1.1 Basic concepts in injury prevention

The importance of injury prevention stems from the analysis of the impact that injuries represent for the athletes who suffer them as well as the institution or team to which the athletes belong. On this account, the negative impact of injuries in social and work settings (absenteeism, loss of earnings, loss of productivity), on athletic achievements (both individual and collective), for psychological and emotional health (the athlete's inability to perform their sport, external and internal pressures, etc.) as well as economic factors (medical supplies for rehabilitation, costs associated with players inactivity) proves significant and underscores the importance of preventing athletic injuries and minimizing the aforementioned impact.

The literature helps to visualize some of the information provided in the previous paragraph, as for example, with the interesting study by Henke, Moschny and Platen (2007). In this study, the authors explored the economic losses suffered by first, second and third division clubs in the professional German soccer league stemming from injury related absences in the 2004-2005 season. Analyzing the population of professional soccer players during this period, they counted 5,361 injuries, representing an economic loss of 90 million euros per season, with knee injuries representing the highest portion of the losses at 33 million euros, or 37% of total losses during the season. Bahr and Engebretsen (2009) present relevant information regarding the impact of sports injuries on public health, showing that in the United States between 1997 and 1998, 11% of all emergency room visits were for athletic and recreational injuries, or 3.7 million visits representing an estimated cost of 500 million dollars per year, only accounting for emergency room services.

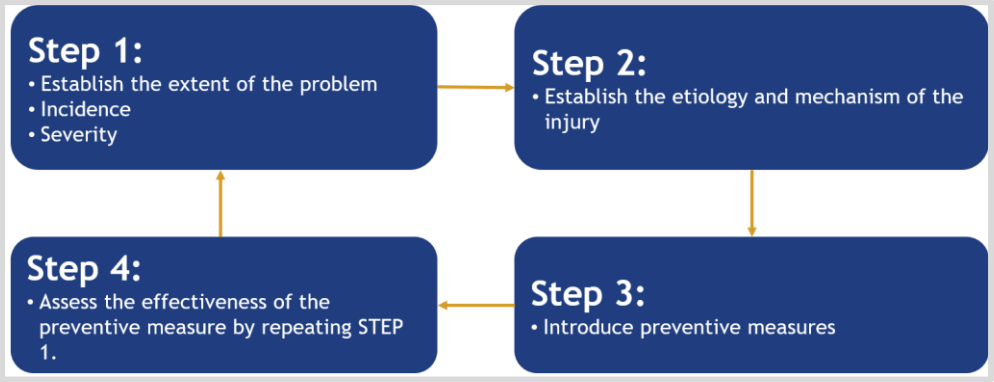
Viewed in this light, the importance of addressing the problem of injuries assumes a different dimension. Likewise, it is worth mentioning that a team's competitive advantage is significantly affected if it cannot count on key players due to injuries, as discussed by Hägglund Martin, Waldén Markus, Magnusson Henrik, Kristenson Karolina, Bengtsson Håkan, and Ekstrand Jan (2013). Thus it follows that establishing measures for the reduction of incidence of injuries in different sports is just as important as the implementation of training methods aimed at improving an athlete's performance level.

1.1.1 Current prevention models

In 1992, Van Mechelen presented the first sequential model for research into the prevention of injuries. The four-step model has since that time been successfully employed. Its success stems from its simplicity and practicality in execution. (Cos Francesc, Cos Miquel Ángel, Buenaventura Lorenzo, Pruna Ricard, Ekstrand Jan. (2010))

The model described by Van Mechelen in 1992 consists of a process comprised of 4 clearly defined steps:

Figure 1: Sequential Model by Van Mechelen (1992) for Research into the Prevention of Injuries



Source: Adapted from Van Mechelen et al., 1992, pg. 84.

The first step involves quantifying and contextualizing the problem, that is, establishing the extent of the problem, the implication of the injuries, their severity, etc. This step is established with the use of an epidemiological analysis to be carried out on a specific population of athletes.

As we will see later, there currently exists a set of extremely detailed studies on the epidemiological realities of each sport, wherein the incidence and distribution of injuries are analyzed, along with the prevalence of certain types of injuries at particular points in the season. The importance of performing an injury profile analysis is magnified by the specific requirements of each sport and by the presence of extrinsic risk factors that accentuate the problem.

