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Soccer Injuries in Children and Adolescents

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abstract

Participation in youth soccer in the United States continues to increase steadily, with a greater percentage of preadolescent participants than perhaps any other youth sport. Despite the wide-ranging health benefits of participation in organized sports, injuries occur and represent a threat to the health and performance of young athletes. Youth soccer has a greater reported injury rate than many other contact sports, and recent studies suggest that injury rates are increasing. Large increases in the incidence of concussions in youth soccer have been reported, and anterior cruciate ligament injuries remain a significant problem in this sport, particularly among female athletes. Considerable new research has identified a number of modifiable risk factors for lower-extremity injuries and concussion, and several prevention programs have been identified to reduce the risk of injury. Rule enforcement and fair play also serve an important role in reducing the risk of injury among youth soccer participants. This report provides an updated review of the relevant literature as well as recommendations to promote the safe participation of children and adolescents in soccer.

Soccer is the most popular youth sport in the world and is 1 of the most popular team sports in the United States.[1] It is estimated that 3.9 million children and adolescents participate in soccer annually,[2] and from 1990 to 2014, the number of youth officially registered with US youth soccer programs increased by almost 90%.[3] Despite the wide-ranging health benefits of participation in organized sports, injuries occur and represent a threat to both athlete health and performance.[4] Unfortunately, recent studies suggest that injury rates in youth soccer may be increasing. Sports-related injuries represent a significant and increasing economic burden to the health care system, and the prevention of sports-related injuries in children has far-reaching health and economic benefits to the patient, the family, and the health care system as a whole. Given the number of children and youth participating in youth soccer, reducing the risk of injury among such a large group of participants has the potential to reduce attrition rates, promote lifelong participation in sport, and facilitate the

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DOI: https://doi.org/10.1542/peds.2019-2759

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PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: No external funding.

To cite: Watson A, Mjaanes JM, AAP COUNCIL ON SPORTS MEDICINE AND FITNESS. Soccer Injuries in Children and Adolescents. *Pediatrics.* 2019;144(5):e20192759

improvements in public health associated with regular exercise. By providing this updated clinical report, the American Academy of Pediatrics (AAP) intends to familiarize pediatric health care providers with current information regarding the risk of injury in youth sport participation, strategies for injury prevention, legislative changes aimed at reducing injury risk in youth soccer, and important concepts with which pediatricians can guide families and sport governing bodies to reduce risk and facilitate participation

INJURY INCIDENCE IN YOUTH SOCCER

Injury incidence rates in youth soccer vary considerably between studies and have been reported to be anywhere from 2.0 to 19.4 injuries per 1000 hours of exposure.[5–7] Injury incidence has been consistently documented to be much greater during games than during training in adolescents[5,8] as well as 7- to 12-year-olds.[5] In a recent systematic review of injury incidence in male soccer players, injury rates among adolescent athletes was found to range from 3.7 to 11.1 injuries per 1000 hours in training but 9.5 to 48.7 injuries per 1000 hours during games.[5] Injury incidence appears to increase with age, such that injuries to players younger than 12 years have been reported to be 1.0 to 1.6 per 1000 hours, whereas adolescents have demonstrated an injury rate of 2.6 to 15.3 per 1000 hours.[6,7,9] Incidence rates may vary depending on the specific reporting mechanism, however, and self-reporting mechanisms may identify an even greater proportion of injuries than those identified through traditional injury reporting mechanisms involving a health care provider.[4,9]

Despite ongoing efforts to reduce the risk of injury in youth sports, injury rates among youth soccer participants may be increasing and are greater than those for a number of other team and individual sports (see Table 1). In a recent retrospective study of 25 years of emergency department visits, Smith et al[10] found that the annual number of soccer-related injuries among 7- to 17-year-olds per 10 000 soccer participants increased 111% from 1990 to 2014. Although it is unclear whether this increase is attributable to greater incidence, increased recognition, or both; a considerable portion of this increase was attributed to a greater number of concussions, with a relatively higher overall injury incidence among girls and adolescent athletes. A similar study also revealed a significant increase in pediatric soccer-related injuries evaluated in the emergency department between 2000 and 2012, with significantly greater numbers of injuries for male youth soccer participants throughout the study.[11]

As observed with other sports, many young athletes now play soccer year-round, including indoor soccer. Indoor soccer involves essentially the same rules as outdoor soccer but is played on a covered field of artificial turf with walls. Futsal is a derivative of indoor soccer but is played on a smaller indoor court with only 5 players to a side and a ball smaller in diameter. Most studies involving the epidemiology of indoor soccer injuries originate in Europe or Asia and involve adult professional teams.[13] Despite early evidence that indoor soccer carried a higher risk of injury than outdoor soccer, a more recent study involving adolescent soccer players revealed no significant differences in overall injury rates by sex or age for indoor compared with outdoor soccer.[14]

