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Chapter 9

How and When to Use an Injury Prevention Intervention in Soccer

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Additional information is available at the end of the chapter

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1. Introduction

Soccer is a high intensity intermittent contact sport exposing elite level players to continual physical, technical, tactical, psychological, and physiological demands (Owen et al, 2011; Dellal et al, 2011). Due to the huge financial rewards of being successful at the elite level of the sport, the demands placed upon the players are ever growing because of increased fixture schedules that generally include less recovery periods between training and competitive match play, disposing players to a greater risk of injury (Dellal at al, 2013; Dupont et al, 2010; Rey et al, 2010; Morgan and Oberlander 2001; Junge and Dvorak 2004). The number of competitive matches played by elite European soccer players (Table 1) during one season can be >80, with 1.6 to 2 matches per week throughout its entirety (excluding friendly games) (Figure 1). It should be noted that, a player competing at the higher echelons of world soccer such as Lionel Messi has accumulated between 64 to 69 official competitive games throughout seasons 2011-2012, 2010-2011, and 2009-2010 as shown in Table 2. As reported in this context, modern day soccer involves a continued, intensive cycle and predisposes players to greater injury risks due to accumulative fatigue or overload. Previous research has already found a correlation between low training and match availability due to injury, with decreased team success (Arnason et al, 2004). This is of particular importance for teams unable to replace players due to limited funds or resources, and subsequently highlights the need for all clubs irrespective of budgets, resources and funding potential to minimize injury risk of players in order to be more successful. After all, there seems to be no point in pushing players constantly to be physically, technically and tactically better if they are consistently unavailable to play.

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Country	Match played in 1st League	Match played in League cup	Match played in National cup	Match played in UEFA Champions League or Europa League	Other games (National or European super cup, champions cup, etc)	National team	Minimal rate of match per years	Maximal rate of match per years	Summer holidays
Spain, *La Liga*	38	1 to 10	0	6 to 15	2 to 4	4 to 11	51	78	30 to 41 days
England, *Premier League*	38	1 to 9	1 to 9	6 to 15	2	4 to 11	52	84	40 to 55 days
Germany *Bundesliga*	34	1 to 5	1 to 6	6 to 15	1	4 to 11	47	72	41 to 53 days
France *Ligue 1*	38	1 to 5	1 to 6	6 to 15	2	4 to 11	50	77	25 to 35 days
Italy *Calcio*	38	2 to 11	0	6 to 15	1	4 to 11	51	76	41 to 53 days

Table 1. Official match played by elite soccer players from European teams.

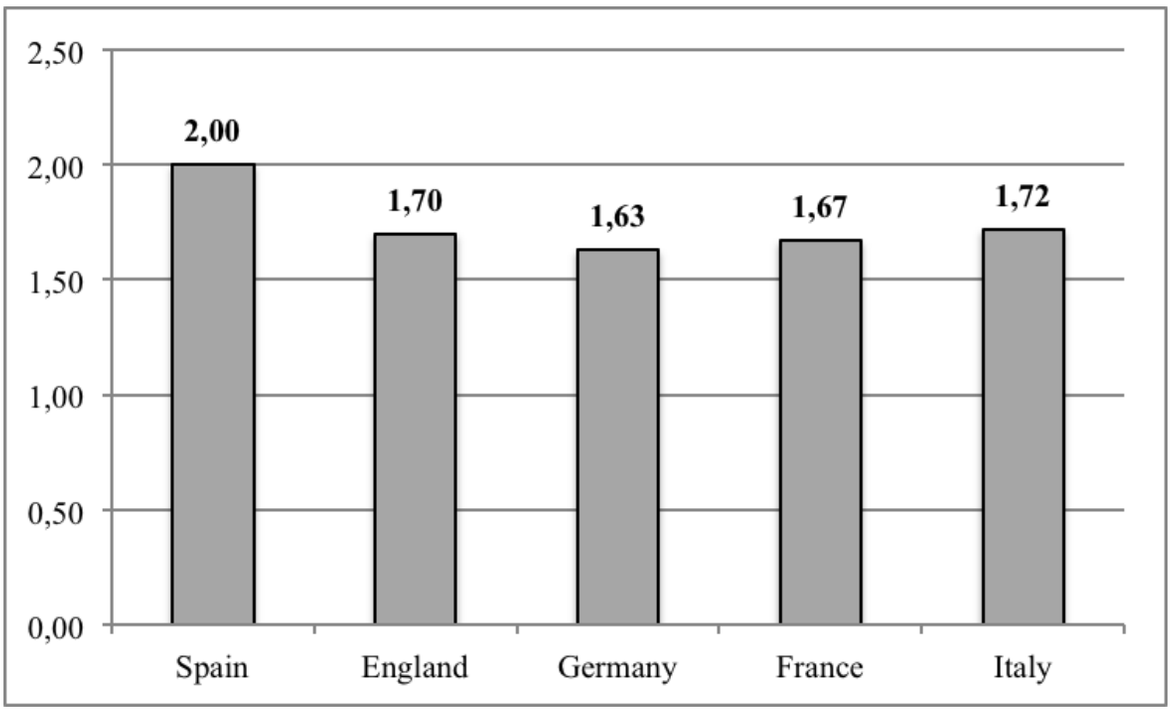


Figure 1. Mean number of official matches per week played across the 5 best European Leagues (excluding the friendly games).

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	Players	Season 2011-2012	Season 2010-2011	Season 2009-2010
1	Messi Lionel	**69**	66	64
2	Ronaldo Cristiano	**69**	59	46
3	Iniesta Andres	47	**50**	41
4	Xavi	51	50	**53**
5	Falcao Radamel	**52**	42	43
6	Pirlo Andrea	**56**	36	51
7	Drogba Didier	47	49	**57**
8	Van Persie Robin	**60**	38	34
9	Ibrahimovic Zlatan	**55**	49	49
10	Alonso Xabi	54	**63**	56
11	Yaya Touré	49	**52**	37
12	Neymar	59	**67**	62
13	Osil Mesut	62	**64**	62
14	Rooney Wayne	**50**	48	49

Table 2. Official matches played by the 14 best players during the 3 last seasons (according to the official "Ballon d'Or" ranking).

The financial outlay clubs make season upon season in order to gain success is well into the high percentages of club turnover (wages, transfer fees and contractual terms agreed). The expense of a player being out through a non-contact injury could be substantial and seen as a negative investment or non-efficient with every game missed through a preventable injury. Consequently, the need to implement a sport-specific injury prevention structure within the organization that technical, conditioning coaches and other individuals involved with the player training status is of paramount importance. According to previous research the most significant injury predictor of soccer players is their injury history (Olsen et al, 2004). The fact that players have some type of chronic problem or low training or match availability over numerous seasons will more than likely manifest itself moving forward unless appropriate injury prevention steps are taken.

It is however, questionable whether some types of exercise-based injury prevention programs actually facilitate true learning of new biomechanical and neuromuscular characteristics (Padua et al, 2012; Paterno et al, 2004). Whereas the effects of short duration exercise-based injury prevention programs may induce transient changes in the performance of functional tasks that regress following cessation of the program. In order to experience biomechanical and/or neuromuscular changes it is likely that extended-duration training periods are necessary to facilitate long-term retention of movement control (Padua et al, 2012). Yet, performing injury prevention drills over a prolonged period, as performed by Owen et al (2013b), may still be insufficient to induce large reductions in the incidence of specific injuries.

Essentially, players may respond differently to intervention programs and this should be a consideration for further detailed investigations. Alternatively, despite certain programs being performed during the entirety of the season, it is possible that specific prevention sessions or individual exercises may have been insufficient in terms of longevity and duration required to elicit large training adaptations. This is pertinent to elite level athletes who generally possess relatively high levels of general fitness and would unlikely experience gains similar to lesser skilled individuals despite being at a greater risk of injury (Ekstrand et al, 1983).

The incidence of injuries among elite adult male soccer players during competitive match-play was described to be approximately between 24.6 and 34.8 per 1000 match hours (Walden et al, 2005; Arnason et al, 2008; Parry and Drust, 2006), and training injuries ranging between 5.8 to 7.6 per 1000 training hours (Walden et al, 2005; Arnason et al, 2008) even if some studies report values outside these ranges. Walden et al (2005) revealed that the risk of injury in European professional soccer is high with the most common injury being the posterior thigh strain. Hawkins et al (2001) reported an average of 1.3 injuries per player per season in English professional soccer, with the propensity of injuries occurring in the final 15min period of each half. Comparatively, fewer injuries occur during the first half of matches compared to the second (Hoy et al, 1992; Hawkins and Fuller 1996, 1999). The stressors encountered during actual match play have been suggested to show no detrimental effect of consecutive games on physical performance, but a greater injury risk (Carling et al, 2012; Dupont et al, 2010; Rey et al, 2010).