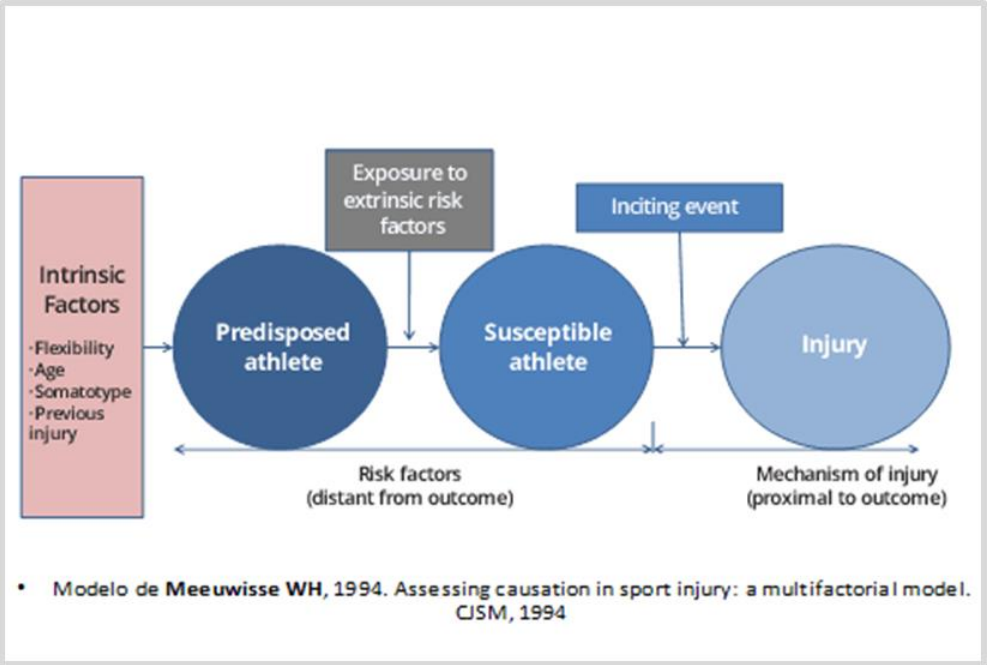
The second step involves establishing the injury mechanisms and risk factors for the most frequent injuries in each sport, determined by the epidemiological analysis performed in the first step. This is where later studies and prevention models have differed, attempting to quantify more precisely these different factors so as to better act upon them. (Casáis Martinez, L., 2008).

The third step consists in the **implementation of the preventive measures** developed out of the analysis of the first two steps, thus attempting to lower the risk of suffering injuries, or at least minimizing their severity.

Finally, the fourth step consists in the **assessment of the effectiveness of the preventive measures** previously proposed, repeating step one (epidemiology) and comparing results. This is generally carried out after a set period of time and with a sufficiently large number of subjects observed. In so doing, we are able with specific statistical methods to reach conclusions about whether the results were significantly influenced by the preventive measures implemented.

In an attempt to expand upon the second step as proposed by Van Mechelen, W., Hlobilm, H., & Kemperm, H. C. (1992); Meeuwisse W (1994) offered a multi-factor model for the analysis of the causes of injuries and their associated risk factors.

Figure 2: Meeuwisse's Multi-Factor Model for Sports Injuries



Source: Adapted from Meeuwisse et al., 1994.

This model suggests that an injury is not the result of an isolated mechanism, but rather appears within a complex network of interrelated factors that merit analysis.

The author's understanding is that intrinsic factors (modifiable or non-modifiable) such as age, sex, prior injury, etc., can predispose an athlete to suffer injuries, and that these factors interact with extrinsic factors such as terrain, the type of training, or time alloted for rehabilitation, all of which increase an athlete's susceptibility to injury. Finally, the same event that produces an injury in a "susceptible" athlete could go undetected in an athlete who is not susceptible.

Bahr and Krosshaug (2005) propose a series of examples for this model, such as Olsen's study (2003), where it was demonstrated that playing fields with a high friction coefficient can act as an important extrinsic factor increasing the risk of ACL injuries among female handball players, thus showing the interrelation of both intrinsic (sex) and extrinsic factors (friction coefficient of the playing field).

We can expand on this example by analyzing the different biomechanical studies of soccer conducted by FIFA (International Federation of Association Football), wherein an attempt was made to determine if artificial turf would increase the risk of injuries. Provided the results of this study, FIFA, the international governing body for soccer, issued a list of technical specifications for playing fields with artificial turf.

