Implementing strength training strategies for injury prevention in soccer: Scientific rationale and methodological recommendations

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Abstract

Due to the negative effects that injuries have on performance, club finances, and long-term player health (permanent disability after a severe injury), prevention strategies are an essential part of both sports medicine and performance.

Purpose: This commentary aims to summarize the current evidence regarding strength training (ST) for injury prevention in soccer and to inform their evidence-based implementation in research and applied settings.

Conclusions: The contemporary literature suggests ST proposed as traditional resistance, eccentric, and flywheel training may be valid methods to reduce the injury risk in soccer players. Training strategies involving multiple components (*e.g.*, a combination of strength, balance, plyometrics) which include strength exercises are effective at reducing non-contact injuries in female soccer. Additionally, the body of research current published support the use of eccentric training in sports, which offers unique physiological responses compared to other resistance exercise modalities. It seems that the Nordic hamstring exercise, in particular, is a viable option for the reduction of hamstring injuries in soccer players. Moreover, flywheel training has specific training peculiarities and advantages which are related to the combination of both concentric and eccentric contraction, which may play an important role in injury prevention. It is authors' opinion strength and conditioning coaches should integrate the ST methods here proposed in their weekly training routine to reduce the likelihood of injuries in their players, however, further research is needed to verify the advantages and disadvantages of these training methods to injury prevention using specific cohorts of soccer players.

Keywords: Football; Performance; Team Sports; Flywheel; Resistance training; Eccentric

Introduction

Scientific rationale and justification of strength training strategies for injury prevention in soccer

The high participation level in soccer with over 265 million FIFA-registered players worldwide, together with its challenging physical demands, suppose a raised injury prevalence.[1] In fact, an average professional soccer team with a 25-player squad typically suffers about 50 injuries (minor and major combined) during the course of a season.[2] For the average player, this means between 1–2 injuries resulting in a layoff time of 24–37 days from competition and practice.[2,3] Due to the negative effects that injuries have on performance (low injury rate strongly correlates with competitive success),[4] club finances,[5] and long-term player health (permanent disability after a severe injury),[6,7] prevention strategies are an essential part of both sports medicine and performance.[8]

It has been shown that 8.1 injuries/1000 hours of exposure occur in soccer, with an injury incidence 10 times higher during competitive matches than during training.[9] Furthermore, it is well known that the most common injury occurs, as expected, in the lower limb, in particular at the muscle/tendon level (4.5 injuries/1000 hours of exposure).[3,9] These injuries represent around 40% of total injuries, showing a high recurrence rate (between 12 and 48%).[4,5,9] Most of the soccer-related injuries had a traumatic mechanism,[10] with an incidence two times higher than the incidence reported in overuse injuries.[9] However, the most severe injuries have been reported during non-contact actions, such as sprinting and cutting, representing approximately 30% of all cases of traumatic injuries.[10] Traditionally, the presence of injuries in team sports has been related to extrinsic factors (*e.g.*, rules, protective and sports equipment), non-modifiable intrinsic factors (*e.g.*, age, sex, injury history), and modifiable intrinsic factors (*e.g.*, player load, warm-up preparation, muscular imbalances and function).[11,12]

Recently, Emery et al.[13] have established that *"primary prevention of injury may be the "low hanging fruit",* which may have the greatest impact in reducing the amount of musculoskeletal injury. In particular, previous research reported that a mix of strategies (*e.g.,* strength training [ST], core training, balance) can have a positive effect on performance[14] and reduce the risk of injuries in soccer players. Moreover, Brunner et al.[15] reported that lower extremity muscle strength and balance exercises should be prioritised in lower extremity injury prevention programmes for team-sport athletes. However, one of the main limiting factors for the effectiveness of preventative programmes is the poor long-term compliance of the players.[16] For this reason, practitioners could be invited to include neuromuscular and ST, during warm-up protocols, which may become one of the main prevention strategies.[13] For example, the FIFA 11+ programme has previously reported to induce a substantial injury-preventing effect by reducing soccer injuries by 39% compared to control protocols.[17] This programme has been reported to be effective in reducing, for instance, groin injuries (which represent 4-19% of all time-loss injuries) but other programmes (*i.e.,* adductor strengthening programme using the Copenhagen adduction exercise) have been shown to be effective as well.[18,19] However, among all training strategies traditionally used by strength and conditioning (S&C) coaches, ST is the prevention method that has shown the greatest benefit in reducing the acute and overuse sports injuries rate by an average of 66%, and were able to more than halve the risk of sports injury.[20] In addition, a positive dose–response relationship between ST and sports injury prevention has been previously reported.[21] This phenomenon may be due to the fact that ST supposes a better neuromuscular function of the involved musculature, improving coordination, strengthening of adjacent tissues reducing critical joint loads, and increasing psychological perception of high-risk situations.[21] Consequently, scientific information and recommendation should be provided to S&C coaches on how to accurately design and prescribe ST strategies for non-contact injury prevention in soccer. Therefore, this commentary aims to summarize the current evidence regarding strength training for injury prevention in soccer and to inform their evidence-based implementation in research and applied settings.

