ACL Injury Prevention in Soccer: The Santa Monica Experience

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Introduction

Soccer is the most widely played sport for both males and females alike. There are approximately 265 million registered players globally, and that number continues to increase, particularly in the female soccer community [17]. In the last 10 years, soccer participation by females has increased by 210 % in the United States, 250 % in Switzerland, and 160 % in Germany [7]. The increase in global participation of the sport has a variety of positive effects on personal health including lower rates of systemic illness and decreased rates of morbid obesity, type II diabetes, and heart disease. In addition to the physical benefits of participation in sport, there has been a concerted effort to combine participation in football with health education in order to promote wellness and health and to prevent the spread of illness and disease. The Federation Internationale de Football Association (FIFA) recently enacted the "Football for Health" campaign for children in South Africa to significantly increase the participants' knowledge in health with respect to preventable noncommunicable diseases [26].

However, with the influx of participation and more athletic exposures being recorded, there is a direct correlation with increased athletic exposure and risk of injury. Numerous studies have documented the risks associated with playing soccer and the epidemiology associated with playing competitively [19, 21, 28, 29, 60, 70]. In the last decade, there has been a global movement to gain a thorough understanding of injuries

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associated with soccer participation and the prevention of such injuries [16, 34, 39, 47, 69, 72].

After the passage of Title IX of the Educational Amendments in 1972 in the USA, allowing equal opportunity for female participation in sport, there has been an exponential surge of females participating in organized sports [1]. With this influx in athletic participation, there have also been more injuries sustained by young females between the ages of 13 and 22. Female athletes have a two- to ten-fold higher incidence rate of anterior cruciate ligament (ACL) injuries compared with their male counterparts [50]. Arendt and Dick [2] examined the increased incidence of ACL injury among National Collegiate Athletic Association (NCAA) Division I athletes participating in basketball and soccer over a 5-year period. The average ACL injury rate was 0.31 per 1,000 athlete exposures (AE) for female soccer and 0.29 per 1,000 AE for female basketball. This was compared with 0.13 for male soccer and 0.07 for male basketball per 1,000 AE. The comparison of this epidemiological data points to the obvious disparity in injury rates between genders in younger age groups. However, the data shifts when we analyze older populations. Men over the age of 27 have a greater incidence of ACL injury compared to women in all sports [45]. This may be due to a greater rate in organized and professional sport participation as athletes become older.

ACL injuries can lead to chronic knee pathology, including instability, secondary injury to the menisci and articular cartilage, and the early onset of osteoarthritis. Approximately 66 % of all patients that incur a complete ACL injury also sustain damage to the menisci and the articular cartilage of the femur, patella, and/or tibia. This injury, coupled with the risk of secondary injury, can significantly interfere with the activities of daily living and quality of life. Having a ruptured ACL surgically reconstructed can significantly reduce the risk for secondary injury [24, 32, 39, 57]. Seitz et al. [65] noted that 65 % of ACL-deficient patients sustained a secondary meniscal injury within 2.5 years of the initial date of injury.

Despite the most earnest efforts of orthopedic surgeons to preserve the integrity of the knee joint during ACL reconstructive surgery, individuals with reconstructed ACLs continue to suffer degenerative changes of the articular cartilage and the inevitable early onset of osteoarthritis. Lohmander et al. [44] completed a 12-year longitudinal study to follow up on female athletes that previously underwent ACL reconstruction after sustaining an injury while playing soccer. They found that 55 women (82 %) had radiographic changes in their index knee and 34 (51 %) fulfilled the criterion for radiographic knee osteoarthritis. The mean age for the participants involved with this study was 31. The implications of this research are ominous, hence increasing the need to prevent these injuries from occurring in the first place.

Critical Points

- Soccer is the most highly participated sport by both men and women.
- Women tend to be at greater risk of ACL injury compared to men, particularly under the age of 23.
- Male injury rates for ACL injury tend to increase with age.
- There is a direct correlation between ACL injury and future radiographic knee changes and early onset of osteoarthritis.