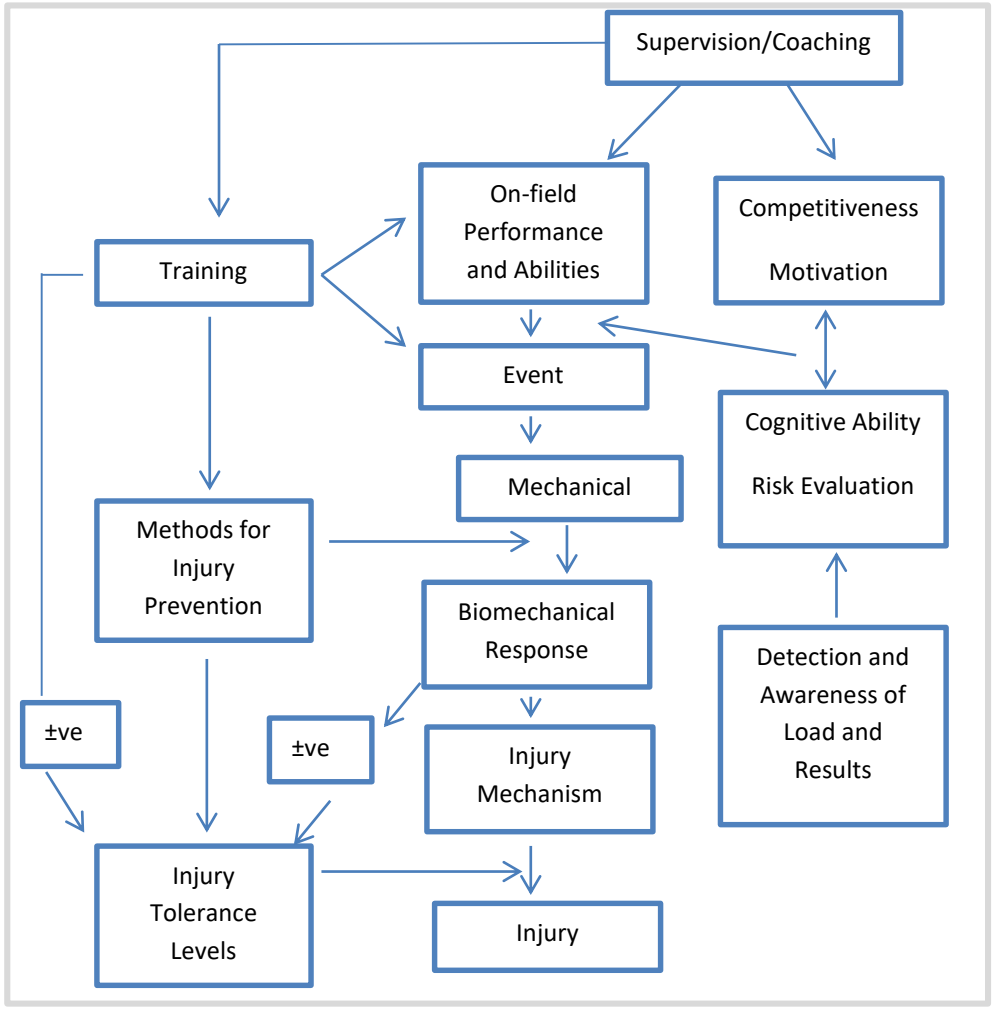
Biomechanical models provide a counterpoint to the epidemiological models for analyzing the process of injuries and injury prevention. These models take into account the biomechanical characteristics of the muscle tissues (specific features of each tissue in question, as well as their relationship with other intrinsic factors such as age) and the nature of the forces acting upon them. They also provide an explanation for how a particular force, in the context of an injury mechanism, exceeds the tissue's biomechanical tolerance capacity and produces structural damage in the tissue in question.

Thus, the preventive measures developed by these models of analysis attempt to ensure that external and internal forces applied to the tissues have an effect smaller than the injury criteria obtained from biomechanical analyses. The aforementioned is achieved by increasing the body's capacity to tolerate or react to such forces through specific training routines, or through the use of specific training equipment that reduces the risk of injury.

These models are generally more complex and detailed than the model proposed by McIntosch (2005), which adopts a broader viewpoint (while still maintaining the biomechanical focus that examines the motivations, attitudes, abilities, training sessions, coaches, opponents and

environment, thus attempting to take into account all of these factors and how they can represent positive or negative influences in terms of the body's biomechanical response to external forces that produce injuries).

