# Module 1. Muscle injuries

## Injury epidemiology

### Introduction

Football is a complex contact sport in which amateur and professional players have high risk of injuries not only in training sessions but also in competitions.

Currently, this sport is played in a faster and more aggressive way than in the past raising, consequently, the fitness standards and the intensity of the training sessions to a professional level. This has led to increase the concern of coaching staff of different teams about a greater propensity to injures associated with these phenomena.

Sports injuries are associated with the players' age, the training load, the level of game, among other factors (Pfirrmann, Herbst et al., 2016). The importance of prevention lies in the analysis of their impact on the athlete and also on the institution they belong to. In this respect, the estimated cost of an athlete's injury for a first league team is around 500,000 euros (Ekstrand, 2013). In the 1st World Congress of Sports Injury Prevention in 2005, The FIFA Medical Assessment and Research Centre (F-MARC) introduced the definitions of concepts related to football injuries (Fuller, Ekstrand et al., 2006). Some of them are mentioned below.

**Injury:**

> Any physical discomfort a player might have that requires medical care or leads to a partial or total loss of training sessions or competitions. An injury that requires medical attention is defined as a Medical Attention Injury, and an injury which prevents the player from fully taking part in training sessions or games is defined as a Time-Loss Injury. (Fuller, Ekstrand et al., 2006, p. 193)

When recording the moment injuries happen in a game, they have to be grouped in defined periods of the game [0-15, 16-30, 31-45 min, 46-60, 61-75, 76-90] and they must be reported as injury percentages occurring in each of these periods. However, injuries during extra time must be informed under the category "extra time".

**Recurrent Injury:**

> Injuries of the same type and at the same site as an index injury and which occur after the player's return to full participation in sports practice. When this recurrent injury occurs within two months of the player's return to full participation in the sporting activity, it is referred to as an early recurrence; within 2-12 months, late recurrence; and over 12 months, delayed recurrence (Fuller, Ekstrand et al., 2006, p. 194).

**Injury Severity:**

"The number of days that have elapsed from the date of injury to the date of the player's return to full participation in training sessions and competitions" (Fuller, Ekstrand et al., 2006, p. 194). The day on which an injury occurs is day "zero" and is not counted when determining the severity of an injury. Therefore, if a player cannot participate on the day of the injury but is available for participation the next day, the incident should be recorded as a time loss injury of "0 days". Consequently, the authors recommend the following classification according to the severity of the time loss injury.

- Slight = injuries with a time loss of 0 days.
- Minimal = injuries with a time loss of 1-3 days.
- Mild = injuries with a time loss of 4-7 days.
- Moderate = injuries with a time loss of 8-28 days.
- Severe = injuries with a time loss of > 28 days.

This is not the only possible classification. There are others based on the need for medical attention. In any case, the severity of the recorded injuries will be influenced by the recording regimen adopted for each study. Below, there are some examples of different classifications based on the criteria mentioned before.

**Table 1: Examples of how to record injuries under different recording regimens**

| Example | | Injury recording regime<br>Medical attention | Time-loss |
|---|---|---|---|
| 1. | A defender sustained a hamstring injury during a match that required 30 days of rehabilitation before the player could return to full training. The player sustained another hamstring injury to the same muscle (same leg) 3 weeks later and required a further 50 days of rehabilitation before he could return to full training | First incident should be recorded as an injury (severity: 30 days); second incident as a recurrence (severity: 50 days) | First incident should be recorded as an injury (severity: 30 days); second incident as a recurrence (severity: 50 days) |
| 2. | A goalkeeper developed shoulder instability and sought medical attention; the condition did not prevent the player from taking a full part in team training or competition even though it caused the player some pain. The team physiotherapist recommended an individual training programme for the goalkeeper to avoid aggravating the condition | Episode should be recorded as an injury (severity: 0 day) | Episode should not be recorded so long as the goalkeeper remained able to take a full part in team training |
| 3. | A defender sustained a groin injury, which the team physician decided did not warrant immediate treatment; the player continued to take a full part in team training and competition. The player underwent elective surgery 2 months later and required 90 days rehabilitation | Incident should be recorded as an injury (severity: 0 day); when the player underwent elective surgery, the severity should be reclassified to 90 days | Incident should be recorded as an injury at the time of the player's elective surgery (severity: 90 days) |
| 4. | A defender suffered groin pain that did not result in time loss; this incident was followed by a 1-month pain-free period; the player then suffered a further period of groin pain, which prevented the player from training and which required 21 days of rehabilitation | First episode should be recorded as an injury (severity: 0 day); second episode should be recorded as a recurrence (severity: 21 days) | First episode should not be recorded; second episode should be recorded as an injury (severity: 21 days) |
| 5. | A forward sustained an ankle sprain during a match but continued to play; the player received medical attention following the match. The player completed full team training using ankle taping (with some pain) for 6 days but aggravated the injury during the next match; the player then required 15 days of rehabilitation | First incident should be recorded as an injury (severity: 0 day) and when the second incident occurred the severity of the index injury should be reclassified to 15 days | First incident should not be recorded and the second incident should be recorded as an injury (15 days) |
| 6. | A midfield player sustained a laceration to the face during a morning training session; the physician sutured the cut but the player missed the afternoon training session. The player was able to take a full part in training on the following day | Incident should be recorded as an injury (severity: 0 day) | Incident should be recorded as an injury (severity: 0 days) |

Source: Fuller, Ekstrand et al., 2006, p. 195

**Injury classification:** Injuries should be classified by location, type, body side, specific mechanism, and recurrence. As regards the mechanism of the injury, we can identify traumatic or overuse injuries. A traumatic injury refers to an injury resulting from a specific, identifiable event. On the other hand, an overuse injury is caused by repeated micro-trauma without a single, identifiable event responsible for the injury. In some cases, a particular type of injury cannot be identified instinctively and a practitioner's diagnosis is required. An example of a form to collect injury data is included below (Fuller, Ekstrand et al. 2006).

**Figure 1: Injury Report Form**

(Team) Player-code:. . . . . . . . . . . . . . . . . . Date:. . . . . . . . . . .

**1A Date of injury:** . . . . . . . . . . . . **1B Date of return to full participation:** . . . . . . . . . . . .

**2A Injured body part**

| | | |
|---|---|---|
| ☐ head/face | ☐ shoulder/clavicula | ☐ hip/groin |
| ☐ neck/cervical spine | ☐ upper arm | ☐ thigh |
| ☐ sternum/ribs/upper back | ☐ elbow | ☐ knee |
| ☐ abdomen | ☐ forearm | ☐ lower leg/Achilles tendon |
| ☐ low back/sacrum/pelvis | ☐ wrist | ☐ ankle |
| | ☐ hand/finger/thumb | ☐ foot/toe |

**2B Side of body**

| | | |
|---|---|---|
| ☐ right | ☐ left | ☐ not applicable |

**3. Type of injury**

| | | |
|---|---|---|
| ☐ concussion (with or without haematoma/ contusion/loss of consciousness) | ☐ lesion of meniscus or cartilage | ☐ bruise |
| ☐ fracture | ☐ muscle rupture/strain/ tear/cramps | ☐ abrasion |
| ☐ other bone injury | | ☐ laceration |
| ☐ dislocation/subluxation | ☐ tendon injury/rupture/ tendinosis/ bursitis | ☐ nerve injury |
| ☐ sprain/ligament injury | | ☐ dental injury |
| ☐ other injury (please specify):. . . | | |

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

**4. Diagnosis** (text or Orchard code):

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

**5.** Has the player had a **previous injury** of the same type at the same site (i.e. this injury is a recurrence)?

☐ no ☐ yes

If YES, specify date of player's return to full participation from the previous injury:. . .

**6.** Was the injury caused by **overuse** or **trauma**?

☐ overuse ☐ trauma

**7. When** did the injury occur?

☐ training ☐ match

**8.** Was the injury caused by **contact or collision**?

☐ no ☐ yes, with another player
☐ yes, with the ball
☐ yes, with other object (specify) . . .

**9.** Did the **referee** indicate that the action leading to the injury was a **violation of the Laws**?

☐ no ☐ yes, free kick/penalty ☐ yes, yellow card ☐ yes, red card

If YES, was the referee's sanction against: ☐ injured player ☐ opponent,

Source: Fuller, Ekstrand et al., 2006, p. 200

**Injury prevalence:** it is the most suitable concept for overuse injuries and it can be defined as the percentage of athletes reporting the same injury at a particular moment and in a particular population. A high injury prevalence can lead to a detection of any failure in the training process. For example, if in a period of the season we observe 40% prevalence of athletic pubalgia, it means that 4 out of 10 athletes have reported that injury over that period. This enables the study of risk factors and injury causes so as to reduce them.

**Injury incidence**: it is defined as the number of injuries over a particular observation period divided by the total number of players exposed to the injury (Junge and Dvorak, 2000). Generally, the injury incidence is calculated every 1000 hours of exposure and can be considered by differentiating games vs. competitions or joining both tasks (*i. e.* 1000 hours in total or 1000 hours of competitions or games). Thus, the risk for every 1000 hours of exposure is defined by the number of new injuries * 1000, divided by the total hours of exposure (it must be added to each player's total hours of exposure), according to the following formula:

**Incidence/ 1000 h = (number of new injuries *1000)/ (total of hours of exposure)**
**Incidence = number of injuries / (number of games * 11 players * duration of the game*) * 1000**

* Duration of the game, using 1.5 factor, based on the standard duration of games of 90 minutes. For example, in a hypothetical study of a football team reporting 6 injuries out of 20 players in the season (38 games), the application of the second formula would estimate an incidence of 9.6 injuries per 1000 hours of exposure to the game.

In the following table, we can observe the total number of injuries and their incidence in different sports over a particular period of time. According to the data introduced, football is the sport with the higher amount of injuries during that period of time. However, when relativizing the incidence per 1000 hours of exposure, we can see that football has an incidence of 2.0 injuries/1000 h of exposure; while other sports, such as winter sports, have higher relative levels of incidence. This way of calculating the injury incidence leads to a less biased analysis of reality and, consequently, it is recommended when evaluating our players' injury risk.

**Table 2: Total Number of Injuries and Injury Incidence per 1000 h of Exposure in Different Sports**

| Sport | N.° of Injuries | Incidence |
|---|---|---|
| **Football** | 620.000 | 2.0 |
| **Futsal** | 109.000 | 6.3 |
| **Field Hockey** | 101.000 | 2.1 |
| **Tennis** | 90.000 | 0.4 |
| **Winter Sports** | 79.000 | 10.1 |
| **Ice Skating** | 68.000 | 2.1 |

Source: adapted from Verhagen, 2008

### Injury Epidemiology in Professional Football

The papers published in the scientific literature about incidence and injury patterns in football date from 1970s and 1980s. However, the greater emphasis on this type of publications has been put since 1990s up to current times.