Epidemiology of ACL Injury in Soccer

The rate of injury in soccer depends on several factors: age, level of competition, position on the field, setting, location of injury, time of injury, and gender. Injuries incurred during soccer most commonly involve the lower extremities and are usually graded mild to moderate sprains, strains, or contusions [3, 10, 12, 25]. In a study analyzing the injury rates of professional male soccer athletes in the United States, Morgan et al. [52] found that the overall injury rate was 6.2 injuries/1,000 h of participation. Interestingly, the rates were strikingly different when the data was stratified for games and practices: the practice injury rates were 2.9 injuries/1,000 h of participation compared to 35.3 injuries/1,000 h in a game setting. Furthermore, the authors noted that 77 % (197 of 256) of injuries involved the lower extremity, with the knee ($N=54$) and ankle ($N=46$) most frequently affected.

The NCAA recorded injury rates for male and female collegiate soccer players over the course of 15 years [1, 2, 15]. The studies noted that for males, the injury rate was four times higher in games compared with practices (18.75 vs. 4.34 injuries/1,000 AE). In both games and practices, more than two-thirds of men's soccer injuries occurred to the lower extremities, followed by the head and neck during games and the trunk and back in practices. Although player-to-player contact was the primary cause of injury during games, most practice injuries occurred without direct contact to the injured body part. Ankle ligament sprains represented the most common injury during practices and games, whereas knee internal derangements were the most common type of severe injury (defined as ≥10 days of time loss).

On the contrary, when women's collegiate injuries were analyzed, the injury rate was more than three times higher in games than in practices (16.44 vs. 5.23 injuries/1,000 AE). The preseason practices had an injury rate that was more than three times greater than the rate for in-season practices (9.52 vs. 2.91 injuries/1,000 AE). Approximately 70 % of game and practice injuries affected the lower extremities. Ankle ligament sprains (18.3 %), knee internal derangements (15.9 %), concussions (8.6 %), and leg contusions (8.3 %) accounted for most of game injuries reported. However, upper leg muscle-tendon strains (21.3 %), ankle ligament sprains (15.3 %), knee internal derangements (7.7 %), and pelvis and hip muscle strains (7.6 %) accounted for most of the practice injuries reported. Player-to-player contact accounted for approximately 54 % of the game injuries but less than 20 % of all practice injuries. The majority of practice injuries involved noncontact injury mechanisms [15].

In a professional analysis of women's soccer injuries, Junge et al. [40] recorded injuries incurred in seven international soccer tournaments. During the tournaments, 387 injuries were reported during 174 games (incidence of 67.4 injuries/1,000 player hours, 95 % CI 60.7–74.1) or 2.2 injuries/match (95 % CI 2.0–2.4). Most of the injuries (84 %; 317/378) were caused by contact with another player, similar to the game data recorded at the NCAA [1, 15]. The injuries frequently involved the lower extremity ($N=48$; 65 %), followed by the head and neck ($N=67$, 18 %), trunk ($N=33$, 9 %), and upper extremity ($N=32$, 8 %). Contusions ($N=166$; 45 %) were the most frequent type of injury, followed by sprains or ligament rupture ($N=96$; 26 %) and strains or muscle fiber ruptures ($N=31$; 8 %). The most common diagnosis was an ankle sprain. On average, 1 injury/match (95 % CI 0.8–1.2) was expected to result in absence from a match or training. The injury rate in women's top-level tournaments was similar to the range reported for match injuries in elite male and female players. However, the diagnoses and mechanisms of injury among the female players differed substantially from those previously reported in male soccer players [40].

With respect to player position, time of injury, and the frequency of injury, Bailey et al. [4] found that strikers and defenders were most commonly injured, especially those playing in amateur leagues. With regard to the position of the injured player on the field, 8 (54 %) injuries occurred in midfielders, 3 (20 %) each in forward and defense position players, and 1 (7 %) in the goalkeeper. The median age of the injured players was 22 years (range, 20–35 years). In addition, the time of injury during the game was significant. The authors noted that most of the injuries occurred in the fourth quarter, followed by the first quarter and the third quarter of the match, respectively. This data could reinforce the hypothesis that neuromuscular fatigue may play a role in injury risk.