Figure 3: Schematic Injury Model



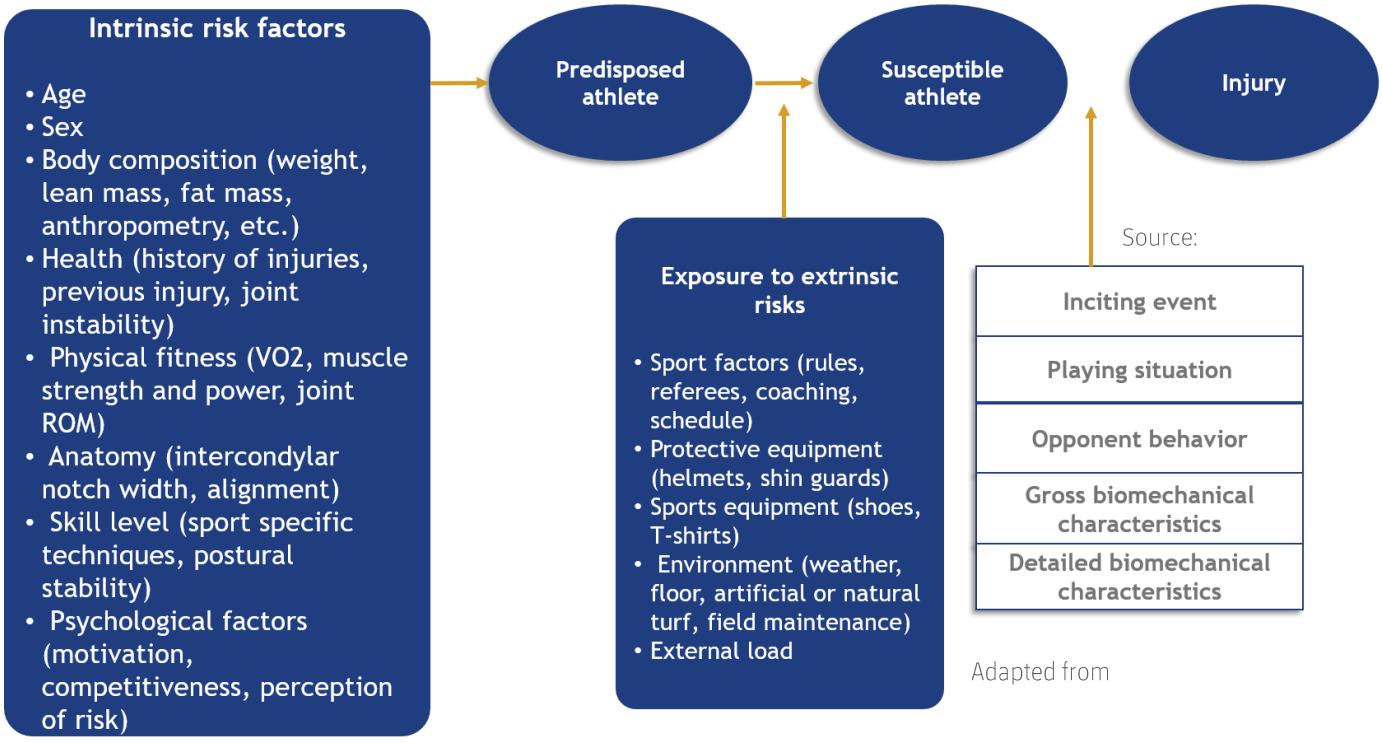
Source: Adapted from McIntosch, (2005).
The +/- signs indicate that training or a biomechanical response during an event can increase or decrease the injury tolerance levels, for example: microtrauma.

Finally, in their analytical work Bahr and Krosshaug (2005) propose an expansion of Meeuwisse's (1994) epidemiological model, including some concepts extracted from the biomechanical perspective of McIntosch (2005), wherein focus is centered on the triggering event or injury mechanism as key to better understanding and mapping injury prevention in sports.

In this model, intrinsic and extrinsic factors can affect force tolerance or load tolerance. In short, this model expands on the understanding of all

the interacting components in order to comprehend the injury mechanism, attempting to combine the most important aspects from both epidemiology and biomechanics. The author concludes that a more precise description of an injury's triggering event or mechanism is key to designing prevention models aimed at reducing the incidence of injuries, with the understanding that both perspectives, taken individually, are insufficient for explaining the process of injury production.

Figure 4: Multi-factor Model Proposed by Bahr et al (2005)