One of the most significant findings of the first epidemiologic studies was the disproportionately high number of training injuries during the preseason and the first stages of the season.

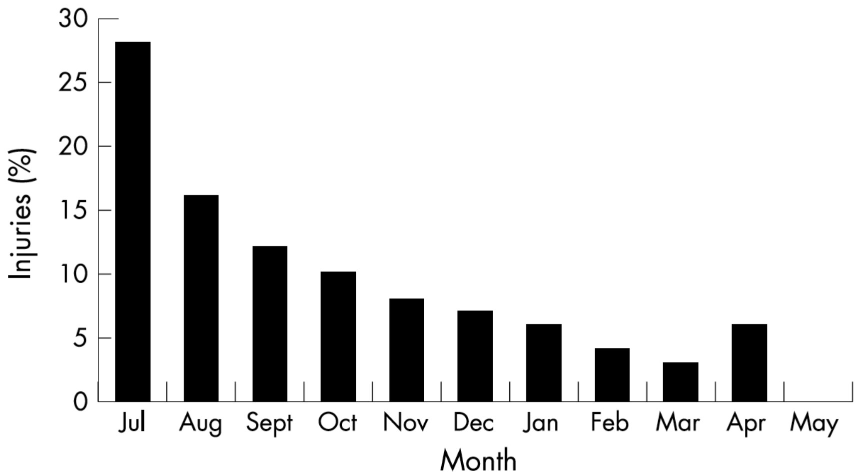
In a study carried out by Woods, Hawkins et al. (2002), preseason injuries were analyzed from data collected from 91 medical staff of professional clubs of the different English football divisions. It was considered that the competitive season in England finishes in May and is followed by a rest period of 2 to 5 weeks. After that, players go back to the clubs for a preseason training period of 4 to 6 weeks to get ready for the next competitive season that starts in August.

This study revealed that 17% of the total injuries occurred during the precompetitive period. The distribution of injuries during this period followed a pattern similar to the one in the competitive period being muscular injuries the most frequent ones (37%) and ligament injuries the second ones (19%).

During the preseason, there was a decrease in muscular contusions and tissue bruising injuries and an increase in tendon related and overuse injuries. This shows a trend towards a decrease in contact injuries and an increase in non-contact injuries during this part of the season.

Figure 2 shows the number of injuries related to Achilles tendon per month. A Total of 32% of injures related to Achilles recorded during the two seasons occurred during the preseason period. There was an average of 3.5 of injuries related to Achilles tendon per preseason week and an average of 1 injury related to Achilles tendon per competitive season week ($p < 0.01$). The most common types of Achilles tendon injuries during the preseason were inflammatory conditions (94%).

**Figure 2: Percentage of Achilles tendon injuries**

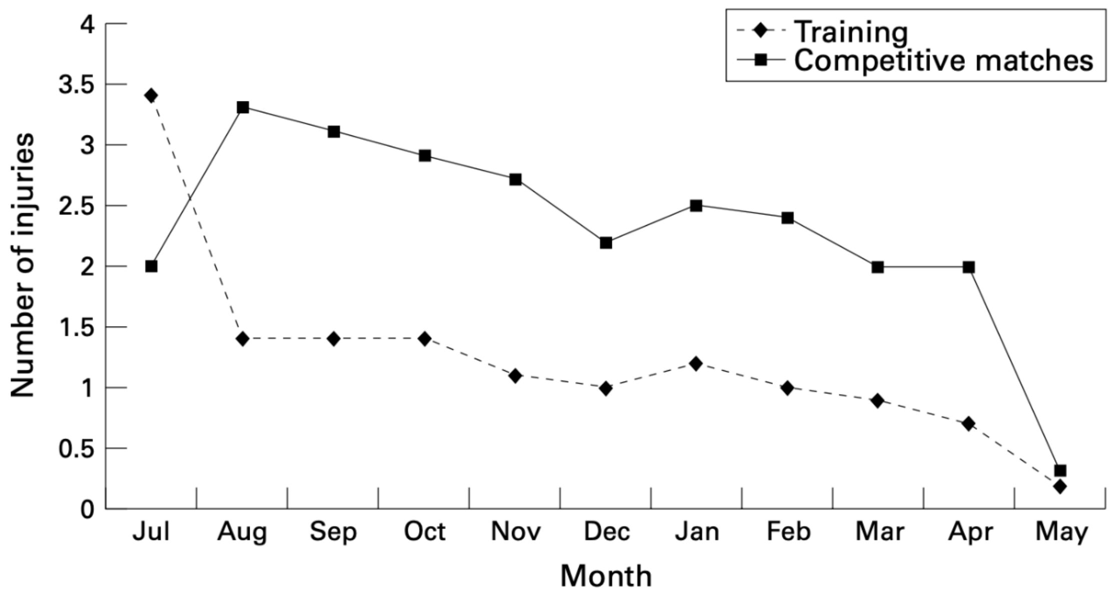



Source: Woods, Hawkins et al., 2002, p. 438

When observing the graph, it is important to consider that the start of the season is in the month of August, the end of the season is in May, and the preseason is between July and August.

It is interesting to consider that the average number of injuries recorded during training sessions reached a peak during the preseason period and was gradually decreasing throughout the season (see figure 3). In contrast, the highest injury incidence in games was observed during August ($p < 0.05$) even though it remained constant during the rest of the game season (Hawkins, Hulse et al., 2001). This can happen due to a higher volume of training during the preseason period. This means that the training sessions and their planning must be taken into account when analyzing injury prevention.

**Figure 3: Average number of injuries recorded during training sessions and games per month**

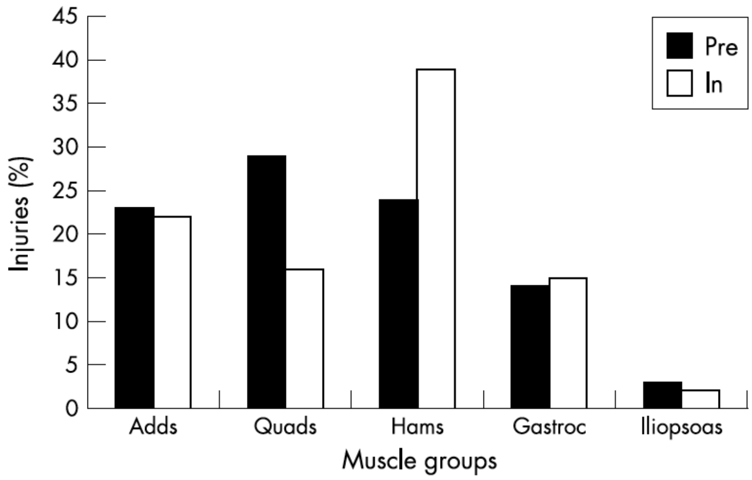



Source: Hawkins, Hulse et al., 2001, p. 44

Another relevant study for identifying the injury incidence, injury risk, and their patterns was the one carried out by Waldén, Hägglund et al. (2005). In this study, the training injury incidence during the preseason outweighed the one in the competitive season. Besides, it was reported that the injuries recorded in training games (friendly games) had a higher incidence in the competitive season in relation to the preseason.

According to this data, it might be suggested that there are two types of risks related to injury incidence during the preseason: on the one hand, the sudden increase in training volumes and intensities, and, on the other hand, the increase in contact injuries during training games. It is also important to highlight that training games are combined with very stressful situations of the planning with the aim of improving the players' physical performance. In this way, an analysis of the particular training models for these special circumstances should be carried out together with an epidemiologic study of each league so as to use it as an injury index and pattern indicator for each of them (Sampietro. 2010). Figure 4 shows a detailed analysis conducted by Woods, Hawkins et al. (2002) of lower limb muscle groups injuries during pre and in season. The only difference found when comparing muscle groups in the preseason vs. the competitive season was that quadriceps strains were relatively more frequent and that hamstrings strains were relatively less frequent during the preseason.

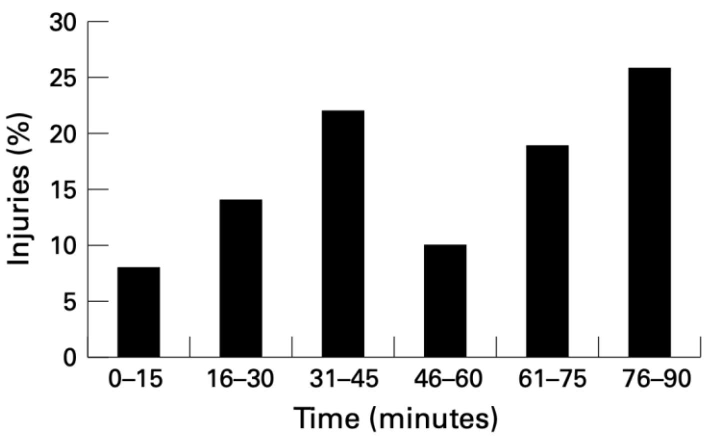
**Figure 4: Percentage of lower limb injuries during pre and in sporting season**




Source: Woods, Hawkins et al., 2002, p. 438

Finally, figure 5 shows the distribution injuries of competitive games in relation to the playing time. Out of the total number of injuries in the study, a higher frequency of them was recorded in the last 15 minutes of the first half and the last 30 minutes of the second half ($p < 0.01$). Although there was a higher injury incidence towards the end of the first half of the game, the highest number of injuries was observed in the second half (57% v 43%, $p < 0.01$).

