acceleration phases of the running cycle, closely followed by stretching injuries 41,1%, the acceleration phase had been previously identified as the leading action to calf injuries (31) (Figure 7).

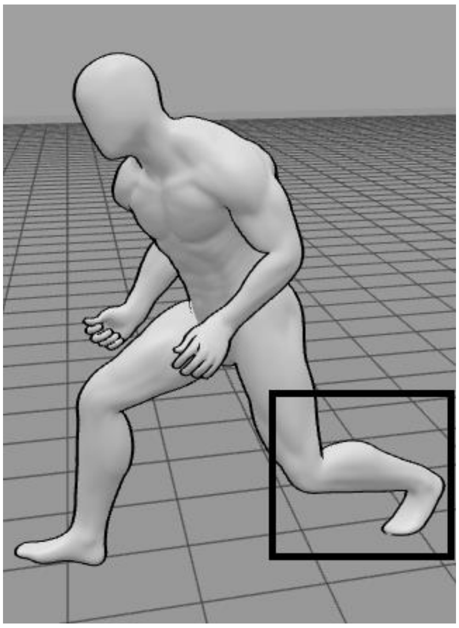


Figure 7. Acceleration injury mechanism

in calf injuries.

4.3 Offensive or defensive action discussion

Most muscular injuries occurred during a defensive action (53.7%) while offensive actions were less leading to injury. The literature suggests that injuries occur largely without the presence of an opponent, 69.7–57.0% or that there are more injuries in the defensive zone (13), while others suggest that there is no difference in the area (midfield, attacking or defending area (32) but few evidence is found relating muscle injuries with offensive or defensive actions.

Also, in this review the calf and the quadriceps muscles were found to be injured mostly in offensive actions (58.8% - 88,9% respectively), the quadriceps was mostly injured while kicking which is considered as an offensive action, and that could explain the higher percentage. While the hamstring was mostly injured during defensive actions (73%) and in the case of the adductors half of the injuries were offensive and the other half were defensive. It has been studied that defensive actions involve different high intensity movements and changes of speed (33) such as acceleration, sprinting, stretches and reaching movements, in which the hamstrings or the adductors are recruited, which could explain that they get injured mostly during defensive actions.

Recent studies start to look at the presence of distractions during the game as another factor that adds to the risk of injury (34), so it may be possible that actions that involve more visual stimuli and more decision making lead to a higher chance of injury, this is explained by Dual Task Interference, when performing a simultaneous cognitive and motor task results in a diminished efficiency in one of the tasks (35).

4.4 Practical Applications

The information regarding action at injury, biomechanics and offensive/defensive actions can be used to understand the mechanisms and the surrounding events of lower limb muscle injuries in soccer, and it helps understand and complement the existing evidence on prevention of muscular injuries.

For the hamstring, the joint position involved in both stretch and running injuries seems to be the leading cause to injury, where the hip is flexed, and he knee fully extended which is the highest stretch position for the hamstring muscles. This position combined with the different actions at injury involve high eccentric loads into the muscle, so augmenting the capacity of the muscle to generate eccentric force should be one of the objectives when discussing hamstring injury prevention (36). Running at speed is a complex movement with a high risk of injuring the hamstring (37), some studies suggest that the ability to do a repeated sprint is a hamstring injury predictor and therefore that ability must be trained in order to diminish injury incidence (38).

The quadriceps was mostly injured while kicking, in a position that involved a rapid change from hip extension to flexion, and knee flexion to extension (where the mechanism at injury was the momentum change right at the start of the swing phase of the kick) and running. Both involve eccentric muscle actions which lead to injury (39) therefore training the eccentric capacity of the muscle alongside flexibility, strength and core stability should be the cornerstone of the treatment (40).

In the majority of occasions, the adductor was injured while kicking and reaching, actions with very similar joint positions except for the hip so the findings suggest that the capacity of the adductor to tolerate rapid loading at a lengthened state is the mechanism that incites adductor injuries, and thus, that capacity should be trained (41). Improving the capacity of the muscle to resist load at a lengthened state can be achieved through eccentric training, and it is included as a tool in current protocols and studies (42, 43).

