Chapter 12
Concussion Prevention

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Clinical Case

A mother and father accompany their 14-year-old son to his preseason pre-participation physical for high school sports. They inquire if there are any strategies or interventions that the high school is implementing to prevent concussions.

The following discussion will provide an overview of prevention strategies developed to reduce SRCs among athletes.

Protective Gear

Question: Are helmets effective at preventing concussions?

Helmets and Headgear

There is consensus among researchers, clinicians, and industry professionals that proper equipment, particularly helmets and headgear, protect against head injuries. The American Medical Society for Sports Medicine, for example, endorses helmet use to reduce scalp lacerations, skull fractures, and intracranial bleeds [1]. For a helmet or headgear to prevent an SRC, it must attenuate linear and rotational acceleration, which are the primary underlying mechanisms of SRCs [2].

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D. S. Patel (ed.), *Concussion Management for Primary Care*,
https://doi.org/10.1007/978-3-030-39582-7_12

Researchers have not been able to prove that helmets reduce SRCs, notwithstanding anecdotal evidence to the contrary. Investigating the effect of helmets to reduce SRC has proven to be challenging, especially in football, hockey, and other team collision sports, due to co-variability and ethical issues around having cohorts of athletes sustain from wearing helmets and comparing the rate of concussions in this group with athletes that are wearing helmets [3]. Players wear a variety of helmet brands and models, and different helmets may perform better under certain circumstances or when used by athletes in specific positions.

Changes to helmet design often involve tradeoffs. For example, heavier helmets typically attenuate linear acceleration but are less comfortable and accelerate rotational momentum and the duration of such rotation [2]. Many new helmet designs significantly reduce direct focal external force transfers, but these designs have not been proven to prevent linear and rotational acceleration. Interestingly, some argue that wearing seemingly more protective equipment, such as full-face masks in hockey and thicker padding in football helmets may, in fact, increase risky behaviors in wearers stemming from a false sense of security thereby exposing them to a greater risk for SRCs and other injuries [1, 4].

Football

Question: Are there specific football helmets that prevent concussions?

Football helmet manufacturers have developed and continue to develop helmets incorporating new designs and materials intended to reduce SRCs. The National Football League ("NFL"), in conjunction with the National Football League Players Association, the NFL players' union, conducts an annual laboratory test, the NFL/NFLPA Helmet Performance Test, which stimulates certain concussion-causing impacts to assess the performance of helmets worn by NFL players [5]. According to the 2019 NFL/NFLPA Helmet Performance Test, approximately 50% of NFL players upgraded to a better performing helmet after reviewing the study's results, and those wearing top performing helmets reported fewer concussions [5]. Nevertheless, research unaffiliated with the NFL has failed to show a meaningful difference in the incidence of SRCs with newer helmet models [6].

Other Sports

Question: Should athletes in soccer and other sports wear headgear to prevent concussions?

Studies have found that ski and snowboard helmets provide protection against head injuries, but, as another study pointed out, the studies did not separate concussions from other head injuries when looking at their efficacy towards concussion prevention

[3, 7, 8]. Several bicycle helmets, especially newer designs, have built-in mechanisms to reduce rotational head acceleration caused by an oblique impact [9–11]. Wearing headgear in soccer has been explored with conflicting evidence for SRC reduction benefit [12]. In the past, rugby headgear has not provided any protection against concussions [13]. However, newer headgear using a viscoelastic material has shown the ability to reduce linear and rotational impact energy in the test setting, which could potentially help reduce the rate of developing and the severity of concussions in rugby [14]. As stated above, the added protection may also inadvertently promote more aggressive and risky behavior.

Mouth Guards

Question: Do mouth guards have any affect in preventing or reducing the severity of concussions?

It is widely accepted that mouth guards protect against overall head injury, especially dental injuries, while playing contact sports. However, the effectiveness of mouth guards in reducing concussions specifically is less clear [15, 16]. A meta-analysis did suggest a nonsignificant trend towards a protective effect of mouth guards against concussions in contact sports, specifically when looking at basketball, ice hockey, and rugby [3].

Fit and Maintenance

Question: Is there any reputable sources to assist in properly fitting headgear?