**Figure 5: Time of injury occurrence during the competitive period**




Source: Hawkins, Hulse et al., 2001, p. 45

**Systematic Review and Meta-analysis of Injury Epidemiology in Football**

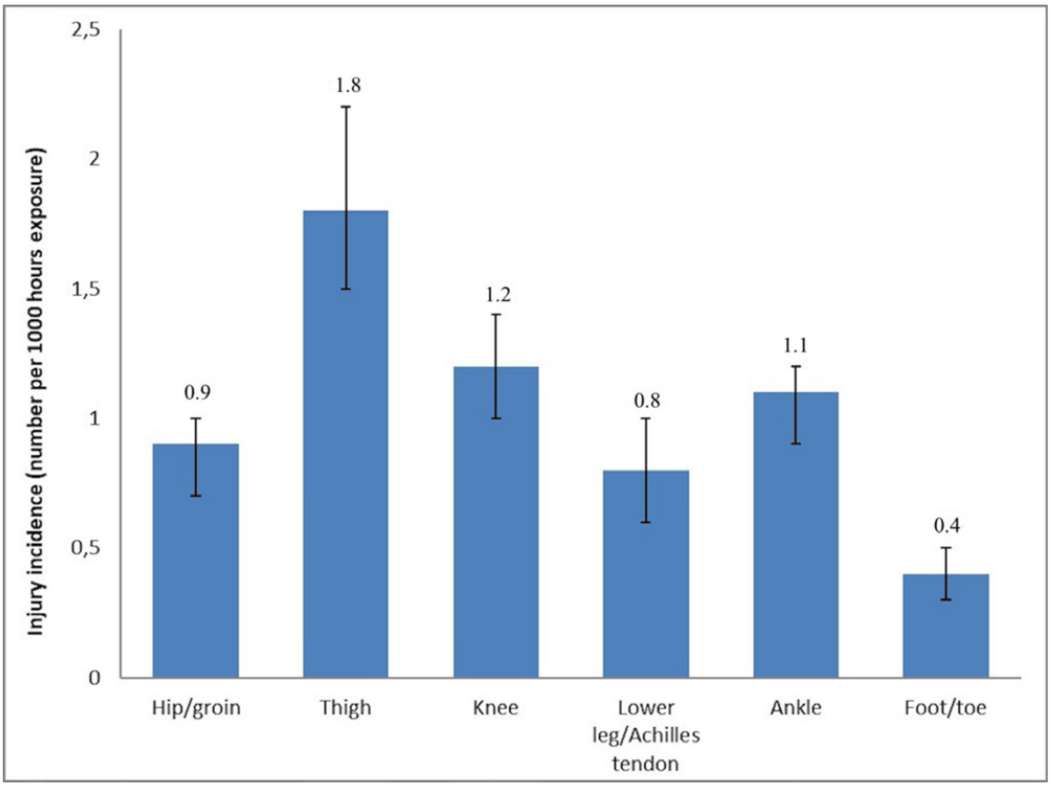
A professional football team of 25 players suffers approximately 50 lost time injuries each season. This equals two injuries per player per season (Ekstrand, Hagglund et al., 2011). The epidemiologic analysis of injuries is a key factor to consider in a sport such as football since it has been observed that the players' availability for games strongly correlates with the team sporting success (i.e. Ranking position, games won, goals scored, total points).

In a recent systematic review and meta-analysis conducted by López-Valenciano, Ruiz-Pérez et al. (2019), 44 research papers carried out until the year 2018 were analyzed and it was found that the general injury incidence in football was 8.1 injuries per 1000 hours of exposure. Among them, the injury incidence in training sessions was 3.7 injuries per 1000 hours of exposure while, in games, it was 36 injuries per 1000 hours of exposure. This data reveals that in football, the injury incidence in games is 10 times higher than in training sessions.

As regards injury location, the lower limbs recorded the highest incidence (6.8 injuries per 1000 hours of exposure) compared to other areas of the body. The second area with the highest incidence was the trunk (0.4 injuries/1000 h), followed by the upper limbs (0.3 injuries/1000 h), and head and neck (0.2 injuries/1000 h).

With regard to lower limbs, six anatomical areas were analyzed where the injury incidence per 1000 hours of exposure was observed in the following decreasing order: thigh (1.8 injuries/1000 h), knee (1.2 injuries/ 1000 h), hip/ groin area (0.9 injuries/ 1000 h), Lower leg/ Achilles tendon (0.8 injuries/ 1000 h), and feet/ toes (0.4 injuries/ 1000 h). The graphic representation of these results could be seen in figure 6.

**Figure 6: Injury incidence per 1000 hours of exposure in lower limbs injuries in football**

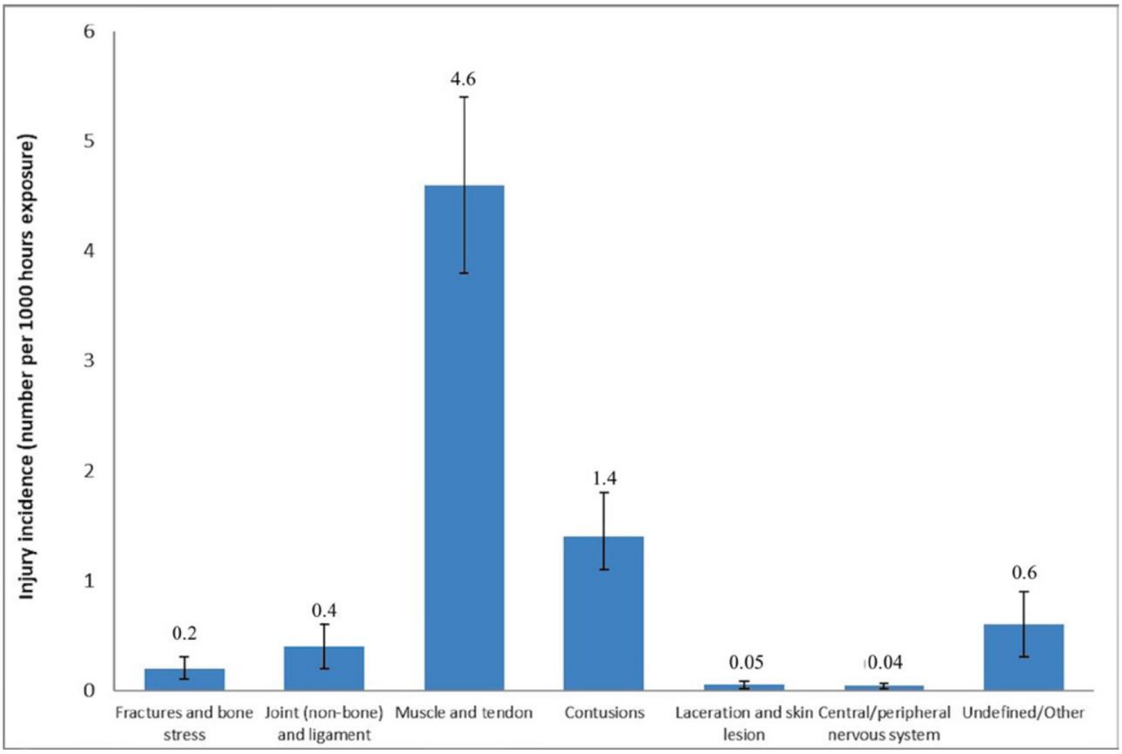



Source: Lopez-Valenciano, Ruiz-Perez et al., 2019, p. 5

As regards the type of injury, the most common ones were muscle/ tendon injury (4.6 injuries/ 1000 h), followed by bruises (1.4 injuries/ 1000 h), other type of injuries/ non-defined (0.6 injuries/ 1000 h), joints/ ligaments (0.4 injuries/ 1000 h), fractures/ bone stress (0.2 injuries/ 1000 h), lacerations/ skin injuries (0.05 injuries/ 1000 h), and central/ peripheral nervous system injuries (0.04 injuries/ 1000 h).

This data suggests that most of the injuries in football occur in lower limbs; moreover, in thighs and tendons. The representation of these results can be observed in figure 7.

**Figure 7: Injury incidence per 1000 hours of exposure per type of injury in football**




Source: Lopez-Valenciano, Ruiz-Perez et al., 2019, p. 5

As regards injury severity, these authors reported that the most common lost time injuries were minimal injuries (1-3 days of time loss; 3.1 injuries/ 1000 h), followed by moderate injuries (8-28 days of time loss; 2.0 injuries/1000 h), minor (4-7 days of time loss; 1.7 injuries/ 1000 h), and severe (>28 days of time loss; 0.8 injuries/ 1000 h).

The most frequent mechanism of injury was traumatic injuries (5.9 injuries/ 1000 h), followed by overuse injuries (2.4 injuries/ 1000 h). This data together with the information mentioned above reveal that most of the injuries are caused by traumatic mechanisms but their severity seems to be slight. Especially, being attacked by or collision with an opponent (i.e. While jumping) seem to be the most common injury incidents and represent approximately the 50% of all types of traumatic injuries. These are closely followed by non-contact injuries such as sprinting and braking.

According to the authors, the application of specific neuromuscular training programmes for football aiming to optimize players' motor skills, joints stability, and delay fatigue could reduce the relative injury risks due to a soft tissues acute overload.

As regards the level of recurrence, it was observed that the incidence rate of new injuries was higher (7.0 injuries/ 1000 h) when compared to recurrent injuries (1.3 injuries/ 1000 h). It has been recently proved that most of the recurrent injuries (lower limbs muscle and tendon injuries mainly) occur within 2 months after the player's return to play. This could reflect a premature return to training/ play and an incomplete or inadequate rehabilitation.

Finally, these authors reported a higher injury incidence in international tournaments (9.8 injuries/ 1000 h) than in local tournaments (7.5 injuries/ 1000 h). Some of the factors leading to an increase in the number of injuries could be: the density of games played, the players' mental stress and anxiety, and the fact that international competitions are normally held in the summer (after a long season in which the accumulated fatigue could be high).

After the analysis of the data introduced in this recently published paper, we can conclude that male professional football players are exposed to a substantial risk of suffering injuries, especially in games. Although the majority of the injuries in this sport are caused by a traumatic mechanism (sudden onset injuries and known cause), most of them seem to be of minimal severity. As expected, lower limbs get injured more often being muscle/ tendon injuries the most common ones. Recurrent injuries seem to be less frequent than new ones. However, the recurrent injury rates may have greater implications for the return to training or play (López-Valenciano, Ruiz-Pérez et al., 2019).

