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Prevention of Muscle Injuries – The Soccer Model

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1. Introduction

Muscle injuries are frequent in sports, and represent about 30% of all time-loss injuries in men's professional football (soccer) [1-8] and almost 20% in men's amateur level [9].

Four muscle groups of the lower limbs account for 92% of muscle injuries (hamstrings 37%, adductors 23%, quadriceps 19%, and calf 13%) [1].

In sports such as soccer, but also in athletics, basketball, volleyball etc, muscle indirect injuries and overuse injuries are more common (about 96% in soccer [1]) than direct injuries (contusions). Contact situations are more frequently involved in muscle injuries in other sports like rugby, American football, ice hockey [10,11]. In elite soccer 16% of muscle injuries are re-injuries and cause 30% longer absence from competitions than first injury [1].

Muscle injuries result from a complex interaction of multiple risk factors and events.

Several parameters are usually identified as risk factors. These are usually classified as either intrinsic, athlete-related, or extrinsic, environmental risk factors.

Gender [1,12], age [2,13-21,45], skill level [12,23,24], body size and composition [14,25,26], previous injury history [2,3,8,13,15,16,19,21,27,28,43-45], anatomy or biomechanics abnormality [19], joints ROM and flexibility [29,30], muscle strength, imbalance and tightness [2,21,22,29], limb dominance [14], training errors such as poor technique, or errors in training program, warm-up or cooling down [33-35], aerobic fitness [25], fatigue [16,26,32,45], are included among intrinsic risk factors. Footwear, climatic conditions and turf type [36-42] are examples of extrinsic risk factors. Some of these risk factors can be modified.

Muscle injury prevention is advocated both by athletes and coaches. Yet, most of techniques for muscle injury prevention used by athletes or taught by coaches are entirely based on their own experience, but without supporting scientific evidence.

The aim of this chapter is to present current concepts about the prevention of the muscular injuries and to test which strategies are best supported by scientific evidence, both with respect to primary prevention (prevention of the first injury) and secondary prevention (re-injury prevention).

In this chapter are also proposed some practical suggestions, dedicated to the members of soccer's team, that are involved in the management of muscle injuries risk factors (coaches, fitness trainers, physiotherapists, team doctors).

When muscle injuries occur, the safe return to competition is often difficult, both in order to get prior level of performance and to avoid re-injury.

The anatomical healing of a muscle injury is a primary condition for safe return to sport, but it is not enough to manage re-injury risk. Thus, anatomical healing is not synonymous of "athletic healing".

A database of aerobic fitness, muscle strength, and other performance related parameters, is also proposed in this paper, to get a reference for the muscle injury rehabilitation program and the full return to competition.

These parameters have to be registered by laboratory and field tests, performed by the healthy athlete, during pre-season and competition period and then, in case of muscle injury, these have to be used as a reference, to programme his return to prior level of competition.

In relation to the authors' personal experience, this chapter will be set on the prevention of muscles injuries in a male professional soccer team: the suggestions and observations here described are, however, applicable to lower levels soccer teams and most others sports.

2. Analysis of risk factors for muscle injuries

2.1. Intrinsic risk factors

- Gender

There is not sound evidence on the impact of gender on muscle injury risk in soccer, mainly because women's soccer has become very popular in the last years and most scientific studies have been carried out using as reference point the data of male players (Figure 1).

In a review [12] seven studies showed that female athletes had a higher incidence of injury, two reported that male athletes showed a higher incidence of injury, five studies found no association between sex and injury, and one found that the rate of ankle and knee specific injuries differed with gender. There is no evidence of difference in the incidence of muscle injuries between males and females. It is also well documented that female athletes have more knee injuries than male athletes, specifically ACL sprains. Within intercollegiate sports, female soccer players were 9 times more likely to sustain an ACL tear than male soccer players [1].

In conclusion, although it is clear that female athletes are at increased risk of suffering ACL injuries, the relation between gender and other types of lower extremity injury is unclear.



Figure 1. Female soccer is today very popular.

- **Age**

Age is a widely studied risk factor for muscle injuries, particularly in recent years, with the increase in the average age of players, especially at the amateur level (Figure 2). In available literature, there are conflicting data about age as a predisposing factor to muscle injuries. Some studies have identified increasing age as an independent risk factor for muscle injuries in Australian footballers [14-16] and soccer players [2,45]. These authors found increased risk in Australian footballers and soccer players older than 23 years [14,45]. Furthermore each year of age has been reported to increase the risk of muscle injuries by as much as 1.3 times in Australian footballers [15] and by 1.8 times in soccer players [17]. In a study on 123 female soccer players (age range 14–39 years), the authors found a significantly increased risk of overall injury in athletes older than 25 years compared with younger athletes [18]. In a study on professional soccer players the incidence of global muscle injuries increases with age, but an increased incidence with age has been found for calf muscle injuries only, and not for hamstring, quadriceps or hip/groin injuries [19]. During training sessions, players in the oldest age group (over 30 years) had a significantly higher incidence than young (below 22 years) players, while there were no differences compared to the intermediate (22–30 years) age group. During matches, young players had a lower incidence than the intermediate and older age groups [19]. All studies that report age as significant risk factor conclude that age increases hamstring injury risk independently of other variables such as previous injury.

The explanation for increased muscle injury risk, with age is quite controversial. Some authors maintain that it is due to an increase of weight and a reduction of the flexibility of the hip flexors in athletes 25 years or older [20]; others indicate the cause in the reduction of lean body mass and strength [21].

Other hypotheses are age-related changes in muscle structure [13] and entrapment of L5/S1 nerve root due to hypertrophy of the lumbo-sacral ligament [22].

However, there are also some studies that found no correlation between aging and increase of muscle injuries [12,22,23].



Figure 2. Soccer: a passion all over the world, for babies and old players.

In consideration of data available in literature further studies of longer duration are required to determine the effective importance of aging on muscle injuries.

- Skill level

Several study analysed the relation between skill level and injury and results in this respect appear contradictory (Figure 3). A study found that young soccer players with low skill level had a twofold increased incidence of all injuries, compared to a group with more skilled athletes. More than 79% of all injuries were in the lower extremity [24].

Similarly another study on soccer players, found a twofold increased incidence of all severe injuries in lower skill level players [23].