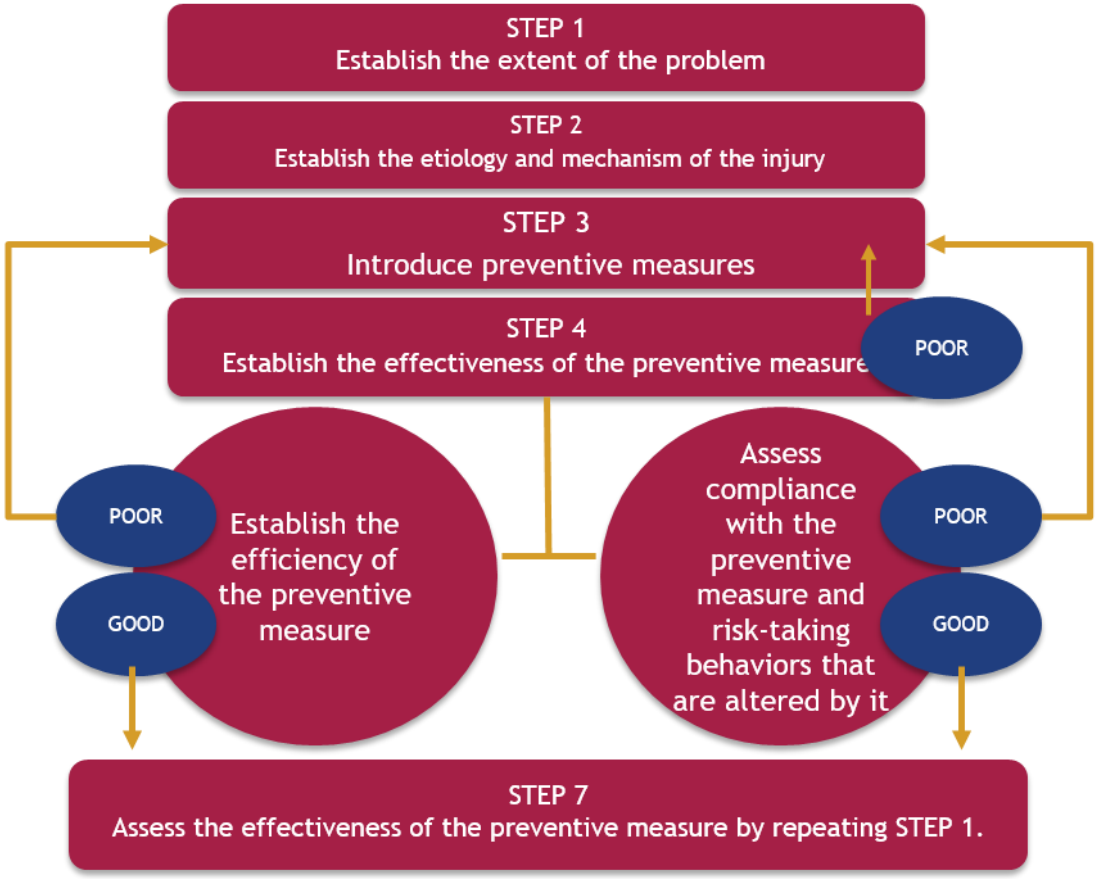
Meeuwisse et al., 2005.

Revisiting and looking more closely at the analysis of the model of Van Mechelen et al. (1992), Finch (2006) and Finch and Donaldson (2010) include an important element, which is the need to better understand and increase the effectiveness of research results when implemented in real-life contexts within the sports community. The aforementioned is important because, no matter if a practice was proven effective in a controlled, randomized study, if it is not widely adopted and maintained by the sports community, it remains unlikely to have a real impact on the health of the athletes. To this end, these authors use the TRIPP framework (translating research into injury prevention practice), based on an analysis of the context where the practice should be applied (personal, environment, social factors and implementation factors, etc.) and on the effectiveness of the measure in real-world contexts (studies

evaluating the effectiveness of the practice in uncontrolled conditions, similar to the day-to-day reality of the sports community).

If we summarize and incorporate the models presented up to this point, especially the four-step model of van Mechelen (1992) and the contributions of Finch (2006), the result is the model contributed by Van Tigelen, Wickes, Stevens, Roosen and Witvrouw, which incorporates three additional steps to be introduced between steps three and four.

Figure 5: Integrated Model from Van Tiggelen



Source: Adapted from Van Tiggelen et al., 2008.

This model incorporates the ideas of efficacy, efficiency and compliance with the preventive measure which should be taken into account in order to be able to more effectively evaluate the impact of the measure on injury prevention in the sports community. The term efficacy refers to whether the proposed measure really has the effect of protecting the structure in question, and therefore if it will reduce the incidence of injury. Efficiency refers precisely to the measure's applicability in a real world context, and especially in a widespread manner within the sports

community, that is, ensuring that there exist the fewest barriers possible to the application of the measure within a broad spectrum of the sports community while simultaneously maintaining its effectiveness. And finally, compliance refers to the necessity of implementing preventive measures that can be carried out in a systemic and frequent manner by the sports community (Van Tiggelen et al., 2008).

In the last instance, whichever model is being followed, the true importance lies, in our opinion, in carrying out these basic steps within our institution in order to be more effective in the establishment of injury prevention measures; that is to say, to understand the importance of and achieve the implementation of injury prevention measures that are effective and applicable within our sports environments.

1.1.2 Important definitions in sports epidemiology

Collecting epidemiological data is crucial for guiding the search for all injury-related factors (risk factors, injury mechanisms, among others) and for their subsequent connection with the effective application of prevention models that diminish the incidence of injuries.