**Importance of The Approach to Injuries Severity**

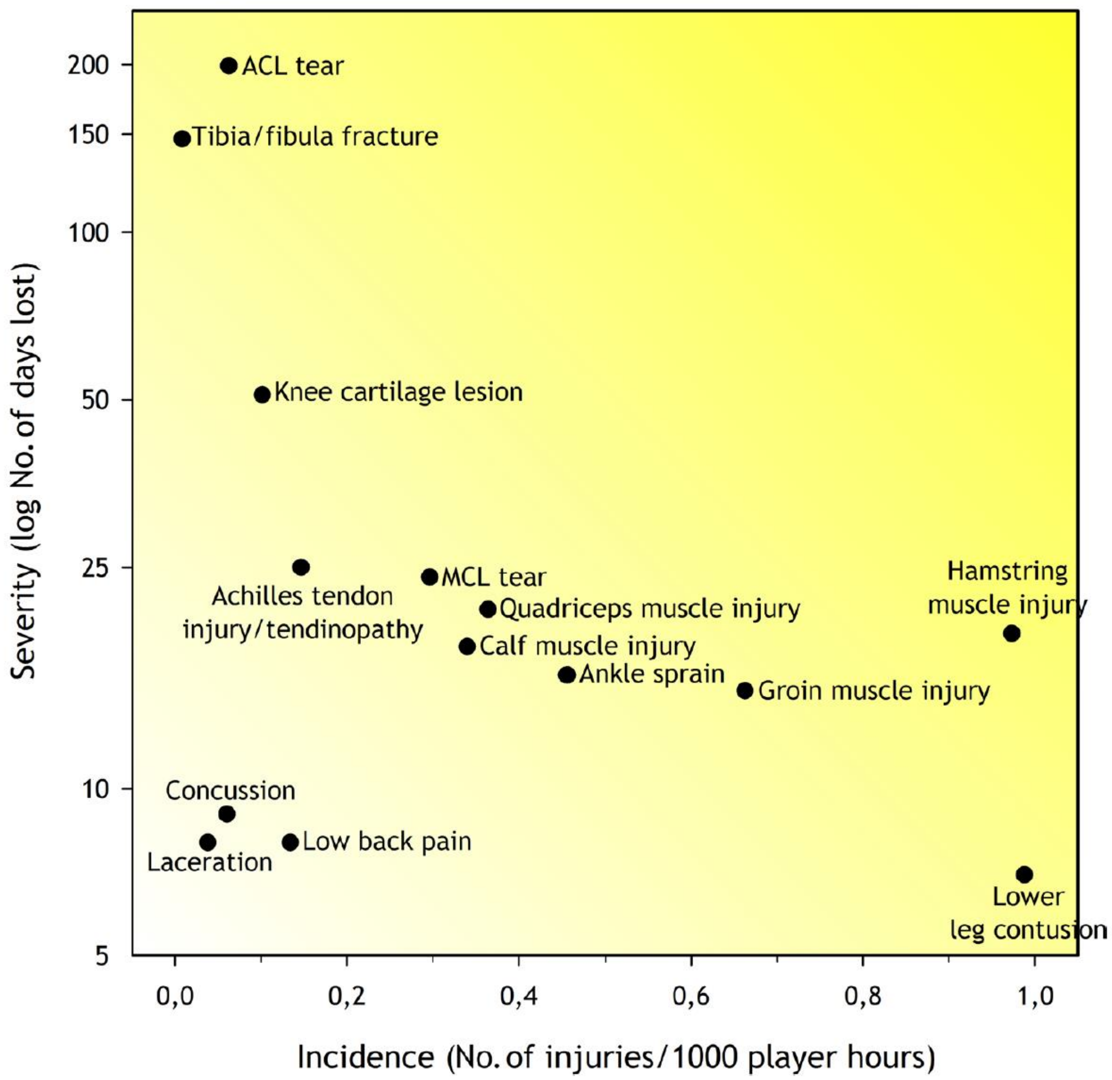
In a recent paper titled "Why We Should Focus on the Burden of Injuries and Illnesses, Not Just Their Incidence" Bahr, Clarsen et al. (2018), three examples are mentioned to ease a better interpretation of data from injury prevention studies in a risk management context. The authors will argue that:

> It is time to go further than informing or evaluating the rate or severity in isolation. Instead, the two factors should be combined in the concept of "burden of injuries as the cross-product of severity and incidence Bahr, Clarsen et al., 2018".

After the consensus published in 2006 to encourage consistency in how injuries are defined and reported in epidemiological studies, more and more sports medicine specialists are adopting an active approach to avoid injuries and illnesses in the team. In general, these consensuses recommend that the rate of injury should be reported as injury incidence, calculated as number of injuries per 1000 hours of exposure. However, these authors argue that focusing on injury/illness incidence alone may give an incomplete and even erroneous picture of risk.

**Example 1: What type of injuries should teams focus on reducing?** Injury data can be illustrated in a risk matrix which highlights risks in terms of likelihood (incidence) and consequences (severity). The example shown in figure 8 results from professional football at UEFA Champions League level and shows the incidence and severity of each type of the most common time-loss injuries. The shaded area illustrates the relative importance of each type of injury (i.e. The darker the colour, the higher the burden of the injury and the greater prevention priority should be given). The risk matrix suggests that injuries in hamstrings, groin, knee, and ankle areas should be top priority, while contusions, for instance, are lower-priority issues. This approach has some limitations to be considered: (1) the risk matrix will generally vary significantly among sports, and it may also vary depending on the level, gender and age group within the same sport; and (2) deaths are not recorded in the epidemiological studies of sporting injuries or illnesses. However, this does not mean to give up the prevention of, for example, sudden death in football. For that purpose, emergency preparedness, the supply of automated external defibrillator (AED), and resuscitation training are important.

**Figure 8: Matrix based on the UEFA Club Elite Injury Study data**



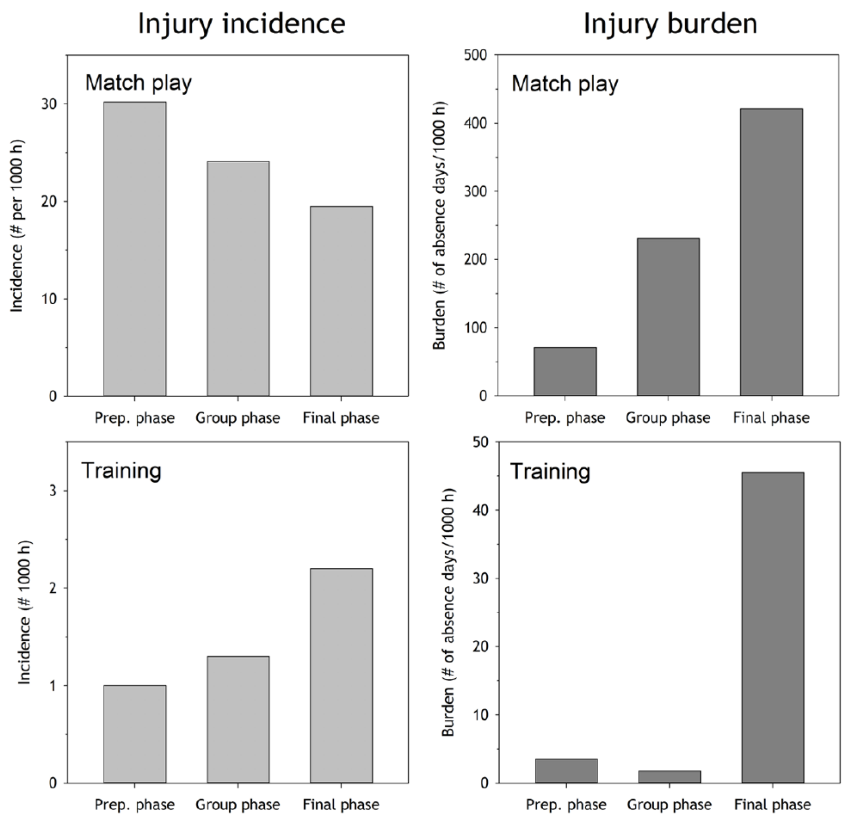

Source: Bahr, Clarsen et al., 2018.

Figure 8 illustrates the relationship between severity and incidence of the 14 most commonly reported types of injuries. For each type of injury, severity is shown as the average of the numbers of lost days in training sessions and competitions; while the incidence is shown as the number of injuries per 1000 hours of exposure in total (combining games and training sessions) for each type of injury.

**Example 2: When is the risk of injury higher?** This question arises from the limited, and sometimes contradictory data about the risk of injury in the different stages of a sporting season. As mentioned before, the burden of injuries can be quantified based on the incidence per 1000 hours of exposure or the burden of injuries.

Figure 9 compares the incidence and burden of injuries during training sessions and games throughout three stages of the European football championship (Euro 2016). When considering incidence in isolation, there seems to be a gradual decrease in the risk of injuries from the training stage until the group stage and the knockout stage, at least during games.  However, when considering the burden of injury as the risk measure, it is clear that the risk increases gradually and it is higher in the final stage. Probably, the reason is that most of the injuries in the training stage are minor ones. Thus, teams normally allow players with minor discomforts to rest for one or two sessions to have them fresh when the tournament starts.

**Figure 9: Injury Incidence**




Source: Bahr, Clarsen et al., 2018.

The previous figure shows the injury incidence (number of injuries per 1000 hours of exposure of the player) and the burden of injuries (number of lost days per injury per 1000 hours of exposure of the player) during games and training sessions throughout the three stages of the European football championships (Euro 2016): the training period, the group stage and the final stage.

**Example 3: Assessment of the Impact of Acute vs. Overuse Injuries vs. Illness.** It must be acknowledged that the recommendations about how to report data of injury epidemiological studies have been really accepted. However, as it was mentioned before, taking time loss to define an injury and evaluate its severity in sports can significantly underestimate the real burden of injuries for overuse. Thus, it is known that even though athletes have some overuse conditions, they usually continue training and competing at least in the first phase of these injuries. The same happens with a lot of illnesses such as a common cold. Consequently, many health issues do not lead to time loss because of the sport as such, and that is why they are not recorded in the injury registration systems. It should be noted that as overuse injuries are often chronic or recurrent and they do not normally lead to time loss, they should be expressed in terms of their prevalence and it becomes necessary to use alternative means to define severity and burden.

Finally, these authors have analyzed the difficulties that appear when considering only the incidence to describe the injury risk. They argue that focusing on injury incidence alone gives an incomplete and, sometimes, even an erroneous picture of risk. On the contrary, it is important to take into account the total burden of injuries and illnesses when carrying out a risk comprehensive evaluation. This can be done by developing a risk matrix similar to the one in figure 9 and calculating the total number of days with time loss due to injuries or illnesses.

We should highlight that the authors do not suggest quitting the individual incidence and severity reports. However, they suggest including in these reports data about the burden of injuries; for example, through the evaluation of the total number of days with time loss per 1000 hours of exposure.

# Injury Mechanisms and Risk Factors Affecting Injury Incidence

### Epidemiological and Biomechanical Models Used in Injury Prevention

Van Mechelen, Hlobil et al. (1992) introduced the first sequential model for Injury prevention research. The model described by these authors consists in a well-defined four-step process (see figure 10).

