

# Intervention Strategies in the Prevention of Sports Injuries From Physical Activity

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## 1. Introduction

Injuries are a serious problem in the training-competition process, since their occurrence leads to the modification or interruption of the activity. Any injury alters training plans and is an important factor in training monitoring. Within the sports community, the most common intervention focuses on recovering from injuries in order to return to previous performance levels; a process that is expensive from both the economic and sporting points of view. However, in many sports, strategies aimed at injury prevention have not been systematically implemented, despite their proven effectiveness. The present chapter reviews some of preventive programs that must be incorporated in training schedules to minimize the impact of injuries. With regard to the introduction of intervention strategies in sport, through preventive measures from physical activity, it is necessary to review the power of the proposed measures and assess their effectiveness. There are numerous published papers on the subject, although it requires a careful study of them, both from the standpoint of methodology as adequacy of proposals, so as to adequately inform such interventions.

## 2. Multifactorial analysis of the model for injury prevention

One of the most important aspects of training and competition would be the control of the process and its development. The control of training comprehends all the aspects that permit the adaptation of the contents and the training load. One of the reasons why the modification of training programs becomes necessary is sports injuries, as they generate a partial or total interruption of the training process. It is a fact that is practically usual in the majority of sports, as a great number of sportsmen and women injury themselves at least once a season (Bahr & Krosshaug, 2005; Van Mechelen et al., 1992). The injuries constitute set-backs, which cannot be totally avoided, as the mere practice of sports carries with it the risk of injury happening. However, their impact could be lessened through the monitoring, controlling and analysing of the factors and their evolution by using adequate means of control.

The objective would be to ensure that the risk is lessened (prevention) or that its evolution is more favourable, and to ensure the incorporation of the sportsperson in as little time as possible (functional recuperation). Until a few years ago, efforts were centred on treating injury, paying special attention to the therapeutic process from a clinical perspective. However, in the last few years interest has become directed towards the development of strategies and multidisciplinary proposals related to the prevention of and the recovery

from sports injuries. Therefore, the intervention performed presents a model of general control, which includes a global evaluation of the specific sporting context (sport, characteristics of the sportsperson, training conditions, etc.), an adequate prevention in the face of multiple factors of injury predisposition (multifactorial model), and a systematic effort in case of the injury appearing, guaranteeing a full recovery.

## 2.1 Sequence of prevention

To establish a plan of prevention one must begin with Van Mechelen et al.'s proposal (1992) in a sequence of four steps: establishing the extent of the injury, identifying the factors and mechanisms of injury, introducing preventive measures and, lastly, evaluating their effectiveness (Figure 1). The last few decades have seen a significant increase in the epidemical studies contributing information on the first two steps: identifying injury incidence in each sport, along with the factors and mechanism involved in the production of the injuries, as well as establishing the possible factors provoking the injury, upon which to act in a preventive manner. To understand the importance of the problem it is necessary to know the injury profile for the different sports: injury frequency (number of injuries per 1,000 hours of training or competition), location of the different body structures, severity, typology and the rest of relevant aspects (Fuller et al., 2006). Meeuwisse (1994) developed a model to explain the different risk factors involved in producing sports injuries, rejecting approaches involving an only factor.

Model/Stage	TRIPP (Finch, 2006)	Van Mechelen et al. (1992)
1	Injury surveillance	Establishing extent of the problem
2	Establishing aetiology and mechanisms of injury	Establishing aetiology and mechanisms of injury
3	Developing preventive measures	Introducing preventive measures
4	"Ideal conditions" / scientific evaluation	Assessing their effectiveness by repeating stage 1
5	Describing intervention context to inform implementation strategies	
6	Evaluating effectiveness of preventive measures in implementation context	

Fig. 1. The "sequence of prevention" of sports injuries (Van Mechelen et al., 1992) and The Translating Research into Injury Prevention Practice, TRIPP (Finch, 2006)

Later, this proposal is completed by showing the complex interaction of the internal and external risk factors and the mechanisms that cause sports injuries (Parkkari et al., 2001). In recent years, the theoretical framework of research has been expanded with contributions from Finch (2006), increasing the number of steps in the sequence of prevention to the implementation and evaluation of injury prevention in a real context.

These injuries are associated to a series of risk factors that need to be identified so as to introduce preventive measures in training (Figure 2). These factors are classified in intrinsic factors (predisposal of the sportsperson) and extrinsic factors (exposal to factors of risk),

although in reality the process indicates that these factors are produced in a complex manner and they interact between them (Larson et al., 1996; Murphy et al., 2003; Peterson & Renström, 1988).