Giza et al. [29] reported data from the first two seasons of the Women's United Soccer Association in order to determine the injury incidence, anatomic location of injuries, and relation of player position. The researchers recorded player position at the time of injury ($N=168$ players). Midfielders sustained the most injuries ($N=57$, 34.1 %) followed by defenders ($N=47$, 28.1 %), strikers ($N=38$, 22.8 %), and goalkeepers ($N=26$, 15.0 %). Compared to all players, midfielders suffered a significantly higher number of injuries ($P < .007$); however, compared to other field players, midfielder injuries did not reach a statistically significant value.

Critical Points

- Midfielders have been statistically shown to sustain higher injury rates than other field players.
- Injury rates in collegiate and professional female players are most often contact in nature.
- The lower extremity is most frequently injured in both game and practice settings.
- Injuries most commonly occur late in the match (last quarter). This could potentially be secondary to neuromuscular and physiological fatigue.

Mechanism of ACL Injury in Soccer

In regard to environmental, anatomic, and hormonal risk factors, there is no conclusive evidence that would indicate any one single risk factor in these respective categories that is directly correlated with an increase in ACL injuries in the female athlete population. They certainly may play a confounding role, and therefore, should not be discounted [14, 18, 22, 23, 27, 30, 31, 33, 53, 57, 59, 63, 64, 66, 68, 73]. However, the emphasis has turned to biomechanical risk factors and the use of neuromuscular and proprioceptive intervention programs to address potential biomechanical deficits [56, 62].

Neuromuscular control is defined as the unconscious efferent response to an afferent signal regarding dynamic joint stability. The afferent proprioceptive signals that elicit motor control can be distinguished by their role: feedback or feedforward. Feedback mechanisms are a result of afferent input (force to the joint) and are reflexive in nature. The time to elicit such a reaction is longer, thus it is thought to be more heavily involved with maintaining posture and slow movement. Feedforward mechanisms are a result of preactivated preparatory activation of muscle [42]. Several research studies have indicated that proprioceptive activities may play a major role in injury reduction [5, 6, 11, 43, 67, 76].

Muscular strength and recruitment patterns are crucial to knee stability. Quadriceps-to-hamstring strength ratios have been examined thoroughly in the literature [56]. The quadriceps serve as an antagonist to the ACL secondary to its attachment site. The quadriceps, upon activation, may increase the anterior shear force on the tibia if it remains unopposed by an antagonist. The hamstrings act as an agonist to the ACL, as they reinforce the ligament by preventing the excessive anterior translation of the tibia. If the hamstrings demonstrate weakness or a delay in contractility from a temporal perspective compared to the quadriceps, the ACL may be at an increased risk for injury and subsequently lead to tensile failure [13, 51].

Landing from a jump with minimal hip and knee flexion increases the ground reaction forces transmitted to the lower extremity and increases the shear force from the activated quadriceps, thus mechanically stressing the ACL [38, 75]. More et al. [51] studied a cadaveric model that incorporated quadriceps and hamstrings muscle loads to simulate the squat exercise. When the hamstring was loaded, anterior tibial translation during flexion was significantly reduced in addition to a reduction in internal tibial rotation during flexion. Hamstrings muscle activity during a squat functions synergistically with the ACL to provide anterior knee stability. McLean et al. [48] compared knee kinematics and gender in 30 high-performance athletes performing side-cutting maneuvers. Women displayed increased intertrial variability for axial internal rotation patterns during cutting compared with men. Gender, however, was not the main determining factor. Instead, the differences in axial rotation were directly related to level of experience. It is important to note that these subjects were high-performance athletes, which might have resulted in a selection bias.

On a follow-up study, McLean et al. [49] studied 10 male and 10 female athletes performing cutting maneuvers with random perturbations at initial contact ($n = 5{,}000$). Injury to the ACL in the sagittal plane was defined as incurring an anterior drawer force greater than 2,000 N. The researchers found that neuromuscular perturbations produced significant increases in external knee anterior force, valgus moments, and internal rotation moments. During the study, the anterior drawer force never exceeded 2,000 N in any model. Valgus loads reached values that were high enough to rupture the ligament, occurring more frequently in females than in males. The researchers concluded that sagittal plane knee joint forces cannot rupture the ACL during sidestep cutting, primarily due to the fact that the muscle and joint mechanics and external ground reaction forces in this plane protect the upward limit of ligament loads. They suggested that valgus loading is a more likely injury mechanism, especially in females [48].