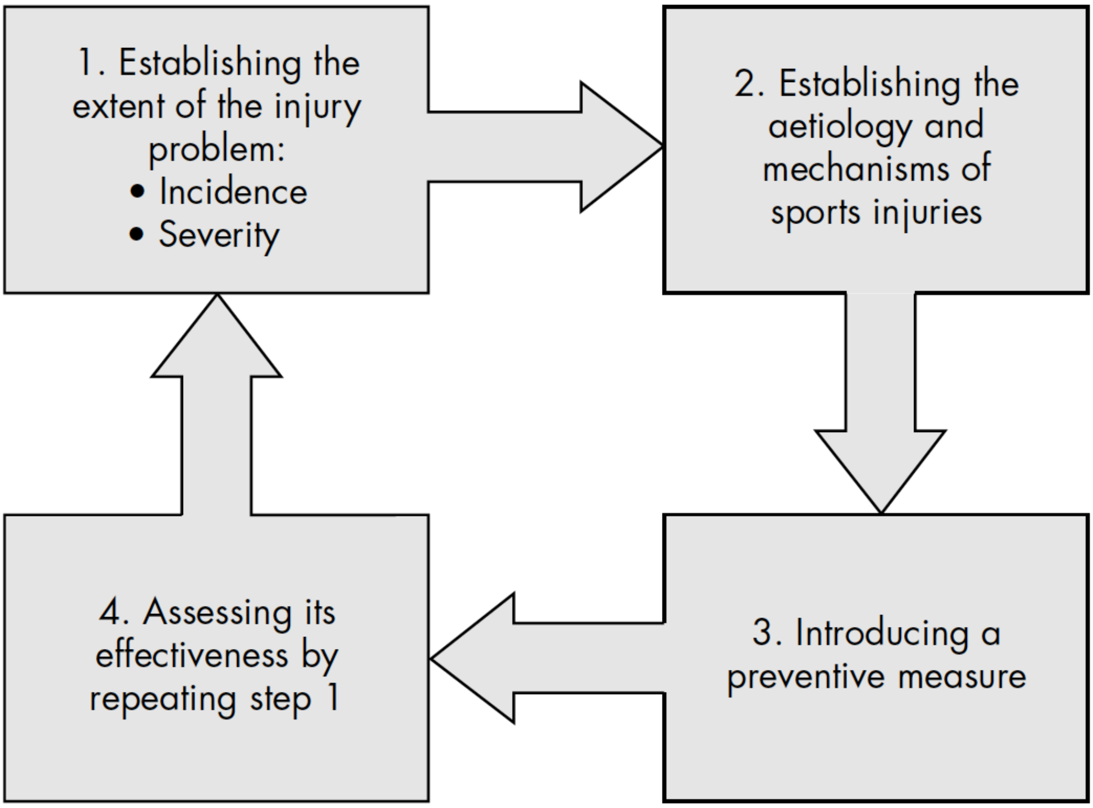
1) Firstly, the extent of the problem must be described in terms of incidence and severity of the sporting injuries. This step is based on an epidemiologic study on a certain population of athletes. So far, many studies about epidemiological realities of each sport have been published in relation not only to injury incidence and its distribution but also to prevalence of some of them at certain moments of the season. The importance of the analysis of the injury profile comes from the specific requirements of each discipline and the existence of extrinsic risk factors that make this problem prominent.

2) The second step is establishing the most common injury mechanisms and risk factors in each sport determined by the epidemiological analysis mentioned in number one. In this process, new prevention studies and models have come up in order to quantify these factors in a more precise way to be able to act on them.

3) The third step is to introduce measures which allow the reduction of the future risk and/or the severity of sporting injuries. Those measures must be based on the etiologic factors and injury mechanisms identified in the second step.

4) Finally, the effect of the measures must be evaluated by repeating the first step, through the analysis of time trends in injury patterns or, preferably, through a randomized clinical trial. Generally, this is carried out after a certain period of time and by analyzing a significant number of subjects to be able to infer, through statistical methods, if the results obtained were significantly influenced by the preventive measures implemented.

**Figure 10: Van Mechelen (1992) sequential model for the investigation of injury prevention**

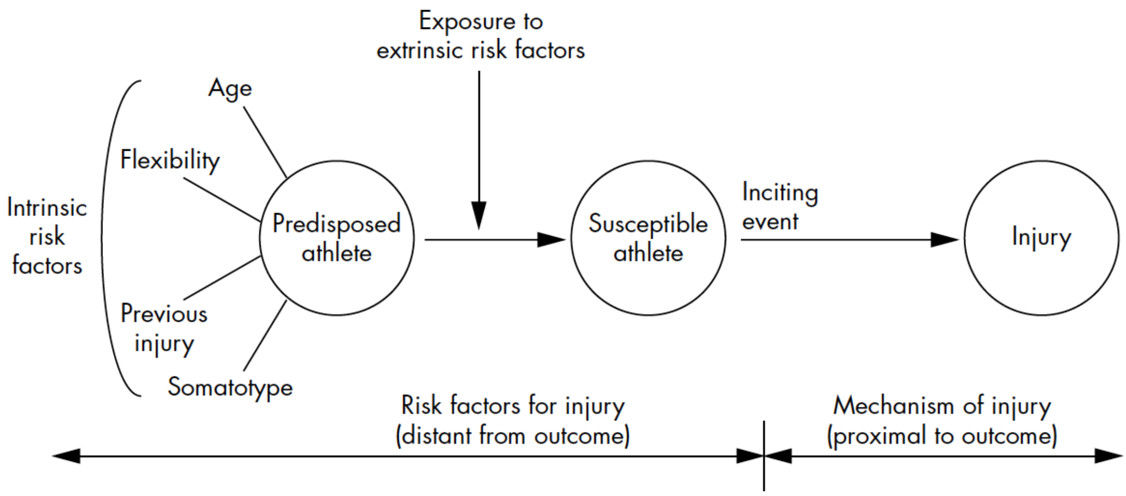



Source: Bahr y Krosshaug, 2005, p. 325

A key step in the sequence model of Van Mechelen, Hlobil et al. (1992) is to establish the injury causes. This includes to obtain information about the risk factors athletes may face and the injury mechanisms associated with them. In order to broaden and deepen step number two suggested by Van Mechelen, Hlobil et al. (1992), Meeuwisse (1994) proposed a multifactorial model of analysis which involves the causes of injuries and the risk factors associated with them. (See figure 11).

As shown in figure 11, while the injury may appear to have been caused by a single inciting event, it could result from a complex interaction between different internal and external risk factors. Meeuwisse (1994) suggests that intrinsic factors such as age, gender or previous injury predispose the athlete to injuries. When these factors interact with extrinsic factors, such as the field, type of training sessions or recovery time may make the athlete even more susceptible to injury. This model states that it is the presence of both internal and external risk factors that may render the athlete susceptible to injury, but the mere presence of these risk factors is not sufficient to produce injury. The sum of these risk factors and the interaction between them "prepares" the athlete for an injury to occur in a given situation. Meeuwisse describes the inciting event as the final link in the chain that causes an injury, and such events are regarded as necessary causes. He also states that such an inciting event is usually directly associated with the onset of injury. Finally, the same event could incite an injury for a "susceptible" athlete but not for a "non-susceptible" one.

**Figure 11: Van Mechelen (1994) multifactorial model for the investigation of injury prevention**



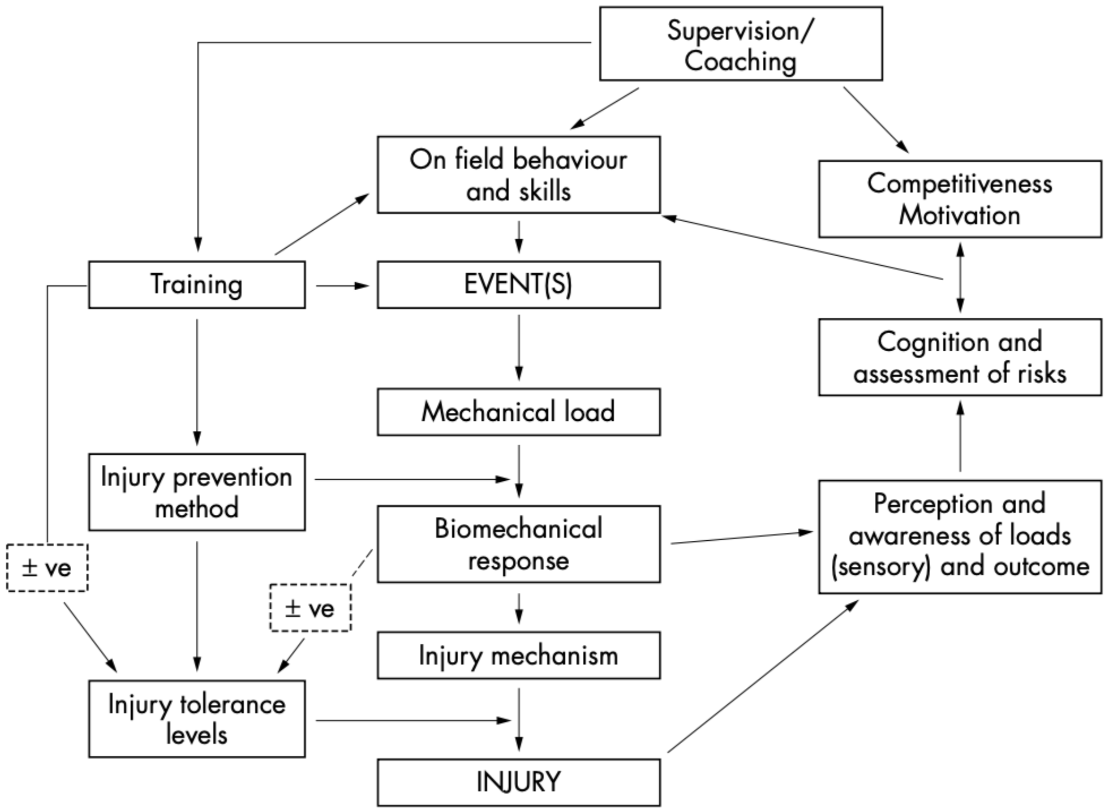

Source: Bahr y Krosshaug, 2005, p. 325

Apart from the epidemiological models of injury and prevention process analysis, there are biomechanical models. These models take into account the biomechanical features of the tissues and the forces acting on them, and they try to explain how a particular force, in an injury mechanism, outweighs the tissue biomechanical capacity of tolerance causing the structural damage on such tissue. Thus, the preventive measures deriving from these models of analysis will aim at keeping the external and internal forces applied to the tissues under the force levels associated with the injury risks obtained from different biomechanical analysis. This could be possible by improving the body's capacity to tolerate and react to such forces after the implementation of certain types of specific training.