However, some data are difficult to interpret: in a review [12], it is evident that two studies have shown that low skill level groups have an increased risk of muscle injury while two report that athletes in high skill level groups are at increased risk.

This discrepancy is due to the difficulty to compare different sports without unique criteria for assessing the skill level.

Also, less skilled athletes may not compete as long as those in higher skill level groups. So they may have the same number of injuries, but show higher incidence rate based on less exposure. Finally, higher skill level groups may play at a higher level of intensity and aggressiveness than lower skill level, thereby increasing the risk of injury.

- Body size

Body size has been analysed in risk factor studies in different ways, including height, weight, lean muscle mass, body fat content, body mass index (BMI). These variables have been considered as risk factors for injury because an increase in any one of the indicators above produces a proportional increase in the forces that stress articular, ligamentous and muscular structures; however, the relation between body size and injury is unclear (Figure 4).

A recent study [25] reported an increased incidence of injury among boys taller than 165 cm in a prospective study of youth soccer players, but body size was not a risk factor for girls. Another author [14] reported an increased incidence of quadriceps injury among Australian football players of height less than 182 cm compared with taller athletes; however, height was



Figure 3. Importance of skill level as muscle injury risk factor is quite controversial.

not associated with hamstring or calf muscle strains. The evidence for weight and body mass index (BMI) as risk for muscle injury is conflicting.

A review [26] shows that five study found no significant association between weight and hamstring injury and only two identified a significant relationship.



Figure 4. Body weight may be a functional stress.

- Previous injury

A detailed clinical history represents the starting point for setting up an adequate prevention program. Soccer team physicians have to investigate previous muscle injuries of each new player recruited during the pre-season training camp: all information available about all previous injuries (anatomic site, degree, time-loss, etc.) have to be registered (Figure 5). Several authors have shown that previous injuries represent a significant risk factor for new injuries, both in male soccer [2-44] and among male athletes in other sports [13,21]. A study [29] shows that the injury risk is doubled among previously injured players and although the results were not significant, the risk seems to increase gradually with the number of previous injuries and

decrease with time since the previous injury. A recent study [19] shows that players with a muscle injury in the previous season have increased injury rates of up to threefold compared with uninjured players. In addition to this, a re-injury tends to cause longer absence than the first injury [3,16]. Improvements in controlled rehabilitation with functional tests before returning to full training and matches might reduce the risk of re-injury [27].

The specific risk factors involved in the recurrence of muscle injury have not been clearly established, but these may be related to the same extrinsic and intrinsic factors that were involved with the original injury. In addition, factors related to modifications after the original muscle injury (tightness or weakness, scar tissue, biomechanical alterations, neuromuscular inhibition, etc), as well as questionable treatment options (incomplete or aggressive rehabilitation, underestimation of an extensive injury, etc), may further predispose an athlete to re-injury [8,28].



Figure 5. Detailed informations about all previous injuries have to be registered.

The presence of scar tissue can alter muscle transmission pathway, decrease tendon/aponeurosis complex compliance and lead to a modification of functional response in the muscle tissue around the fibrous scar.

Similarly, a study [15] found that a history of knee or groin injury increased the risk of hamstring muscle injuries, and the authors postulated that the biomechanical properties of the lower extremities may change, increasing the risk of further injury.

For this reason, athletes must be aware of the importance of adequate rehabilitation before returning to full competition.

The team medical staff, early in pre-season, must plan a working program to influence properly the functional response of the scars. This work, involving doctors, physiotherapists, fitness coach, field rehabilitator, is focused on the aim of improving the elasticity of scars and make them, as much as possible, functionally similar to the surrounding healthy muscle tissue.

- Anatomical alignment

The joint forces and the structures that must resist them (articular surfaces, menisci, ligaments, tendons and muscles) are related through anatomical alignment (Figure 6) of the joints and skeletal system. For this reason, alignment of the hip, knee, and ankle has been suspected to be a potential risk factor for lower extremity injuries.

Several studies reported no association between anatomical alignment and subsequent muscle injury. There are only a few studies that associate anatomical alignment with injuries to joints, ankles and knees [19].



Figure 6. Anatomical mal-alignment of knee.

- Flexibility

Muscle flexibility is the ability of a muscle to lengthen, allowing the joint (or more than one joint in a series) to move through a range of motions (Figure 7). Good muscle flexibility allows muscle tissue to tolerate stress more easily and allow efficient and effective movement.



Figure 7. Soccer players need a good muscle flexibility

It is proposed that greater flexibility may reduce the risk of strain injury, due to an improved ability of the passive components of the muscle-tendon unit to absorb energy as a result of a better compliance [29].

However, this point is disputed in the literature. A recent review [30] shows that seven prospective studies demonstrated no relationship between flexibility of knee flexor and hamstring injury, while three studies showed an association, in professional European soccer players, between flexibility values obtained in pre-season and injuries suffered during the season. This discrepancy of results is due mainly to the use of different tests to assess muscle flexibility, which are not always comparable. The flexibility is, however, a parameter that sports physician should carefully consider, especially for soccer players affected by hamstring injury.

In the next sections of this chapter the usefulness of stretching to improve flexibility and reduce muscle injury risk will be considered.

- Muscle strength, imbalance and tightness

Strength deficits or imbalances have been suggested to increase muscle injury risk, above all for hamstring [29].

The relationship between muscle injury and strength deficit (Figure 8) is controversial. More specifically, it is unclear when strength imbalances were only the consequence of the original injury or a risk factor for re-injury, or both. Strength deficits between the two limbs or between agonist and antagonist have been reported in sports with asymmetric kinetic pattern like soccer [2]. In soccer strength imbalance has been involved in injuries of the lower limbs [22], because the players usually use, when kicking, nearly always the same side of their lower limbs. This alters the strength balance between the two leg or between antagonist muscle groups.