Evidence-based strength training methods for injury prevention in soccer

Traditional resistance training

It is important to first identify that traditional resistance training is a term that encompasses many methods or exercises. For example, exercises that are bilateral or unilateral, with or without external load, free-weight (*e.g.*, barbell, dumbbells, kettlebells) or resistance machines, can all fit into this category.[22]

A recent meta-analysis investigated the effectiveness of training interventions used in female soccer, with the intention of reducing non-contact injuries.[23] Unsurprisingly, multiple components were typically programmed in each intervention (*e.g.*, a combination of strength, balance, plyometrics). However, of the 11 studies included in the final analysis, strength was the most commonly programmed physical component, with all but a single study employing strength exercises. Collectively, the injury incidence ratio (IRR) favoured training interventions over matched controls (IRR = 0.73 [95% CI 0.59, 0.91]), indicating that training strategies which include strength exercises are effective at reducing injuries. Furthermore, these training strategies were also effective at specifically reducing anterior cruciate ligament (IRR = 0.55 [95% CI 0.32, 0.92]) and hamstring injuries (IRR = 0.40 [95% CI 0.17, 0.95]). Despite most studies utilizing strength exercises and this promising data in favour of ST to reduce the incidence of injury, it is worth noting that few studies successfully respect the following criteria: a minimum of two sets and at least one form of progression implemented throughout the intervention.[23] Previous research has highlighted that traditional resistance training should use loads $\geq$ 85% of one repetition maximum (1RM), which equates to approximately six repetitions.[22] Thus, it appears that there is still scope to conduct training interventions with heavier loads and some form of progression, in soccer athletes, using traditional resistance training formats, especially in light of recent evidence on team sport athletes.[24] Nevertheless, a recent systematic review investigated the effectiveness of training interventions to prevent muscle injuries in male elite players,[8] and contrariwise to female athletes, found limited scientific evidence to support exercise-based strategies to prevent muscle injury. For further information, the readers are addressed to the following paper by Fanchini et al.[8]

Eccentric training

The high presence of eccentric actions in soccer, such as decelerations, changes of direction, and sprints, has generated interest on eccentric exercise among S&C coaches and medical staff, especially since a high proportion of the injury incidence collected in soccer occurs in the running "swing-stance" transition period (*i.e.*, eccentric phase of sprinting).[25–28] Compared to traditional concentric based training, eccentric training may produce similar or greater adaptations in the neuromuscular system, including function and cross-sectional area, ultimately leading to increases in performance and injury mitigation.[8,29,30]

A recent meta-analysis has demonstrated that injury prevention programs that include the Nordic hamstring exercise in isolation or in combination with other exercises (*e.g.*, strength, balance and trunk exercises) decrease the risk of hamstring injuries among soccer players by up to 51% long term.[30] This notion was supported by Buckthorpe et al.,[11] who identified reduced eccentric hamstring strength as one of four key risk factors for the occurrence of hamstring injuries (along with previous injuries to the hamstrings, weekly speed exposure and resistance to fatigue in the hamstrings). Additionally, eccentric training vs. lumbo-pelvic training were recently investigated for the prevention of hamstring injuries.[31] Evidence for lumbo-pelvic training is limited with only one study showing an association between anterior pelvic tilt, lateral trunk flexion and increased hamstring injury.[32] In contrast, a number of studies have now demonstrated the efficacy of the Nordic hamstring exercise for the reduction of hamstring injuries.[33–35] Thus, it seems that eccentric strength training, and the Nordic hamstring exercise in particular, are viable options for the reduction of injuries in soccer players. Furthermore, recent reviews by Suchomel et al.,[36,37] have described various eccentric training modalities including accentuated eccentric loading (AEL) with proposed adaptations based on load and the velocity of the eccentric muscle action. With eccentric training, coaches can prescribe loads above what an athlete can lift concentrically, thus providing a further opportunity to overload the neuromuscular system.[38] For example, via the use of a weight release system (or the use of spotters), AEL training enables the athlete to lift a heavier load during the eccentric phase compared with the concentric phase, the load is then reduced, and the athlete can then perform the concentric phase.[39] Contrariwise, plyometric training used as an alternative to reduce hamstring injuries in adult male amateur soccer players did not prove its validity in a recent trial with 400 players. This study reported no statistically significant differences in hamstring injury incidence (odds ratio = 0.89 [95% CI 0.46, 1.75]) or severity between the groups.[40]