Almost one third of all soccer related injuries are muscle related and the majority (92%) affect the major muscle groups of the lower extremity: hamstrings, 37%; adductors, 23%; quadriceps, 19%; and calf muscles, 13% (Ekstrand, 2011). Over a period of two seasons, the Football Association Audit of Injuries also showed the hamstrings to be the most commonly injured muscles, constituting 12% of all strains (Hawkins et al, 2001). The implications manifesting in players being 2.5 times more likely to sustain a hamstring strain than a quadriceps strain during a game (Hawkins et al, 2001). This is clear evidence as to why clubs invest heavily in time and resources of injury prevention in an attempt to reduce the prevalence of injuries (injury rate). However, eagerness to return to play resulting in an incomplete rehabilitation has shown the increase the re-injury rate for hamstring injuries thus, questioning the success of current injury prevention programs (Croisier, 2004; Hagglund et al, 2005).

Previous research has suggested that muscle strains may occur due to insufficient warm-up (Kujala et al, 1997; Worrell, 1994), poor flexibility (Kujala et al, 1997; Worrell, 1994; Hartig and Henderson, 1999) even if some recent research are conflicting in this regard, muscle imbalances (Worrell, 1994), muscle weakness (Croisier et al, 2002), neural tension (Turl and George, 1998), fatigue (Kujala et al, 1997; Worrell, 1994), previous injury (Engebretsen et al, 2008), increasing age and poor running technique although the evidence to represent these findings are both minimal and conflicting. Chamari et al (2012) has recently showed Ramadan Intermittent Fasting to induce higher injury rates in Muslim elite soccer players with a higher number of contractures for muscles themselves, and some tendinosis for tendons. Over-emphasis on one-sided activities, such as kicking, lateral movements and single-leg jumping, may also lead to asymmetry and dominance of one leg, which in turn may cause greater than

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normal differences in strength between compared to contra-lateral muscle groups. Furthermore, an unfavorable difference between agonist and antagonist muscle groups is considered to leave the weaker muscle group at a disadvantage and such an example, hypertrophy of the quadriceps at the expense of the hamstring may lead to hamstring injuries. Indeed, Croisier et al (2008) and Knapik et al (1991) suggested that players with a strength imbalance greater than 15% were 2.6 times more likely to suffer injury in the weaker leg.

Ekstrand and Gillquist (1984) have showed that intervention prevention strategies allowed players to have 75% fewer injuries than a control group (ankle, sprain, strain). **In this context, the aim of the present book chapter will be to present the literature review showing how different prevention methods and strategies appear to result in the reduction of injuries to soccer players both during training and matches.** However, the combination of concurrent prevention programs could further positively affect the injury rate, especially the high incidence of lower extremity non-contact muscle injuries. Therefore, based on all the previous research findings and suggestions, the importance of injury prevention at the elite level of professional soccer led to the development of this review. The current review aims to examine the impact a 4-part structured injury prevention intervention would have on injuries occurring within elite level professional soccer clubs.

2. Prevention techniques used in soccer

The majority of injury prevention training studies have generally examined the effects of individual components on injury incidence. However, this is not representative of a soccer specific environment where the time constraints dealt necessitates the development of a mixed conditioning approach that allows for the simultaneous development of several fitness qualities. From a practical perspective, injury prevention programs are implemented with the expectation that they will elicit improvements in performance (through increasing players' availability and reducing lay-off durations when injury occur) and reduce the incidence of injury, however, this is not always representative of research findings. Recently, it has been suggested that a multicomponent injury prevention intervention may increase motivation through an integrated approach within a team sport environment (Owen et al, 2013b). This particular investigation recently reported that significantly less muscle injuries were observed during integration of a 4-part injury prevention program concomitant with a bigger squad size (large effect, $p<0.001$) when compared to a control season (Owen et al, 2013). It was reported during this investigation that high levels of contusion injuries were apparent within this study, which led the author to suggest that the multicomponent prevention technique is beneficial when integrated in order to reduce muscle injuries but may not be able to prevent other types of injuries (contact injuries). Prevention exercise is commonly included before, during or/and after the training sessions and matches. Within this chapter, we are going to describe the most common prevention technique used in soccer specific, especially by fitness coach. Sometimes one out of these is enough to reduce the injury occurrence, sometimes it is the combination of 2 or more that appears necessary.

2.1. Functional strength

Muscular strength is an important component of physical performance in sport, in terms of both performance and injury prevention (Fousekis et al, 2010). As a factor contributing to success in soccer, the quadriceps muscle plays a fundamental role in jumping, ball-kicking, and to a lesser extend, in sprinting, whereas hamstring contributes to the knee flexion, which is a major factor in stride power (sprinting or accelerate and decelerate). In addition to their direct contribution to athletic performance, the hamstring muscles are of paramount importance during running and stability activities (Zakas et al, 1995), which are continually required in intermittent team play such as soccer, which induces many short, explosive actions, directional changes and decelerations. Impairments in the eccentric muscle contractions involved in explosive phases of elite level soccer such as accelerations and the aforementioned decelerations may be linked to an increased risk of joint and muscle injury (Greig and Siegler, 2009). As a result, training interventions are continuously evolving in order to address this issue, for example Askling et al (2002) suggested that the addition of pre-season strength training for the hamstrings through eccentric overloading brings significant benefits for elite soccer players, both from an injury prevention and performance enhancement viewpoints.

A recent large scaled randomized controlled trial by Petersen et al (2011) addressed the efficacy of the Nordic hamstring exercise program (NHE, see more details here under in the eccentric strength section of the present chapter) for preventing acute hamstring injuries in soccer players. They found that introducing this ten-weeks program to reduce eccentric weakness, a common intrinsic factor associated with hamstring injuries, reduced the incidence of these injuries by 70%. This backed-up previous findings by Arnason et al (2008). Using a larger sample size Arnason's study looked at a total of 24 teams, with over 650 soccer players, over a four years period. These players professional belonged from soccer teams in the Icelandic and Norwegian leagues. The study showed that teams combining the Nordic eccentric exercise protocol and the stretching program were on average undergoing 65% fewer hamstring injuries. When discussing functional strength within a preventative structure it is important that a gradual overload with the primary aim of increasing muscle strength through soccer specific movements is adhered to. Consequently, it is reasonable to suggest that a multicomponent approach to function strength is followed as a closer analysis of the Nordic hamstring exercise that only involves movement at the knee joint. The fact that the hamstring involves work over two joints (hip and knee), the Nordic hamstring exercise clearly doesn't replicate any of the functional activities used in football specific training and therefore should not be used in isolation, but as part of a preventative strength program. In this context, Owen et al (2013b) had suggested that implementing a functional strength program as part of a multicomponent injury prevention structure may significantly reduce muscle strains/tears.

Since the physiological demands of soccer combine repetitive high-speed bouts with constant change of directions as well as physical contact with opposition players on a continuous basis, the fact that muscle injuries are accounted for a significantly high percentage of all injuries should not be unexpected. The hamstring muscle groups are responsible for accelerating and decelerating during high-speed running and sprints. Previous research has suggested that several reports from European elite soccer leagues revealed how hamstring strains are the most

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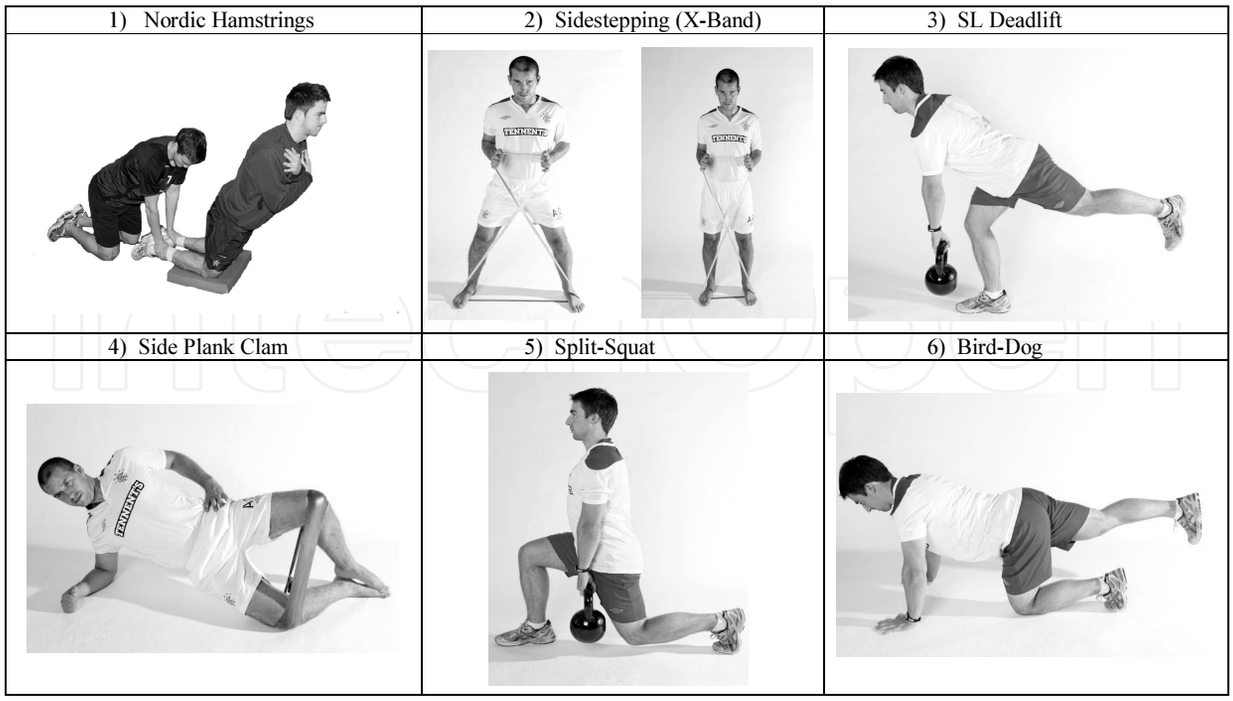


Figure 2. Functional strength program (from Owen et al, 2013b)

common type of injury in male soccer players (Junge and Dvorak, 2004). This is the reason for the functional strength aspect of prevention programs to include unilateral exercises that stress the hamstring and gluteal muscle groups through various ranges of lengthening. Figure 2 provides different possibilities of functional strength exercising.