Figure 8. Training of muscle strength

The development of muscle strength symmetry and balanced ratio in the function of knee flexors and extensors can reduce muscle injuries in soccer [32]. The players with untreated strength imbalances were found to be 4 to 5 times more likely to sustain a hamstring injury. Some authors have shown that in football players is important to compare the strength of the

flexor and extensor muscles of the thigh, of the two limbs, where differences over 15% can be predictive for flexor injuries [32]. A lower hamstring to quadriceps (H:Q) ratio suggests a relatively poor capacity for the hamstring to act as a “brake” at the flexing hip and extending knee joints during the terminal swing phase of running. An author [29] shows a significant association between pre-season hamstring muscle tightness and subsequent development of a hamstring muscle injury. The same relationship was also found for quadriceps muscle tightness and for the development of quadriceps muscle injuries. Another study [21] confirmed that a simple program of eccentric exercise could reduce the incidence of hamstring injuries in Australian football. For this reason it is essential to work to get a correct balance between the two leg and especially between hamstrings and quadriceps.

- Limb dominance

In some sports, the dominant leg may be at increased risk of injury because it is preferentially used for kicking (figure 9), pushing off, jumping. However, the association between limb dominance and injury is controversial. Several risk factor studies have reported that limb dominance has an effect on injury.



Figure 9. Soccer players have usually a dominant kicking leg

A study [14] reported that quadriceps strains were more commonly sustained by the dominant leg than the non-dominant side but there was no association between limb dominance and injury of the hamstrings or calf muscles.

Quadriceps and adductor injuries were more common in the kicking leg, most probably due to a greater volume of shooting and passing/crossing actions with the dominant leg. These cause a greater exposure to high-risk movements and can affect the correct balance of the whole kinetic chain. However, it has also been suggested that specific limb dominance in soccer players may result in lingering muscle imbalances that could lead to an increased predisposition for injury.

- Poor technique, errors in training program, warm up, cooling down

Every sport, at any level of practice, involves knowledge and mastery of technical movements, which are both sport- and role-specific. Soccer teams' technical and medical staff knows from experience that even top level players can make errors when performing specific technical movements. Poor technique, errors in training program, carelessness in warm up or cooling down modalities are suspected to be involved in the pathogenesis of muscle injuries. The importance of stretching exercises (Figure 10) and the modality of warm up and cooling down are also controversial. Stretching and warm up are commonly practiced before sport activity, but there are conflicting opinions regarding methods of reducing muscular injury through warm-up and stretching techniques [33-35]. The effects of following athletic performance and injury prevention are not fully understood. A recent review examined the available literature on the effects of stretching on sports injury and performance [34]. The conclusions of this study are, in opinion of this paper's authors, widely acceptable. It is well known that a single session of stretching impairs acutely muscle strength and power (even if on power the effect is lower). These effects are less evident when stretching is associated with other pre-participation activities performed in warm-up, such as practice drills and low intensity movements. With respect to the effect of pre-participation stretching on injury risk, the studies reviewed show that pre-participation stretching in addition to warm-up has no impact on injury risk during activities with preponderance of overuse injuries (such as military recruits or recreational runners). However, the stretching interventions applied in these studies may have been insufficient to induce an acute change in the viscoelastic properties of the muscles stretched. There is some evidence to indicate that pre-participation stretching does reduce the risk of muscle strains. However, further research is needed in this area.



Figure 10. Stretching exercise

The first step in assessing any potential effect of pre-participation stretching on muscle injury is to plan the optimal stretching prescription. The following stretching recommendations for injury prevention are suggested by authors [34]:

- target pre-participation stretching to muscle groups known to be at risk for a particular sport, e.g. hamstring strains in soccer;
- apply at least four to five 60-s stretches to pain tolerance to the target muscle groups and perform bilaterally, in order to be confident of decreasing passive resistance to stretch;
- in order to avoid any persistent stretch-induced stretch loss, perform some dynamic pre-participation drills before actual performance, e.g. sub-maximal ball kicking and dribbling drills in soccer.

- Aerobic fitness

Soccer teams physicians sometimes observe re-injuries when players come back to team training and competition, apparently full healed by muscle injuries. This situation sometimes occurs in athletes that have perfectly passed all clinical, imaging, functional assessment. It is likely that a poor level of aerobic fitness (Figure 11) in early period of return to competition may be involved in re-injury. So it seems reasonable that poor level of aerobic fitness could be a risk factor also for first injury, because athletes fatigued can change their muscle recruitment patterns and this event may impair the distribution of forces loading on the articular, ligamentous and muscular structure. At the beginning of the season and before the come-back after an injury, it is important to assess the level of physical condition. A study on severe injury in male soccer players [25] found poor physical condition to be a risk factor for all injuries.

For the same reason it is extremely important that our athlete achieves a good aerobic condition before starting technical and tactical work, sports- and role-specific.

Even after an injury that does not involve muscles, the achievement of a good aerobic fitness is strictly required in order to operate a safe return to competition.



Figure 11. Aerobic fitness care

- Fatigue

Closely linked to aerobic fitness, fatigue (Figure 12) and its associated performance failures are an important risk factor for injuries. Some studies have shown that a greater rate of muscle

injuries occur in the later stages of matches and training sessions [16,32,45]. Some studies have evaluated the effects of fatigue on muscles, especially on the hamstring. The data showed a decrease in hip and knee flexion during sprinting [26] and a significant reduction in combined hip flexion and knee extension angles, with reduced hamstring length and consequent increased risk of injury.



Figure 12. Fatigue is a not-negligible risk factor.

2.2. Extrinsic risk factors

- Shoe type

In available scientific literature, there are not studies based on relationship between soccer footwear and muscle injuries. The majority of the studies are performed on articular (ankle and knee) footwear related risk injury.

- Playing surface

Natural grass has always been the traditional surface for playing soccer, both for matches and training. Nevertheless, in countries with extremely cold or dry climate, it is difficult to develop a pitch of adequate quality accessible all year round. Furthermore, this would also involve high maintenance costs. The use of artificial surfaces has thus been introduced in order to solve these problems.

Since the appearance of artificial grass playing surfaces, athletes, coaches, fitness trainers, physiotherapists and doctors have suspected a relationship between this type of surface and injuries in soccer, rugby, American or Australian football.

Certainly there has been an evolution of the quality of surfaces over the years. Artificial turf first gained considerable attention in the 1960's, when it was used in the construction of Houston Astrodome stadium, in Houston, Texas (Figure 13).