In contrast, Malinzak et al. [46] compared knee-motion patterns in male and female recreational athletes. Three-dimensional coordinates and EMG data were collected for knee flexion-extension, valgus-varus, and internal-external rotation angles. Female athletes demonstrated less knee flexion and greater knee valgus when landing from a jump and with cutting maneuvers. The study also determined that female athletes demonstrated greater quadriceps activity (based on electromyographic analysis) in concert with decreased hamstring activity. In addition, the frequency and intensity of hamstring activity was less in females versus males. Female athletes typically contracted their hamstring fibers 50 ms slower than their male counterparts (200 ms for females vs. 150 ms for males) and with less intensity (55.2 % females vs. 71.8 % in males at initial contact).

When we consider the role of trunk musculature activation with respect to dynamic knee movements, we note how optimal strength of the core is a vital component to injury prevention. Hewett et al. [37] assessed the role of lateral trunk and knee abduction angles during an actual ACL injury. The researchers analyzed video still captures from 23 coronal (10 female, 7 male ACL-injured players and 6 female controls) and 28 sagittal plane videos performing similar landing and cutting tasks. The lateral trunk and knee abduction angles were higher in female compared to male athletes during ACL injury ($P < .05$) and trended toward being greater than the uninjured female controls ($P = .16$ and .13, respectively). Female ACL-injured athletes showed less forward trunk lean than female controls at initial contact ($1.6 \pm 9.3°$ vs. $14.0 \pm 7.3°$, $P = .01$). The researchers noted that female athletes landed with increased lateral trunk motion and knee abduction during an actual ACL injury than did male athletes or uninjured control females during similar landing and cutting tasks.

Brophy et al. [8] analyzed the role of leg dominance with respect to ACL injury and gender in competitive soccer players. The researchers completed a retrospective analysis of 93 (41 male, 52 female) ACL injuries that occurred while playing soccer. Nearly half of the injuries occurred in the dominant kicking leg ($N = 30$), while the other half occurred in the contralateral leg ($N = 28$). However, when the data was stratified for gender, there was a significant difference in the distribution of noncontact ACL injury; 74.1 % of males (20/27) were injured on the dominant kicking leg compared with 32 % (10/31) of females ($P < .002$). When limited to a noncontact injury mechanism, females were more likely to injure the ACL in their supporting leg, whereas males tend to injure their kicking leg (Table 16.1). This research suggests that limb dominance does serve as an etiological factor with regard to ACL injuries sustained while playing soccer. Future research should investigate the cause for this discrepancy, which could potentially be due to underlying gender-based strength differences and neuromuscular alterations during sport participation.

Critical Points

- Biomechanical assessment of male and female athletes suggests that gender differences do exist.
- Female athletes tend to demonstrate frontal plane deficiencies, whereas males tend to demonstrate sagittal plane deficiencies.
- Female athletes tend to demonstrate decreased hip and knee flexion upon landing from a jump.

Table 16.1 Noncontact ACL injury with respect to gender and leg dominance

		Dominant leg		Noncontact ACL injury	
Gender	*N*	Right	Left	Right	Left
Female (*N* = 52)					
Professional	3	2	1	2	2
College	17	16	1	1	5
High school/club	17	16	1	2	7
Youth/recreational	15	13	2	5	7
Total	52	47	5	10	21
Average age (injury): 20.4 ± 7.99				32.26 %	67.74 %
Total noncontact ACL injuries: 31					
Male (*N* = 41)					
Professional	12	11	1	5	3
College	6	5	1	5	1
High school/club	4	3	1	2	1
Youth/recreational	19	18	1	7	2
Total	41	37	4	20	7
Average age (injury): 30.6 ± 8.84				74.07 %	25.93 %
Total noncontact ACL injuries: 27					

- Furthermore, females tend to utilize their quad and adductors during landing and cutting maneuvers, which increases the sheer and tensile forces applied to the ACL.
- Female athletes tend to show decreased activation of their hamstring musculature upon landing, take a longer time to reach their peak flexion angle, and land in a more shallow peak flexion angle (decreased hip and knee flexion).