2.2. Eccentric strength

Eccentric strength is considered as an important component of muscular strengthening. Despite complex eccentric strengthening protocols do exist, some simple on-field exercises have been implemented and proposed as a means to reduce injury risks. One of these is the famous ''Nordic Hamstring Exercise (NHE)'' (mentioned above in the functional strength section of the chapter) that have been proposed to deal with the high injury and re-injury rates of soccer players' hamstrings. The reasons of this muscular group for getting injured has been proposed by Proske and Morgan (2001), with the heterogeneous arrangement of individual muscle sarcomeres inducing microscopic damage coming from non-uniform stretching during eccentric actions. If eccentric movements are repeatedly performed, such as in soccer, this might provide a weak point at the level of muscle architecture, inducing a higher injury risk. Hamstrings are susceptible to injury during terminal swing phase of the leg while sprinting (Schache et al, 2009) because firstly, peak hamstring musculo-tendinuous stretch seems to occur during the swing phase before the foot contact with the ground; and secondly, hamstrings are undergoing an active lengthening contraction during late swing, producing the potential conditions or a strain injury to occur.

The interest of the NHE lies in the fact that it has been shown that it elicits higher activation of the hamstrings compared to a selection of exercises that are routinely used in classical "strength training" or injury rehabilitation (Ebben et al, 2006). In this context, it has been suggested that an eccentric peak torque increase could improve the capability of the hamstrings to absorb energy prior to failure, therefore, reducing the risk of injury (Stanton and Purdham, 1989). Therefore, Arnasson et al (2008), have prospectively investigated over four consecutive soccer seasons (1999-2002) the number of hamstring strains vs. players' exposure for 17 to 30 elite soccer teams from Iceland and Norway. They reported a lower incidence of hamstring strains amongst teams utilizing the eccentric training program vs. the controlled group of players. It was revealed that NHE combined with warm-up stretching appeared to significantly reduce the risk of hamstring strains. Additionally, the authors reported that no effect was observed from flexibility training alone. Arnasson et al (2008) have provided a detailed explanation of the NHE exercise (mentioning Bahr and Maehlum 2004): NHE is a partner based exercise that involves the one partner stabilizing the performer legs and can be easily performed with soccer players performing it alternatively by couples of players (Figure 3). The goal of the performer is to hold as long as possible while achieving maximum loading of the hamstring during the descending eccentric phase. Throughout the movement the player leans forward while keeping his back and hips extended, working towards resisting the forward fall through engaging the hamstring muscles as long as possible until he lands on his hands. Upon landing, players touch-down with their hands moving to touch the ground with his chest. Following on, players forcefully push-off back to the kneeling position with minimal concentric load on the hamstrings. The load is progressively increased through the training program by attempting to withstand the forward fall longer. When the performer can withstand the whole range of motion for 12 repetitions, the load can be increased by adding speed to the starting phase of the motion. Finally, the initial speed and, thus initial load can be developed further by having a partner pushing the performer at the back at the moment of the motion start. More functionally though, players may increase loads through weighted vests or light dumbells being held.

Recently, Iga et al (2012) investigated the neuromuscular activation characteristics of the hamstrings during NHE in soccer players combined with the associated alterations in the eccentric strength of the knee flexors.. The NHE exercise is easily performed amongst soccer players, with them performing it alternatively in pairs pre-game or training. The study of Iga et al (2012) investigated the isokinetic eccentric peak torques of the dominant and non-dominant limbs of a training and a control group isokinetically at 60, 120, and 240 °/s, pre- and post-training. The study comprised of four weeks NHE training as shown in Table 3. No difference was observed when both limbs were compared for EMG activity, showing that some authors were wrong to suggest that the dominant limb of soccer players were activated to a higher degree compared to the non-dominant limb during NHE (Brughelli and Cronin 2007). This study also showed that the EMG activity was greater at more extended knee positions during NHE, highlighting the importance of performing the NHE on the whole range of motion of the movement. Specific training significantly improved peak torque by up to 21% in all assessment conditions and data showed that both hamstrings of dominant and non-dominant limbs were engaged identically during the NHE pre- and post-training. Therefore,

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training induced significant gains in the eccentric peak torque of both soccer players' limbs. In accordance, this study showed that the NHE exercise is a simple exercise that can be easily implemented in the soccer players' training routine inducing eccentric hamstring force in order to allow hamstring muscles to withstand high levels of force and eccentric movements throughout various lengthening movements, consequently reducing the risk of injury. The NHE, also called the "YoYo Hamstring Curl" or "Nordic Hamstring Lowers", even if mono-articular when the trunk remains in-line with the thighs, can be easily implemented during soccer training sessions, up to 3 times per week. These exercises are suggested to not only improve eccentric hamstring peak torque, but will probably impact on sprint performance which will provide a good basis for injury prevention. In this context, it has been shown amongst French soccer players, that professionals revealed higher eccentric hamstring torques than amateurs, and were also faster on short sprints (10m), emphasizing the possible role of hamstring force on sprint performance (Cometti et al, 2001). Moreover, Saliba and Hrysomallis (2001) showed that isokinetic assessment of lower limbs showed low to moderate significant correlations with vertical jump height of Autralian footballers. Nevertheless, given the paucity of well-controlled studies dealing with eccentric strength and athletic performance, further research is still needed in this area (Brughelli and Cronin 2007).

Another possible role of eccentric exercise lies on the fact that it has been suggested that after certain types of eccentric exercise, the optimal length of tension development in muscle shifted to longer muscle lengths. In their review, Brughelli and Cronin (2007) suggest that the latter adaptation may result in greater structural stability at longer muscle lengths, therefore presenting interesting implications for injury prevention and athletic performance.

In this context, it has been suggested that optimum length may be a greater risk factor for muscle strain injuries than classical isokinetic strength ratios warranting future research in this area (Brughelli and Cronin 2007). In the context of injury prevention, with particular emphasis on eccentric training, Malliaropoulos et al (2012) have recently published a review on hamstring injury prevention. They introduced exercise classification criteria for guiding clinicians in designing and implementing strengthening programs adapted to track and field athletes. The various types of exercises presented and the principles exposed may serve as a foundation for future applications of new eccentric programs aiming at decreasing the high incidence of hamstring injury in other sports such as soccer. O'Sullivan et al (2012) have also showed the effect of eccentric exercise on musculo-tendinous flexibility (see "stretching" section of the present chapter).

Finally, evidence has suggested that eccentric strengthening is a way of potentially treating patellar tendinopathy, achile tendinopathy and hamstring strains (Fields et al, 2010), while it could also increase the strength (Potier et al, 2009; Clark et al, 2005) and the angle where the peak torque occurs (Brughelli et al, 2009).

Hamstrings have the higher risk of re-injury (Maliliaropoulos et al, 2011; Alonso et al, 2009), which cause significant problems within soccer. Although players participate regularly within a NHE program, hamstring injuries are possible due to the effects of previous injury history. Players who present hamstring injury histories, maintain a level of scar-tissue (cicatrix) deep

Week	Session per week	Sets and Repetitions
1	1	2x5
2	2	2x6
3	3	3x6
4	3	3x8

Table 3. NHE training protocol in soccer players (adapted from Iga et al, 2012)

within the injury location which has the potential to reinjure continually. The work of prevention begins also when players get injured because if it is not immediately well treat, reinjury is risk is high. The role of the technical staff and fitness coach is to use the physiologic delay that the injury requires to be totally treated and to propose progressive exercise to the players in order to lead him to an official game. Individuals involved with the rehabilitation phase (e.g. technical, medical and fitness staff) must then use the physiological delay due to injury in order to treat and to implement a progressive exercise structure aimed at bringing the player to the correct physical, injury free state leading up to an official game.