The specific product used was called Astroturf. This surface was known for its abrasive properties, and the risk of carpet burn injuries was experienced by anyone who tried to make a slide tackle on this surface. In addition to this disadvantage, playing soccer on first- and

second-generation artificial turf had the problem of a distorted bounce and roll of the ball, which appeared to make control more difficult for the players and was suspected to lead to an increased risk of injury. Carpet burns were not the only injuries suspected to have a relation to early artificial surfaces, and some studies analyzed the risk of other injuries on these pitches [36-39].



Figure 13. Houston Astrodome Stadium, Houston, Texas.

Some of the studies observed an increased injury rate on artificial turf, but these were not statistically significant, probably in reason of small numbers.

Another study [40] found a significantly higher injury risk on artificial turf versus natural grass (25 v 10 injuries/1000 hours of exposure, $p < 0.01$).

The development of new technologies, has led to the production of new surfaces, specifically dedicated to soccer. The use of the term “football turf” without any reference to generation is now the official terminology recommended by FIFA for artificial turf devoted to soccer.

In 2001 FIFA introduced the FIFA Quality Concept for Football Turf to ensure the quality of football pitches. Today within the FIFA quality program, a certification and licensing programme that guarantees the quality of turfs based on uniform criteria has been created. The certification is named “FIFA RECOMMENDED” as described in the following official FIFA classification (table 1).

FIFA Recommended 1 Star	Dedicated football turf standard for amateur and grassroots football
FIFA Recommended 2 Star	Turf standard that meets the very highest demands of professional and elite football.

Table 1. “FIFA RECOMMENDED” certification for football turfs (FIFA Quality Program).

The modern third and fourth generation surfaces are very different respect to early surfaces and often these are promoted as possessing the same properties and injury-risk profiles as grass (Figure 14).

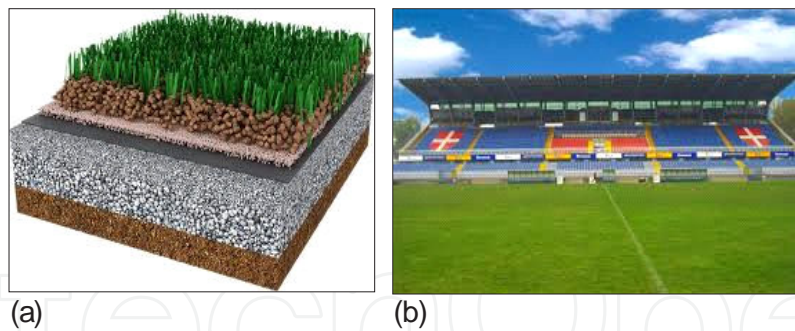


Figure 14. a) Modern artificial grass b) Silvio Piola Stadium - Novara - Italy

Recent reviews evaluated the effect of playing surface of third-generation [41] and of third- and fourth-generation [42] on injury rate.

The studies reviewed provide a few specific data about these pitches and muscle injuries.

The first review reported that the effect of these synthetic surfaces on injury rates has not been clearly established because the available literature is largely limited to football and soccer data with a majority of short-term studies. In their conclusions the authors reported that many peer-reviewed studies cite a higher overall rate of injury on first- and second-generation artificial turf surfaces compared with natural grass, but despite differences in injury type, the rate of injury on third-generation and natural grass surfaces appears to be comparable.

In the second review, the purpose of the authors was to compare the incidence, nature and mechanisms of injuries on last generation artificial turfs and natural turfs about football codes (rugby union, soccer, American football). The authors searched in electronic databases using the keywords 'artificial turf', 'natural turf', 'grass' and 'inj*'. Delimitation of all articles sourced, resulted in 11 experimental papers. These 11 papers provided 20 cohorts that were assessed and statistically analyzed. Analysis demonstrated that 16 of the 20 cohorts showed no significant effects for overall incidence rate ratios between artificial and natural surfaces. About muscle injuries, two cohorts showed beneficial inferences for effects of artificial surface on muscle injuries for soccer players, even if there were also two harmful, four unclear and five trivial inferences across the three football codes.

In conclusion the authors stated that new studies of effects of artificial surfaces on muscle injuries are required given inconsistencies in incidence rate ratios depending on the football code, athlete, gender or match versus training evaluation.

3. Management of risk factors

- Team medical organisation

In modern soccer, both at professional top level and at lower levels, an optimal link between the functions of technical staff and medical staff is essential.

Proper planning of workloads, individualized as much as possible (sport-specific, role-specific, single player-specific work load), and a continuous flow of informations between technical and medicals staff are required. These two groups of staff have to work as one big team.

Technical staff mainly includes head coach, assistant coach, fitness coach or athletic trainer, goalkeeper coach. Medical staff includes the head of medical department who coordinates the work of a group of doctors, physiotherapists, chiropractors.

Currently, compared to soccer 15-20 years ago, the number of professional duties of the head coach has increased (matches, training sessions, increased number of players to train in teams' ranks, media sessions, trips). With such an organisation of soccer teams, the head coach and his staff cannot be directly engaged, daily and with the appropriate continuity, in the field training program of the injured player.

According to the authors' experience, a new professional figure, linking between the two staff, is taking on increasing importance: the field rehabilitator.

The field rehabilitator, in the authors' opinion, is the key professional link, necessary for the proper management of re-injury risk factor. He must possess the professional skills of both the physiotherapist and the fitness coach (Figure 15).



Figure 15. Fitness coach (l) and field rehabilitator (r)– Genoa C.F.C. 2012-13

He begins his work when the injured player ends the rehabilitation program and starts the reconditioning work on the field. In case of muscle injury (or other injury), the aim of his work is to take the player to a level of physical fitness and technical training comparable to his usual standard, ready to rejoin the group of healthy players to normal training sessions.

To achieve this goal, it is imperative to set the field rehabilitation program on a scientific basis, thus referring to well known parameters of physical fitness, which are specific to each player.

The setting up of a database with these parameters will be presented in a later section.

With respect to muscle injury prevention program, all components of technical and medical staff are involved in the management of risk factors.

Team's doctors have to plan examinations for detecting any previous muscle injury, scars, anatomical malalignment, poor flexibility, muscle strength deficit, or imbalance and tightness.

Each member of the medical and technical staff, according to his competence, works to correct, where possible, any anatomical, biomechanical, functional abnormality.