INJURY TYPES AND MECHANISMS

The majority of youth soccer injuries are acute events resulting from player-to-player contact, with a considerably greater proportion of injuries occurring during competition than practice.[5,15,16] With respect to severe injuries (time loss >21 days), incidence remains considerably higher during games than practice, and girls demonstrate a greater incidence than boys (3.3 vs 2.5 per 1000 athletic exposures).[17] In fact, the incidence of injuries among high school soccer players that resulted in medical disqualification (career- or season-ending injuries) between 2005 and 2014 was found to be 0.17 and 0.10 per 1000 athletic exposures for girls and boys, respectively.[16] Among the 11 sports evaluated, the injury rate for soccer for boys was lower only than those for football, ice hockey, and lacrosse, and for girls, only gymnastics had a greater rate of disqualifying injury. Although not as common, youth soccer players are also at risk for overuse injuries, with a recent study identifying injury rates of 0.15 and 0.20 injuries per 10 000 athletic exposures among high school male and female soccer players, respectively, with knees and lower legs being the most common locations of injury.[18] Although data are limited, a single study revealed that tendinitis, patellofemoral pain, and Osgood-Schlatter disease were the most common overuse injuries in youth soccer players.[19]

Although rates of soccer injuries evaluated in the emergency department appear to be lower among younger soccer athletes compared with older players,[10] the types of injuries differ by age. A prospective study of emergency department visits for soccer-related injuries between 1990 and 2003 suggested that 5- to 14-year-old athletes were more likely to suffer upper-extremity injuries than high school athletes, and high school athletes were more likely to suffer a concussion.[20] More recently, a similar study of soccer-related injuries presented to emergency departments between 1990 and 2014 revealed lower overall injury rates among 7- to 11-year-olds compared with 12- to 17-year-olds, with younger athletes more likely to suffer

TABLE 1 Rates of Severe Injuries, Fractures, and Season-Ending Injuries in High School Sports

Injury Type	Sport	Rate per 1000 AEs
Severe[a]		
Boys		
	Football	0.69
	Wrestling	0.52
	Basketball	0.24
	Baseball	0.19
	Soccer	0.25
Girls		
	Basketball	0.34
	Soccer	0.33
	Volleyball	0.15
	Softball	0.18
Fracture		
Boys		
	Football	0.44
	Ice hockey	0.31
	Lacrosse	0.26
	Wrestling	0.23
	Soccer	0.20
	Basketball	0.16
	Baseball	0.15
	Track and field	0.02
	Swimming or diving	0.00
Girls		
	Lacrosse	0.26
	Basketball	0.16
	Softball	0.15
	Gymnastics	0.15
	Soccer	0.14
	Field hockey	0.14
	Cheerleading	0.07
	Volleyball	0.06
	Track and field	0.03
	Swimming or diving	0.003
Season ending		
Boys		
	Football	0.26
	Wrestling	0.17
	Lacrosse	0.16
	Ice hockey	0.12
	Soccer	0.10
	Basketball	0.069
	Baseball	0.056
	Cross country	0.021
	Track and field	0.018
	Volleyball	0.018
	Swimming or diving	0.002
Girls		
	Soccer	0.16
	Basketball	0.11
	Lacrosse	0.093
	Softball	0.068
	Field hockey	0.061
	Cross country	0.056
	Track and field	0.048
	Volleyball	0.040
	Cheerleading	0.033
	Gymnastics	0.019
	Swimming or diving	0.005

Adapted from Darrow et al[17]; Swenson et al[12]; and Tirabassi et al.[16] AE, athletic exposure.

[a] Severe injury is defined as any injury resulting in ≥21 days of time lost from sport.

a fracture and less likely to suffer a concussion (see Table 2).[10] Nonetheless, the differences between these age groups appear to be relatively small, and the types of injuries suffered by both groups appear to be similar overall.

Lower Extremities

The majority of injuries among youth soccer players involve the lower extremities. The ankles and knees are the most commonly injured body parts, whereas sprains and/or strains and contusions are the most commonly reported injury types.[5,8,9,21,22] Fractures represent only approximately 3% to 10% of all injuries but up to 28% of soccer-related injuries seen in emergency departments.[7,8,10,23] Younger athletes tend to have a lower overall injury incidence but typically demonstrate similar injury locations. In a study of time-loss injuries among 417 soccer players ages 5 to 17 over a 2-year period, ankles and knees were the most commonly injured body parts (20.9% and 16.3% of all injuries, respectively), whereas sprains, contusions, and muscle injuries were the most common diagnoses (20.6%, 22.5%, and 20.6% of all injuries, respectively). Although overuse injuries are less common, they appear to be more common among female youth soccer players, with feet and/or ankles and lower legs being the most commonly injured areas among boys and girls.[18] Among high school athletes, the majority of overuse injuries were less severe, with only 7.7% resulting in time loss greater than 21 days.[18] Although the majority of overuse injuries involve apophysitis and tendinopathy, stress fractures are another important consideration for youth soccer athletes.