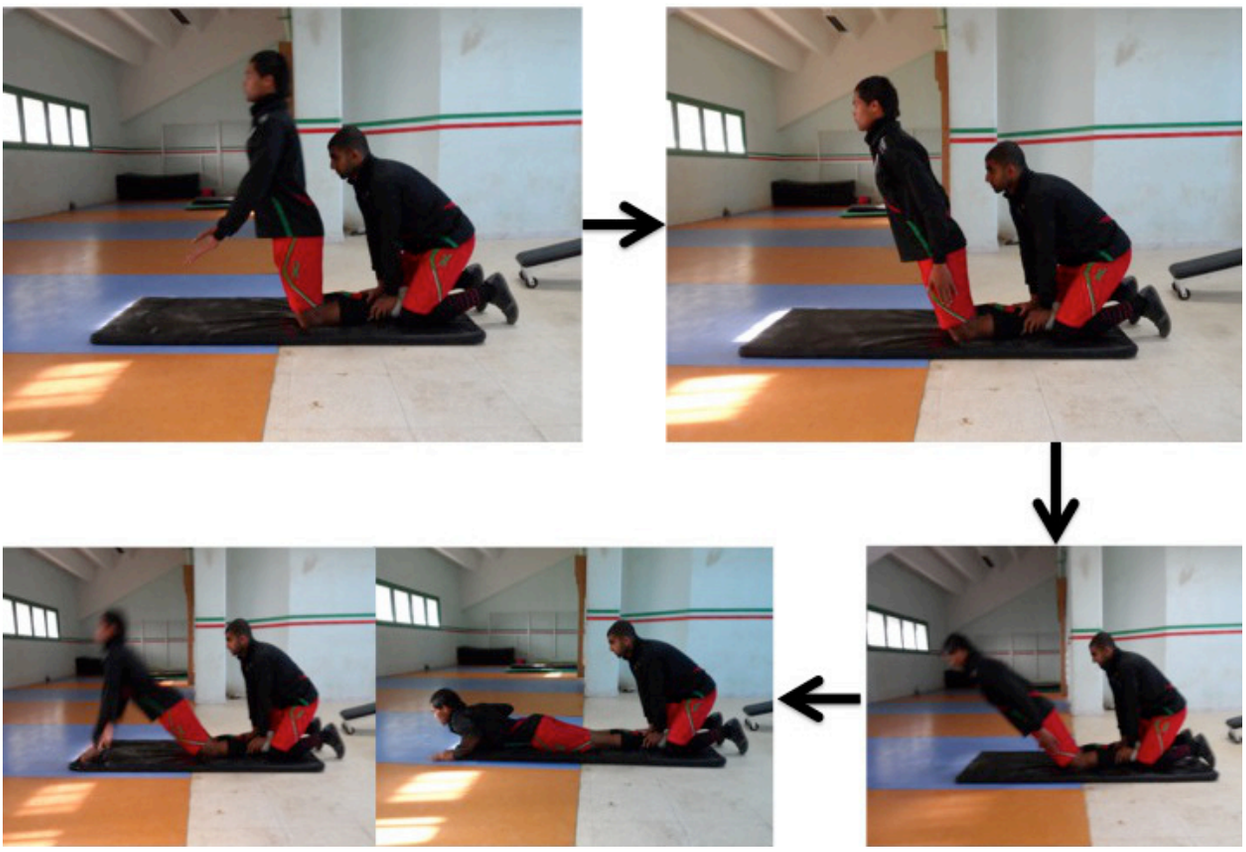


Figure 3. Illustration of a Nordic Hamstring Exercise repetition (NHE).

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2.3. Isokinetic testing

Initial research have used isokinetic testing evaluation to study the ''balance'' of the main body joints, as the knee for example, by comparing the force and power of the agonists (knee flexors) to those of the antagonists (knee extensors). This comparison was achieved by the calculation of the Hamstring/Quadriceps ratio (HQ). For a long period of time the suggested ratio was provided as Hconcentric / Qconcentric forces and ''balanced knees'' were considered for ratios ranges of 0.48 to 0.66 when measured at low (60°/s) or fast (240°/s) angular velocities (Croisier, 2004). In this context, Aagaard et al (1995) have then presented a functional H/Q ratio that was defined by calculating eccentric hamstring strength relative to concentric quadriceps strength (Hecc/Qconc representative for knee extension). They also calculated the opposite ratio, i.e., hamstring strength relative to eccentric quadriceps strength (Hconc/Qecc representative for knee flexion). The ratio was obtained at 50° (with 0° representing full extension) at angular velocities of 30, 120, and 240 °/s. They also corrected the measured values on the basis of gravity which had high influence on the change in H/Q ratio. A ratio of 1:1 H/Q strength relationship was demonstrated for fast knee extension, showing the functional capacity of the hamstrings for providing knee-joint/muscular stability at such high-speed movements. Thus, this study showed that conventional H/Q (both concentric) ratios had to be interpreted with caution as not functional. Later, Impellizzeri et al (2008), demonstrated that the isokinetic variables and ratios measured were reliable allowing their use in clinical follow-up.

In early isokinetic studies, Bennell et al (1998) suggested that isokinetic muscle strength testing (including functional H/Q ratios) was unable to directly discriminate between higher hamstring risk players of Autralian Rules Football. In this context, it has to be noted that the assessments of that study were performed in 102 senior male Autralian Rules footballers assessed isokinetically at 60 and 180°/s, which represents relatively low-speed angular velocities. In a further study, Dauty et al (2003) have investigated the relationship between knee isokinetic assessment and injuries in 28 elite soccer players on a one-year follow-up basis. They showed that a mixed ratio: Hecc/Qconc (measured at 60°/s) lower than 0.6 was associated with a previous hamstring injury history despite the resumption of competitive soccer. Nevertheless, this ratio and all other isokinetic measured and calculated variables did not predict a recurrence or a new hamstring injury. In a wider study, Croisier et al (2008) had prospectively completed the entire season follow-up in 462 soccer players, of whom 35 injured hamstring muscles. Significantly higher muscle injury risks in subjects with untreated strength imbalances compared to players with no imbalances in pre-season with a relative risk of 4.66 have been found. Nevertheless, when the isokinetic variables got normalized by appropriate strength training, the risk of injury did decrease to that of players without imbalances in pre-season (relative risk =1,43). The authors concluded that (1) the isokinetic evaluation is of great importance in pre-season for the detection of strength imbalances, as a factor that increases the risk of hamstring injury and (2) when the imbalances got restored to a normal strength profile, this induced a decrease of muscle injury risk to normal values. This study, completed on a wide sample of soccer players, showed that isokinetic assessment could be used before, and during the season, in order to detect potential at-risk players, and thereafter, work to correct the eventual observed imbalances, inducing a decrease of the hamstrings injury risk.

In the same context, Yeung et al (2009) have investigated 44 sprinters from Hong-Kong that reporting the eight of them sustained hamstring injuries during the season. The injury rate was of 0,87 per 1000-h of exposure, being higher at the beginning of the season with 58,3% of injuries occurring in the first 100-h of exposure. Statistical analysis showed that athletes with a low the H/Q peak torque ratio of less than 0.60 assessed at an angular velocity of 180°/s have a 17-fold increased risk of hamstring injury. The authors concluded that pre-season H/Q peak torque ratio assessments should be performed in order to identify the sprinters prone to hamstring injury.

Furthermore, Fousekis et al (2011) recently studied 100 soccer players from four professional teams undergoing a composite musculoskeletal assessment at pre-season with numerous associated injury-risk factors that have been controlled. Thirty-eight of the players did sustain one or several lower-limb muscle strains. Sixteen and seven of the players were clinically diagnosed for non-contact muscle strains in their hamstrings and quadriceps, respectively. For hamstrings: players with eccentric hamstring strength asymmetries, functional leg length asymmetries, and no previous hamstring injuries were at a greater risk of sustaining a hamstring muscle strain. For quadriceps: players with eccentric strength and flexibility asymmetries in their quadriceps muscles as well as the heavier and shorter players were at greater risk of sustaining a quadriceps strain. These authors concluded that soccer players showing functional asymmetries displayed a higher risk of hamstring strain. In this context, they suggested that the systematic isokinetic evaluation of the soccer players' lower limbs during pre-season can provide therapists and coaches data about the predictive elements of non-contact hamstring strains and therefore allow for eventual implementation of preventive training programs. Overall, although isokinetic exercise is widely used in rehabilitation in order to prevent injuries, apart from some situations, isokinetic assessment does does not fully predict functional measurements associated with on-field performances and injury occurrence. In this context, Rochcongar (2004) suggested that for optimal use, isokinetic assessment should be used in association with other techniques of evaluation as clinical methods and imagery to improve the quality of diagnosis.