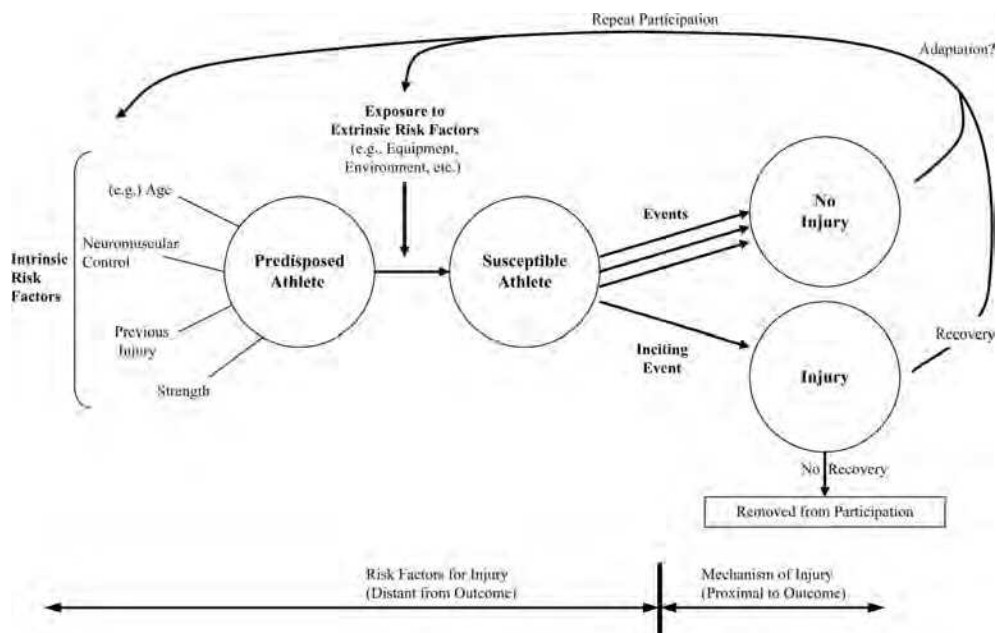


Fig. 2. Recursive model of aetiology in sport injury (Meeuwisse, 2007).

Among the most important intrinsic factors would be the existence of a previous injury and inadequate rehabilitation, age, the sportsperson's state of health, psychological state and aspects, etc. With regard to extrinsic factors, these are: type of activity and motive gestures specific to the sport, dynamics of the training load, training and competition exposition time, material and equipment, type of surface of the playing, environmental conditions and anatomic fatigue (Galambos et al., 2005; Junge & Dvorak, 2000).

Once the most frequent injuries of each modality and their risk factors are known, preventive measures can be introduced (Figure 3). The efficiency of these measures and their suitability from the methodological point of view (Finch, 2006; Shepard, 2005) are known beforehand. The prevention programs should be evaluated through more rigorous designs, with not only random experimental designs of group control, but also quasi-experimental designs that permit more representative samples (professional sportspeople) and more realistic practice contexts (training - competition processes), with truly ideal intervention programmes. Only in this way can the efficiency of the preventive intervention in sports be evaluated (Junge & Dvorak, 2004).

## 2.2 Different levels of sports injury prevention

### 2.2.1 Primary Level

The objective of the Primary Level of prevention is to avoid injury before it happens. It consists of a general preventive intervention taking into account the general factors and

mechanisms characteristic of a given person and their effect on a sportsperson with an injury risk. This level implies a change in beliefs, attitude, habits and behaviour towards prevention, and their training by both coaches and sportspeople.

The main measures are of an indirect type: they will control the type, quality and state of the training grounds and competition surfaces; the type of footwear that respects cushioning, traction and rotation upon the field; the use of protective elements; the organization of travel; sleeping and eating habits; the use of taping as a possible factor in reducing ligamentous affectations; or hydration, controlling the number and quantity of liquid intake and the combination with other sports drinks.

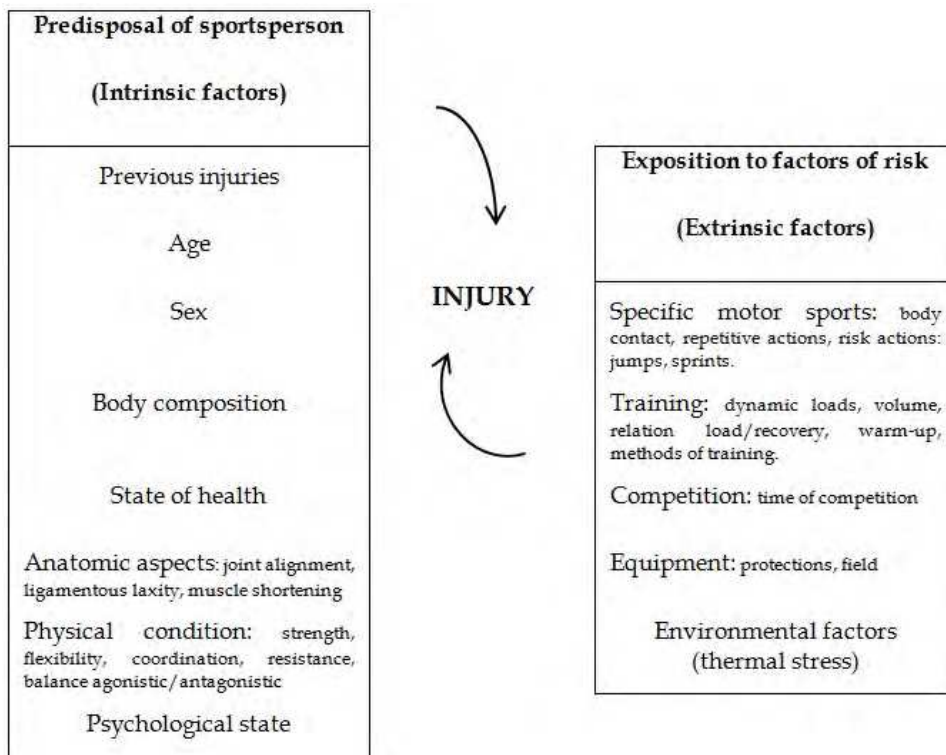


Fig. 3. Factors related to the occurrence of sports injuries (adapted from Bahr & Krosshaug, 2005; Meeuwisse, 1994; Parkkari et al, 2001; San Román, 2005).