The prevalent cause for calf injuries was the acceleration phase of a sprint or running action, existing literature points in the direction of total volume rather than intensity to be one of the main factors in calf injuries (44), the management of the load alongside with the task specific training could be used as tools for calf injury prevention.

4.4 Limitations

Few of the articles contained information relating the player role with the injury suffered, so it wasn't included as a variable in the review. Some studies have found statistical differences between injury patterns and player role, groin injuries were found to be lower in defenders and goalkeepers while significantly higher in forwards, whereas midfielders had a statistically higher chance of having an adductor injury compared to any other positions (45). Other studies show that defenders suffer a high incidence in hamstring injuries in non-contact situations (13). But there is still few evidence linking the player's role and the risk of suffering a specific muscle injury.

.

All the articles included in the review were based on professional soccer athletes, so there is no comparison with lower leagues or amateur players. The existing information in the literature is diverse, some authors suggest that there is a decrease in the number of injuries as the level of play increases (due to player awareness of injury, team prevention strategies, better nutrition), but with no statistical differences with other levels of competition (46). And others discard that idea and only relate the number of injuries with the design of a correct training/prevention protocol (47).

The population in the selected articles is all male based, as mentioned previously in the "Filters" section, none of the articles sought for retrieval that included video analysis were performed on female players, so the findings may not correlate with the injury etiology of female players. The existing evidence shows that men are more likely to suffer mild injuries, and hamstring strains or pubalgia cases were more frequent than in women. While women are more likely to sustain anterior cruciate ligament ruptures, ankle injuries or quadriceps injuries (48,49).

5. SUMMARY

In summary, these are the conclusions observed in the review: first, almost all articles were based on a European sample which was attributed to more scientific research being done in European leagues with the help of federations and organizations. Second, the muscle groups that were found to be injured mostly were the hamstring, quadriceps, adductors, and calf (in order of injury incidence), and although there was a variety of actions that lead to injury, each muscle group could be linked with an action and anatomical position that predominantly led to it. In the case of the quadriceps, loading the kicking action with a high eccentric component for the muscle seems to be the predominant cause of injury, meanwhile the cause of most hamstring injuries was the eccentric force present in both high velocity sprints and in stretches, in the adductors the abduction and external rotation of the leg in different hip angles during kicks and reaching actions were found to be high risk patterns , and finally the calf with the predominant injury action being the acceleration phase during running. Third, the tendency was towards defensive injuries, especially in the hamstring while the other muscle groups tended to get injured in offensive actions. All these findings were represented as charts and figures during the review and discussed alongside the existing evidence in muscle injury prevention to formulate the main practical applications of this review.

6. BIBLIOGRAPHY AND SUPPLEMENTARY MATERIALS

1. (Mendez-Villanueva A, Buchheit M, Simpson B, Bourdon PC. Match play intensity distribution in youth soccer. Int J Sports Med. 2013 Feb;34(2):101-10. doi: 10.1055/s-0032-1306323. Epub 2012 Sep 7. PMID: 22960988.
2. (López-Valenciano A, Ruiz-Pérez I, Garcia-Gómez A, Vera-Garcia FJ, De Ste Croix M, Myer GD, Ayala F. Epidemiology of injuries in professional football: a systematic review and meta-analysis. Br J Sports Med. 2020 Jun;54(12):711-718. doi: 10.1136/bjsports-2018-099577. Epub 2019 Jun 6. PMID: 31171515; PMCID: PMC9929604
3. Ekstrand J, Hägglund M, Waldén M. Epidemiology of muscle injuries in professional football (soccer). Am J Sports Med. 2011 Jun;39(6):1226-32. doi: 10.1177/0363546510395879. Epub 2011 Feb 18. PMID: 21335353.
4. Hawkins RD, Fuller CW. A prospective epidemiological study of injuries in four English professional football clubs. Br J Sports Med. 1999 Jun;33(3):196-203. doi: 10.1136/bjsm.33.3.196. PMID: 10378073; PMCID: PMC1756169.
5. Ekstrand J, Bengtsson H, Waldén M, Davison M, Khan KM, Hägglund M. Hamstring injury rates have increased during recent seasons and now constitute 24% of all injuries in men's professional football: the UEFA Elite Club Injury Study from 2001/02 to 2021/22. Br J Sports Med. 2022 Dec 6;57(5):292–8. doi: 10.1136/bjsports-2021-105407. Epub ahead of print. PMID: 36588400; PMCID: PMC9985757.,
6. Junge, A., Dvorak, J. (2000). Influence of Definition and Data Collection on the Incidence of Injuries in Football. The American Journal of Sports Medicine, 28.
7. Krosshaug T, Andersen TE, Olsen OE, Myklebust G, Bahr R. Research approaches to describe the mechanisms of injuries in sport: limitations and possibilities. Br J Sports Med.