For this reason, it is necessary that all staff members are fully informed about the risk factors related to each player.

In the following sections all steps involved in the management of risk factors are discussed.

- Medical history and clinical evaluation of the athlete

In this section we aim to suggest some guidelines to set up an appropriate prevention program, available to use "on the field".

The following suggestions are referred to each new player recruited in the team ranks. Obviously, in case of a "veteran" player, a large part of the work is ready since the first incorporation. All the information provided should be linked to the personal experience of medical staff, the club organization, the quality and compliance of the athletes and, not least, to the economic availability of the soccer club. We start with simple evaluations, applicable also to recreational athletes, to enter tests progressively more complex, some of which are more expensive and mainly dedicated to professional clubs and high level players. As it is not strictly related to the subject of present chapter, we will skip the details about the cardiological and clinical checkup for eligibility to competitive sports, compulsory in Italy. According to Italian laws, the athlete can neither play nor train without the certificate of eligibility to competitive sport, main guarantee for the athlete, the medical team and the club.

The first step is to perform a complete and accurate medical history. All information will help the medical team to obtain a full view of the athlete's physical characteristics, his strengths and weaknesses and a better knowledge of his previous problems. The prevention program must be simultaneously a training and rehabilitation/physiotherapy program, and must follow the athlete through the season in collaboration with medical and technical staff. Simple and targeted questions must be placed, if possible in the same language of the player (in case of foreign player), if necessary with the help of a translator.

To get the best collaboration and compliance, our experience shows that it is useful to avoid the topic "previous injury" before having established some feeling with the athlete, who often initially "forgets" to report some previous injuries, especially muscular ones.

A good approach would be providing the athlete full information about the medical staff and physiotherapy organization of the new team, the modalities and equipment available in physiotherapy service, the role of the field rehabilitator, before training (preventive work) and/or in recovery after injury. Then we get information on the player's knowledge and habits about prevention work.

After this first approach, we analyze the intrinsic risk factors identified in medical history: focus on the characteristics of joints (ankles, knees, back and shoulders - especially in case of a goalkeeper) and then we proceed to the past problems, therapeutic interventions (conservative and surgery), recovery time and the use of bandages, orthotics, bite that must always be checked carefully.

Finally, we evaluate the muscular structure. It is important to review every single muscle, making specific questions about past trouble, in particular relating to hamstring and quadriceps, heavily stressed in soccer players. It is necessary to dwell on the dynamics of accidents, the diagnosis, the treatments carried out and the period of absence from competitions, and any discomfort felt by the athlete after his full return to competition.

After performing a detailed history, we go on by physical examination, which must start with the postural control on podoscope to evaluate plantar stance, knee and column alignment and check for any length imbalance.

The assessment of main joints stability is the following step, as well as the verification of the joints ROM (range of movement), in particular of hip, knee and ankle.

Then we evaluate some additional intrinsic risk factors involving the muscles: check for possible strength imbalances or muscle stiffness - especially for hamstrings - and with manual evaluation of the muscles, "feel" the presence of scars that may lead to changes in contraction. These are important functional outcomes for the preventive program assessment, both for physiotherapy, with manual treatment of stiffness areas, and rehabilitation, with correct work for muscle flexibility improvement.

The final doctor report should emphasize every aspect of the clinical examination that can be useful for planning the prevention program, also through the creation of a database easily accessible, for instance using a graphic model of immediate interpretation (Figure 16).

These evaluations are easy to perform and cheap, and can be used with both professional and amateur athletes. After medical history and clinical evaluation, a full muscles and tendons ultrasound examination - the importance of which is emphasized in a special section - should be performed. Finally, in case of a new athlete's evaluation protocol, the MRI evaluation of lumbar spine can be added, to check for possible structural failures related to muscle injuries, and knee MRI, to highlight ligament, meniscus or cartilage damages. These last evaluations, more expensive, will be set according to the economic budget of each club.

In our experience, two more points are to be considered for a good preventive program drawing up: -1 clinical or functional simple and repeatable tests, that must be performed several times during the season both to get new medical information and to check the effectiveness of our program -2 weekly collegial meeting with all the members of the team medical staff, to present the problems found, organize and discuss the preventive program and give each ones specific tasks, to ensure that athletes follow strictly their personal prevention program.

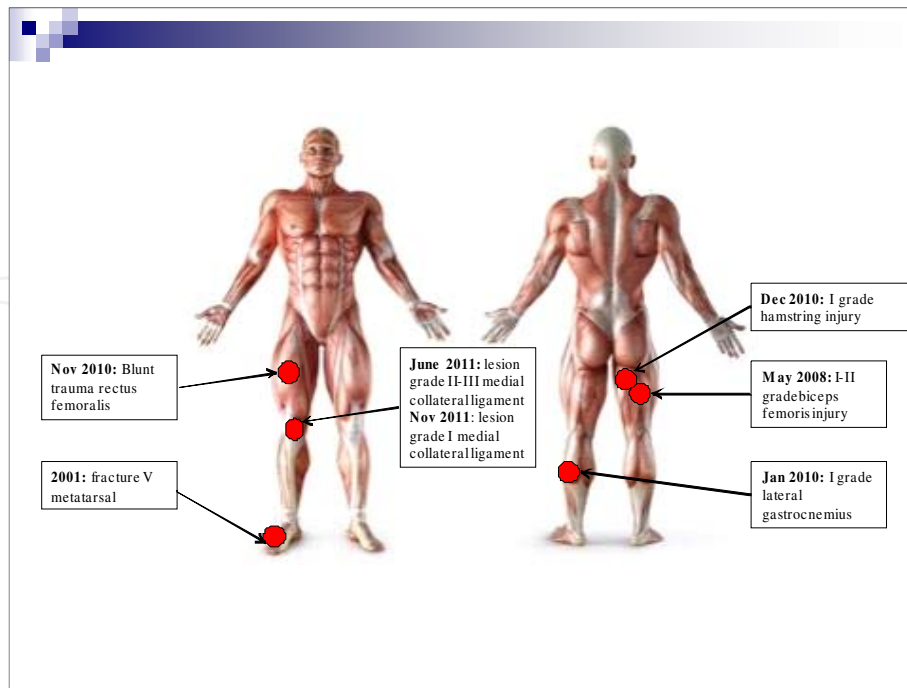


Figure 16. Graphical model to remind sites of previous injuries.