2.4. Core stability

Within many sports, especially the team-contact sports, the need to develop the players' capacity in order to maintain possession of the ball either in rugby, hockey, or soccer for example is fundamental to the outcome of the game. Due to the nature of these contact sports, the coming contact of players when competing for the ball is part of the game and happens continually throughout the duration of the match (e.g. tackles, set-pieces). In order to be able to compete and deal with physical contact in trying to maintain possession, players must have a solid, stable, balanced core/foundation on which to produce moments of strength. Stability of the 'core' commonly referred to as the lumbar-pelvic hip complex, is crucial in providing a foundation for movement of the upper and lower extremities, to support loads, and to protect the spinal cord and nerve roots (Willson et al, 2005).

Core stability is achieved by the muscular system of the trunk providing the majority of the dynamic restraint coupled with passive stiffness from the vertebrae, fascia, and ligaments of

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the spine. It is believed that the core is made up of the paraspinals, quadratus lumborum muscle, abdominal muscles, hip girdle musculature, diaphragm and the pelvic floor muscles. Core stability is defined as the ability to control the position and motion of the trunk over the pelvis to allow optimum production, transfer and control of force and motion to the terminal segment in integrated athletic activities (Borghuis et al, 2011). Indeed, the central role of the body core for stabilization and force generation in all sporting activities is being increasingly recognized. Indeed, core stability training is seen as being pivotal for efficient biomechanical function necessary to maximize force generation, and minimize joint loads in all types of activities (Hibbs et al, 2008) ranging from running to throwing and subsequently decrease the incidence of injury (Willson et al, 2005). The player's capacity to be strong and to resist to opponents could also allow avoiding bad movement and involuntary sprain.

According to Goodstein (2011) it is important to have a strong, stable core as this impacts on all functional soccer related movements. The primary function of the core is to maintain dynamic stability of the body's center of gravity as indicated earlier. The diagrams included in Figure 4, as well as pelvic tilts and dead bugs, show different preventive exercises for reach the different aim of the core stability training. Due to the repetitive forward flexion of the core region, it is of paramount importance to strengthen the lower hip and upper extensors (Owen et al, 2013b). It is also vitally important to increase strength levels through multi-plane diagonal and rotational exercises such as those shown within Figure 4.

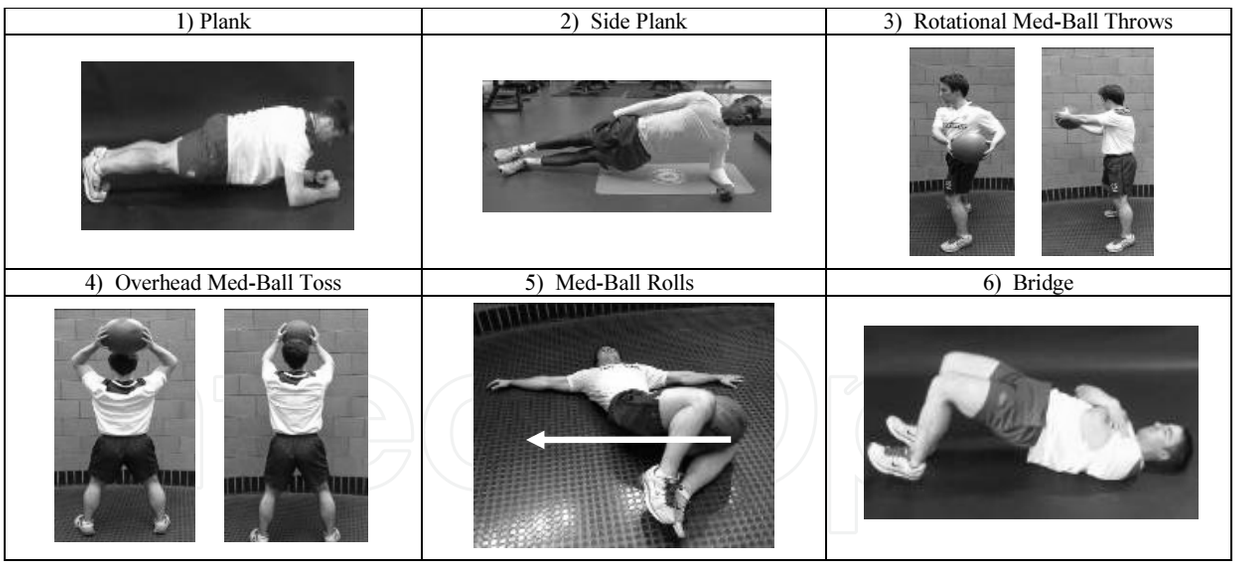


Figure 4. Core stability program (from Owen et al, 2013b)

2.5. Balance and proprioception training

The importance of training stability, balance and coordination skills are becoming more important in many disciplines (Hrysomallis, 2011; DiStefano et al, 2010). This type of training is considered to be an efficient strategy for the prevention of injury by improving functional

postural activation. The support for this training method is further substantiated by their cost effectiveness and ease to administer nature, making it accessible to clubs of all levels/status, statures and totally independent of resources and available finances. Proprioception can be defined as a specialized variation of sensory modality of touch that encompasses the sensation of joint movement and joint position (Lephart et al, 1997). Proprioception is a key component of the body physiology as it allows the neuromuscular system to maintain balance, stability and mobility while activated muscle stabilize a joint (Laskowski et al, 1997). Proprioceptors are found within joint capsules, ligaments, muscles, and tendons, and in the skin. Their main function is to make sure body joints are kept in stable avoiding damaging unstable positions.

Recent research has postulated the significant positive effect of balance training in its attempts to reduce the risk of ankle sprains in competitive team sports players and its benefits for the prevention of ankle sprain recurrences (Verhagen et al 2004). Stasinopoulos (2004) performed a research study investigating the effects of preventative interventions on the incidence of ankle inversion sprains among team sports players. It was revealed that proprioceptive training is an effective method that led to a reduced rate of ankle sprains. More specifically, ankle-strengthening exercises have been indicated to improve strength and joint position sense, in subjects with a history of ankle sprains. In this context, the implementation of balance training within elite level sport has been suggested to decrease injury rates for hamstring, patellar tendinopathy, gastrocnemius strains, and overall lower extremity issues (Willardson, 2007; Kraemer and Knobloch, 2009).

Soccer players may be predisposed to injuries due to the dynamics involved within the sport. Single leg dominance is a fundamental issue within elite level soccer and this dominance may lead to imbalances within players and predispose them to an increased risk of injury. According to Goodstein (2011) it is vitally important that soccer injury prevention programs focus on strengthening the posterior chain on the dominant side including the hip extensors, abductors, and external rotators, while strengthening the adductors and hip flexors of the non-dominant side. Indeed, these muscles are suggested to frequently become tight and weak as the antagonists of the continuing kicking motion. Balance and coordination are the basics for every sports movement, but vitally important within training and competitive soccer match-play due to the fact that the key soccer specific skills are produced from a single-leg stance. Soccer player's balance involves the entire kinetic chain (knee, pelvis, torso, and head). Earlier research involved a study following 600 male soccer players over three seasons (Cerilli et al., 2001) with half the group was placed within the proprioceptive and balance training group consisting of 20min per day for a minimum of 6 weeks training, and results showed a significant decrease of ACL injuries when compared to the control. More precisely, Caraffa et al (1996) revealed that this training program induce sevenfold lower incidence in ACL injuries both in amateur and semi-professional players. However, there were differences according to the age (adult vs. youth soccer players) and gender (male vs. female). Indeed, it was clearly showed that female players presented between 2 and 3 times higher risks of ACL injuries than male soccer male players (Vescovi and Van Heest, 2010; Walden et al, 2011). This has been shown to be caused by different morphology with especially an impaired alignment.

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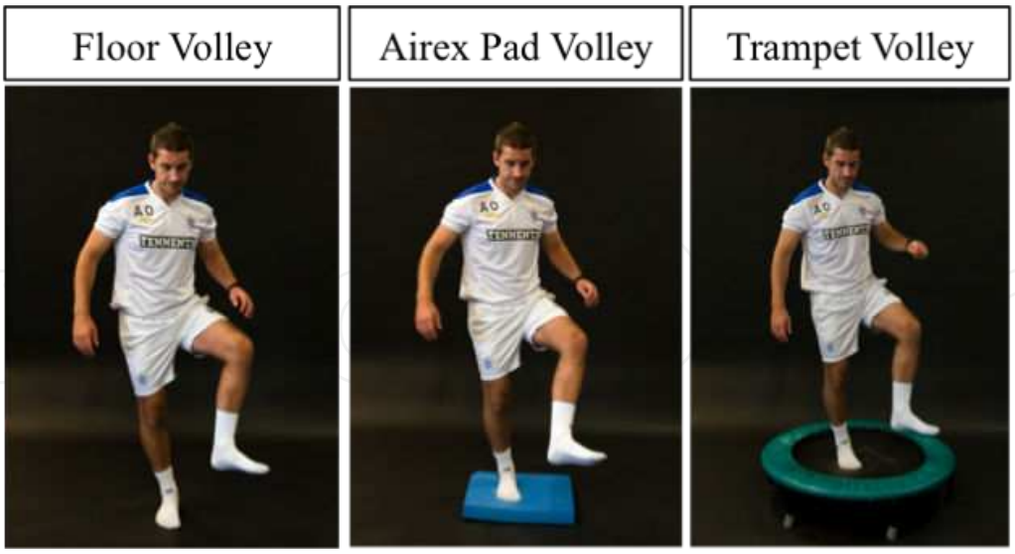