### 2.2.2 Secondary Level

The Secondary Level of prevention constitutes an early level of detection in which intervention takes place in the stages immediately previous to injury or when it has already happened. At this level, one must be in contact with the sportsperson in risk of injury with the objective of diagnosing and detecting the injury once it has occurred by means of the appearance of signs and symptoms. Through the analysis and the discovery of the different risk indicators, there is the possibility of intervening by organizing programmes of intervention at an individual or group level (Muir & Fowler, 1990).

The tendency nowadays entails identifying risk values by means of an exhaustive process of evaluating and monitoring of the sportsperson. Clinical, physical and motor tests will be used to obtain risk indicators, as well as registering and analysing the clinical history of said sportsperson and his/her injuries in previous seasons. Age, competition experience, fatigue and overtraining will be taken into account with regard to exposal to training and competition, as well as psychological factors, reducing or controlling those situations which are potentially stressing for the sportsperson.

### 2.2.3 Tertiary Level

The Tertiary Level of prevention is the prediction and treatment of possible complications during the post-injure phase. This constitutes an individual level of prevention that involves reducing the grade of injury incidence by eliminating all those contents and work means that could worsen the injury or its consequences and executing programmes directed towards developing the elements of protection from a specific injury.

The elements of intervention at this level should be directed towards regulating and reducing mechanical, muscular, articular, ligament or tendon imbalance that a sportsperson may be exposed to after a specific injury.

## 3. Review of the basics of preventive measures through physical activity

### 3.1 Warm up

The efficiency of warm up in the training-competition process is explained by the change of the viscoelastic properties of tissues with increasing temperature or the improvement of metabolic conditions. Content such as joint mobility, jogging, stretching, and proprioceptive technical training (Figure 4) prior to the main activity provide an important preventive security (Fradkin et al., 2006).



Fig. 4. Examples of exercises with preventive content in warm-up.

Different studies have found a relation between the absence or deficient execution of warm-up and posterior injury in specific actions of the sport (Agre & Baxter, 1987; Ekstrand, 1983; Hopper, 1986; Seward & Patrick, 1992) and, in contrast, proposed tactics that introduce preventive contents, which include the previously mentioned elements, manage a decrease of the number of injuries (Dvorak & Junge, 2000; Ekstrand, 1983; Hewett et al., 1999; Olsen et al., 2005; Wedderkopp et al., 1999).

### 3.2 Strength

Strength plays an important role in the stabilisation of different bodily structures through the normal functioning of passive stabilizers (articular: ligamental structures and meniscus) and active stabilizers (muscles), as well as the interaction between both (Gleeson et al., 1998). The bibliography argues the protective factor that muscle can provide by contributing active stability to the different articular structures, as well as the correct balance between the different muscular groups, developing a fixative and balancing function which allows the individual to develop specific actions with the greatest safety possible, without risk of injury. The main goal of working strength as a means of prevention is to ensure the correct balance between the different bodily structures, thus permitting the safe development of the different actions specific to each sport (Árnason, 2008; Askling et al., 2003; Brooks et al., 2006; Croisier et al., 2005, 2008; Domínguez & Casáis, 2005; Hölmich et al., 2010; Mjølshnes et al., 2004; Parkkari et al., 2001; Thacker et al., 2003, 2004; Tyler et al., 2002).

#### 3.2.1 The right artromuscular balance as preventive tool

The practice of sports implies the practice of certain structures in a repetitive manner, which generates a muscular imbalance between antagonistic/agonistic groups. Maintaining a correct artromuscular balance, permitting a lessening of the effects of muscle shortening and weakening, and maintaining the integrity of articulations would be the main preventive objective of strength work.

With this goal in mind, there are different evaluation measures, such as isokinetic appreciation, that can determinate the grade of functional balance between agonistic and antagonistic muscle (Table 1 and 2). The main investigations about this topic establish a ratio that connects both values, fundamentally in the thigh muscle (hamstrings/quadriceps) whose incidence is related to muscle injure and a protective function of the knee articulation (Aagard et al., 1995, 1996; Askling et al., 2003; Croisier et al., 2005, 2008).

Main investigations place adequate ratio values at the following reference values:

Kannus et al. (1988)	0.31 – 0.80 (recommended > 0.50)
Orchard et al. (1997)	< 0.61 larger injury risk
Clanton & Coupe (1998)	0.50-0.60
Brockett et al. (2004)	0.55
Benell et al. (1998)	0.59 – 0.69
Newton et al. (2006)	0.72 – 0.77
Holcomb et al. (2007)	0.78 (PD) – 0.92 (PND)
Lehance et al. (2008)	0.60

Table 1. Reference values of conventional ratio:  $H\text{ CONC}/Q\text{ CONC} < 60^\circ/s^{-1}$  and  $H\text{ EXC}/Q\text{ CONC} > 60^\circ/s^{-1} - 240^\circ/s^{-1}$  (Naclerio, 2007).

The value of functional ratio that discriminates the probability of injury is between 0.60 and 0.70 (Aagaard et al., 1995; Croisier et al., 2005). This same value is the one shown for an imbalance bearing a muscular recurrence.

Agaard et al. (1998)	1 - 1.4 (240°/ s <sup>-1</sup> )
Tourney-Chollet et al. (2003)	0.8 (60°/s <sup>-1</sup> ) - 0.88 (240°/ s <sup>-1</sup> )
Holcomb et al. (2007)	0.94 (PD) - 1.11 (PND) (120°/ s <sup>-1</sup> )
Lehance et al. (2008)	>1.4 (240°/ s <sup>-1</sup> )

Table 2. Functional ratio values: H EXC/Q CONC >60°/s<sup>-1</sup> - 240°/ s<sup>-1</sup> (Naclerio, 2007).