McIntosh (2005) has recently described a biomechanically oriented model of injury in order to consider additional factors that could have an influence not only in the load and the positive or negative tolerance of the load, but also on the behaviour/attitudes, training, skills, team, other competitors, and the environment. In this model, the event (i.e. Players, environment, etc) determines the mechanical load. The mechanical load is quantifiable as velocity, mass, momentum or energy. Therefore, a faster game or ''stronger'' competitors will result in higher energy impacts.

An injury prevention method will influence the biomechanical responses. For example, a helmet will attenuate impact energy, thereby reducing the head impact force. On the other hand, skills training might enable the player to maintain their balance over the weight bearing knee, thus reducing knee loads, in terms of the frontal and transverse plane. An improvement in the physical fitness can protect the tissue from injuries through the training effect over its material properties, but it can also prompt the application of higher forces over the tissue. If a tennis player, by training his strength, physical fitness or skill, develops a faster service, this can result in a higher shoulder load. A summary of the mechanisms involved in this model can be seen in figure 12.

**Figure 12: McIntosh (2005) schematic model for the investigation of injury prevention**



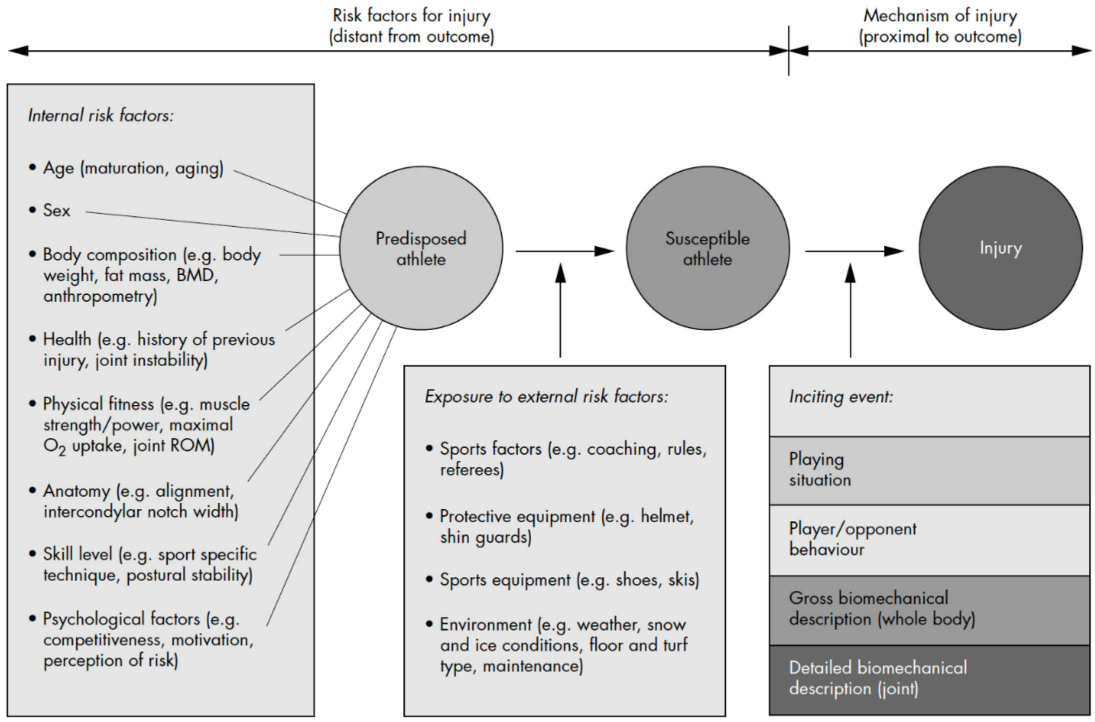

Source: McIntosh, 2005, p. 3

Finally, Bahr y Krosshaug (2005) propose an expansion of the Meeuwisse (1994) epidemiological model including some concepts taken from the biomechanical perspective of McIntosh (2005). However, this model focuses on the inciting event or injury mechanism to understand and diagram the injury prevention in sports (see figure 13). In this model, the intrinsic and extrinsic factors can affect the tolerance towards loading forces. This model can also be used to study the interaction among different factors that cause injuries. For example, ankle sprains in volleyball or football. In both sports, the risk of ankle sprains is 4 to 5 times higher if there is a previous injury background in the same ankle (i.e. Internal risk factor), mainly due to a limited neuromuscular function. Ankle sprains in volleyball occur mainly at the net when the player lands on an opponent's or a team mate's foot after blocking or spiking. Ankle sprains in football occur mainly as a result of the impact by an opponent on the medial aspect of the leg just before or at foot strike. This shows that a significant proportion of ankle injuries are contact injuries resulting from: (1) a player landing on another player's foot (volleyball); or (2) an impact on the medial side of the ankle or lower leg (football).

According to these mechanisms, we could infer that prevention strategies such as balance or proprioceptive training for the ankle joint do not have a protective effect. However, direct contact might not be the cause of the tearing of the ligaments but it can simply lead to a vulnerable ankle position when landing or running, especially of players with reduced neuromuscular control. Thus, based on this, it can be hypothesized that a higher neuromuscular control through the training of this joint could help the player place his foot correctly before loading his weight on the ankle.

In conclusion, this model broadens the understanding of all interacting components in order to understand the injury mechanism trying to homogenize the most important aspects of both the epidemiological and the biomechanical perspectives. The final conclusion of this author is that a more precise description of the inciting event or injury mechanism is the key to designing the prevention models, understanding that each perspective as such is not sufficient for the achievement of the goals.

**Figure 13: Bahr y Krosshaug (2005) multifactorial model for the investigation of injury prevention**




Source: Bahr y Krosshaug, 2005, p. 327

## Intrinsic and Extrinsic Risk Factors

Risk factors are defined as those characteristics athletes have that can increase the risk of suffering an injury. A risk factor can be the sum of factors that, when interacting with one another, are capable of causing or generating a sporting injury. This point represents a challenge in the investigation of injury prevention due to its complexity in the methodological approach to specify the real influence of a particular factor in the sporting injury occurrence.

Injury risk factors are divided into two main categories: **Intrinsic risk factors**, athlete-related factors such as age, gender, somatotype, physical fitness or performance; and **Extrinsic or external risk factors** such as the sports rules, clothing, the use or not use of protection equipment that could increase or cushion the intrinsic risk factors (Bahr y Krosshaug, 2005).

The intrinsic risk factors can in turn be divided into modifiable and *non*-modifiable. Non-modifiable risk factors are those which cannot be altered such as age, gender or sex, and injury history or previous injury. Modifiable risk factors refer to those which can be altered such as physical fitness, the body mass index, the neuromuscular control of lower limbs, etc. (Bahr y Krosshaug, 2005)

## Intrinsic Factors

It has been suggested that intrinsic factors are more determining in the occurrence of muscle injuries in football. One of the most common risk factors in football is the history of an identical previous injury. In a study carried out by Hagglund, Walden et al. (2013), the authors reported that players with a muscle injury in the previous season had experienced up to a three-fold injury rate increase compared to players with no previous injuries. This suggests that the preseason evaluation of previously injured players could be valuable for reducing the injury rates. Particularly, in 21-30% of cases recorded, the player had suffered an identical muscle injury before during the study period with a 12-14% of early recurrence (i.e. Within 2 months after the player's return to play).

Another interesting finding of this study was that the history of previous injuries in other lower limbs muscle groups has made the quadriceps and calves injury rate increase in a 68-91% (Hagglund, Walden et al., 2013). Based on these findings, the authors have suggested that inadequate compensation after an initial injury could predispose the player to an additional injury. Besides, they have highlighted the importance of doctors deeply evaluating the cause of the injury and monitoring additional factors to the healing of the tissue such as biomechanical evaluation before allowing player to return to training sessions and competitions.

Many studies have demonstrated that older players are more susceptible to muscle injuries, especially to hamstrings. Consequently, it was reported that for every additional year of age in excess of 22, the risk of suffering a hamstrings injury increases in up to 1.8 times in professional football players (Henderson, Barnes et al., 2010). In the study conducted by Hagglund, Walden et al. (2013), we observed a two-fold increased rate of calf injury for older players, whereas no association was seen for adductor, quadriceps or hamstrings injury. The reason why older players may be at risk for muscle injury is unclear, but it has been suggested that those changes related to increased body weight and a loss of flexibility may partially explain the risk increase.

Hagglund, Walden et al. (2013) observed that injuries in quadriceps and adductors were more common in the kicking leg, probably due to a higher volume of shooting and passing/crossing with the dominant leg (i.e. A higher exposure to high-risk actions). Thus, it has been suggested that specific limb preference in football players may result in lingering muscle imbalances that could lead to an increased propensity for injury. Correction of muscle imbalances at preseason has also been found to decrease hamstrings injury rates in football players during the sporting season (Croisier, Ganteaume et al., 2008).

Finally, goalkeepers had reduced rates of all muscle groups compared to other playing positions. These differences in incidence were 33-50% lower in goalkeepers, even when adjusting for possible confounders such as player age, stature and body mass. Similarly, a twelve-month prospective study in Danish elite players reported a lower frequency of hamstrings injuries in goalkeepers compared to outfield players (Petersen, Thorborg et al., 2010).

Table 3 shows the main results of Hagglund, Walden et al. (2013) study in relation to intrinsic risk factors. Intrinsic risk factors can be observed on the left, and the Hazard Ratio (HR), 95% confidence intervals (95%CI), and p-values (associated with a $\alpha < 0.05$) on the right columns. The Hazard Ratio is a ratio that represents the probability of an event to happen in either an experimental or a control condition. The null value for the HR is one and it indicates the equality of likelihood for the event to happen in both groups at a particular time interval. If the HR is $> 1$, it indicates more production risk in the treatment group, and if it is $< 1$, it indicates a lower risk in the treatment group than in the control one (Molina Arias, 2015). The HR data needs to be combined with the p-value analysis in which a p-value lower than 0.05 will show a significant difference between the experimental and control conditions. Thus, a p-value $<0.05$ together with a HR $>1$ will indicate a significant difference of this variable with regard to the reference or comparison variable.