With respect to severe injuries, player-to-player contact is the most common mechanism for injuries resulting in significant time loss (>21 days)[24] as well as medical

TABLE 2 Soccer-Related Injuries Among Children 7 to 17 Years of Age Evaluated in US Emergency Departments by Age Group, From 1990 to 2014

	7–11 y, *n* (%)	12–17 y, *n* (%)
Body region injured		
Upper extremity	222 833 (27.3)	396 813 (18.2)
Ankle	99 479 (12.2)	432 344 (19.9)
Head or neck	124 239 (15.2)	404 356 (18.6)
Knee	75 038 (9.2)	260 526 (12.0)
Foot or toe	87 483 (10.7)	204 786 (9.4)
Hand or finger	113 490 (13.9)	174 373 (8.0)
Upper or lower leg	46 379 (5.7)	151 743 (7.0)
Trunk	42 992 (5.3)	141 842 (6.5)
Other	4471 (0.5)	10 990 (0.5)
Subtotal	816 404 (100.0)	2 177 773 (100.0)
Diagnosis		
Sprain or strain	242 814 (29.8)	793 437 (36.5)
Fracture	231 776 (28.4)	461 611 (21.2)
Soft tissue injury	192 396 (23.6)	463 469 (21.3)
Concussion or CHI	45 016 (5.5)	172 346 (7.9)
Other	56 598 (6.9)	139 166 (6.4)
Laceration	40 339 (4.9)	102 626 (4.7)
Dislocation	6793 (0.8)	43 747 (2.0)
Subtotal	815 732 (100.0)	2 176 402 (100.0)

Adapted from Smith et al.[10] CHI, closed head injury.

disqualification.[16] The knees are the most commonly affected body part in season-ending injuries, and player-to-player contact is the most common mechanism for both boys and girls.[16] Anterior cruciate ligament (ACL) rupture remains a significant lower-extremity injury among youth soccer players, with noncontact valgus hyperextension during rapid change of direction or deceleration as the most common mechanism.[25,26] Female soccer players appear to be at an increased risk for ACL injury compared with their male counterparts, and this has been attributed to a number of factors, including lower-limb anatomy, hormonal influences, and neuromuscular activation patterns.[25,27]

Concussion

Recent data suggest that concussion rates may be increasing among youth soccer athletes, and concussion remains more common among girls than boys.[28–30] In a recent 9-year study of high school soccer players, concussion incidence was found to be 0.28 and 0.45 per 1000 athletic exposures for boys and girls, respectively. For both sexes, concussion incidence has been found to be greater during games than during practice, and concussion rates during both practices and games increased significantly during the study period.[30] Finally, a recent study of soccer-related injuries among 7- to 17-year-old children presenting to the emergency department revealed that concussion incidence increased nearly 1600% between 1990 and 2014.[10] It is unclear, however, whether this increase in concussion rates is the result of a greater number of concussions sustained or of increased recognition and diagnosis of concussions as a result of previous education efforts.

Heading is the most common sport-specific activity during which concussions occur, although the majority of injuries are attributable to contact with another player while heading rather than contact with the ball itself.[30,31] Concussions are a result of brain acceleration after contact. Theoretically, concussion incidence could be reduced if the magnitude of horizontal head acceleration could be reduced. In addition to the mass and velocity of the player, factors that affect horizontal acceleration include the mass, size, speed, and inflation pressure of the ball. Therefore, balls that are overinflated or inappropriately large for the age and size of the athletes may increase the risk of head injury in young soccer players.[32] Data are insufficient to determine if concussions or subconcussive impacts (repetitive heading or blows to the head that do not result in concussive symptoms) result in potentially detrimental long-term cognitive effects.[33]

Facial and Ocular Injury

Although there are limited data regarding ocular injuries in youth soccer, a recent 10-year study among soccer players identified the incidence of eye injuries to be 1.0 and 0.8 per 100 000 athletic exposures for boys and girls, respectively.[34] The incidence of eye injuries was found to be higher than that in a number of other sports but lower than in wrestling, basketball, and baseball for boys and lower than in field hockey and softball for girls. The use of appropriate protective eyewear can substantially decrease the risk of ocular injuries in athletes. A recent 5-year study has revealed that among youth soccer players, lacerations were the most common facial injury, followed by contusion and fracture. The nose was the most common site of injury, and contact with an opposing player's head or upper extremity was the most common mechanism.[35] Dental injuries also occur with a frequency similar to eye injuries (1.1 per 100 000 athletic exposures), with injuries occurring more commonly during competition (3.2 per 100 000) than during practice (0.3 per 100 000).[36]