A methodologically correct epidemiological study consists of observing and following either prospectively or retrospectively the most frequent injuries and the behavior of these injury patterns in relation to the dynamics and characteristics of the particular sports being studied.

In this sense, Junge A, and Dvorak (2000) suggested the need to create a consensus around the definition and collection of data related to sports injuries in soccer. This work began by defining some principles for a similar process of data collection, thus allowing for comparison with the rest of the body of work in this area.

Based on a review of the literature, Fuller et al. (2006) propose a consensus regarding the definition of important concepts and on the methodology for gathering data, using soccer as a starting point but allowing for application to other sports. The aforementioned takes place in light of the well-documented fact that differences in definitions and methodologies in the collection of statistical data produce significant divergences in the results and conclusions for sports injury studies.

With regards to the appropriateness and applicability of the following definitions to other sports as a whole, the work of Cumps, E., Verhagen, E., & Meeusen, R. (2007), Deitch, J., Starkey, C., Waltersheri, X. & Moseley, J. (2006), Meeuwisse et al. (2003) in basketball; of Verhagen (2004) in volleyball; of Brooks and Fuller (2005) in Rugby, among others, can be

used as references, given they propose a methodological model for their epidemiological work with these sports, using similar or identical definitions to those presented below.

Definitions

In order to understand and plan epidemiological research, we should be clear about a series of definitions and concepts that will allow us to classify the injuries in our sport and compare the data with other reference data where a similar methodological framework was used.

Below are the most important definitions to take into account.

Injury

Any physical discomfort suffered by a player that requires medical attention or results in missing, fully or partially, training sessions or competitions. An injury that requires medical attention is defined as a medical-attention injury, and those injuries that prevent a player from fully participating in training sessions or matches is defined as an injury causing a loss of participation.

It is important to underscore that this definition marks a departure from classic concepts that define an injury based on structural damage suffered by the player. This epidemiological definition was created with the goal of gathering statistical data towards the objective of including the greatest quantity of injuries that an athlete can suffer. Furthermore, the objective was to quantify the data based on suspension of the athlete's normal sports activity, rather than basing the severity of the injury on structural or functional damage. Example: a strained muscle classified as level 1 in terms of structural damage indicates that the number of affected muscle fibers is minor or minimal, and thus categorized as light. However, if the muscle's recovery requires more than 21 days, for epidemiological purposes, this injury is classified as moderate or severe as related to the loss of training sessions or games, as was seen in the preceding paragraphs

Recurrent Injury

This refers to all injuries that are of the same type and in the same location as a previously recorded injury, sustained after the player has resumed normal athletic activity. When this recurrent injury appears within two months of the full resumption of activity, it is considered an early recurrence; when occurring between 2 and 12 months, a late recurrence, and after 12 months, a delayed recurrence.

According to these authors, in studies that collect data on recurrent injuries it is important to specifically describe the injured structure and not limit the description to the general zone (for example, specify injury as pertaining to the "internal collateral knee ligament", and not just "recurrence in the knee").

As we will see shortly, this definition proves useful given that when we analyze risk factors for injury, previous injury is a repeated factor across all sports, and thus gathering this data allows us to establish conclusions about, for example, the importance of rehabilitation after the first episode of an injury.

Injury Severity

Also important is the definition of vocabulary related to the severity of an injury, where the aforementioned idea marks an important shift from the study of sports injuries to the development of epidemiological studies.

In this sense, Junge and Dvorak (2000), in their study debating the impact of data gathering and records on the incidence of injuries in soccer, employ a classification from the National Athletic Injury Registration System that bases the severity of the injuries on the length of time the athlete is unable to participate in training and competition, with the following categorization:

- Mild: injuries with a disability time between 1 and 7 days.
- Moderate: from 8 to 21 days.
- Severe: more than 21 days, up to permanent damage.

On the other hand, in order to carry out a prospective epidemiological study of the English professional soccer league, Hawkins, Hulse, Wilkinson, Hodson and Gibson (2001) used a severity classification scheme divided into four categories, following the same concept of severity as determined by the number of days that the injury prevents the player from full participation in the sport, with these categories:

- Slight: from 0 to 4 days.
- Minor: from 4 to 7 days.
- Moderate: from 7 days to 4 weeks.
- Severe: more than 4 weeks.

In light of our experience, we consider the latter severity classification scheme more useful, as it better identifies minor injuries or pains (which

is not to say that for being minor, they should not be taken into account) and potentially provides us with specific information about the characteristics of training or the particularities of a game, for example.