ACL Injury Prevention

ACL injury prevention programs focusing on skiing, basketball, European team handball, and soccer have been performed in the past with results ranging in an overall reduction of severe ACL injuries from 60 to 89 % [20, 23, 41].

Henning and Griffis [35] implemented a prevention study in 2 division I basketball programs over a course of 8 years. The program focused on changing the individual player's kinematic technique, stressing knee and hip flexion upon landing from a jump, using accelerated rounded turns instead of an abrupt or more acute angular turn or cutting cycle, and deceleration with a multistep stop as opposed to a one-step stop deceleration. Henning noted an 89 % reduction in the rate of occurrence of ACL injuries in his intervention group compared to the age- and skill-matched control group.

Caraffa et al. [9] and Cerulli et al. [11] implemented a proprioceptive balance training program using 600 semiprofessional and amateur soccer players in Italy. The study consisted of a 20-min training program divided into five phases of balance training with increasing difficulty. The prospective study was completed over the duration of three complete soccer seasons. The researchers found an incidence rate of 1.15 ACL injuries per team per year in the control group compared with a 0.15 incidence rate in the trained athletes. These ratios demonstrated an overall 87 % decrease in ACL injuries compared to the age- and skill-matched control group.

Hewett et al. [36] completed a prospective analysis of 1,263 male and female soccer, basketball, and volleyball athletes using a 6-week preseason neuromuscular training program. The intervention program consisted of stretching, plyometrics, and weight training with emphasis on proper biomechanical alignment and technique.

The group noted that the incidence of serious knee injury was 2.4–3.6 times higher in the untrained group compared with the trained group. When examining the rate of noncontact ACL injuries, five untrained female athletes sustained ACL injuries (relative injury incidence 0.26), no trained females sustained an ACL injury (0), and one male athlete sustained an ACL injury (0.05).

Ettlinger et al. [20] implemented the "guided discovery" technique in Vermont that focused on avoiding high-risk skiing behavior and positioning (i.e., "phantom foot"), recognizing potentially dangerous skiing situations, and responding quickly to unfavorable conditions. During the 1993–1994 ski season, 4,700 ski instructors and patrollers completed the comprehensive training program at 20 ski areas throughout the United States. As a result, the rate of serious knee injuries decreased by 62 % among the trained individuals compared with those who did not participate in the training program.

Heidt et al. [34] studied 300 female adolescent soccer players between the ages of 14 and 18 years of age over a 1 year period. Forty-two athletes participated in the Frappier Acceleration Training Program, a 7-week preseason training program consisting of strength training, flexibility, sports-specific cardiovascular exercise, plyometrics, and sports-cord drills. The study found that the trained group incurred a lower percentage of ACL injuries (2.4 %) compared with the skill- and age-matched control group (3.1 %).

Myklebust et al. [55] instituted a proprioceptive training program for elite female team handball players. This 5-phase training program consisted of floor exercises, wobble board activities, and a balance mat performed two to three times a week over the course of a 5–7-week preseason session and once a week in season. Fifty-eight teams participated (855 players) in the first season (1999–2000) and 52 teams (850 players) participated in the second season (2000–2001). Sixty teams (942 players) in the 1998–1999 season served as the control. There were 29 ACL injuries in the control season, 23 ACL injuries in the first intervention season, and 17 injuries in the second intervention season.

Wedderkopp et al. [74] conducted a randomized controlled trial in 16 European team handball squads. The intervention, similar to Caraffa and Cerulli's intervention, used an ankle disc for proprioceptive training. The control group demonstrated significantly higher number of traumatic injuries (16 vs. 6). The incidence of traumatic injuries in the intervention group was 2.4 (95 % CI 0.7; 6.2) injuries per 1,000 game hours and 0.2 (95 % CI 0.02; 0.7) injuries per 1,000 practice hours. In the control group, the incidence was 6.9 (95 % CI 3.3; 12.7) injuries per 1,000 game hours and 0.6 (95 % CI 0.2; 1.3) injuries per 1,000 practice hours. A significantly higher multivariate odds ratio (4.8) was found in the group not using the ankle disc. The intervention group had significantly fewer moderate and major injuries.