Besides, recent investigations (Árnason et al., 2004; Hewett et al., 1999; Impellizeri et al., 2007; Newton et al., 2006) highlight the relationship between the balance of strength values between a dominant and non-dominant leg. It is established that a good balance should not exceed 10% between them, and in case of exceeding this percentage, the probability of injury would increase, and risk limit of bilateral asymmetry in the strength is at 15%.

In other muscle groups also involved in many sports, the normal ratios between agonist and antagonist muscles are in: adduction/abduction of hip, with hand-held dynamometer, between 0.96 and 1.4 depending on the rating, side lying position and supine position respectively (Hollman, 2006; Thorborg et al., 2010); and, concentric isokinetic 60°/s<sup>-1</sup> and 120°/s<sup>-1</sup> are between 0.68 and 0.76, also depending on the position in which the test is performed (Alexander, 1990; Pontaga, 2004). Concerning the shoulder joint, the ratios measured with isokinetic vary depending on the sport practiced so for the rotation ratio internal / external rotation, 60°/s<sup>-1</sup> and 120°/s<sup>-1</sup>, between 1 and 1.3, but can reach a value of 2 for specialists sports pitches, both team sports and individual sports; and, for adduction/abduction and extension/flexion, normal values are 30% higher than for adduction to abduction, and 50% higher for extensors than for flexors (Codine et al., 2005).

Functional jump tests are also used to determine possible asymmetries associated to bilateral strength deficits. The majority of them are taken from evaluations of the functional state of the lower extremity after anterior cruciate ligament (ACL) injury, and many studies show their usefulness. Although jump distance tests do not contribute with the sophisticated analysis of the working of the lower extremity that can be obtained from studies of running and strength platforms, jump tests seem useful as an evaluation of early detection that does not require a specialised equipment, it can be done in a short time and uses opposite extremity as control. The highly specific nature and low number of false positives makes these tests useful in confirming asymmetries of lower extremities. By associating them with other clinical evaluating tools, they confirm the magnitude of functional limitations (Noyes, 1991).

It seems that both the progressive test (Shuttle Run) and the vertical jump have a low sensibility to detect functional limitations of the lower extremity (Noyes, 1991). Cates & Cavanaugh (2009), in their revision of lower extremities evaluation during rehabilitation, introduce different types of horizontal jumps (Figure 5) that imply a large coordinative component as a measure of evaluating dysmetrias, comparing the values established between one leg and the other, determining a symmetry index obtained after dividing the result of one extremity by the other and multiplying by 100.

One of the latest technologies applied to the analysis of muscle properties of the superficial muscles of each individual is Tensyomiography (TMG), which is a diagnostic method that observes the time parameters and the maximum displacement of muscles during contraction.



Its analysis could direct the strength work to be done on bodily structures (Dahmane et al., 2005). The evaluation permits a muscular symmetry or asymmetry to be established, Tc Time (the time that a muscle takes to contract) and Dm (muscular tone or volume), that adopts as lateral and functional symmetry between two muscles or muscle groups above 85%, although in certain muscle groups it can tolerate up to 30% Dm and 15-20% Tc (Table 3).

The implementation of preventive programs directed both at reinforcing artromuscular structures as well as the tendinous have proved themselves as extremely efficient (Árnason et al., 2008; Askling et al., 2003; Croisier et al., 2005; Mjøl̄snes et al., 2004; Öhberg et al., 2004; Young et al., 2005).

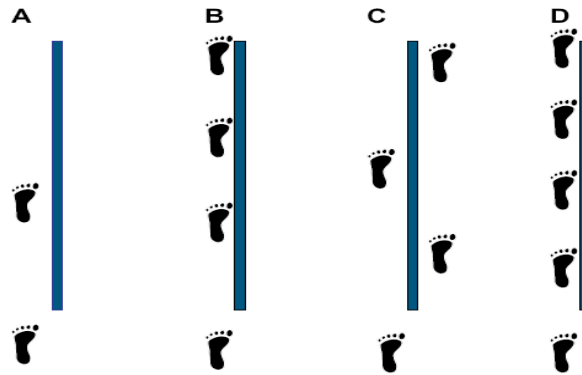


Fig. 5. Example of functional tests of one foot jumps in order to evaluate asymmetric functions; A: Single-leg hop for distance, B: Triple hop for distance, C: Crossover triple hop for distance, D: One-legged timed hop (Cates & Canavaugh, 2009).

VL (Vastus Lateralis)	Dm: 3 - 8 mm Tc: 17ms - 24ms
VM (Vastus Medialis)	Dm: 5-10mm Tc: 22ms - 28ms
RF (Rectus Femoris)	Dm: 3-10mm Tc: 22-30ms
BF (Biceps Femoris)	Dm: 2 - 6 mm Tc: 17-30 ms

Table 3. Range of Tc and Dm in TMG in the main high thigh muscle groups.

### 3.2.2 Eccentric work as preventive measure

In the last few years, numerous publications that establish the benefits of eccentric strength work with a double objective have appeared: improving the muscular strength values developed by the individual, and exerting a protective function for the prevention of sports injuries (Askling et al., 2003; Brockett et al., 2001). The positive effects of eccentric work on sports injuries are: the increase of the capacity to absorb muscle tension, a higher hypertrophic level, a protective effect upon the tension-length parameters and the increase of sarcomeres in series (Brockett et al., 2001; Hortobagyi et al., 2001; Proske, 2001).