**Table 3: Intrinsic risk factors analysis for lower extremity injuries in professional football players**

| Variable | Adductors | | | Hamstrings | | | Quadriceps | | | Calf | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | HR | 95% CI | *P* Value | HR | 95% CI | *P* Value | HR | 95% CI | *P* Value | HR | 95% CI | *P* Value |
| Age (above mean)[b] | 1.24 | 0.96-1.59 | .094 | 1.02 | 0.84-1.23 | .881 | 1.06 | 0.79-1.41 | .710 | 2.02 | 1.45-2.82 | <.001 |
| Stature (above mean)[b] | 0.97 | 0.75-1.24 | .792 | 0.82 | 0.68-1.00 | .049 | 0.88 | 0.66-1.17 | .367 | 1.04 | 0.76-1.43 | .819 |
| Body mass (above mean)[b] | 1.08 | 0.84-1.38 | .559 | 0.87 | 0.72-1.06 | .169 | 0.91 | 0.68-1.21 | .500 | 1.19 | 0.87-1.64 | .282 |
| Playing position | | | | | | | | | | | | |
| Goalkeeper | 0.58 | 0.33-0.99 | .048 | 0.11 | 0.06-0.23 | <.001 | 0.46 | 0.23-0.90 | .023 | 0.43 | 0.20-0.96 | .038 |
| Defender | 1.19 | 0.83-1.70 | .345 | 0.80 | 0.61-1.04 | .094 | 0.95 | 0.62-1.43 | .791 | 1.31 | 0.83-2.07 | .242 |
| Midfielder | 1.10 | 0.77-1.58 | .591 | 0.97 | 0.75-1.25 | .792 | 1.18 | 0.62-1.43 | .418 | 1.16 | 0.73-1.85 | .524 |
| Forward[c] | 1.0 | | | 1.0 | | | 1.0 | | | 1.0 | | |
| Previous injury[d] | | | | | | | | | | | | |
| Adductors | 1.48 | 1.06-2.06 | .020 | 1.22 | 0.93-1.62 | .154 | 1.88 | 1.31-2.69 | .001 | 1.87 | 1.26-2.77 | .002 |
| Hamstrings | 1.25 | 0.94-1.68 | .131 | 1.64 | 1.32-2.04 | <.001 | 1.25 | 0.89-1.76 | .202 | 2.10 | 1.51-2.54 | <.001 |
| Quadriceps | 1.31 | 0.89-1.91 | .170 | 1.44 | 1.08-1.93 | .014 | 3.47 | 2.49-4.84 | <.001 | 1.09 | 0.65-1.83 | .742 |
| Calf | 1.01 | 0.63-1.64 | .959 | 1.40 | 1.00-1.95 | .050 | 2.08 | 1.37-3.17 | .001 | 2.83 | 1.86-4.31 | <.001 |

Source: Hagglund, Walden et al., 2013, p. 331

(In table 3: [b] Reference group below average; [c] Reference groups in analysis; [d] The previous injury refers to injuries in the preceding season).

## Extrinsic Factors

Factors such as the type of game, playing home or as guests, and the result obtained were determined to be influential for the general injury rates in football. For example, Ekstrand, Walden et al. (2004) found a significantly greater frequency of injuries in lost games compared to won or drawn games (52.5 vs. 22.7 / 1000 h, p = 0.026). According to the authors, there are three reasons for this: (1) injuries have a direct impact on the game result (i.e. The team weakens if somebody gets injured); (2) injuries have an indirect impact on the result (i.e. If somebody in the initial alignment is replaced due to an injury, the game strategy is interrupted and the tactical pattern as well as the team rhythm can be altered); and (3) the result and importance of the game have an influence on the injury profile (i.e. Teams that need to win or draw often play more intensely and, thus, increase the risk of injuries). On the other hand, Carling, Orhant et al. (2010) retraced a French first division football club during four consecutive seasons and they observed that the incidence of joints sprains differed among the competition types, with a higher rate recorded in the Copa and Europa League respectively (10.1 vs. 3.0 / 1000 h, p<0.05). In the study carried out by Hagglund, Walden et al. (2013), it was found that there was an increase in the number of calves injuries and a decrease in the quadriceps injuries in UEFA games compared to The League games. However, no associations with adductors and hamstrings injuries were observed. The reason for this discrepancy is unclear, but according to the authors it could be related to differences in intensity and style of play in different types of competitions.

Finally, this study did not show any influence of the climatic region in the muscle injury rate of lower limbs (Hagglund, Walden et al., 2013). These results contrast the findings of a previous study conducted by the same research group in which it was observed that professional football teams from the North of Europe had a higher general rate of injuries than those teams from the South of Europe (Walden, Hagglund et al. 2013).

Table 4 shows the main results of Hagglund, Walden et al. (2013) study in relation to extrinsic risk factors. Extrinsic risk factors can be observed on the left, and the *Odds Ratios* (OR), 95% confidence intervals (95%CI), and p-values (associated with a $\alpha < 0.05$) on the right columns. In this case, the *odds ratio* has been used to evaluate the probability of occurrence of an event. Even though the calculation is the same as the HR one, its interpretation is slightly different. In this case, an *odds ratio* of 2 means that the event is 2 times more likely given an increase of a unit in the predictor. Instead, for the HR a risk reason of 2 means that the event will occur twice in each point in time given an increase of a unit in the predictor.

**Table 4: Analysis of Extrinsic risk factors**

| | Adductors | | | Hamstrings | | | Quadriceps | | | Calf | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | OR | 95% CI | *P* Value | OR | 95% CI | *P* Value | OR | 95% CI | *P* Value | OR | 95% CI | *P* Value |
| Match type | | | | | | | | | | | | |
| League[b] | 1.0 | | | 1.0 | | | 1.0 | | | 1.0 | | |
| UEFA Champions League | 1.17 | 0.83-1.64 | .374 | 1.05 | 0.81-1.37 | .703 | 0.51 | 0.25-1.01 | .053 | 2.43 | 1.61-3.67 | <.001 |
| UEFA Europa League | 1.05 | 0.59-1.87 | .865 | 0.72 | 0.43-1.18 | .190 | 1.19 | 0.55-2.60 | .656 | 1.23 | 0.53-2.84 | .636 |
| Other cup | 0.60 | 0.37-0.97 | .035 | 0.77 | 0.56-1.06 | .106 | 1.36 | 0.83-2.22 | .227 | 0.89 | 0.47-1.68 | .708 |
| Match venue | | | | | | | | | | | | |
| Home[b] | 1.0 | | | 1.0 | | | 1.0 | | | 1.0 | | |
| Away | 0.56 | 0.43-0.73 | <.001 | 0.75 | 0.62-0.91 | .003 | 1.02 | 0.71-1.47 | .901 | 0.90 | 0.63-1.28 | .544 |
| Part of season | | | | | | | | | | | | |
| Preseason (July-August)[b] | 1.0 | | | 1.0 | | | 1.0 | | | 1.0 | | |
| Fall (September-November) | 1.39 | 0.81-2.38 | .237 | 2.24 | 1.34-3.74 | .002 | 0.97 | 0.50-1.90 | .936 | 0.88 | 0.42-1.86 | .745 |
| Winter (December-February) | 1.13 | 0.65-1.96 | .660 | 2.56 | 1.54-4.26 | <.001 | 0.95 | 0.48-1.85 | .870 | 1.13 | 0.55-2.35 | .740 |
| Spring (March-May) | 1.43 | 0.83-2.47 | .201 | 2.56 | 1.54-4.28 | <.001 | 0.67 | 0.33-1.37 | .270 | 1.34 | 0.65-2.77 | .429 |
| Climate region[c] | | | | | | | | | | | | |
| Northern group[b] | 1.0 | | | 1.0 | | | 1.0 | | | 1.0 | | |
| Southern group | 1.04 | 0.77-1.40 | .803 | 1.08 | 0.87-1.35 | .474 | 0.87 | 0.55-1.36 | .528 | 0.89 | 0.57-1.39 | .614 |

Source: Hagglund, Walden et al., 2013, p. 333

In table 4, we can observe an analysis of extrinsic risk factors of lower limbs injuries in professional football players according to variables: [b] reference group in analysis, [c] climatic region according to the Köppen-Geiger classification system

A recent systematic review carried out by Hughes, Sergeant et al. (2017) aimed at identifying the risk factors of musculoskeletal, spinal cord, and lower limbs injuries in adult professional football players. The main finding of this study was that the scarcity, heterogeneity and methodological limitations of the literature show that the current evidence as regards the risk factors in football is very low or low quality. At the same time, these limitations in general could be partially explained due to a possible clubs' reluctance to share data in the research community for fear of losing a competitive advantage. According to these authors, after analyzing many studies, there were only two factors found which allowed a consensus about the prognostic value. In this respect, not only a history of previous hamstrings injuries but also an increase in age seem to increase the risk of injuries for this muscle group in male professional football players. According to authors themselves:

> Our results suggest that the current evidence does not support the ability of the medical detection tests to predict the specific risk of musculoskeletal

> injuries. The non-modifiable extrinsic factors such as age and previous injuries can be the only risk factors associated with injuries, this is supported by low quality evidence, though. Currently, the detection tests should only be considered as individual musculoskeletal function or performance markers and, thus, they are mainly useful as benchmarks (Hughes, Sergeant et al., 2017, p. 16).

### Injury Mechanisms Associated with Playing Actions and Football Field Zones

As it was previously analyzed, a large amount of research on football injuries has been carried out and a series of events about its nature, causal mechanisms and characteristics has been established. Even though the risk of injury is influenced by many factors, it is traditionally evaluated by the injury incidence rate per time of exposure. However, this approach is not able to identify the risk associated with specific actions that can lead to injuries. In this respect, Rahnama, Reilly et al. (2002) conducted a study with the aim of evaluating the players exposure to risk of injuries in the English Premier League football games in relation to a series of selected factors that could have an influence on that risk. In this study, a total of 17,877 playing actions were recorded, 7,667 out of them were considered potentially harmful, and 20 resulted in actual injuries (i.e. ~ 2 per game).

The data analysis determined that slight injuries were caused by receiving a *tackle* (50%), making a *tackle* (20%), receiving a "charge" (10%), kicking the ball (10%), and catching the ball (10%). Moderate injuries were caused by receiving a *tackle* (83%) and making a *tackle* (17%). Finally, severe injuries were in all cases caused by receiving a *tackle* (100%).