Environmental Injuries

As an outdoor sport, soccer also carries a potential risk for dehydration, exertional heat illness, and other environmental dangers. Heat illness encompasses a variety of conditions and can range from heat cramps and heat exhaustion to life-threatening heat stroke.[37] Although these issues may occur at any ambient temperature, the incidence increases with increasing temperature and humidity. Heat cramps are painful involuntary muscle contractions that usually occur during preseason conditioning and are treated with stretching the muscle, rest, and rehydration. Heat exhaustion is a moderate heat illness characterized by the inability to continue exercising because of cardiovascular insufficiency resulting from strenuous exercise, environmental heat stress, dehydration, and energy depletion.[37] Heat exhaustion typically manifests as a headache, nausea, profuse sweating, incoordination, weakness, syncope, and mildly elevated core body temperature. Heat stroke is a life-threatening condition characterized by elevated core body temperature >104°F (>40°C) resulting in central nervous system dysfunction, circulatory failure, and potential multiorgan failure.[37] Initial treatment of heat stroke includes immediate cooling via whole body immersion, if available, and transfer to the nearest emergency department. Guidelines to minimize risk of exertional heat illness in youth sports are applicable to soccer, particularly during hotter months and the early part of the season, when players may not be sufficiently acclimatized.[37]

Another potential hazard for those engaging in outdoor activities is lightning. According to the National Oceanic and Atmospheric Association, lightning strikes an average of 400 people and kills 49 of these victims every year in the United States.[38] Although there are no specific data with respect to youth soccer, this remains a risk in all outdoor physical activities, and careful monitoring during inclement weather can identify potentially dangerous conditions so prevention strategies can be implemented.

Fatalities in Soccer

Fatalities in youth soccer are rare and have historically been attributable to blunt trauma with goalposts.[39,40] A previous study of 1.6 million emergency department visits attributable to soccer injuries from 1990 to 2003 identified 2 fatalities resulting from a brain hemorrhage and a ruptured spleen caused by blunt trauma.[20] The US Consumer Product Safety Commission has reported 36 previous fatalities in soccer as a result of falling goalposts since 1979 and has published specific recommendations regarding proper installation, use, and storage of goalposts to reduce the risk of injury.[41]

Footwear and Playing Surface

Footwear type and playing surface may affect lower-extremity injury rates. Outdoor soccer shoes are cleated and have either bladed studs or a combination of bladed and conical studs. Generally, bladed studs afford greater traction and speed; however, they may be associated with increased rates of injury. In a systematic review of 23 studies investigating the relationship between cleat-surface interaction and injury rates, Silva et al[42] found that bladed studs were associated with an increased risk of injury related to higher pressure on the lateral foot border when compared with rounded studs. Conical studs allow for quicker release and provide a greater degree of stability because they offer more points of contact with the playing surface. Although this stabilizing feature may translate to a lower risk of injury, more in vivo studies are needed. The pattern of stud placement on cleated shoes may also affect injury rates. A study on American football revealed that shoes with longer irregular cleats placed at the peripheral margin of the sole and a number of smaller pointed cleats positioned interiorly were associated with a higher risk of ACL injuries than flat, soccer-style cleats on which the studs on the forefoot were the same height, shape, and diameter.[43]

When artificial turf debuted, an increase in lower-extremity injuries was noted.[44] Authors of initial studies postulated that increased shoe-surface friction produced increased torque at the knee and ankle.[42] The most recent third generation of artificial turf has longer grass-like fibers embedded in granules of sand, rubber, and/or silica and more closely mimics natural grass. Several recent studies reveal no difference in injury rates during games played on grass or turf but higher injury rates during training on grass.[45,46] In youth soccer specifically, a 2016 study revealed that players who suffered a lower-extremity injury were 2.83-fold more likely to have played on a grass surface and were 2.40-fold more likely to have worn cleats on grass in practice (versus cleats on artificial turf) compared with players who were uninjured. These researchers also found that training on grass was associated with a 2.8-fold increased risk of lower-extremity injury, but game injuries did not vary significantly when comparing artificial turf with grass.[46] This finding mirrors a similar study in adults that revealed no significant differences in the incidence of lower-extremity injuries on artificial turf or grass for male and female elite soccer players in games.[45]

In the last few years, media reports have surfaced suggesting a possible relationship between playing on synthetic turf and the development of certain childhood cancers, particularly leukemia and lymphoma.[47] The basis for these media reports has been anecdotal, and to date, no epidemiological or longitudinal research regarding a causative relationship between artificial turf and neoplasia has been published.[48]

INJURY RISK FACTORS

Considerable recent research has undertaken the goal of identifying modifiable risk factors for injury in youth soccer, specifically related to lower-limb injuries and concussions. A number of neuromuscular imbalances have been suggested as risk factors for injury, including quadriceps dominance, leg dominance, dynamic instability, and neuromuscular activation patterns.[49] In previous research of biomechanical risk factors for overuse injuries in youth soccer players, increased quadriceps, hamstring, and hip flexor strength were found to be protective, but increased knee valgus was found to increase risk.[19] In a single prospective study of 11- to 15-year-old female soccer players, low normalized knee separation during drop-jump testing was found to be a significant predictor of subsequent lower-limb injury.[50] All of these risk factors may be exacerbated by fatigue because injury risk appears to be greater during the later portions of practices and games[51,52] as well as among players with decreased levels of aerobic fitness.[53] In addition, previous lower-extremity injury has been consistently identified as an important risk factor that may reduce strength and alter neuromuscular recruitment patterns.[49,54,55] Although this has not been studied in youth soccer specifically, history of previous concussion may also increase the risk of subsequent lower-limb injury among collegiate athletes and represents an important area of future investigation.[56,57]