Figure 5. Proprioception program (from Owen et al, 2013b)

2.6. Plyometric and proprioceptive exercise on sand

Exercise on sand is commonly used in rehabilitation and in order to prevent injuries. Moreover, knowing that plyometric is considered as a method allowing reducing the severity of injuries (Heidt et al, 2000, Chimera et al, 2004; Miyama et Nosaka, 2004), several technical staff and fitness coaches use the combination of plyometric and proprioception on the sand in order to reduce the risk of lower limb's joints sprain and to increase the proprioceptive capacity. Impellizzeri et al (2010), have showed that plyometric training on sand improved squat jump height, and sprint performance (10 and 20m) while the muscle soreness was lower as compared to plyometric training applied on grass. This was probably due to effects on neuro-muscular factors related to the stretch-shortening cycle. Unfortunately, no studies have demonstrated that this prevention training reduces the risk on injury. Future studies are needed to work on this field.

2.7. Stretching

There are several types of stretching, nevertheless, static stretching is the most common form used worldwide (Fields et al, 2010). Passive static stretching consists of an athlete lengthening a muscle group and holding the position for a set duration ranging from 10 to 60-s. For a long period of time it was believed that static stretching had many potential positive benefits, of which one was the prevention of muscle injury. Thus, despite the data reported in the scientific literature, the consensus among sports coaches and practitioners still leans in favor of the use of stretching in each training session (Fields et al, 2010). In this context, Shehab et al (2006) have published a survey showing how strong belief in stretching remains among coaches. They showed that 95% of coaches believed that pre-exercise stretching decreases injury risks and 73% of them felt that there were no drawbacks at all with the use of stretching during training.

Nevertheless, despite its large use among sport practitioners, stretching does not seem to clearly prevent muscle injuries.

In this context, two large meta-analyses came with strong evidence to question the value of pre-exercise stretching as a part of training routine of runners. A review of 12 major studies including 8806 runners investigated the role of passive stretching in possibly preventing lower limbs muscle injuries. The results showed that were no trends showing any beneficial effect of stretching in preventing running injury. In their comprehensive meta-analysis of articles spanning 1997-2002, Thacker et al (2004) examined the role of pre-exercise passive stretching to prevent sports injuries showing that there was no evidence at all for any reduction in the injuries in general, and muscle injuries in particular. These two large meta-analyses reinforced the findings of original investigations that had rather surprisingly showed a trend toward a small increase in injuries among runners who stretched compared to control groups, going against the intuition of many sports practitioners. In this context, Van Mechelen et al (1993), conducted a randomized trial with 421 runners with stretching, warm-up, and cool-down performed before and after running. The results showed a slightly lower injury rate in the control group compared to the one that used static stretching as a pre-running intervention. Later, Pope et al (2000) studied 1538 military recruits assigned to either static stretching or a no-intervention control group also showing no difference between groups for the injury rate. Twellar et al (1997) reported a 4-years prospective trial results, showing no evidence that flexibility decreased sports injuries, suggesting again, that flexibility from stretching was not necessarily a beneficial attribute to runners. Accordingly, in their review, Herbert and Gabriel (2002) concluded that static stretching had no effect on delayed muscle soreness or injury rate. In the same context, Andersen et al (2005) published a meta-analysis of original studies. The main results showed that with respect to injury risk, the combined risk reduction of 5% indicates that the stretching protocols used in these investigations do not meaningfully reduce lower limbs injury risks of army recruits undergoing military training. Later, in their original investigation, Arnasson et al (2008) reported hamstring strains and player exposure prospectively collected during four consecutive soccer seasons (1999 to 2002) for 17-30 elite soccer teams from Iceland and Norway. These authors clearly showed that there was no difference in the incidence of hamstring strains when comparing the teams that used flexibility training program and those who did not.

Conversely, the study of Hartig et al (1999) reports conflicting results. These authors studied two different military companies undergoing basic training at the same time. Hamstring flexibility was assessed at the start and end of the 13-weeks infantry basic training program. The control group was composed of 148 subjects that proceeded through normal basic training, i.e., not including any stretching. The intervention group composed of 150 members underwent the same program but added three hamstring stretching sessions per week. The results showed that hamstring flexibility significantly increased in the intervention group vs. the control group. Along, with flexibility, the number of injuries was also significantly reduced in the intervention group. Forty-three injuries were reported for the control group giving an incidence rate of 29.1% compared to the 25 injuries in the "stretching" group for an incidence of 16.7%. In this particular study, the number of lower limbs overuse injuries was significantly

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lower in the infantry basic trainees that achieved increased hamstring flexibility at the end of the training intervention. Nevertheless, these authors did not categorize the types of the reported injuries, and therefore, data about muscle injuries can not be extracted from this study. Of interest, is the fact that this study data have suggested that flexibility demonstrates a significant U-shaped relationship with the incidence of injury; subjects at both extremes of flexibility are at more risk than the average group. This raises the need to study flexibility and injury rates in the "normal" range of flexibility, as both, too stiff or too flexible subjects might flaw the investigations' results. Therefore, unless a need for an extreme range of motion as needed for some rare sports as gymnatics, it seems not necessary to reach very wide ranges of flexibility, as this might be linked to an augmented risk of injury.

In this context, it is also of interest to note that whether stretching has a potential but discussed role in the prevention of muscle injuries might also depend on the type of sport practiced (Witrouw et al, 2004). Indeed, these latter authors believe that part of the contradictions that are reported by the literature regarding the effects of stretching on injury prevention can be explained by considering the type of sports practiced. They state that sports involving bouncing and jumping activities with a high intensity of stretch-shortening cycles (SSCs) as soccer require a muscle-tendon unit that is compliant enough for being able to storing and release the high amount of elastic energy that will therefore benefit performance. If the athletes of such sports have non-compliant muscle-tendon units (MTU), the energy absorption and release could exceed the capacity of the MTU, leading to increased risk of injury. Consequently, the rationale for injury prevention in these sports is to check for non-compliant (stiff) athletes and train them for flexibility. In contrast, in the sports containing low-intensity SSCs as for jogging, cycling, or swimming, there is no special need for a very compliant MTU. Indeed, in such sports, most of the power generation comes from active muscle activity which is directly transferred through the tendons to the articular system in order to generate motion. Therefore, flexibility training inducing very compliant MTU may not be advantageous. This conjecture is supported by the literature about runners (see above) where strong evidence exists of no beneficial effect of static stretching on injury rates in these sports.

Another consideration about flexibility training is the "timing" of stretching for optimal injury prevention (Fields et al, 2010). In this context, many athletes have adopted the strategy of stretching post-activity rather than before. Indeed, one investigation provides data showing that this might offer injury protection. Verrall et al (2005) have published a prospective study in which they followed hamstring injuries in a single soccer team through four playing seasons. The intervention program consisted of the athletes stretching after practicing and while fatigued (end of session). The intervention also comprised sport-specific training drills with an emphasis on augmenting the amount of high intensity interval training. The results favored the intervention in that in pre-intervention 9 and 11 players sustained hamstring injury compared with 2 and 4 after intervention. In addition there has also been an effect on the severity of injuries. Indeed, competition days missed were reduced from 31 and 38 to 5 and 16 after intervention (Verrall et al, 2005). Therefore, it seems safer to stretch in post-sessions rather than before.

In the context of flexibility training, it is of interest to stress that a good (normal) flexibility might be achieved not only by static stretching, but also by other means as eccentric exercise. Indeed, O'Sullivan et al (2012) have recently systematically checked six electronic databases to identify the randomized clinical trials having compared the effectiveness of eccentric training to either a different intervention, or a no-intervention group on flexibility. Both studies assessing flexibility using range of motion and muscle fascicle length were included. This meta-analysis individualized six studies that met the inclusion/exclusion criteria showing consistent, strong evidence in all the six investigations in three different muscle groups that eccentric training improves lower extremity flexibility. Therefore, obtaining a "normal" range of motion can not only be achieved by post-session static stretching, but also by eccentric exercise.