Critical Points

- Several researchers have demonstrated a significant reduction in ACL injury by virtue of participation in a structured neuromuscular training program.
- The utilization of proprioceptive balance equipment does not seem to positively or negatively affect the efficacy of such programs on injury rates.
- When designing such a program, you must consider the time required, the equipment necessary, and cost associated with an intervention program. All of these factors may directly impact the level of compliance necessary to impart a positive benefit to the athlete.

The Santa Monica Experience: ACL Injury Prevention

Mandelbaum et al. [47] developed the Santa Monica Prevent Injury and Enhance Performance (PEP) ACL program in 2000 to address the high incidence of ACL injuries that was being reported throughout the literature in female soccer players. This program was developed to address the major clinical deficits that were fairly ubiquitous among

ACL-injured athlete. The program was used with 2 age cohorts: 14–18-year-old female club soccer players and 18–22-year-old female soccer athletes participating in division I NCAA soccer. The program consisted of a 20-min dynamic warm-up protocol that preceded the normal soccer training session or competitive game.

During the first year of the study, a total of 2 ACL tears, confirmed by magnetic resonance imaging, were reported for the intervention group. This translated to an incidence rate of 0.05 ACL injuries per 1,000 AE. Thirty-two ACL tears were reported for the control group: an incidence rate of 0.47 ACL injuries per 1,000 AE. These results translated to an 88 % overall reduction of ACL injury compared to an age- and skill-matched control group. During the second year of the study, 4 ACL tears were reported in the intervention group, with a corresponding incidence rate of 0.13 injuries per 1,000 AE. Thirty-five ACL tears were reported in the control group, with an incidence rate of 0.51 injuries per 1,000 AE. This corresponded to an overall reduction of 74 % in the intervention group compared with an age- and skill-matched control group.

During a collaborative effort between the Santa Monica Sports Research Foundation and the Centers for Disease Control (CDC), the prior study was followed by a randomized, controlled trial using the PEP Program in Division I NCAA Women's Soccer Teams [28]. Sixty-one teams with 1,429 athletes completed the study; participating athletes were divided into 854 athletes on 35 control teams and 575 athletes on 26 intervention teams. No significant differences were noted between intervention and control athletes with regard to age, height, weight, or history of past ACL injuries. After using the PEP program during one season, there were 7 ACL injuries in the intervention athletes (IA) compared with 18 in control athletes (CA), 0.14 versus 0.25 ($P=.15$). There were no ACL injuries reported in IA during practices compared with 6 in CA (0.10; $P=.01$). Noncontact ACL injuries in the CA group occurred at over 3 times the rate of the IA group (0.14 vs. 0.04; $P=.06$). Control athletes with a prior history of ACL injury suffered a reoccurrence 5 times more frequently than the IA group (0.10 vs. 0.02; $P=.06$); this difference reached significance when limited to noncontact ACL injuries during the season (0.06 vs. 0.00; $P<.05$). There was a significant difference in the rate of ACL injuries in the second half of the season (weeks 6–11; IA 0.00 vs. CA 0.18, $P<.05$). This would support the concept that it takes approximately 6–8 weeks for a biomechanical intervention program to impart a neuromuscular effect.

Pfeiffer et al. [61] used two of the five components of the PEP program in a prospective randomized controlled trial in high school volleyball, basketball, and soccer athletes for two seasons. The intervention group participated in a plyometric-based exercise program twice a week throughout the season that was completed after training. A total of 1,439 athletes (862 in the control group and 577 in the treatment group) were monitored. There were 6 confirmed noncontact ACL injuries: 3 in the intervention group and 3 in the control group. The incidence of noncontact ACL injuries was 0.167 per 1,000 exposures in the intervention group and 0.078 in the control group, yielding an odds ratio of 2.05 ($P>.05$). This research may demonstrate that isolating certain components of a comprehensive neuromuscular training program and completing those components post-training, ostensibly in a physiological and neuromuscular fatigued state, may directly nullify the positive impact and efficacy of an injury prevention program.