Sport participation history and training loads may also influence the risk of injury in youth athletes,[58–60] but further information is needed to guide recommendations for soccer players specifically. Injury risk does seem to increase with age, but the relationship with competition level is unclear.[61–64] A single study of youth soccer players revealed that children in higher skill-level leagues had reduced injuries per 1000 hours compared with age-matched counterparts, although players at a higher competition level had a much higher participation volume, leading to a similar number of absolute injuries per year.[65] Early sport specialization has been shown to be associated with an increased risk of overuse injury across a number of youth sports.[59,66–68] There are few data regarding sport specialization and injury risk specifically among soccer players, with a single recent study of elite male adolescent soccer athletes revealing that specialization was associated with a decreased risk of previous injury overall and was not related to previous overuse injury.[69] Inadequate sleep and fatigue have been shown to be risk factors for injury in youth athletes,[60,70] although this has not been specifically studied in soccer. Finally, overtraining is considered an important risk factor for injury in a number of sports, and acute increases in training load have been shown to be an independent risk factor for injury in youth soccer players, perhaps as a result of impairments in sleep and subjective well-being, which serve as early indicators of overtraining.[58,71,72]

An often overlooked risk factor for injury is illegal play.[73] Collins et al[73] analyzed data regarding rates of injury attributable to activity that was deemed to be a violation of the rules of the game in high school athletes involved in various sports. Soccer had the highest rates of injury related to illegal activity, and a greater proportion of injuries related to illegal activity involved the head and neck, including concussion, compared with injuries from legal activities.[73]

INJURY PREVENTION

Injury prevention involves the identification of risk factors and subsequent modification of those factors to decrease the likelihood of injury. Risk factors can be proper to the athlete, also called intrinsic factors (such as anatomy or emotional well-being), or can originate outside the athlete, also called extrinsic factors (such as environmental conditions or playing surface).[74] Injury prevention can be classified as primary or secondary. With primary prevention, the aim is to prevent injuries before they occur, whereas the goal for secondary intervention is to reduce the impact of an injury once it has occurred.[74] Most of the strategies discussed in this report will be focused on the primary prevention of injuries in youth soccer through modification of both intrinsic and extrinsic modifiable risk factors.

Preparticipation Physical Examination

The preparticipation evaluation (PPE) is a critical opportunity for primary prevention and takes place before the athlete even touches the soccer field. Although few concrete data exist to validate its use as a screening tool, a uniformly applied PPE is generally believed to be the optimal opportunity to detect any medical conditions that may be potentially life-threatening or disabling or that may predispose the athlete to injury.[75] The PPE monograph is a collaborative effort among several national medical organizations, including the AAP, and serves as a useful tool for pediatricians regarding best practices for performing the examination.[76]

For soccer players, noting any previous musculoskeletal injuries, especially lower-extremity injuries such as ankle sprains, knee injuries, or groin strains, as well as a detailed history of previous concussions or head injuries allows for rehabilitation if deficits are identified. Given that cardiac etiologies account for 56% of nontraumatic causes of sudden death in collegiate athletes,[77] noting the presence of any cardiac-related symptoms as well as a detailed family history of any cardiac conditions, especially hypertrophic cardiomyopathy, allows for further workup. As part of a complete physical examination for sport, critical areas of focus include assessment of the cardiovascular system, a baseline ocular examination, and a thorough musculoskeletal examination with special attention to the weight-bearing joints of the lower extremities.[75]

Neuromuscular and Biomechanical Training

As previously mentioned, ACL injuries represent a source of significant morbidity for youth soccer players, especially girls. The reasons for the relatively high prevalence of ACL injuries in girls are likely multifactorial.[25] Most noncontact ACL injuries occur when landing from a jump, stopping abruptly, or quickly changing direction during deceleration. Compared with boys, girls tend to have a higher degree of internal rotation at the hip and external rotation of the tibia when decelerating or landing. Girls also have a higher tendency to land with insufficient knee and hip flexion.[78] Additionally, girls tend to have a greater degree of quadriceps activation and differences in muscle recruitment, timing, and strength, which appear to increase the risk for ACL injury. Given that these biomechanical factors represent a potentially modifiable risk factor for ACL injuries, authors of multiple studies have investigated the effectiveness of teaching proper landing and deceleration techniques, muscle strengthening and recruitment, neuromuscular warm-up, proprioception, and plyometrics.[79–81] Mandelbaum et al[79] studied the effectiveness of such a program and demonstrated a 74% to 88% reduction in ACL injury. In 2011, LaBella et al[81] investigated the effects of a neuromuscular warm-up program in female athletes in Chicago public high schools and showed a 56% reduction in noncontact lower-extremity injuries and a lower ACL injury rate in the intervention group. General recommendations for strengthening programs include an emphasis on gluteal and hamstring strength and recruitment as well as core strength and trunk stabilization.[82] Pediatricians can access a video demonstration of such ACL injury prevention exercises on the AAP Web site (https://www.aap.org/en-us/about-the-aap/aap-press-room/aap-press-room-media-center/Pages/preventingACLinjury.aspx). The Fédération Internationale de Football Association (FIFA) developed a warm-up program called “FIFA 11+” that consisted of 10 strengthening, plyometric, and proprioceptive exercises designed to decrease the frequency and severity of injuries in soccer.[83] Multiple studies have revealed the program to be significantly effective at decreasing the incidence of injury in male and female youth players.[80,83–86]