It is necessary to highlight that these descriptions of slight, moderate and severe injuries do not correspond to the general definition of severity of injuries used in the literature since there was no information about the aftereffect of the injury. In this case, a slight injury was considered when there was evidence of injury and the player got first aid attention on the playing field but with no extra treatment; a moderate injury was determined by the fact that the player got treated out of the playing field but he continued playing the rest of the game; and a severe injury was considered as such when the player received treatment and left the playing field for the rest of the game.

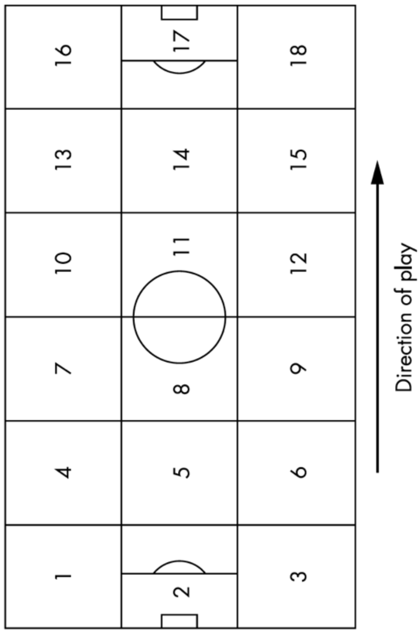
At the same time, every playing action was classified under one of the three categories depending on its probability of causing an injury. These categories were "with a potential for injury", "with no potential for injury" (both subjectively evaluated on the probability of the actions to cause an injury), and "actual injuries" (defined as receiving treatment on the field). The category "with no potential for injury" was used for actions such as an easy pass to a player of the same team in which there was no noticeable probability of injury.

In order to evaluate the number of injuries in each field zone, the field was divided in 18 zones of equal size (see figure 14). In total, 40% of actual injuries occurred on the midfield area (zones 7-12), 30% on the defending area (zones 1-6), and the other 30% on the principal attacking area (zones 13-18). On the other hand, 38 % of the events with injury potential occurred on the midfield area (zones 7-12), 31 % on the attacking area (zones 13-18), and the other 31 % on the defending area (zones 1-6).

Besides, these authors found a significant association between the number of actions with different injury potential (high, moderate, mild) and the playing zones. In this respect, 60% of the total actions with a mild injury potential occurred in attacking zones (14, 17), defending zones (2, 5), and midfield zones (7, 12). On the other hand, 40% of the total number of actions with moderate and high injury potential also occurred in the same attacking and defending zones.

**Figure 14: Injury potential and actual injuries per zones of the playing field**

| Zone | Mild IP | Moderate IP | High IP | Actual injury | Total IP+AI |
|---|---|---|---|---|---|
| 1 | 124 | 21 | 11 | | 156 |
| 2 | 633 | 146 | 36 | 1 | 816 |
| 3 | 143 | 28 | 15 | 1 | 187 |
| 4 | 187 | 41 | 18 | | 246 |
| 5 | 538 | 140 | 66 | 2 | 749 |
| 6 | 169 | 64 | 21 | 2 | 256 |
| 7 | 463 | 141 | 56 | 1 | 661 |
| 8 | 305 | 92 | 37 | 2 | 436 |
| 9 | 306 | 87 | 32 | | 425 |
| 10 | 321 | 109 | 42 | 1 | 473 |
| 11 | 234 | 72 | 31 | | 334 |
| 12 | 397 | 114 | 50 | 4 | 565 |
| 13 | 164 | 44 | 13 | | 221 |
| 14 | 595 | 142 | 87 | | 824 |
| 15 | 188 | 37 | 21 | | 246 |
| 16 | 86 | 26 | 13 | 3 | 128 |
| 17 | 638 | 124 | 32 | 3 | 797 |
| 18 | 127 | 21 | 19 | | 167 |
| Total | 5618 | 1449 | 600 | 20 | 7687 |




Source: Rahnama, Reilly et al., 2002, p.357;Rahnama, Reilly et al., 2002, p. 355
(In Figure 14: IP = injury potential - AI = actual injury).

Finally, these authors analyzed the influence of the playing period on the injury incidence. In this respect, there were no significant differences found among the six 15-minute periods of the game as regards actual injuries.

However, a significant difference among the periods of the game with respect to the injury risk was found. The first 15 minutes contained significantly more actions with mild injury potential than any other period of the game. It could be said that the game is more intense in this first period since the players are fresher and more energetic. On the other hand, the last 15 minutes of the game contained the highest number of actions with moderate injury potential. This could be the result of the musculoskeletal fatigue in this period of the game in which the muscle glycogen reserves start to deplete and the players are usually hypo-hydrated. In this stage of the game, players are usually tired but the competition can still be intense. The consequence of this can be that the predisposition to injuries is higher as fatigue and game intensity increase towards the end of the game.

## References

**Bahr, R., Clarsen, B. y Ekstrand, J.** (2018). Why we should focus on the burden of injuries and illnesses, not just their incidence (traducción propia). In *Br J Sports Med 52*(16) pp. 1018-1021.

**Bahr, R., Krosshaug, T.** (2005). Understanding injury mechanisms: a key component of preventing injuries in sport. In *Br J Sports Med 39*(6) pp. 324-329.

**Carling, C., Orhant, E. y LeGall, F.** (2010). Match injuries in professional soccer: inter-seasonal variation and effects of competition type, match congestion and positional role (translated by authors). In *Int J Sports Med 31*(4) pp. 271-276.

**Croisier, J. L., Ganteaume, S. J. Binet, Genty, M. y Ferret, J.M.** (2008). Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study (translated by authors). In *Am J Sports Med 36*(8) pp. 1469-1475.

**Ekstrand, J.** (2013). Keeping your top players on the pitch: the key to football medicine at a professional level (translated by authors). In *British Journal of Sports Medicine 47*(12) p. 723.

**Ekstrand, J., Hagglund, M. y Walden, M.** (2011). Injury incidence and injury patterns in professional football: the UEFA injury study (translated by authors). In *Br J Sports Med 45*(7) pp. 553-558.

**Ekstrand, J., Walden, M. y Hagglund, M.** (2004). Risk for injury when playing in a national football team (translated by authors). In *Scand J Med Sci Sports 14*(1) pp. 34-38.

**Fuller, C. W., Ekstrand, J.A. Junge, T. E. Andersen, R. Bahr, J. Dvorak, M. Hagglund, McCrory, P. y Meeuwisse, W. H.** (2006). Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries (translated by authors). In *Clin J Sport Med 16*(2) pp.193-201.

**Hagglund, M., Walden, M. y Ekstrand, J.** (2013). Risk factors for lower extremity muscle injury in professional soccer: the UEFA Injury Study (translated by authors). In *Am J Sports Med 41*(2) pp. 327-335.

**Hawkins, R. D., M. A. Hulse, M.A., Wilkinson, C., Hodson, A y Gibson, B.** (2001). The association football medical research programme: an audit of injuries in professional football (translated by authors). In *British Journal of Sports Medicine 35*(1) pp. 43-47.

**Henderson, G., Barnes, C. A. y Portas, M. D.** (2010). Factors associated with increased propensity for hamstring injury in English Premier League soccer players (translated by authors). In *J Sci Med Sport 13*(4) pp. 397-402.

**Hughes, T., Sergeant, J. C., Parkes, M. J. y Callaghan, M. J.** (2017). Prognostic factors for specific lower extremity and spinal musculoskeletal injuries identified through medical screening and training load monitoring in professional football (soccer): a systematic review (translated by authors). In *BMJ Open Sport Exerc Med 3*(1) pp. 1-18.

**Junge, A., Dvorak, J.** (2000). Influence of definition and data collection on the incidence of injuries in football (translated by authors). In *Am J Sports Med 28*(5). pp. 40-46.

**Lopez-Valenciano, A., Ruiz-Perez, I., Garcia-Gomez, I., Vera-Garcia, F. J., De Ste Croix, M., Myer, G. D. y Ayala, F.** (2019). Epidemiology of injuries in professional football: a systematic review and meta-analysis (translated by authors). In *Br J Sports Med 54*(12) pp. 1-9.

**McIntosh, A. S**. (2005). Risk compensation, motivation, injuries, and biomechanics in competitive sport(translated by authors). In *British Journal of Sports Medicine 39*(1) pp. 2-3.

**Meeuwisse, W. H.** (1994). Assessing Causation in Sport Injury: A Multifactorial Model (translated by authors). In *Clinical Journal of Sport Medicine 4*(3) pp. 166-170.

**Molina Arias, M.** (2015). Hazard ratio: cuando el riesgo varía a lo largo del tiempo. In *Pediatría Atención Primaria 17* pp. 185-188.

**Petersen, J., Thorborg, K., Nielsen, M. B. y Holmich, P.** (2010). Acute hamstring injuries in Danish elite football: a 12-month prospective registration study among 374 players (translated by authors). In *Scand J Med Sci Sports 20*(4) pp. 588-592.

**Pfirrmann, D., Herbst, M., Ingelfinger, P., Simon, P. y Tug, P.** (2016). Analysis of Injury Incidences in Male Professional Adult and Elite Youth Soccer Players: A Systematic Review (translated by authors). In *J Athl Train 51*(5) pp. 410-424.

**Rahnama, N., Reilly, T. y Lees, A.** (2002). Injury risk associated with playing actions during competitive soccer (translated by authors). In *British journal of sports medicine 36*(5) pp. 354-359.

**Sampietro, M.** (2010). *Distribución de las lesiones producidas en entrenamiento vs. Producidas en partidos* [unpublished material].

**van Mechelen, W., Hlobil, H. y Kemper, H.C.** (1992). Incidence, severity, aetiology and prevention of sports injuries. A review of concepts (translated by authors). In *Sports Med 14*(2) pp. 82-99.

**Waldén, M., Hagglund, M. y Ekstrand, J.** (2005). UEFA Champions League study: a prospective study of injuries in professional football during the 2001–2002 season (translated by authors). In *British Journal of Sports Medicine 39*(8) pp. 542-546.

**Walden, M., Hagglund, M., Orchard, J., Kristenson, K. y Ekstrand, J.** (2013). Regional differences in injury incidence in European professional football (translated by authors). In *Scand J Med Sci Sports 23*(4) pp. 424-430.

**Woods, C., Hawkins, R., Hulse, M., y Hodson, A.** (2002). The Football Association Medical Research Programme: an audit of injuries in professional football-analysis of preseason injuries (translated by authors). In *Br J Sports Med 36*(6) pp. 436-441.