Taking into account that a great number of muscular injuries take place after eccentric contractions have been done (Thacker et al., 2003), it seems advisable to adapt muscle and tendinous structures to these requests that are produced during the specific actions of each sport, in order to avoid or minimize their seriousness. With the publications of Fyfe & Stanish (1992), the histological modification was established by observing the implications of eccentric training in the rehabilitation of tendinopathy. Later publications (Hortobagyi et al., 2001; LaStayo et al., 2003), confirm that the main effects of eccentric work on tissues allow an increase in elasticity, bringing about an increase in strength and in resistance of the tendon-muscle complex, as well as re-educated the proprioceptive sensibility.

In the last decade, studies by Alfredson et al. (1998) and by Young et al. (2005) have reaffirmed the proposals of Fyfe & Stanish (1992). They have suggested slight modifications, with more aggressive training, going from 10 to 15 repetitions, working on slow speeds, doing the program twice a day for at least 12 consecutive weeks, through "painful exercises".

One of the main biomechanical characteristics of eccentric muscle work is that muscular stretching is obtained whilst producing tension, which implies the stretching of the tendon – muscle, while increasing the levels of muscle strength and improving functional muscle properties at high speed movements. This basis is used in diverse published studies about the prevention of muscle injury in sportspeople, above all, directed at the hamstrings (Árnason et al., 2007; Askling et al., 2003; Croisier et al., 2005; Mjøl̄snes et al., 2004).

### **3.2.3 Scientific evidence of the work strength as preventive work**

It is necessary to approach this section distinguishing those experiences centred on the protection of tendon structures and those directed towards muscle function.

At a tendon level, the main references to apply preventive work in sport to tendinopathy Achilles and patellar are by Mafi et al. (2001), Silbernagel et al. (2001) and by Young et al., 2005, with adaptations, following the steps indicated by Fyfe & Stanish (1992). The obtained results indicate that eccentric work improved the state of the tendon significantly in comparison to concentric work, especially if the eccentric work is done on inclined plane with 25° degrees overload.

The main studies that deal with eccentric work applied to muscular structures are centred mainly on the hamstrings (Árnason et al., 2008; Askling et al., 2003; Brooks et al., 2006; Dadebo et al., 2004; Mjøl̄snes et al., 2004), combining the flexibility exercises with FNP modalities and even using isoinertial devices, Yo-yo Technology (Figure 6).

## **3.3 Flexibility**

The lack of muscle extensibility or the high tone of the antagonist muscle, are factors that enhance sports injuries, especially muscle injury.

### **3.3.1 Improved flexibility as preventive tool**

Muscular injury where no external agent is involved generally occurs during the eccentric phase of muscle contraction. In this case, the muscle develops tension whilst increasing in length. Weakness and fatigue make muscle structures more susceptible to injury (Garret, 1996) when at a specific moment they are incapable of absorbing the generated tension.

When overstretching occurs in a muscle during a quick motor action, its ideal stretching tolerance may be surpassed, jeopardizing its integrity and allowing a possible injury (Askling et al., 2000, 2006). An imbalance in the level of flexibility in a muscular group, or in

the adequate range of movement for the normal actions in the sport, could predispose to injury (Knapik et al., 1991).

Achieving a correct balance of artromuscular and the structures that make up the locomotor system, as well as achieving an adequately wide level of movements will allow a more fluid movement and coordination in the execution of technical actions and displacements.

### 3.3.2 Scientific evidence of the use of flexibility

The use of flexibility as a prevention method has been a topic of much controversy in the last few years. There are two fundamental strategies that the studies follow to be able to determine the influence of flexibility levels on injuries and, on the other hand, whether improving flexibility could act as an element protective of and preventive from injuries (Thacker et al., 1999, 2003; Petersen & Hölmich, 2005).



Fig. 6. Examples of eccentric work exercises.

Diverse authors have found a predisposition to injury in sportspeople with low flexibility levels. Low flexibility levels put hamstrings and quadriceps muscles at risk; therefore, it would be interesting to find this type of deficiency to establish adequate prevention programmes (Ekstrand & Gillquist, 1983; Liemohn, 1978; Witvrouw et al., 2000; Worrell, 1991). The use of standard stretching programs, the stretching technique used, and the stretching maintenance time are probably involved in a complex synergism that can reduce muscle injury, modifying the patterns of modern training in professional sportspeople (Dadebo et al., 2004). In opposition to these authors, Orchard et al. (1997) and Hannesey & Watson (1993) found no correlation between flexibility levels and muscle injury.

Training and better flexibility are programmed to preserve sportspeople from possible muscular injuries through a stretching superior to the usual range required in the sport. It seems appropriate to achieve a good residual level of flexibility, to have a range of articulate and muscular reserve, in case an unexpected or unusual gesture is superior to the flexibility

or mobility of work. As an important part of muscular injuries in physical sport activities is found in the myotendinous junction, it would be advisable to improve the mechanical properties of this area. Kubo et al. (2001) has shown how repeated training of flexibility can alter the viscoelastic properties of the myotendinous junction, increasing its capacity to absorb to traction force especially in eccentric actions, a typical mechanism, in muscular injury (Witvrouw et al., 2004). In this sense, the stretching work with an eccentric dynamic phase or stretching in active tension or some modalities of FNP would be an interesting stimulus to allow the contractile component to better absorb these types of contractions so common in sports activities.