Individual Player Monitoring

Overtraining, stress, and inadequate rest may individually or jointly contribute to risk of injuries among athletes in soccer and other youth sports.[58,87,88] As previously mentioned, an acute increase in training load has been shown to be an independent risk factor for injury in youth soccer players. Spurred by advances in development of wearable technology, individual player monitoring has exploded in popularity in the last few years.[24,89–91] Although not as prevalent as in collegiate or professional teams, youth teams, especially elite club and travel teams, are beginning to employ user-friendly wearable technologies to measure training loads, accelerations, and decelerations as well as heart rate. Many training staffs use such technologies to adjust the design, pace, and components of practice sessions in an effort to maximize performance and reduce injuries; however, there is limited research regarding the effectiveness of such technology in achieving these aims.

Because fatigue and inadequate sleep may be risk factors for injury,[60,70] multiple technologies exist for monitoring sleep, such as sensor-embedded wristbands and smart phone applications; however, there is a paucity of medical literature regarding their effectiveness, particularly in young athletes. Various studies have revealed an inverse relationship between psychological well-being and risk of injury. Steffen et al[92] discovered that in female youth soccer players ages 14 to 16 years, the risk of injury was 70% greater among players with a high degree of perceived life stress. Many professional and collegiate programs are now using athlete self-report measures to gauge their athletes’ response to training with respect to mood, motivation, perception of well-being, and stress levels. In addition, programs are also training athletes in mindfulness skills, coping mechanisms, and stress-reduction strategies in an attempt to mitigate the effects of negative self-perception and stress. Swedish investigators conducted a randomized study in junior elite soccer players and found that 67%

of the players in the intervention group who received mindfulness-based training remained injury free at the end of the season, compared with 40% in the control group.[93]

Concussion

Eliminating all concussions from soccer is unattainable; however, implementation of prevention strategies may reduce the number and severity of concussive injuries.

All 50 states and the District of Columbia have passed concussion legislation mandating schools to develop concussion protocols and restrict participation after suffering a head injury.[33] Most are modeled after Washington State's Lystedt Law, which mandates automatic removal from play for any suspected concussion, medical clearance before returning to sport, and education for parents, athletes, and coaches. Pediatricians and other health care providers are encouraged to familiarize themselves with the precise language and requirements in the legislation regarding concussion in their individual states.

As mentioned previously, the majority of concussions in soccer occur during the act of heading but are attributable to player-player contact, not player-ball contact.[30] In a recent study, contact with another player was the most common mechanism of injury in heading-related concussions among boys (68.8%) and girls (51.3%).[28] Because of concerns regarding heading, the US Soccer Federation unveiled an initiative aimed at reducing concussions by banning heading for children 10 years and younger and limiting the amount of heading in practice for children between the ages of 11 and 13 years.[94] More research is needed to evaluate whether this program will reduce the number of concussions in these age groups. Instructing young soccer players in proper heading techniques once the athletes demonstrate body awareness and visual tracking skills and have developed the requisite core and cervical strength is imperative. Following manufacturer recommendations for proper ball inflation and size for the age of the players also is recommended. Finally, adherence to fair-play practice and enforcement of rules may reduce the number of foul plays and dangerous contacts and may therefore reduce the risk of concussive injuries.[30]

Current evidence is insufficient to support the uniform use of headgear or mouth guards to prevent concussion.[95,96] Mouth guards have been shown to prevent orofacial injuries; however, evidence is mixed regarding risk reduction in sports-related concussion.[95,97] The use of soft headgear has been studied more extensively in rugby, in which it has been shown to reduce superficial abrasions but not affect the overall rate of concussion.[98] In laboratory testing, by using head forms, soccer headgear has not been shown to attenuate the head impacts during simulated soccer ball heading.[99] Although Delaney et al[100] concluded that headgear use in youth soccer players may reduce the risk of concussion, the national governing body for soccer in the United States does not permit its members or affiliates to require the use of headgear by players.[101] Use of padded headgear is controversial because of the paucity of rigorous medical studies as well as concern for possible increased risk of injury resulting from a false sense of security.[96]