To make the preventive program easy to use and apply by athlete, medical and technical staff guidelines have to be written in a simple way, printed together with images that show the correct execution of the field and gym exercises.

There are several tests that can be used to predict the risk of injuries, to identify the muscles to work on and to evaluate the effectiveness of our strategies.

We suggest two tests that we normally use, and that are giving effective responses: further investigations are, however needed in this area.

One, named Functional Movement Screen (FMSTM), simple and easy to use, and the other, based on use of tensiomyography (TMG), more technological, expensive and not easy to use but which allows to evaluate the individual muscles of the lower limbs.

3.1. FMS: Functional Movement Screen

This is a test based on the execution of a series of simple exercises that allow the assessment of postural balance and symmetry of the different muscle chains [46,47].

For each exercise is given a score from 0 (impossible to carry out the proposed exercise) to 3 (perfect exercise). The maximum score is 21 (Figure 17).

The exercises are the following:

Deep Squat, Hurdle Step In-Line Lunge, Shoulder Mobility, Active Straight Leg Raises, Trunk Stability Push Up, Rotary Stability [46,47].

In addition, according to the scores in each exercise, it is possible to draw up a preventive exercise program to improve movement harmonization.

Scoring Sheet FMS			
NAME:		AGE:	HEIGHT:
WEIGHT:		M/F:	PHONE:
ADDRESS			
SPORT:			
HAND DOMIN:		R) L	LEG DOMINANCE: R) L
TEST	RAW SC	FINAL	COMMENTS
Deep Squat		0	
Hurdle STEP.L		0	
Hurdle STEP.R			
In-Line LUNGE.L		0	
In-Line LUNGE.R			
Sho.Mob.L		0	
Sho.Mob.R			
Active IMP.L			
Active IMP.R			
ASLR.L		0	
ASLR.R			
TSPU		0	
EXT			
Rot.STAB.L		0	
Rot.STAB.R			
FLX			
TOTAL		0	

Figure 17. FMS score schedule

This test should be repeated periodically to assess the effectiveness of our work protocol, and before the return to the field after an injury to check if functional alterations still persist.

3.2. TMG or tensiomiography: (In our practice we use TMG SYSTEM 100 ® TMG-BMC Ltd)

This is a device provided with a special sensor which, positioned on the muscle to be analyzed, records the muscle contraction induced artificially by electric pulse.

The sensor measures the radial enlargement of the muscle: the values are detected at different stimulation intensities and the results are placed in a time/displacement chart (Figure 18). The processing of these data through a specific software provides a measure of possible muscle imbalances, directing the work on strengthening exercises or, if muscle show an excessive tightness, on flexibility improvement protocols. In addition, this test gives us information on the balance between agonists/antagonists muscles and between the muscle groups of the two legs.

The test should be performed systematically to check the effectiveness of the preventive program, to improve the quality of the muscle contraction, and it should be performed also before full return to the field, in case of injury.

There is no safe scientific evidence that prove efficiency of this test in preventing injuries, but it is now used by some professional soccer teams, and can represent an opportunity for further investigations.

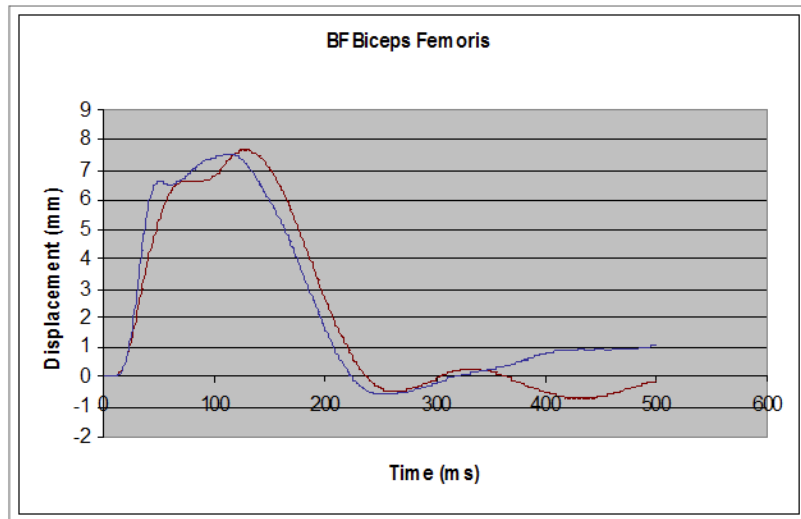


Figure 18. Displacement/time biceps femoris chart

- Ultrasound evaluation

Several studies report that a previous muscle injury is an important risk factor for muscle injury [2,3,8,13,15,16,19,21,27,28,43-45]. Ultrasound and MRI are the reference modalities of imaging for the diagnosis and monitoring of muscle injuries (Figure 19).

At the beginning of each season new players are recruited in the ranks of soccer teams. A detailed medical history sometimes cannot detect all previous muscle injuries, mainly due to two reasons. First of all, the reluctance of some players to report all previous injuries (i.e.: fear to be considered a player with a high injury risk). Secondly, the possible forgetfulness of long standing muscle injuries.

Ultrasound may be the preferred primary modality to complete medical history and clinical evaluation of previous muscle injuries, because of its portability, ease of use and decreased costs. Ultrasound also, compared to MRI, allows a rapid and complete examination of all muscle compartments, both under rest standard condition and real-time functional and dynamic assessment. MRI must be used as a second step, to increase the information on the outcomes of some injuries.

All information collected by ultrasound (muscle scars and calcifications, their site, size, orientation, dynamic response) have to be related to what is reported by the player (comfort, discomfort, pain, tightness).

The knowledge of these anatomical outcomes represents a basic step, both for the technical and medical staff, in order to plan a correct prevention work on these non-negligible risk factors.