Witvrouw et al. (2007) and Mahieu et al. (2007) argue that the use of repeated dynamic stretching can improve the properties of the tendon just as eccentric training can, being an important weapon in the prevention of tendon injuries.

Stretching as part of a warm-up is one of the most extended practises in training, and permits the achievement of a series of adaptations that help in the performance and minimise the risk of injury, which is why they are a clear recommendation of the most prestigious associations of exercise prescription (Franklin et al., 2000; Holcomb, 2000). In the same way, it has been confirmed that stretching as part of warm-up content can prevent possible muscular injuries due to overstretching (Shellock & Prentice, 1985). Although there are contradicting opinions, perhaps due to the type of stretching techniques used (static stretching, FNP, rebounds) or to doing the same in different conditions (with or without previous increase of muscle temperature) (Shrier, 2002).

Nowadays, many studies are being published that fuel this important controversy about the type of stretching that should be done in warm-up of sports such as football, with explosive and velocity predominance (Cramer et al., 2004; Fletcher & Jones, 2004; Cometti, 2007). It is being pointed out that passive or static stretching have a contra productive effect, whilst the dynamic one would generate it in a positive way.

The majority of the existing investigation about static stretching focused on its application previous to exercise, reporting negative effects on explosive force when done 60 minutes before training or competition (Shrier, 2004), as well as an increase in time in a 20 meter sprint both in track runners and cross country runners who compete in power events (Nelson et al., 2005), making them inadequate for activities where the production of elastic-explosion and reactive power are decisive, as in the case of football, resulting inappropriate in their short-term effect (Barnett, 2006).

Static stretching reduces power peak, inhibiting the explosive properties of muscle, reducing reaction times and movement, and in some cases jumping capacity (Fowles et al., 2000; Cornwel et al., 2001; Young & Elliot, 2002; Behm et al., 2004; Cramer et al., 2004; Power et al., 2004; Mahieu et al., 2007). Therefore, it is not advisable as previous activity when preceding physical sporting activities dependant on rapid muscle tension or on explosive-elastic or reactive regime (Young & Behm, 2001; Cornwell et al., 2002; Cramer et al., 2004; Fletcher & Jones, 2004; Wittmann et al., 2005; Little & Williams, 2006; Cometti, 2007; Yamaguchi et al., 2007). In these cases, the practice of dynamic or ballistic stretching beforehand improves muscular provision, providing an increase in race speed, or agility actions.

### 3.4 Proprioception

A normal joint is dependent on the proper functioning of the neuromuscular control to avoid injury, as this allows dynamic control of the loads applied to it. Several authors have

highlighted the role of proprioception in the prevention and treatment of sports injuries. Work towards a better neuromotor control of movement has been shown to be effective, specially, in view of an articular injure, and there are very interesting proposals in this regard.

#### **3.4.1 Fundamentals of proprioception as method of preventive work**

Sherrington (1906, as quoted in Hewett et al., 2002) defined this concept as the culmination of the neural inputs originated in the different proprioceptors of the human body. However, this term has evolved, and as years have gone by the interaction between the sensorial, to which more importance was given before, and the motor, which is the formation of this somatosensorial system, has been included and studied and is a central theme of this section.

Actually, the present definitions of proprioception do not only include sensorial information but also position conscience and articular movements, speed and the detection of movement strength (Saavedra et al, 2003). We are therefore speaking of a source of sensorial information that anticipates information for intervening in the neuromuscular control with the objective of improving the functional articular stability (Lephart et al., 2003).

Proprioception consists of a ringlet from the stimulation of the sensorial receptors (cutaneous, articular, muscular) that are found in the visual, vestibular, and auditory systems that translates the mechanic event into a neurological signal (Saavedra et al., 2003) that goes through the spinothalamic tract.

The concept of proprioceptive training based on what has been explained, was initially introduced in the area of rehabilitation, with the objective of restoring the “neurological alteration” produced in the receptors when injury occurs (Freeman, 1965, as cited in Ergen & Ulkar, 2008), as it causes a destruction of proprioceptive of the injured tissue, these are not completely recovered (Griffin, 2003).

An injury produces a proprioceptive alteration, which reduces the neuromuscular control of this structure and those adjacent to it, which in turn causes general functional instability. The proprioceptive work in the field of rehabilitation restores the deficit caused by the injury incidence to values that do not generate functional instability. After recovering from it, the prevention work improves stability and neuromotor control and avoids a possible posterior relapse.

Parallel to previous investigations and in the last few decades, the advances in proprioceptive work in the prevention of injury were also aimed at achieving quicker reaction of the fixative musculature of the articulations after an imbalance. Because of this “anticipation” of the movements, a sportsperson can improve his/her performance by putting into action faster than their physical capabilities, such as strength.

The bibliography explains this phenomenon as anticipatory postural adjustments programmed beforehand without following the usual response steps, which predict possible disorders that can occur during the execution of said movement, acting as a “trigger” of the preparatory adjustments before even doing the movement, avoiding a loss of balance (De Guez, 1991, as cited in Del Abril, 2001). The proprioceptive work, as a learning process requiring repetitive practice and systematic movements, is capable of anticipating voluntary movement and do the bodily adjustments, which requires a previous muscular activation so as not to lose balance.