Fair Play and Rule Enforcement

Foul play, or actions that violate the rules of the game, has been associated with an increased incidence of injuries in various levels of many sports, including soccer. In a study of professional soccer players, foul play was found to be involved in 14% to 37% of all injuries.[102] Peterson et al[65] studied soccer injuries over a 1-year period in different age groups and skill levels and found that 82% of players suffered at least 1 injury. Forty-six percent of the injuries were attributable to contact, and almost half of these were associated with foul play.[65] With respect purely to youth soccer, Emery et al[103] discovered that direct contact was involved in 46.2% of all injuries. Limiting foul play, penalizing dangerous behavior, and properly enforcing the rules are generally believed to reduce the risk of injury in sport. Referees, players, and spectators all have a responsibility to advocate for fair play and sportsmanship.

Protective Equipment

Shin guards are the only protective devices that are required by FIFA, the National Collegiate Athletic Association, and the US Soccer Federation.[104–106] Currently, shin guards are typically made of polypropylene and plastic composites, although some also contain fiberglass, para-aramid synthetic fibers, or copper. Although they certainly protect against leg abrasions and contusions, the role of shin guards in reducing the risk of fractures has not been fully demonstrated to date.[107,108] Nevertheless, laboratory studies indicate that shin guards significantly dissipate the forces and strain on the tibia that could cause fracture.[109,110] Appropriately sized shin guards should cover most of the anterior tibia, and the National Operating Committee for Standards in Athletic Equipment has established standards for function.[111]

Dental injuries can occur in all contact sports, and soccer is no exception. Two older studies revealed that dental injuries account for 0.2% of all high school athletic injuries,[112,113] and more recent data suggest an overall incidence rate of 0.06 and 0.11 dental injuries per 10 000 athletic exposures in boys' and girls' high school soccer, respectively.[36] In all of these studies, the rate of dental injuries appears to be lower for soccer than for many other contact sports.[36,112,113] Although most studies affirm that custom-made mouth guards confer better protection than the more common "boil and bite" type, a vast majority of studies reveal that simply by wearing mouth guards, athletes can significantly decrease the frequency and severity of orofacial injuries in contact sports.[114–116]

Injuries to the eye and surrounding orbit can occur in any contact or projectile sport. Traumatic ocular injuries have the potential for significant long-term morbidity. Boys account for a significantly greater proportion of injuries than girls, and the peak incidence occurs in mid-to-late adolescence. A recent study revealed that soccer accounted for almost 7% of all ocular trauma.[117] Approximately 90% of serious eye injuries are preventable through use of appropriate protective eyewear.[118] The AAP and the American Academy of Ophthalmology classify soccer as a moderate-risk sport and strongly recommend that all young participants wear eye protection that meets the American Society for Testing and Materials standard F803,[119] which specifies that protective eyewear be made of polycarbonate, impact-resistant plastic and be worn by all athletes who are functionally monocular or who have a history of major eye surgery or trauma.[119]

Given that sudden cardiac arrest is the leading cause of nonaccidental death in youth and can occur with athletic activity, physicians involved with soccer organizations are encouraged to advocate for basic life-support training of coaches as well as placement of automated external defibrillators at practice and competition sites.[120]

Environmental Safety

Heat and lightning pose an extrinsic risk to participants in outdoor sports. The number of heat-related injuries increased 133% from 1997 to 2006, and youth accounted for the largest proportion of those injuries.[121] Additionally, recent evidence suggests that heat-related illness may be increasing with climate change.[122,123] Every year, lightning accounts for dozens of deaths in the United States, although data regarding the incidence among youth soccer participants are not available.[124] Precautions and simple strategies may reduce the risk of injury due to adverse environmental conditions.

Heat

Some primary prevention strategies for heat illness include acclimatization, activity modification, development of an emergency action plan, and hydration.[37] The risk of heat illness appears to be highest in deconditioned athletes at the start of the season.[37] Allowing athletes 7 to 14 days to acclimate their bodies to heat is essential. Several state high school organizations have formal policies regarding heat acclimatization. It is recommended that all youth teams and institutions have a policy regarding heat that incorporates an emergency action plan that addresses properly monitoring ambient weather conditions, ideally with a wet-bulb globe temperature device, and modifying training sessions in certain hot and humid conditions.[37] Some activity-modification strategies include limiting warm-ups, scheduling hydration and rest breaks, shortening sessions or holding them earlier or later in the day, and canceling events in case of dangerous conditions.[37] Although the incidence of heat illness has not been directly compared between artificial turf and natural grass surfaces, significantly elevated surface temperatures have been reported on in-filled turf fields,[125] and this may need to be considered for soccer played on turf.