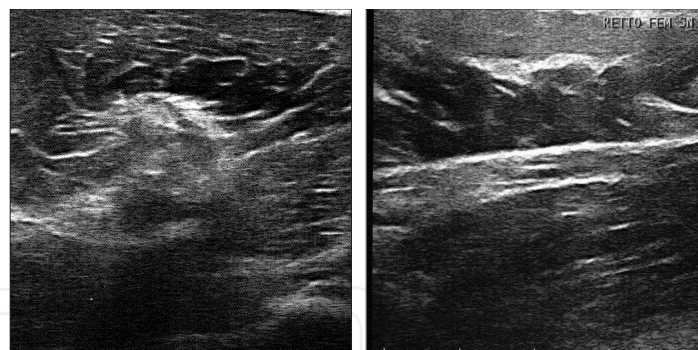


Figure 19. Ultrasound images of scars: biceps femoris (left), rectus femoris (right).

- Evaluation and analysis of parameters related to performance: Database

A good medical, rehab and physiotherapy organization and the best communication between all members of the team are the basic properties required for a successful prevention program. The other component involved during the implementation and collection of additional data is the technical staff, mainly in the person of the fitness coach who takes care of physical work in the gym and on the field.

A continuous dialogue between medical staff and fitness coach is important in order to provide information on players' health, and to liaise on the problems that some exercises or excessive loads can cause. For this reason it is important to set a database where the team staff can enter medical, physiological and functional data, always respecting the privacy of the athlete.

All the parameters of the test to which the athlete has been subjected have to be placed, to monitor constantly the psychophysical condition of the athlete.

Blood tests and all examinations required by law for the eligibility of professional athletes must be entered in the database.

Other parameters that we would suggest to insert in the database include: how much time the athlete passes in the massage room, the number of manual treatments that he runs during the week and the fatigue perception experienced in training or game, assessed by the CR-10 Borg scale [48] (Table 2). These data allows us to understand when an athlete's fatigue is disproportionate to the workload and when he feels the need to be processed manually in order to reduce stiffness. When these two parameters begin to rise over the standard average values the risk of possible muscle injuries increases.

In addition to the FMS e TMG results, we also recommend to enter in the work program some field and laboratory tests that provide information on some of the intrinsic factors listed above: aerobic fitness, strength imbalance, body size.

To assess body size, we are interested in monitoring the weight, lean body mass and body fat percentage as well as the state of hydration. These can be evaluated in a simple way with the use of a scale, a caliper and, if available, a machine for bio-impedance body composition analysis (BIA).

Rating	Perceived Exertion
0	Nothing at all
0,5	Very very light
1	Very light
2	Fairly Light
3	Moderate
4	Somewhat hard
5/6	Hard
7	Very hard
8	
9	Very very hard
10	

Table 2. CR-10 Borg scale.

For the aerobic fitness evaluation many field tests have been proposed. According to our experience we prefer submaximal test, as the Mogroni test, in place of the maximal test used a few years ago, because the latter is highly dependent on the compliance of the athlete.

While to assess the maximal frequency and fatigue we use the yo-yo intermittent recovery test, to evaluate the strength imbalance we prefer an isokinetic test and for a rapid measurement of the explosive force we use the jump test.

Mogroni test. This is a test that allows to determine the speed and, consequently, the frequency of the anaerobic threshold and consists in allowing the player to travel the distance of 1,350 meters in 6 minutes while maintaining a constant speed of 13.5 km/h. To facilitate the correct execution, we should put on the path signals at regular intervals (50 meters), and make the athletes follow a call sound that indicates when they have to come to the signal.

At the end of the test, the concentration of blood lactate is measured through a sample and the threshold speed and consequently the threshold frequency are extrapolated through a mathematical formula (Table 3).

Moreover, we also assess the fatigue perception by the CR-10 Borg scale.

The periodical execution of the test allows on the one hand the technical staff to verify the aerobic capacity of the athlete and to modulate the workload during the season, and on the other hand the medical staff to monitor his state of health. Furthermore, testing the athlete also before his return to the field after a long muscle injury allows us check if he has found a good physical condition, an aspect that reduces the risk of re-injury.

blood lactate (mmol/l ⁻¹)	threshold speed (Km/h)
1,5	15,55
2,0	15,04
2,5	14,55
3,0	14,11
3,5	13,70
4,0	13,26
4,5	12,98
5,0	12,66
5,5	12,38
6,0	12,33

Table 3. Correlation between concentration of lactate in the blood and threshold speed (Source: "Il libro dei test" Marella-Risaliti ed. Correre 1999)

Yo-Yo intermittent recovery test (Bangsbo, 1997): assesses the subject ability to recover during progressively increasing exercise. The test involves running a shuttle between two cones placed 20 meters away from each other, performing at the end of each fraction of 40 meters, 10 seconds of active recovery. The running speed and the recovery time are dictated by a pre-recorded sound signal.

The initial speed is 10 km/h and increases progressively. When the athlete is unable to maintain the suggested speed for two consecutive step, the test ends. The meters run and final speed are included in the database.

This test is useful for performance evaluation in sports involving the alternation of high and low intensity phases, as in soccer. This test periodically repeated allows an evaluation of the improvements determined from training through the distance travelled. In addition, the test performed after long muscle injuries evaluates fitness to fatigue, which is another intrinsic risk factor for muscle injury.

Jump tests: these tests that are performed with the use of a force platform. We recommend to perform two exercises:

Squat Jump: the athlete with hands on hips reaches the position of semisquat (90°) and jump as high as possible. In the database we record the best performance of the three that we usually ask to carry out. The results are measured in cm or msec and give us an indication of the explosive force

Countermovement jump: the athlete with free arms turns quickly to reach the semisquat position (90°) and jump as high as possible. In the database we record the best performance of

the three that we usually ask to carry out. The results are measured in cm or msec and give us indication of the explosive elastic force.

Isokinetic tests: the isokinetic devices are tools which allow to perform muscle exercises with constant angular velocity throughout the range of movement; after a determined angular velocity is reached during an acceleration phase, the device does not allow this speed to be overcome. In this way, the resistance that the athlete meets is equal to his effort, allowing him to perform a safer and less traumatic exercise for muscle than an isotonic one. The isokinetic test should not be considered useful to evaluate only the maximum force but also to evaluate muscle functionality throughout the whole range of movement.

The most important parameter to consider is the peak force, the maximum force that the athlete is able to express during the exercise, followed by the work done and the power developed. It is essential to compare the values obtained in the two legs to evaluate possible imbalances and work to correct them.