Beyond the classification established or selected by each research group (where, for the methodological performance of an epidemiological study, the system selected as a point of reference should be clearly indicated), it is clear that, in competitive sports, the severity of an injury will be defined by the days of full athletic participation that the athlete must forgo, rather than the classic definition of the severity of an injury based on the level of structural damage sustained by the injured anatomical structure. This is not to say that this classic classification is incorrect, but rather that, in practical and epidemiological terms, the use of time-disabled as a factor in the categorization of the injury becomes necessary.

Location of the Injury

Location of the injury is important for the development of epidemiological studies and has a direct relationship with the physical, biomechanical, technical, and tactical characteristics of the sport, given that, depending on these factors, the distribution of injuries among the different zones of the body will be different.

The table below may prove useful for distinguishing the injury zone.

Table 1: Principal Categories and Groups for Categorizing the Location of Injuries

Principal Groups	Category	Equivalent Figure in OSICS
Head and Neck	Head/Face	H
	Neck/Cervical Spine	N
Upper Body	Shoulder /Clavicle	S
	Arm	U
	Elbow	E
	Forearm	R
	Wrist	W
	Hand/Fingers	P
Trunk	Sternum/Upper Back	C, D
	Abdomen	O
	Lower Back/Pelvis	B, L
Lower Body	Hips / Pubis	G
	Thigh	T
	Knee	K
	Calf / Area of the Achilles Tendon	Q, A
	Ankle	A
	Foot	F

Source: OSICS Orchard sport injury classification system, (s.f.).

Calculating Injury Incidence

The incidence of injuries in a sport is defined as the number of new cases in a given observation period or study, divided by the total number of players exposed to the injury (that is, the population at risk) (Junge and Dvorak, 2000).

Thus, the risk per player per year is equal to the number of new injuries during the year divided by the number of at-risk players during that year.

Risk*Player*Year=(Total New Injuries)/(Number of At-Risk Players)

The authors state that the incidence could be calculated more precisely (at least in sports with similar qualities to soccer) if exposure time were considered in terms of hours, including training sessions and competitions.

The risk of injury by exposure is defined as the number of new injuries divided by the total time that all players spend in training and in competition. (Junge and Dvorak, 2000).

This is usually calculated per 1,000 hours of exposure, and can be comprehensive or more specific (1,000 hours total or 1,000 hours of

competitions or matches). For this reason, the risk per 1,000 hours of exposure is defined as the number of injuries per 1,000, divided by the total hours of exposure (adding up the total hours of exposure of each player).

Risk*1,000 h= (Number of New Injuries*1000)/ (Total Hours of Exposure)

Another way to calculate exposure, used in particular for certain epidemiological studies in basketball, specifically in the NBA or WNBA (National Basketball Association and Women's National Basketball Association) and in the American school leagues, is calculation by number of athlete-exposures; that is, the ratio of the incidence of new injuries divided by the number of athlete-exposures within a given period of time or per 1,000, with AE (athlete exposure) defined as an athlete who has participated in a match or practice. For example:

Risk* Athlete-Exposures = (Number of New Injuries)/ (Number of Athlete-Exposures)

Independent of the measurement used, which would depend on the methodological design of the study, the utility of incidence calculation consists in the possibility of achieving a better analysis of the real problem of injuries in a given sport. To better understand this, we will examine here an example of the injuries in different sports practiced in the Netherlands, as referenced by Verhagen (2008).

In the first table, we can see the different total number of injuries occurring in the different sports under analysis, where it is clear that soccer is the sport with the highest incidence of new injuries. This is hardly surprising, given the popularity of the sport, and hence its large quantity of players. All the same, if we only examine this piece of data, we will have a mistaken or at least incomplete view of the actual situation, given we would be led to conclude, for example, that winter sports do not present a high number of injuries, and therefore focus all of our preventive efforts on soccer (Verhagen, 2008).

Table 2: Total Injuries in the Netherlands

Sport	Total Number of Injuries
Soccer	620,000
Futsal	109,000
Field Hockey	101,000
Tennis	90,000
Winter Sports (Skiing, etc.)	79,000
Ice Skating	68,000

Source: Adapted from Verhagen, (2008).

If we examine these injury incidence numbers in terms of risk of injury per 1,000 hours of exposure, as in the above calculations, we can see that the relative incidence, that is, the relative risk of injury in each sport, will provide us with a different picture. Thus we see, for example, that soccer presents an incidence of 2.0 injuries per 1,000 hours of exposure, which is a reasonable number and is within the degree expected for this sport; by contrast, other sports with a lower total number of injuries present a much higher risk, as in the case of winter sports, with a relative risk of 10.1 injuries per 1,000 hours (Verhagen, 2008).