Flywheel training

To promote eccentric overload during ST, non-gravity-dependent technology such as isoinertial flywheel devices have been introduced.[41–43] This technology allows us to accentuate eccentric actions by using the energy stored in the flywheel system after a maximal concentric action (*i.e.*, inertial kinetic energy that results from the unwinding of the flywheel's strap) when a brief and concentrated braking action occurs at the end of the eccentric phase.[44] S&C coaches can manipulate exercise intensity using different flywheel wheels, which are characterized by the different moment of inertia.[26,42,44] Thus, lower inertias with higher velocities, shorter eccentric-concentric coupling time and greater power production were suggested to favour explosive muscle characteristics adaptations, whereas higher inertias with lower velocities were shown to call for greater eccentric load.[45,46] This technology has shown functional and structural changes related to sports performance optimization such as gains in muscle mass,[47,48] concentric and eccentric force,[48] changes of direction performance,[41,49,50] and running speed, [28,51] as well as injury risk reduction.[26–28]

It appears that the greater overall load and mechanical stress placed on the muscle, caused by the maximal nature of the concentric action, as well as the eccentric overload during the eccentric phase, are responsible for its unique physiological responses and training-induced musculoskeletal adaptations of flywheel training,[41,52,53] which may play an important role for injury prevention. Askling et al.[28] found that a 10-week complementary flywheel training program consisting of 4 sets of 7 repetitions of the leg curl exercise performed once or twice a week, led to increases in concentric and eccentric peak torque in professional soccer players. As such, these increases were associated with a lower injury rate in the experimental group (3/15) when the occurrence of injuries suffered throughout the season (10 months) was compared to the control group (10/15) that did not perform any complementary ST program. Thereafter, de Hoyo et al.[27] with a similar research design, demonstrated that 17 sessions of a combination of flywheel squat and flywheel leg curl exercises led to a reduction in muscle-injury incidence during matches (23.7%) and severity (65%). Despite the evidence about the effectiveness of flywheel training to prevent muscle injuries, one of the limitations for the systematic implementation of these devices into the preventative programs in soccer could be associated with their cost and the S&C expertise of the users. However, these issues are largely related to amateur clubs with restricted budgets and limited qualified S&C coaches.

Practical applications: recommendations for effective implementation of strength exercises and training.

Traditional resistance training

a) Training intensity: although previous research has shown benefits from loads that use 6-15 repetitions (which is likely to correspond to 65-85% 1RM),[23] but true strength adaptations are likely to be achieved at loads $\geq$ 85% 1RM.[22]

b) Training volume and frequency: these factors are likely to depend on the time of year (*e.g.*, pre or in-season). For the pre-season, a minimum of 2 strength sessions should be conducted per week with a minimum of 4 working sets across 2 exercises (2 sets per exercise).[54] However, during the competitive season, time is finite and schedules vary depending on the number of matches played.[55] Thus, although the same minimum dose for volume and frequency would be recommended as the pre-season, previous research has shown that a single session per week is viable at eliciting positive adaptations.[56]

c) Exercise selection: given players are required to be proficient at multiple movement patterns and in all three planes of direction,[54] it is suggested that a combination of both bilateral and unilateral strength exercises are employed (*e.g.*, bilateral: back squats and trap bar deadlifts; unilateral: rear foot elevated split squat, step ups and single leg squats). These suggestions are supported from recent empirical research comparing bilateral vs. unilateral training interventions in elite academy soccer players.[57]

Eccentric training

a) Training intensity: Load should be above "equivalent" concentric 1RM during eccentric exercises (*e.g.,* AEL). The load used will dictate the velocity of the movement *e.g.*, higher loads incurring higher velocities. Instead, Nordic hamstrings are bodyweight exercises, which could also be performed with extra weight (*e.g.,* discs) to enhance the eccentric load.