Critical Points

- The PEP Program is a dynamic warm-up designed to address the deficits most commonly seen in ACL-injured athletes.
- The program should be completed in its entirety and prior to training or a game in a non-fatigued state. When two elements of the program were tested post-training, the effects of the intervention were nullified.
- The program can be initiated in youth athletes over the age of 8 years old.
- The program has been tested in high school-aged and collegiate soccer players and has been shown to reduce ACL injury significantly in each of those respective cohorts.

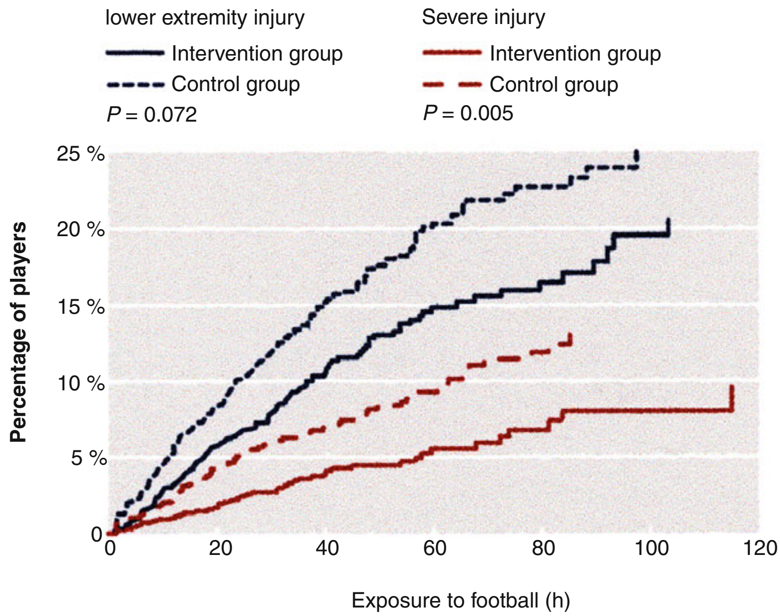

Fig. 16.1 Survival curves based on Cox regression for players with lower extremity injury and severe injury [71]

Analysis of the Efficacy of the FIFA 11+ Program

The Oslo Sports Trauma Research Center also attempted to reduce the incidence of ACL injuries in Norway by using an intervention program known as the "FIFA 11" [72]. A cluster-randomized controlled design was used to test the efficacy of the "11" on injury risk in female soccer players (IA, 59 teams, $N=1{,}091$) compared with a control group (CA, 54 teams, $N=1{,}001$). The "11" was a 15-min warm-up program for core stability, lower extremity strength, neuromuscular control, and agility used over an 8-month season.

A total of 396 players (20 %) sustained 483 injuries. There was no difference in the overall injury rate between the IA (3.6 injuries/1,000 h, confidence interval (CI) 3.2–4.1) and CA (3.7, CI 3.2–4.1; RR = 1.0, CI 0.8–1.2; $P=.94$) or in the incidence for any type of injury. The training program was used during 60 % of the soccer training sessions in the first half of the season, but only 14 out of 58 intervention teams completed more than 20 prevention training sessions. The researchers noted no effect of the injury prevention program on the injury rate secondary to the exercises, perhaps, not being specific enough to address the biomechanical deficiencies present in this population and the low compliance with the program.

To address the issue of decreased compliance and, perhaps, some of the deficits of the content initially selected for the "11" protocol, the Oslo researchers collaborated with FIFA and the Santa Monica Sports Research Foundation. The researchers reconvened, restructured, and renamed the program to the "FIFA 11+." Soligard et al. [71] completed a cluster, randomized controlled trial in 125 soccer clubs from the south, east, and middle of Norway: 65 clusters in the intervention group (IA) and 60 in the control group (CA) followed the protocol for one league season (8 months). There were 1,892 female players ages 13–17 (1055 IA; 837 CA). A comprehensive warm-up program (11+) was used to improve strength, awareness, and neuromuscular control during static and dynamic movements.