2005 Jun;39(6):330-9. doi: 10.1136/bjsm.2005.018358. PMID: 15911601; PMCID: PMC1725235.

8. Andersen TE, Larsen Ø, Tenga A, Engebretsen L, Bahr R. Football incident analysis: a new video based method to describe injury mechanisms in professional football. Br J Sports Med. 2003 Jun;37(3):226-32. doi: 10.1136/bjsm.37.3.226. PMID: 12782547; PMCID: PMC1724642.
9. Aromataris E, Munn Z (Editors). JBI Manual for Evidence Synthesis. JBI, 2020.
10. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, Chou R, Glanville J, Grimshaw JM, Hróbjartsson A, Lalu MM, Li T, Loder EW, Mayo-Wilson E, McDonald S, McGuinness LA, Stewart LA, Thomas J, Tricco AC, Welch VA, Whiting P, Moher D. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021 Mar 29;372:n71. doi: 10.1136/bmj.n71. PMID: 33782057; PMCID: PMC8005924.
11. Gronwald T, Klein C, Hoenig T, Pietzonka M, Bloch H, Edouard P, Hollander K. Hamstring injury patterns in professional male football (soccer): a systematic video analysis of 52 cases. Br J Sports Med. 2022 Feb;56(3):165-171. doi: 10.1136/bjsports-2021-104769. Epub 2021 Dec 7. PMID: 34876406.
12. Hoenig T, Rahlf L, Wilke J, Krauß I, Dalos D, Willwacher S, Mai P, Hollander K, Fohrmann D, Krosshaug T, Gronwald T. Appraising the Methodological Quality of Sports Injury Video Analysis Studies: The QA-SIVAS Scale. Sports Med. 2024 Jan;54(1):203-211. doi: 10.1007/s40279-023-01907-z. Epub 2023 Aug 26. PMID: 37632664; PMCID: PMC10799118.
13. Argibay-González JC, Vázquez-Estévez C, Gutiérrez-Santiago A, Paramés-González A, Reguera-López-de-la-Osa X, Prieto-Lage I. Analysis of Injury Patterns in Men's Football between the English League and the Spanish League. Int J Environ Res Public Health. 2022

Sep 8;19(18):11296. doi: 10.3390/ijerph191811296. PMID: 36141571; PMCID: PMC9517621.

14. Della Villa F, Massa B, Bortolami A, Nanni G, Olmo J, Buckthorpe M. Injury mechanisms and situational patterns of severe lower limb muscle injuries in male professional football (soccer) players: a systematic video analysis study on 103 cases. Br J Sports Med. 2023 Nov 30;57(24):1550-1558. doi: 10.1136/bjsports-2023-106850. PMID: 37898508.
15. Jokela A, Mechó S, Pasta G, Pleshkov P, García-Romero-Pérez A, Mazzoni S, Kosola J, Vittadini F, Yanguas J, Pruna R, Valle X, Lempainen L. Indirect Rectus Femoris Injury Mechanisms in Professional Soccer Players: Video Analysis and Magnetic Resonance Imaging Findings. Clin J Sport Med. 2023 Sep 1;33(5):475-482. doi: 10.1097/JSM.0000000000001131. Epub 2023 Feb 28. PMID: 36853900; PMCID: PMC10467807.
16. Jokela A, Valle X, Kosola J, Rodas G, Til L, Burova M, Pleshkov P, Andersson H, Pasta G, Manetti P, Lupón G, Pruna R, García-Romero-Pérez A, Lempainen L. Mechanisms of Hamstring Injury in Professional Soccer Players: Video Analysis and Magnetic Resonance Imaging Findings. Clin J Sport Med. 2023 May 1;33(3):217-224. doi: 10.1097/JSM.0000000000001109. Epub 2022 Nov 25. PMID: 36730099; PMCID: PMC10128906.
17. Serner A, Mosler AB, Tol JL, Bahr R, Weir A. Mechanisms of acute adductor longus injuries in male football players: a systematic visual video analysis. Br J Sports Med. 2019 Feb;53(3):158-164. doi: 10.1136/bjsports-2018-099246. Epub 2018 Jul 13. PMID: 30006458.
18. Sandelin J, Santavirta S, Kiviluoto O. Acute soccer injuries in Finland in 1980. Br J Sports Med. 1985 Mar;19(1):30-3. doi: 10.1136/bjsm.19.1.30. PMID: 3995226; PMCID: PMC1478236.
19. Waldén M, Hägglund M, Ekstrand J. UEFA Champions League study: a prospective study of injuries in professional football during the 2001-2002 season. Br J Sports Med. 2005 Aug;39(8):542-6. doi: 10.1136/bjsm.2004.014571. PMID: 16046340; PMCID: PMC1725291.