Table 3: Injuries and Incidence or Rate per 1,000 Hours of Exposure

Sport	No. Injuries	Incidence
Soccer	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).

This does not mean that all preventive measures should be focused on those sports with the highest relative incidence of injury, or that we should ignore the total numbers, as the implementation of preventive efforts in soccer is vital, especially for certain injuries that prove costly due to their severity. Taking this into account,we are able to obtain a more complete picture of the reality and problems involved in sports injuries, thus allowing us to make more accurate conclusions about their causes.

Prevalence

Another important concept to highlight is prevalence. This concept best applies to injuries derived from overuse and can be defined as "the percentage of athletes with the same injury in a given population at a given moment" (Bahr and Maehlum, 2007, p. 43). This piece of data may indicate a high prevalence for a particular injury, possibly pointing to an error committed in the training process, or at least a certain tendency that should be studied in order to reduce this percentage.

For example, if in a particular period of time we encounter a prevalence of 30% for athletic pubalgia, we can say that 3 out of every 10 athletes have shown symptoms of this pain during the period studied, encouraging us to study the risk factors and causes of the injury in order to lower its prevalence.

1.1.3 Intrinsic and extrinsic risk factors

Risk factors are certain characteristics that athletes possess that could potentially increase their risk of suffering an injury. A risk factor can be part of a set of other factors that, acting and interacting together, create sufficient cause to produce a sports injury. The aforementioned presents a real challenge for injury prevention research, largely due to the complexity of the methodological approach involved in determining the real influence of a given factor in the incidence or absence of a sports injury. (Bahr R., & Maehlum, S., 2003).

There are two broad risk factor groups: intrinsic risk factors, which refer to the qualities unique to a given athlete such as age, gender, somatotype, physical ability or performance, etc., and extrinsic risk factors, which are those factors external to the athlete that can strengthen or weaken the effects of intrinsic risk factors. Examples of extrinsic risk factors include the rules of the game or sport, sports attire, the use or lack of protective equipment, etc. (Bahr R, & Krosshaug, T., 2005).

Intrinsic risk factors can be divided into modifiable and non-modifiable factors. Non-modifiable risk factors are those that cannot be modified through any kind of intervention, for example, factors such as age, gender, sex, injury history or previous injury. Modifiable risk factors refer to those factors that can be modified by relevant interventions, for example factors related to physical conditioning, body mass index, lower limb neuromuscular control, etc. (Bahr R., & Krosshaug, T., 2005).

1.1.4 Aspects to consider in the application and management of a prevention program within a team

Among the most important challenges faced by the medical staff of a sports team is the development, application, monitoring and evaluation of an applied prevention program. In this sense, it is important to know which aspects are decisive for guaranteeing effectiveness. Focusing on this analysis, and taking into account the analysis developed in the previous sections, it is necessary reconstruct the prevention model.

Some important aspects for developing and applying a prevention program include:

- Use of a model for gathering epidemiological data. It is important to gather the necessary information regarding the existence of injuries in a team, as well as regarding exposure during practices and games (the number of players available for each practice and game, and the participation time of each player). On this point, it is also important to have available the published epidemiology for each sport in question, as well as the corresponding generic risk profiles.
- Analysis of the schedule of competitions and training sessions. Before the beginning of the season and competition, it is important to carry out an analysis of the instances and conditions that could increase the risk of injury (changes in training surfaces, "tapering" or transition between the preseason and competitive season, traveling and means of transportation, breaks, etc).
- Preseason screening. It is crucial to be able to gather definitive information about the condition of our athletes prior to the beginning of the season. This is accomplished through an organized process of exams and tests that provide us with concrete information about the risk profiles of the athletes.
- Design and application of the prevention program. The latter is the result of the information gathered from our team's epidemiological studies, information drawn from existing literature about the sport, the risk profile detected in the preseason screening and based on an examination of the year's schedule. The prevention program should include general actions for the whole group, for subgroups according to the increased risk for certain injury groups, individual actions, monitoring of external training loads, post-exertion recovery methods, nutrition and hydration programs, etc.
- Monitoring and decision-making regarding returning to competition. It is important to determine when players are fit to

return to their previous level of training and competition after an injury, such that the risk of recurrence or new injuries stemming from the loss or lack of capabilities accrued during rehabilitation is minimal or non-existent.

- Guarantee the minimum equipment and technology necessary to be able to carry out the program.
- Ensure and monitor that technical staff and players are adhering to the specific actions set out in the prevention program.
- End-of-season analysis of the program's application, allowing for the data collected at the end of the season to serve as a vital and important source of information for the program during the following season.

The development and the execution of each of the items detailed in the previous paragraph will determine the effectiveness of the prevention program used by our team.