During the season, 264 players had relevant injuries: 121 players in the intervention group and 143 in the control group (rate ratio 0.71, 95 % confidence interval 0.49–1.03). In the intervention group, there was a significantly lower risk of injuries overall (0.68, 0.48–0.98), overuse injuries (0.47, 0.26–0.85), and severe injuries (0.55, 0.36–0.83). Though the primary outcome of reduction in lower extremity injury did not reach statistical significance, the risk of severe injuries, overuse injuries, and injuries overall was reduced (Fig. 16.1). In addition, the intervention groups that performed the program more often reaped the benefit of lower injury rates overall.

The risk of injury was 35 % lower in intervention players in the highest third of compliance (2.6 [20. to 3.2] injuries/1,000 player hours, mean 49.2 [range 33–95] sessions). This was compared to players in the intermediate third (4.0 [3.0–5.0] injuries/1,000 player hours, mean 23.4 [range, 15–32] sessions) (rate ratio 0.65, 0.44–0.94, $P = .02$). The 32 % reduction in risk of injury compared with the third with the lowest compliance (3.7 (2.2–5.3) injuries/1,000 player hours, mean 7.7 [range, 0–14] sessions) did not reach significance (rate ratio 0.68, 0.41–1.12, $P = .13$). There was an inverse correlation between compliance and injury rates. The study indicated that a structured warm-up program can prevent injuries in young female soccer players.

An emphasis on proper landing technique; landing softly on the metatarsal heads and rolling back to the rearfoot; engaging in knee and hip flexion upon landing from a jump or header and during lateral (cutting) maneuvers; avoiding excessive genu valgum at the knee upon landing and squatting; increasing hamstring, gluteus medius, and hip abductor strength; and addressing proper deceleration techniques are activities that are inherent in each of the aforementioned ACL prevention protocols (Figs. 16.2, 16.3, and 16.4).

Critical Points

- The FIFA 11 Program, the initial attempt at a global soccer injury prevention program was largely unsuccessful secondary to ineffective content and decreased compliance within the intervention group.
- The protocol was revamped and renamed the FIFA 11+ program. The program has demonstrated a significant decrease in all lower extremity injury rates and time loss secondary to injury.
- This program is an on the field warm-up designed, similarly to the PEP program, to be completed prior to training or a game. It takes approximately 20 min to complete and does not require additional equipment.

Fig. 16.2 Russian hamstring

Future Directions

The growth and popularity of the sport of soccer is unprecedented. It infiltrates nearly every community in a global fashion. The benefits of sport participation are numerous and far outweigh the risks. However, the likelihood of incurring a soccer-related injury should not be underestimated. As clinicians, it is integral to our collective ethos to recognize the risks associated with the game of soccer and to profess the merits of prevention protocols like those cited in the peer-reviewed literature.

The literature on ACL injury prevention has consistently found that a neuromuscular training program may significantly reduce

Fig. 16.3 Bounding agility run

the incidence of ACL injuries in the female and male soccer athlete [9, 11, 20, 28, 30, 31, 36, 47, 54, 55, 71, 72]. A prophylactic training program that focuses on developing and improving neuromuscular control of the lower extremity though strengthening exercises, plyometrics, and sport-specific agilities may address the proprioceptive and biomechanical deficits and pathokinematics that high-risk female and male athletes tend to demonstrate. Future studies should strive to identify which of the components of present-day prevention programs are most significant in decreasing the rate of noncontact ACL injuries.

These studies demonstrate the critical need for further randomized clinical trials on the relevance of fatigue with respect to injury, age, gender, role of early sport specificity, and the timing of the implementation of a neuromuscular injury prevention program [58, 61]. Researchers should continue to seek innovative ways of improving the quality and efficacy of existing prevention programs within each sporting community and recognize and embrace the need for further randomized controlled trials to further elucidate the epidemiology, etiology, mechanism of injury, and, ultimately, the prevention of sports-related ACL injury.

Fig. 16.4 Single-leg eccentric squat

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