### 3.4.2 Scientific evidence as a preventive proprioceptive work

Over the last three decades this form of work has been introduced in the field of injury prevention, being one of the first studies published by Tropp et al. (1985). From the moment when this study was published and the following two decades, more studies were done showing that the most effective prevention of injury was by means of a prevention plan that had as principal content proprioceptive and neuromuscular training. Diverse studies have shown that there is a reduction of injury incidence when exercises on a stable and unstable plan are done, increasing the difficulty in balance within stability as a methodological progression, causing bipodal and unipodal support combining these with jumps (Bahr et al., 1997; Caraffa et al., 1996; Eils et al., 2001; Hewett et al., 2006; Knobloch et al., 2005; McGuine et al., 2006; Mohammadi et al., 2007; Myklebust et al., 1998; Paterno et al., 2004; Wedderkopp et al., 1999). In the same way, there are also some studies that find no significant differences in their results (Söderman et al., 2000; Petersen & Hölmich, 2005; Verhagen et al., 2004).

The publications related to proprioceptive training aimed at injury prevention that have obtained results present two different work angles (Figure 7):

1. Authors who emphasize “static” proprioceptive work (balance and rebalancing), mainly on unstable plan in bipodal and monopodal support, which at times is combined with technical elements (Tropp et al., 1985; Bahr et al., 1997; Caraffa et al., 1996; Eils et al., 2001; Knobloch et al., 2005; McGuine et al., 2006, Mohammadi et al., 2007; Vergahen et al., 2004; Wedderkopp et al., 1999).
2. Authors who emphasize dynamic proprioceptive work (neuromotor control) through specific actions which require a great control of the different bodily structures, like jumps and receptions, on bipodal and monopodal support, and on the stable and unstable plan (Heidt et al., 2000; Hewett et al., 1999, 2002, 2006; Myklebust et al., 1998; Paterno et al., 2004; Petersen & Hölmich, 2005; Zebis et al., 2008).

Proprioceptive work has shown itself useful for the decrease of injuries in sport, especially in the case of those of articular character in knees and ankles, particularly ACL (Caraffa et al., 1996; Hewett et al., 1999; Knobloch et al., 2005; McGuine et al., 2006; Mohammadi et al., 2007; Myklebust et al., 1998; Paterno et al., 2004; Wedderkopp et al., 1999); the common aspects of training load in the studies show (Table 4) that the positive results are:

Hewett et al. (1999, 2002, 2006) also suggest that for knee injury prevention, concretely ACL, proprioceptive work based on “static balance” was not effective, and that it needed to be combined with other techniques to obtain significant results in lessening ACL injuries (combining sports technique exercises, dynamic proprioception and/or plyometric, postural control and/or “core”).

Surface	Stable and instable
Type of support	Monopodal and bipodal
Neuromuscular implication	Jumps and receptions
Number of weekly sessions	Season: 1-3 trainings/Preparatory period: 3-5 trainings
Session time	Between 15 - 20 minutes
Number of exercises	Between 2 and 12 exercises
Work time for each exercise	Between 15 and 45 seconds
Sensorial information	Without sensorial privation (SP) (eyes open)/with SP (eyes shut)

Table 4. Common elements of training load in proprioceptive work.

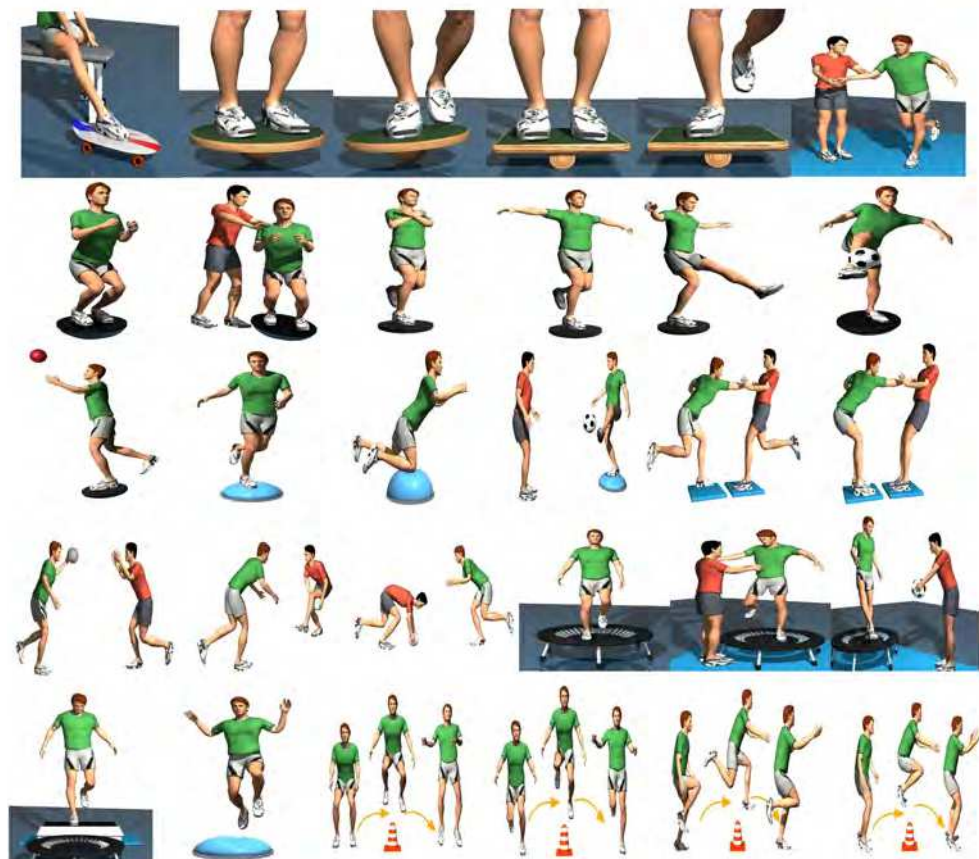


Fig. 7. Examples of proprioceptive exercises on different surfaces.