Ensuring proper hydration before starting a workout and replacing fluids lost through sweating during and after exercise are important considerations for athletes.[37,126] Although fluid requirements will vary between individuals and environmental conditions, fluid intake of 300 to 750 mL/hour for 9- to 12-year-olds and 1.0 to 1.5 L/hour for adolescents is typically sufficient to offset sweat losses and reduce the risk of dehydration during intense exercise in hot conditions.[37] Water is generally sufficient for hydration during soccer competition, although sports drinks that contain additional electrolytes and carbohydrates may be considered during periods of prolonged, intense activity.[127] In general, caffeine and energy drinks do not play a role in proper hydration during exercise and are not recommended in children and adolescents.[127]

Lightning

Primary prevention of lightning injuries requires careful monitoring of weather conditions. Strategies for prevention of lightning injuries by the Centers for Disease Control and Prevention include having venue-specific emergency action plans, suspending activities when thunder and lightning are present (typically within 6 miles), and moving athletes and spectators to shelters designated specifically for lightning.[128] Activities may resume 30 minutes after the last strike of lightning is seen (or at least 5 miles away) and after the last sound of thunder is heard.[38,128,129]

Footwear, Playing Surface, and Field Conditions

Some studies in soccer athletes indicate that shoes with bladed cleats improve performance during changes of direction but may increase the torque and rotational movements on the ankle and knee joints, which may theoretically lead to injury; however, most studies reveal no increased rate of injury when comparing cleat type.[42] General recommendations for soccer footwear include ensuring that the shoe fits properly, that the laces are fastened completely, and that the cleat type is appropriate for the surface of play. Although practicing on artificial turf may be associated with a decreased injury risk compared with natural grass, injury rates during games appear to be similar between the 2 surfaces.[45,46] Regardless of the playing field type, players as well as coaches and referees may consider checking the condition of the field before playing to identify potential hazards, remove any debris, fill any divots or holes, and assess for areas of poor water drainage. The US Consumer Product Safety Commission recommends that movable soccer goals be securely anchored to the ground and only used on level playing fields and that no one climbs or hangs from a post.[41]

CONCLUSIONS AND GUIDANCE FOR PEDIATRICIANS

1. Soccer remains the most popular youth sport in the United States, with a relatively large proportion of preadolescent participants. Although injuries occur in soccer, injury rates appear lower than those for many other contact sports and are particularly low in soccer players younger than 12 years of age. Pediatric health care providers can feel comfortable with advocating for participation in soccer as a means of promoting physical fitness and the wide-ranging benefits of exercise.
2. Soccer is associated with certain types of injuries that commonly present to pediatric offices, school-based health clinics, and emergency departments. These injuries include lower-extremity sprains, strains, fractures, and concussions. Familiarity with the management of these injuries will aid the pediatrician in the care of this large and growing population of young athletes.
3. ACL tears are a significant cause of morbidity in young soccer players, especially girls. Neuromuscular training programs have been shown to reduce the risk of injury by teaching proper landing and stopping techniques and developing strength and balance. Pediatricians can access a video demonstration of such ACL injury prevention exercises on the AAP Web site (https://www.aap.org/en-us/about-the-aap/aap-press-room/aap-press-room-media-center/Pages/preventingACLinjury.aspx).
4. Concussions are relatively common in soccer. Data are insufficient regarding the long-term effects of repetitive heading in youth soccer. Further research is needed regarding the potential protective effect of headgear or intervention programs on reducing the risk of concussion. The majority of concussions occur as a result of contact with an opposing player rather than the ball; however, an emphasis on fair play, rule enforcement, and proper age-appropriate heading techniques may reduce the risk of concussion in youth soccer participants. Encouraging athletes to report subjective symptoms facilitates proper diagnosis and management.
5. Other injury reduction strategies for soccer include completion of a PPE before the start of the season to identify any risk factors for injury, proper hydration and rest, modification of activities in hot and humid weather, use of appropriately sized shin guards and mouth guards, and use of proper protective eyewear, especially for athletes who are functionally one-eyed.
6. Adherence to fair-play rules may reduce injuries. Physicians who work with soccer organizations are encouraged to advocate for enforcement of rules and promotion of fair play at all levels of the game. Parents, spectators, and coaches can assist referees by honoring and promoting the spirit of fair play with young athletes.

RECOMMENDED RESOURCES

The US Consumer Product Safety Commission guidelines for movable goals[41]: www.cpsc.gov/safety-education/safety-guides/sports-fitness-and-recreation/guidelines-movable-soccer-goals

The Centers for Disease Control and Prevention lightning safety tips[128]: www.cdc.gov/disasters/lightning/safetytips.html

The AAP ACL injury prevention video demonstration: https://www.aap.org/en-us/about-the-aap/aap-press-room/aap-press-room-media-center/Pages/preventingACLinjury.aspx

The AAP climatic heat stress policy statement.[37]: http://pediatrics.aappublications.org/content/128/3/e741

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ABBREVIATIONS

AAP: American Academy of Pediatrics
ACL: anterior cruciate ligament
FIFA: Fédération Internationale de Football Association
PPE: preparticipation evaluation

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

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