Static stretching has been questioned not only for its potential role in slightly increasing injury risk, but also for its' detrimental effect on sport performance. In this context, Behm and Chaouachi (2011) have provided recommendations as to the use of stretching in sports. There are clear differences of the effects of static or dynamic stretching on sport performance. Thus, the latter authors have suggested that a warm-up to minimize impairments and enhance performance should not include static stretching and rather be composed of a submaximal intensity aerobic activity followed by large amplitude dynamic stretching followed by sport-specific dynamic activities. For the sports that necessitate a high degree of static flexibility, warm-ups should include short duration static stretches with lower intensity stretches in a trained population to minimize the possibilities of sports performance impairments. Indeed, Chaouachi et al (2008) have shown that the detrimental effects of static stretching on performance are less pronounced in subjects use to such static stretching. In this context, future studies should investigate the effects of dynamic stretching on injury prevention, since recent literature have shown that dynamic stretching should be used rather than static stretching, increasing number of practitioners have replaced the static stretching in their training programs, by active dynamic stretching.

Therefore, the present chapter authors do believe that intense static stretching should be avoided during warm-up and training sessions and should rather be performed at the end of the sessions for flexibility training purposes. The latter, could also be achieved through other means, as eccentric exercise which has also many potential positive effects muscle injury prevention (see the "*Eccentric exercise*" section of the present chapter).

2.8. Training load (intensity & volume) — The training approach

Periodization, and the capacity to plan and design a schedule with the appropriate training load (intensity, volume, and frequency) is a key factor in attempt to avoid injury. In this this context, the term 'advanced planning' or 'periodization' should be considered as a functional injury prevention strategy. Every individual involved with the physical development of players (e.g. technical, medical and conditioning staff) have their own views on the planning, design and execution of training programs but whatever the method is planned and used, the final target is to manage and manipulate the players fatigue and level of performance whilst minimizing injury risk. More often than not, the technical staff spend more time exerting the players through technical drills and SSGs, however, the conditioning or medical staff are held

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responsible for injuries. This section of this book chapter aims to highlight the role of the technical staff in injury prevention techniques and through advanced planning or periodization of training, they will limit the risk of imposing accumulated fatigue upon their players which lead to muscle strains or overuse injuries.

As indicated previously, hamstring injuries are the most prevalent muscle injury in professional soccer. Due to the multifactorial nature of these injuries it's becoming increasingly apparent that the interplay between these factors has a significant role to play when we consider how we should best attempt to prevent these injuries. The game has significantly evolved over these last two decades and performance data provided each season is showing significant increases in position specific performance markers (Di Salvo et al, 2007). Coaches are considered to have the greatest influence on player development; the next generation of professional coaches needs to be able to deliver quality sessions that can achieve multiple outcomes. This would include a coaching curriculum that stretches the players over a season whilst ensuring injury rates are maintained at an acceptable and hopefully low rate with an optimal performance. In this context, it is of interest to note that the RPE (rating of perceived exertion) method has been validated for training load monitoring purposes in numerous sports, of which soccer (Impellizzeri et al, 2004). Only rare scientific studies have reported training load manipulation and injury rates measures. In this context, Gabett (2004) have showed in rugby league Australian players, using the RPE-method to monitor training load, that the manipulation of the latter variable induced alterations in the injury rate. Indeed, when pre-season training load was set at high standards, this induced higher muscular injury rates compared to seasons when the training load was reduced. It is of interest to note that high pre-season loads were not only detrimental for injuries in general, and muscle injuries in particular, but also had a negative effect on aerobic fitness. Therefore, in order to achieve good endurance fitness and low injury rates, the training load has to be monitored and maintained at relatively low standards. In this context, it is the opinion of the present chapter authors, that team sports as soccer do not need very high levels of physical training loads. Rather, the technical staff should monitor the latter training variable and emphasize on optimal fitness training while insisting on technical and tactical training which is of paramount importance of the outcome of the games.

According to recent research by Owen et al, (2013a) due to the varying physical and technical demands of particular sided game formats (3vs3 to 11vs11), in elite professional soccer, performing the correct type of sided-game at specific times of the training week may enable technical, sports science and conditioning staff to maximally prepare players physically, technically and tactically thus increasing the efficiency of their training sessions and weekly schedule. This may be beneficial to the players from an injury prevention perspective as well as performance enhancement in relation to applying an overload of different energy systems and inducing higher speeds at the correct time in order to minimize the fatigue risk effect moving towards competitive match-play. Arguably, this strategy of 'advanced planning' may be the most important factor influencing injury prevention due to the fact that the technical staff implement and dictate most of the pitch based training sessions. Advanced planning between technical, conditioning and medical staff is vital in order to elicit the correct volume,

duration, and intensity of training and ensure maximum player freshness pre-game (Owen et al, 2013a).

3. Which prevention program should be used?

The previous review of literature presented in this book chapter and describing the different methods of prevention strategies, should help the coach, the technical staff and the medical staff to reduce the injury occurrence. They have to adapt the prevention program according to the sport, the athletes' morphology, age, gender, their injury history, and the period of the season.

First of all, all players should to be tested at the beginning of the pre-season in order to detect what prevention program they eventually need. They should be tested in isokinetic, functional strength, mobility (lumbar-pelvic, ankle, knee, hip), flexibility, balance and theirs morphologies. These results have to be combined to their injury history. All of these information will allow to draw the needs for each player, and therefore designing individual specific prevention programs.

A Cochrane review by Goldman and Jones (2010) on such interventions concluded that there was insufficient evidence from randomized controlled trials to draw conclusions as to the effectiveness of interventions used to prevent injuries. This current lack of evidence for interventions and the current high incidence of injuries seen in the game could also suggest that injuries should be considered multifactorial in their etiology. Therefore, we have yet to understand how works the interplay between all of the intrinsic and extrinsic factors that may contribute to each specific injury. It could also be suggested that there is some element, be it intrinsic or extrinsic, in the day to day management of the players that maybe a significant contributing factor in the aetiology of these injuries and we have yet to establish what this might be.

For example, a recent large scaled randomized controlled trial by Petersen et al (2011) addressed the efficacy of the Nordic hamstring exercise program for preventing acute hamstring injuries in soccer players. They found that introducing this ten weeks program to reduce eccentric weakness, a common intrinsic factor associated with hamstring injuries, reduced the incident of these injuries by 70%. This backed up previous findings by Arnason et al (2008). Using a larger sample size Arnason's study looked at a total of 24 teams, with over 650 soccer players, over a four years period. These players were from professional soccer teams in the Icelandic and Norwegian leagues. The study showed that teams combining the Nordic eccentric exercise protocol and the stretching program were on average seeing 65% fewer hamstring injuries. However, when we look closely at the Nordic hamstring exercise it's clear to see that it only involves movement at one joint-the knee. We know that the hamstrings work over two joints, the hip and knee, and when we consider the mechanism of hamstring injuries then the Nordic hamstring exercise clearly doesn't replicate any of the functional activities used in football specific training.

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Each player needs a specific program according to his injury risks (Table 4) which has been determined by the pre-season tests, his injury history, morphology, and his playing positions. Indeed, Mallo and Dellal (2012) have showed that the frequency of injuries was not uniformly distributed by playing positions with forwards and central defenders sustaining the greatest number of injury episodes and the highest match absence. Consequently, it is important to link the prevention program in taking in consideration the playing positions of each player in team sports.

	Strain / tear injury	Sprain	Anterior Cruciate Ligament	Groin Pain
Functional strength	X	X		X
Eccentric exercises	X			
Core stability		X	X	X
Isokinetic	X		X	
Balance/proprioception	X	X	X	X
Stretching	X		X	X
Plyometric and proprioceptive exercises on sand	X	X	X	
Training load	X	X		X

Table 4. Prevention exercises to applied for decrease the injury risk.

4. Which factors affecting injury risk?

It has been identified in two studies by Heiderscheit et al (2010) and Orchard et al (2005) that clinical experience shows us that it is extremely difficult to decide at which point during rehabilitation the athlete is ready to a return to sport, and thus this is usually based on subjective evidence. These difficulties may well be the reason why there is a conspicuously high injury recurrence rate, particularly within the first few weeks of a return, as identified by Walden et al (2005). Additionally, there are a difference of risk injury according to the age (adult vs. youth soccer players) and gender (male vs. female). Indeed, it was clearly showed that female players presented between 2 and 3 times higher risks of ACL injuries than soccer male players (Vescovi and Van Heest, 2010; Walden et al, 2011). It is cause by different knee morphology with especially an impaired alignment. All these information show that different factors could affect and be at the origin of an injury

4.1. Factors impacting the injury risk

- **Warm up.** Adapted warm up is considering as a prevention strategies because it reduces the injury risk (Fields et al, 2010; Soligard et al, 2010). These studies showed that a specific intervention program based on specific "The11" FIFA warm up focusing on core stability, eccentric training of thigh muscles, proprioceptive training, dynamic stabilization and plyometrics with straight leg alignment induce lower knee injuries in comparison to a

control group. This is contrasted by Junge et al (2002) who did not find that "the11" had a preventive effect on youth soccer players, probably due to the fact that youth players are growing and they don't have a control of a large pattern. Olsen et al (2004) confirmed that specific warm up and cool down, adapted training shoes analyzed, prophylactic taping (especially in players formers sprain and ankle instability), reduce the injury risk.