20. Sadat-Ali M, Sankaran-Kutty M. Soccer injuries in Saudi Arabia. Am J Sports Med. 1987 Sep-Oct;15(5):500-2. doi: 10.1177/036354658701500513. PMID: 3674274.
21. Yoon YS, Chai M, Shin DW. Football injuries at Asian tournaments. Am J Sports Med. 2004 Jan-Feb;32(1 Suppl):36S-42S. doi: 10.1177/0095399703258781. PMID: 14754858.
22. Al-Hazzaa HM, Almuzaini KS, Al-Refaee SA, Sulaiman MA, Dafterdar MY, Al-Ghamedi A, Al-Khuraiji KN. Aerobic and anaerobic power characteristics of Saudi elite soccer players. J Sports Med Phys Fitness. 2001 Mar;41(1):54-61. PMID: 11317148.
23. Eirale C, Tol JL, Smiley F, Farooq A, Chalabi H. Does Ramadan affect the risk of injury in professional football? Clin J Sport Med. 2013 Jul;23(4):261-6. doi: 10.1097/JSM.0b013e31828a2bfb. PMID: 23528844.
24. Chamari K, Haddad M, Wong del P, Dellal A, Chaouachi A. Injury rates in professional soccer players during Ramadan. J Sports Sci. 2012;30 Suppl 1:S93-102. doi: 10.1080/02640414.2012.696674. Epub 2012 Jun 15. PMID: 22697802.
25. Geiss Santos RC, Van Hellemnondt F, Yamashiro E, Holtzhausen L, Serner A, Farooq A, Whiteley R, Tol JL. Association Between Injury Mechanisms and Magnetic Resonance Imaging Findings in Rectus Femoris Injuries in 105 Professional Football Players. Clin J Sport Med. 2022 Jul 1;32(4):e430-e435. doi: 10.1097/JSM.0000000000000935. Epub 2021 May 26. PMID: 34050059.
26. Mendiguchia J, Alentorn-Geli E, Idoate F, Myer GD. Rectus femoris muscle injuries in football: a clinically relevant review of mechanisms of injury, risk factors and preventive strategies. Br J Sports Med. 2013 Apr;47(6):359-66. doi: 10.1136/bjsports-2012-091250. Epub 2012 Aug 3. PMID: 22864009.
27. Aiello F, Di Claudio C, Fanchini M, Impellizzeri FM, McCall A, Sharp C, Brown SJ. Do non-contact injuries occur during high-speed running in elite football? Preliminary results from a novel GPS and video-based method. J Sci Med Sport. 2023 Sep;26(9):465-470. doi: 10.1016/j.jsams.2023.07.007. Epub 2023 Jul 22. PMID: 37544819.