Another important parameter is the muscle agonists/antagonists strength ratio because, as we have previously pointed out, muscle imbalances are an intrinsic risk factor for muscle injury.

The battery of all the tests listed above should be performed at the same time, in order to integrate the results and obtain a complete picture of the health state of the athlete and his fitness. These results are then processed by the team doctor to detect possible situations of risk and to provide information both to therapists and rehabilitators for immediate action. Moreover, they should be repeated several times (4-5) during the season and entered into the database to assess how the indices change with training.

Once again, it is important to emphasize that all these tests should also be performed before returning to the field from a long injury and values should be similar to those obtained when the athlete was in a good physical condition

In fact a good physical condition, a proper adaptation to fatigue, a good balance of strength between the two limbs are the key parameters to minimize the risk of muscle injury.

- Other practical suggestions

In the available scientific literature, there are many conflicting data about the significance of different risk factors on incidence of muscle injuries, and therefore it is difficult to organize a prevention program universally recognized and validated. We can suggest performing a work protocol, which is developed in relation to the availability of medical structures and the compliance of the athlete. The protocol must be modified and improved over time, according to further scientific evidence.

As suggested above, a careful history and physical examination are essential to detect, since the first control, all intrinsic and extrinsic factors (shoes, orthotics, etc.) that may increase the risk of injury.

Then the data must be processed and shown to all medical staff, especially doctors, physiotherapists and rehabilitators.

The physiotherapists need to focus on the manual treatments that have been agreed and programmed. In fact, the possible muscle scars or areas of stiffness need special care and must be systematically monitored and managed. We prefer to avoid deep manual treatments and massage before and after strength session, and close to the matches, as in some athletes these treatments can cause a feeling of discomfort on match day.

It is recommended that scar treatments, with technique of deep transverse massage, are performed earlier in the week, especially after the aerobic session and at least 24 hours before the next training session. For the following days, our advice is to treat the antagonist muscles and the other muscles involved in the same kinetic chain.

We also recommend the assessment of the lumbar and dorsal muscles, strictly related to hamstring. In athletes with previous hamstring injuries we suggest to treat them, manually at least once a week.

The other important figure for the preventive work is the field rehabilitator. For this reason, the advice is to select a person with a degree allowing him/her to serve as both physical therapist and fitness coach. This figure must be placed in the medical staff and should be accountable to the doctor.

His work should be set in order to dedicate to each athlete 3 session a week, 45-60 minutes before training and 10-15 minutes during cooling-down.

In fact, we should not insert extra workload after the physical and tactical training, because usually the attention and compliance of the player are lower at the end of the session. After training, simple postures or exercises of muscle compensation are well tolerated.

To assess the degree of fatigue, as described above we use the Borg CR-10 scale, that shows us if the results are consistent with the athlete workloads, compared to the average values of the team and the typical values of the athlete.

We also suggest to set a good warm-up program, using different exercises according to the problems of the single athlete such as exercise bike 10-15 min, varying seat height, number of revolution/min and intensity of exercise, or walking/running on the treadmill. Finally, continue with mobilization exercises focusing on the mobilization of the spine, hips and knees.

As a result we recommend that proprioceptive exercises are carried out using traditional tablets or skimmy, setting circuits with different proprioceptive stimuli. According to our experience, it is better to plan proprioceptive exercise early in the week and then reduce it with the approach of the match.

Other exercises in preparation to the match can be performed by bouncer and trampoline equipment, to enhance the work of propulsion and thrust by the limbs.

As a final step it is important to introduce some muscles strengthening exercises. We think it is important to give different stimuli to the muscles and for this reason it is better to vary the types of exercises, especially in order to improve muscular balance and strength.

We propose to perform eccentric exercise especially on the hamstring and quadriceps, if possible manual and managed by the rehabilitator that can modulate the loads. These exercises

can be associated with working sessions with elastic bands. Finally, we suggest exercises with isoinertial equipment, which allow us to work on different eccentric muscle chains and allow an excellent simulation of the field work.

These three methods: manual eccentric, working with elastic bands, isoinertial works can be combined successfully, both within the same session and alternating during the week.

At the end of the training session, we can propose 5-6 minutes of postural exercises to relax the posterior chain and the column or through 10-15 min of relaxing work in the pool.

Last useful advice is to use cryotherapy after training to reduce possible overload inflammation affecting the tendons, joints and muscles

There are several ways to perform cryotherapy, the simplest of which is to use cold water (10-12 degrees) for a period of time ranging from 5 to 7 min. After cryotherapy it is recommended to avoid manual treatment.

4. Conclusion

Muscle injuries are frequent in soccer and involve mainly four muscle groups of the lower limbs (hamstrings, quadriceps, adductors and calf). Re-injuries risk represents a serious problem in order to plan safe return to full training and competitions. Some factors are suspected to be related to the onset of muscle injuries in soccer players and are described as intrinsic and extrinsic risk factors. The relationship between these risk factors and muscle injuries is currently not completely understood. Nevertheless, the management of risk factors involves medical and technical staff of soccer teams, in order to plan a muscle injury prevention program. The program has to be performed both for general prevention (dedicated to all players) and personal prevention (player-specific). Several prevention programs have been proposed by some authors and are experimented by coaches, medical staffs and athletes. The effectiveness of these programs on many occasions is not corroborated by scientific evidence. This is probably due to the large number of factors that affect the neuromuscular performance in soccer. The assessment of the athlete, however, represents the first step to program the prevention work. Personal history and clinical evaluation, imaging evaluation, laboratory and field tests are needed for all new players recruited in the team's ranks. The setting up of a database with many parameters of healthy athletes is also proposed, with the aim of evaluating each single player in pre-season and competition period. In case of injury this will be used as a reference to plan return to competition. Finally, we offer some practical suggestions to be used in prevention programs of football teams.

The wide border between empiricism and scientific evidence is often an obstacle to the realization of practical proposals. It should not become an excuse for inaction. We cannot ignore the experience accumulated in years of work by medical and technical staff of soccer teams. For this reason, while we are aware that the development of new studies is certainly desirable, we hope in a growing collaboration between all the components involved in the

management of the players, in order to improve current knowledge and direct future guidelines about the prevention of muscle injuries in soccer.

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