- **Congested period.**Dellal et al (2013) and Dupont et al (2010) have shown that a congested period could affect and increase the injury risk. Consequently, when a team plays 6 or 7 matches in about 20 days for example, a global preventive plan has to be settled including the training load monitoring, the use of post-efforts recovery method (alternating cold and hot water immersion for example)

- **Change of temperature and external conditions.** To the best of our knowledge, no study has ever attempted to show if the brutal change of external temperature has any effect on the injury occurrence. However, it is suggested that several fast change of temperature from heat to cold induce a greater risk of injury, especially hamstring strain (personal unpublished observations). Moreover, the external conditions could modify the type of grass pitch and therefore, the run and the footstep will be altered too. When the pitch is firm, hard or soft, it affects the players' muscle contraction pattern at ground contact and thus could increase the risk of injury. For example, when the pitch is "heavy" the fatigue appears more quickly, especially at the hamstrings but to the best of our knowledge, no study has ever investigated this.

- **Equipment modification and playing surface.** Specific running shoes adapted to the players' anatomy (if the players is under pronation, supination, genu varus and rear foot with varus) could possibly be a preventive injury risk factor to be a determinant factor (Fields et al, 2010), but this has not been widely investigated. However, it is essential for the staff to pay a special attention that each player having the adequate equipment for playing football, running, to perform strength exercise training (belt), or stretching (carpet). The playing surface has a essential roles (Ekstrand et al, 2006), but as it was showed, this is the change of playing surface which induce an increase of the injury risk.

- **Fatigue and training monitoring.** The workload is the key factor to prevent injury. Periodization, and the capacity to plan and to design a schedule with the appropriate intensity and frequency of training is a key factor to avoid injury and in this context, it should be consider as a prevention strategy. Every coach, technical staff and fitness training have a special view of the planning design but whatsoever the method used, the final target is to manage and manipulate the players fatigue and level performance and to avoid injury. Technical staff has to determine and control precisely the training and the match performance.

- **Playing positions.** It was showed that the frequency of injuries was not uniformly distributed by playing positions with forwards and central defenders sustained the greatest number of injury episodes and the highest match absence (Mallo and Dellal, (2012) whereas it was the wide and central midfielders who have the lowest number of injuries during two consecutive season in Spanish professional soccer players. Complementarily, Woods et al (2004) revealed that defenders sustained 15% more hamstring strains than forwards.

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However, Debedo et al (2004) demonstrated the opposite results with forwards sustained 10% more hamstring strains than defenders. Whatever, the prevention program has to be plan according to the playing position, the region, the country and the championship.

- **Injury history and re-injury.** As it was previously described, the injury history is a determinant factor to design the prevention training for players (Hagglund et al, 2006). The different adaptation resulting from previous injuries will direct the manner to manage the prevention program and to be careful for one or more specific players. Previous injuries, which are not well treated, could be the origin of a re-injury (in the same scarb area). In this context, it is very important to take the time in order to the organism recover totally its physiological and biomechanical components. The rehabilitation work, the prevention exercises and the re-training needs to pay a special attention after players took part in the collective training. The high risk of re-injury concerns the hamstring strain, and indirectly, after an ACL, there are a possibility of compensation and of re-injury on the same knee, and the contro-lateral knee, or muscle (hamstring, quadriceps, gastrocnemius).
- **Nutrition and dehydration.** A bad management of the food and the fluid intake could increase the risk of injury according to the period of the season and external conditions. Appropriate nutrition, regular and adapted hydration is the basic behavior to have.
- **The period of the season.** The risk of injury differs according to the period of the season. To illustrate it, the highest incidence of sprains was achieved during pre-season and the beginning of the competition period. The risk to sustain a muscular strain peaked at the beginning and in the final weeks of the competition period and was related (r=0.72; P<0.05) to mean heart rate during training. (Mallo and Dellal, 2012). Concerning the in-season, recent research has shown that performing an injury prevention program twice weekly for the entirety of the entire season (58 prevention sessions) can lead to significantly less muscle injuries. The findings from this study identified a multi component injury prevention training program may be appropriate for reducing the number of muscle injuries during a season but may not be adequate to reduce all other injuries. A recent study by Mendiguchia and Brughelli (2012) has attempted to provide a return-to-sport algorithm. In general, the pre-season requires a greater proprioception (ankle and knee), eccentrics, core stability and stretching program whereas the in-season needs to increase the attention to prevent the sprain with each player participating in a specific preventive training. However, sometimes it is no chance due to player-to-player contact, because it could reach 32% of the injury causes.

4.2. Prevention in young soccer players

The injury risk and the type of injury are age dependent. Soligard et al (2010) suggested that most earlier the prevention program is started, greater will be the effect. Literature showed that youth soccer players have between 61-82% of overall injuries located at the lower extremity especially at the ankle (28%) and knee (19%) (Emery and Meeuwisse, 2010; Junge et al, 2002). The incidence of injuries decreases with a specific strength program (resistance training) in youth soccer players during in-season and off-season (Lehnhard et al, 1996). Emery and

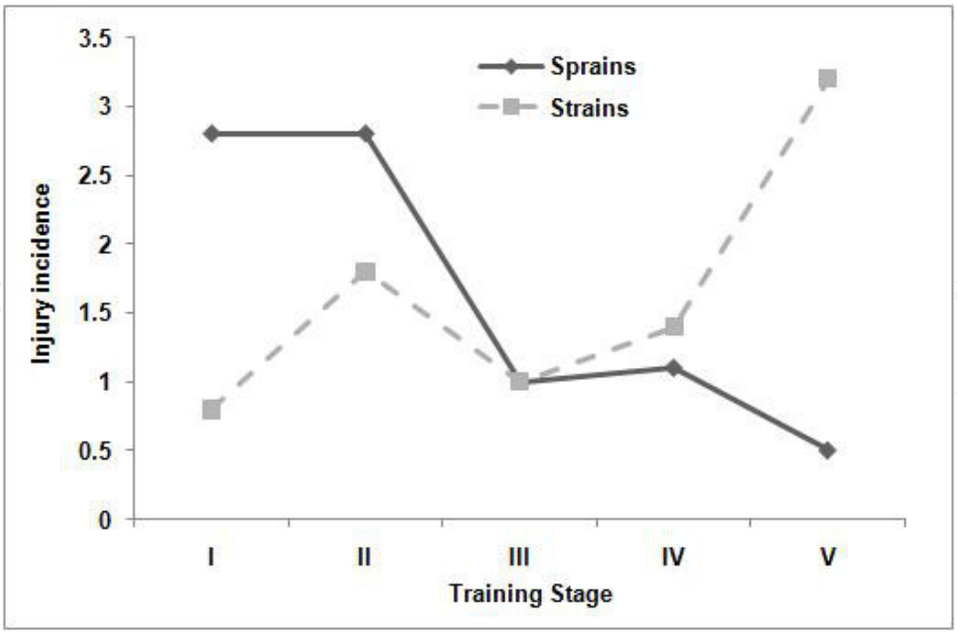


Figure 6. Ligament sprains and muscle strains incidence (per 1000 hours) during each training stage during two consecutive seasons (from Mallo and Dellal, 2012)

Meeuwisse (2010) added that most studies showed a high effect of an intervention until 88% reduction in injuries. Specifically, they showed that prevention strategies including hamstring eccentric exercise, neuromuscular training, warm up, balance board exercise, and core stability induced lower risks for acute injuries, lower extremity injuries, ankle sprain and knee sprains than no intervention strategy in youth soccer players (U13-U18). In this context, injury prevention strategies should be applied very early in youth soccer players' categories.

5. Conclusion

This particular book chapter has tried to provide an analysis of the main injury prevention strategies commonly used in soccer with the primary aim being to decrease the injury rates during both soccer training and matches. The combination of different prevention methods (functional strength, eccentric strength, isokinetic ratio, core stability, balance, proprioception, stretching, flexibility, stability, work on sand) have not been discussed due to the fact that each of them as a separate method has been reported to reduce the risk of injury.

However, the key point running throughout the chapter is the necessity to individualize prevention programs according to the athlete or players injury history, morphology, gender, age, testing data (e.g. medical and fitness tests) and their playing position. As suggested, pre-season training allows a foundation to be provided through general and sport specific training (i.e. specific musculature, joints, tendons) whereas the competitive period needs individual preventive exercises (i.e. aimed at hamstring/quads). Moreover, the prevention exercises need

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adjustment according to the collective training in positioned the exercises before, during or after the training (or before and after games).

Additionally, recovery strategies have constituted a prevention strategy in order to reduce injury risk because they decrease the soreness. In, this context, hydrotherapy (after training and matches), a good nutrition and hydration with supplements for some players (during, before or after the training and matches). The technical staff should also considered the warm up, the number of match played (congested period), the change of temperature, the type and change of playing surface, and adapted shoes as a preventive strategies.

Finally, all these prevention strategies will be efficient if they are include in the training, and considering the individual characteristics of all players as a unique person. However a complementary question is when the players could take part in the collective training after a specific injury.

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