#### 4. General protocols for injury prevention in sports, intervention strategies: Group vs. individual

The measures successfully introduced in sports to prevent injuries and mentioned previously, allow adequate preventive programs to be designed for each context. This design and its application demand a profound prior reflexion regarding the specific needs of the sportsman/woman with whom the program is to be developed and the best way of tackling the problem.

When introducing a preventive program, one can organise the session or apply the contents of the preventive program in two ways: the first one more generally directed towards dealing with problems generated in each sport, data that will be extracted from the injury profile of the activity and the team sports, being able to organise these programs as parts of

the session (warm-up, main part and return to calm) in a group manner. The other direction is more specific and for its organization the individual needs of the sportsperson will be required. It can be done before training with individualised sessions, or reduced group sessions, so as to better attend to their needs.

#### **4.1 Implementation of team sports prevention programs**

Currently there are numerous published proposals that seek to encompass different prevention protocols in general, studying their effects in complex ways. The main general preventive published proposals based them on “multistation” work, putting together exercises that present scientific evidence directed towards the protection of muscular-tendon structures and the articular of the lower body.

One the most extended preventive programs in sport, directed towards ACL prevention is the Prevent Injury and Enhance Performance Program (PEP Program), designed by the Santa Monica Sports Medicine Foundation (SMSMF), and which i will be summarised below.

In terms of popularity, another programme by the Fédération Internationale de Football Association (FIFA) is the F-MARC or “The 11”, referring to the number of exercises designed in the program directed to reducing injuries in the lower body in football. One of the last programmes to appear, develop and be promoted by the Mayor Soccer League (MLS) and the SMSMF, the MLS Groin Injury Prevention Protocol, is directed at preventing injuries in the groin, through a protocol.

The programs directed towards general preventive aspects in sport, which try to influence the imbalances particular to the specialty, can be developed in training directed in a group or individual manner and can be developed in parts of the session or in complete sessions with the objective of prevention. The work could be organized in form of a circuit, with different work stations or organising the group in such a way as to have everyone doing the same task at the same time, during a warm-up session, for example.

Such programmes have been developed in elite sportspeople of different team sports such as football, handball and volleyball (Söderman et al., 2000; Myklebust, 2007; Olsen et al., 2005; Steffen et al., 2008). Besides, in schools there are models such as the iPlay Study, where they develop a school-based physical activity injury prevention programme (Collard et al., 2009; Emery et al., 2006).

#### **4.2 Implementation of individual prevention programs**

Individual prevention programs are those directed towards particular preventive aspects taking into account the characteristics of each individual, their injury history, previous evaluation and reports about sports life. They are developed in an individual manner, although it allows a greater grade of control by club technicians, a great implication of the player is necessary so that the proposed session has the necessary quality and brings about the desired effects.

The work contents must be individual and adjusted to the individual’s injury history, with contents including one or various of the following aspects: rebalance of the strength values in the concentric and/or eccentric work, strengthening of the “core”, adjustment of the levels of work flexibility to the specific sport, improving the postural stability through the neuromuscular control and proprioceptive work.



## 5. Conclusion

The measures indicated have been contrasted in terms of efficiency in different studies. Currently, there are numerous published proposals which aim to encompass them in different ways in protocols of general prevention, studying their effects in a complex way. In conclusion, it can be stated that the preventive measures that have greater scientific evidence are the use of functional bandaging, flexibility and strength training (with special attention paid to eccentric work), and proprioceptive work.

However, the programmes should be evaluated by more rigorous designs, not only with randomised experimental designs control group, but also quasi-experimental designs to use more representative samples (professional athletes) and more realistic practice contents (competition-training process), and intervention programs with really powerful measures. In this way, they must be valued with the rigour required of different preventive measures, thus usually refuting works quoted and taken as reference samples using insignificant and limited prevention protocols.

The next challenges in injury prevention should be to use the opportunities we have to implement methods of preventive work in a real context through programmes that take into account the evaluation of its effectiveness, in order to offer the sportsperson an anticipatory care, considering that the gain in injury prevention is given by the interaction of different changes in behavior and beliefs in all levels of sport. The future of intervention strategies in the prevention of injury from physical activity overcomes barriers to implementation and at each level should be designed in a different programme, adapted to each context.

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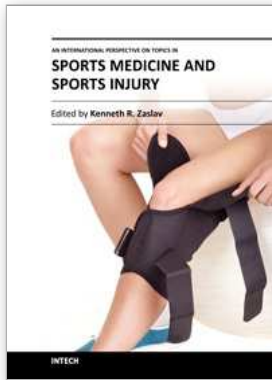
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For the past two decades, Sports Medicine has been a burgeoning science in the USA and Western Europe. Great strides have been made in understanding the basic physiology of exercise, energy consumption and the mechanisms of sports injury. Additionally, through advances in minimally invasive surgical treatment and physical rehabilitation, athletes have been returning to sports quicker and at higher levels after injury. This book contains new information from basic scientists on the physiology of exercise and sports performance, updates on medical diseases treated in athletes and excellent summaries of treatment options for common sports-related injuries to the skeletal system.

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