28. Danielsson A, Horvath A, Senorski C, Alentorn-Geli E, Garrett WE, Cugat R, Samuelsson K, Hamrin Senorski E. The mechanism of hamstring injuries - a systematic review. BMC Musculoskelet Disord. 2020 Sep 29;21(1):641. doi: 10.1186/s12891-020-03658-8. PMID: 32993700; PMCID: PMC7526261.
29. Dupré T, Tryba J, Potthast W. Muscle activity of cutting manoeuvres and soccer inside passing suggests an increased groin injury risk during these movements. Sci Rep. 2021 Mar 31;11(1):7223. doi: 10.1038/s41598-021-86666-5. PMID: 33790373; PMCID: PMC8012386.
30. Charnock BL, Lewis CL, Garrett WE Jr, Queen RM. Adductor longus mechanics during the maximal effort soccer kick. Sports Biomech. 2009 Sep;8(3):223-34. doi: 10.1080/14763140903229500. PMID: 19891200.
31. Green B, McClelland JA, Semciw AI, Schache AG, McCall A, Pizzari T. The Assessment, Management and Prevention of Calf Muscle Strain Injuries: A Qualitative Study of the Practices and Perspectives of 20 Expert Sports Clinicians. Sports Med Open. 2022 Jan 15;8(1):10. doi: 10.1186/s40798-021-00364-0. PMID: 35032233; PMCID: PMC8761182.
32. Rahnama N, Reilly T, Lees A. Injury risk associated with playing actions during competitive soccer. Br J Sports Med. 2002 Oct;36(5):354-9. doi: 10.1136/bjsm.36.5.354. PMID: 12351333; PMCID: PMC1724551.
33. Williams, A.M., Ford, P., Reilly, T., & Drust, B. (Eds.). (2003). Science and Soccer (2nd ed.). Routledge. https://doi.org/10.4324/9780203417553.
34. Wilke J, Giesche F, Niederer D, Engeroff T, Barabas S, Tröller S, Vogt L, Banzer W. Increased visual distraction can impair landing biomechanics. Biol Sport. 2021 Mar;38(1):123-127. doi: 10.5114/biolsport.2020.97070. Epub 2020 Aug 8. PMID: 33795921; PMCID: PMC7996376.
35. Leone C, Feys P, Moumdjian L, D'Amico E, Zappia M, Patti F. Cognitive-motor dual-task interference: A systematic review of neural correlates. Neurosci Biobehav Rev. 2017 Apr;75:348-360. doi: 10.1016/j.neubiorev.2017.01.010. Epub 2017 Jan 16. PMID: 28104413.

36. Hu C, Du Z, Tao M, Song Y. Effects of Different Hamstring Eccentric Exercise Programs on Preventing Lower Extremity Injuries: A Systematic Review and Meta-Analysis. Int J Environ Res Public Health. 2023 Jan 23;20(3):2057. doi: 10.3390/ijerph20032057. PMID: 36767424; PMCID: PMC9916392.
37. Girard O, Mendez-Villanueva A, Bishop D. Repeated-sprint ability - part I: factors contributing to fatigue. Sports Med. 2011 Aug 1;41(8):673-94. doi: 10.2165/11590550-000000000-00000. PMID: 21780851.
38. Dawson B. Repeated-sprint ability: where are we? Int J Sports Physiol Perform. 2012 Sep;7(3):285-9. doi: 10.1123/ijspp.7.3.285. PMID: 22930690.
39. Glick JM. Muscle Strains: Prevention and Treatment. Phys Sportsmed. 1980 Nov;8(11):73-7. doi: 10.1080/00913847.1980.11710969. PMID: 27421528.
40. Mendiguchia J, Alentorn-Geli E, Idoate F, Myer GD. Rectus femoris muscle injuries in football: a clinically relevant review of mechanisms of injury, risk factors and preventive strategies. Br J Sports Med. 2013 Apr;47(6):359-66. doi: 10.1136/bjsports-2012-091250. Epub 2012 Aug 3. PMID: 22864009.
41. Serner A, Jakobsen MD, Andersen LL, Hölmich P, Sundstrup E, Thorborg K. EMG evaluation of hip adduction exercises for soccer players: implications for exercise selection in prevention and treatment of groin injuries. Br J Sports Med. 2014 Jul;48(14):1108-14. doi: 10.1136/bjsports-2012-091746. Epub 2013 Mar 19. PMID: 23511698.
42. Krommes K, Bandholm T, Jakobsen MD, Andersen LL, Serner A, Hölmich P, Thorborg K. DYNAMIC HIP ADDUCTION, ABDUCTION AND ABDOMINAL EXERCISES FROM THE HOLMICH GROIN-INJURY PREVENTION PROGRAM ARE INTENSE ENOUGH TO BE CONSIDERED STRENGTHENING EXERCISES - A CROSS-SECTIONAL STUDY. Int J Sports Phys Ther. 2017 Jun;12(3):371-380. PMID: 28593090; PMCID: PMC5455186.
43. Jensen J, Hölmich P, Bandholm T, Zebis MK, Andersen LL, Thorborg K. Eccentric strengthening effect of hip-adductor training with elastic bands in soccer players: a

randomised controlled trial. Br J Sports Med. 2014 Feb;48(4):332-8. doi: 10.1136/bjsports-2012-091095. Epub 2012 Jul 4. PMID: 22763117.