b) Training volume and frequency: Eccentric training is normally included as part of regular resistance training sessions; therefore, the intensity, volume and frequency of eccentric training need to take into account the planned concentric training, and *vice versa*. The planning of the right dose of eccentric training needs to consider the players' experience with this type of training. With regards to injury prevention and in particular hamstring strains, then Nordics are typically recommended and performed over 1-3 sets, with 3-6 repetitions.[30] AEL training would be best implemented using cluster sets,[58] where a volume of 3-5 sets at 3-5 repetitions is usually appropriate.

c) Exercise selection: Nordic hamstring and AEL (*e.g.*, bilateral or unilateral exercises) are generally the most popular modes of eccentric training, however, other exercises (involving manual resistance with focus on the eccentric contraction) might be performed.

Flywheel training

a) Training intensity: Flywheel training intensity is characterized by the different moment of inertia of the flywheel.[44] The most common moment of inertia used (which varies according to the chosen exercise) is between 0.05 kg·m^2 and 0.145 kg·m^2.[26,41] However, adjusting the inertia to the highest concentric or eccentric power output of each selected exercise seems to be an interesting approach to individually prescribe flywheel training.[26,59,60]

b) Training volume and frequency: Flywheel training is normally integrated into a holistic ST program that also features traditional resistance training, ballistic exercises, and other training methods (*e.g.*, core training).[26] It has proven to be an effective stimulus in injury prevention when 1-2 exercises were implemented 2 days a week, with a volume of 3-6 sets at 6-8 repetitions.[27,28] Although during in-season, at times with higher competitive load, a single weekly session may be a suitable frequency.[26,48]

c) Exercise selection: The exercises most reported in the scientific literature are: squat, lunge, leg curl, rear foot elevated split squat, and conic-pulley unilateral hamstring kicks.[41,50] In addition, the versatility of flywheel devices allows to perform functional exercises in different planes (*e.g.*, soccer-specific multidirectional movements),[61,62] as well as the ability to use the device in multiple training locations (*e.g.*, portability),[36,50,63] may play an important role for the design of injury prevention protocols.

Limitations and future directions

From the existing literature the following limitations and future research questions emerge:

a) Few studies evaluating the effect of preventative strategies have enrolled professional soccer players, while the majority of them have been carried out enrolling amateurs and youth players. More robust study designs should be used such as randomized controlled trials involving players of different levels and against matched controls, where possible.

b) One of the main limiting factors for the effectiveness of preventive programmes is the poor long-term compliance of the players,[16] therefore, future studies should verify the ecological validity of such protocols in professional contexts.

c) It is not clear what is the correct weekly training frequency and volume to use in order to reduce the injury risk in soccer players. Moreover, it is not very clear when is the most appropriate moment to schedule preventative protocols (*e.g.,* eccentric lower limb injury prevention exercises) into the micro-cycle in soccer where the right balance between recovery and tapering phases is needed.[64] Thus, further research is needed to verify the right training dose of each of the training methods here proposed.

d) Future studies should verify if a specific training methodology offers some advantages compared to others (*e.g.*, eccentric training vs. flywheel training) or if a combination of methods could be more effective than a single training method used in isolation (*e.g.*, traditional and flywheel training vs. flywheel training).

e) Some exercises (*e.g.*, flywheel or AEL) require proper execution technique to generate eccentric overload.[26] Thus, an adequate familiarization process is needed, as well as load monitoring to ensure proper load prescription is needed.[26,43,65]

Conclusions

This commentary reports the scientific rationale and justification of ST strategies for injury prevention in soccer, some evidence-based methods, and the recommendations for their effective implementation into applied soccer settings. The contemporary literature suggests ST proposed as traditional resistance, eccentric, and flywheel training may be valid methods to reduce the injury risk in soccer players. Training strategies involving multiple components (*e.g.*, strength, balance, plyometrics) which include strength exercises are effective at reducing non-contact injuries in female soccer. Additionally, the body of research current published support the use of eccentric training in sports, which offers unique physiological responses compared to other resistance exercise modalities. It seems that the Nordic hamstring exercise, in particular, is a viable option for the reduction of hamstring injuries in soccer players. Moreover, flywheel training has specific training peculiarities and advantages which are related to the combination of both concentric and eccentric contraction, which may play an important role in injury prevention. It is authors' opinion strength and conditioning coaches should integrate the ST methods here proposed in their weekly training routine to reduce the likelihood of injuries in their players, however, further research is needed to verify the advantages and disadvantages of these training methods to injury prevention using specific cohorts of soccer players.

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