44. Green B, McClelland JA, Semciw AI, Schache AG, McCall A, Pizzari T. The Assessment, Management and Prevention of Calf Muscle Strain Injuries: A Qualitative Study of the Practices and Perspectives of 20 Expert Sports Clinicians. Sports Med Open. 2022 Jan 15;8(1):10. doi: 10.1186/s40798-021-00364-0. PMID: 35032233; PMCID: PMC8761182.
45. Leventer L, Eek F, Hofstetter S, Lames M. Injury Patterns among Elite Football Players: A Media-based Analysis over 6 Seasons with Emphasis on Playing Position. Int J Sports Med. 2016 Oct;37(11):898-908. doi: 10.1055/s-0042-108201. Epub 2016 Jul 28. PMID: 27467906.
46. Hawkins RD, Fuller CW. An examination of the frequency and severity of injuries and incidents at three levels of professional football. Br J Sports Med. 1998 Dec;32(4):326-32. doi: 10.1136/bjsm.32.4.326. PMID: 9865406; PMCID: PMC1756112.
47. Ekstrand J, Gillquist J, Möller M, Oberg B, Liljedahl SO. Incidence of soccer injuries and their relation to training and team success. Am J Sports Med. 1983 Mar-Apr;11(2):63-7. doi: 10.1177/036354658301100203. PMID: 6846683.
48. Larruskain J, Lekue JA, Diaz N, Odriozola A, Gil SM. A comparison of injuries in elite male and female football players: A five-season prospective study. Scand J Med Sci Sports. 2018 Jan;28(1):237-245. doi: 10.1111/sms.12860. Epub 2017 Mar 27. PMID: 28207979.
49. Hägglund M, Waldén M, Ekstrand J. Injuries among male and female elite football players. Scand J Med Sci Sports. 2009 Dec;19(6):819-27. doi: 10.1111/j.1600-0838.2008.00861.x. Epub 2009 Oct 13. PMID: 18980604.

Anexus 1

Anexus 1. Quality Evaluation																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A																		
B																		
C																		
D																		
E																		
F																		

-A: Indirect Rectus Femoris Injury Mechanisms in Professional Soccer Players: Video Analysis and Magnetic Resonance Imaging Findings.

-B: Hamstring injury patterns in professional male football (soccer): a systematic video analysis of 52 cases.

-C: Injury mechanisms and situational patterns of severe lower limb muscle injuries in male professional football (soccer) players: a systematic video analysis study on 103 cases.

-D: Analysis of Injury Patterns in Men's Football between the English League and the Spanish League.

-E: Mechanisms of acute adductor longus injuries in male football players: a systematic visual video analysis.

-F: Mechanisms of Hamstring Injury in Professional Soccer Players: Video Analysis and Magnetic Resonance Imaging Findings.

-1: Objective stated.
-2: A representative sample was chosen.
-3: Information about sample is included.
-4 Information about video source and quality of the footage are included.
-5 Applied methods are described comprehensively.
-6 A systematic approach to video analysis was chosen.
-7 Medical report information is included.
-8 Background/expertise of rater(s) is stated.
-9 Findings are observed by more than one researcher.
-10 A control group is included 14 1.00 1.00–1.00 100.
-11 A quantitative biomechanical analysis was conducted using validated methods.
-12 The main results of the study are clearly described.
-13 Absolute numbers or proportions of injury cases (for each/the main outcome) are reported.
-14 Details about the injury context are included.
-15 Example screenshots/video frames are included.
-16 Findings are discussed within the context of the current evidence.
-17 Clinical/practical implications of the results are discussed.
-18 Limitations of the study are addressed