Ensuring the proper fit of equipment is paramount. The use of an ill-fitting helmet, for example, is a risk factor for concussions with more symptoms and of longer duration [17]. The Centers for Disease Control and Prevention launched a mobile web-based application as part of their larger Heads Up: Concussion program to help find a properly fitting helmet for various sports [18]. It is also important to periodically inspect helmets, mouth guards, and other equipment throughout sports seasons in addition to at the beginning of each season and repair or replace whatever has become deformed, worn down, or no longer fits [17]. Moreover, designating a specific person to monitor for proper fit is essential, especially in youth and high school athletes where head size and hairstyle may change throughout the season.

Cost

Unfortunately, protective equipment in contact sports can be expensive. In 2016, *The Gadsden Times*, an Alabama newspaper, estimated that the cost of outfitting a high school football player for a practice and a game might be between $800 and

$1000 [19]. The list price of the top-ranked helmet in the 2019 NFL/NFLPA Helmet Performance Test is $950 [20].

Such expenses typically present, at minimum, financial hardship to parents and/or school districts and may even bar youth participation in the sport altogether. Programs that help provide youth athletes or youth sports teams with new or gently used equipment, such as Good Sports [21], Sports Matter [22], and The Sports Shed [23], may help reduce these costs. Additional care is required to ensure that such equipment is appropriate and fits correctly [24].

Athlete Bias

Question: Do athletes use the safety-related equipment that is designed to reduce the risk of concussion?

Countless examples exist of professional athletes resisting safety-related equipment upgrades for behavioral and even cosmetic reasons [25, 26]. For example, the overwhelming majority of Major League Baseball pitchers do not wear protective liners and caps designed to protect them from dangerous line drives hit back at them. Such intransigence has been addressed through a combination of rule changes at professional and youth levels designed to socialize these players from a young age to the more protective equipment [27].

Technique

Question: Are organized sports organization incorporating skill instruction in an attempt to reduce the risk of sport-related concussions?

More than ever, organized sports have largely replaced neighborhood pickup games beloved by previous generations of Americans. While the proliferation of organized sport has its detractors and disadvantages, one potential benefit is an increase in opportunities for youth participants to learn proper techniques, especially in high-risk maneuvers associated with SRCs, such as football tackling, hockey body checking, and soccer heading [1, 28, 29].

Using this time for skill development and instruction instead of games may reduce SRCs. Athletes learn better body control to prepare them for the inevitable collisions that will occur when they grow older and join leagues that permit these maneuvers. Additionally, this training now incorporates sport-specific techniques to reduce head acceleration.

Football

USA Football, a youth football governing body, heavily promotes Heads Up Football ("HUF"), a series of online and in-person courses for coaches to learn about proper equipment fitting, tackling technique, and instruction in drills designed to reduce head contact [30]. HUF's tackling module includes fundamentals of and systems for teaching shoulder tackling and draws on principles of rugby tackling, which does not use the head [31]. A 2015 study found that HUF reduced injury rates but *The New York Times* raised issues with how USA Football and the study's authors presented certain data from that study [28, 32, 33]. Further, that study evaluated the entire HUF program so the efficacy, if any, of the HUF tackling model on reducing SRCs was debated. A more recent prospective study demonstrated a 33% reduction in SRC with HUF, providing some potential for benefit [34].

Soccer

Strategies to reduce head acceleration when heading the ball in soccer include achieving head-neck-torso alignment and neck strengthening (discussed below) [35, 36]. Other experts recommend using lightweight soccer balls to teach and perfect heading techniques [36]. In theory these recommendations make sense but lack the support of strong evidence-based clinical research.

Hockey

Coaching and education programs in the United States and Canada emphasize teaching youth to keep their heads up, especially when about to receive a check. Since the implementation of programs emphasizing these skills there has been a decrease in cervical spine injuries, but the effectiveness of these techniques have not been formally assessed [37]. USA Hockey's American Development model emphasizes skill and skating development including proper body control, angling, and body contact but does not teach body checking skills until 11–12-year-old age group [37].

Neck Strengthening

Question: Do neck strengthening exercise prevent concussions?

Small and/or weak neck musculature is an SRCs risk factor [38]. Neck strengthening may help prevent SRCs by reducing head acceleration [39, 40]. Support for neck strengthening exists primarily based on anecdotal evidence- and lab-based testing,

but not clinical evidence. One such lab study found that every 1-pound increase in neck strength contributes to a 5% decrease in odds for a concussive event to occur [38]. This protective benefit is likely due to the decreased kinematic response of the head to controlled impulsive loading with greater neck strength [39]. It is also believed that neck-strengthening exercises are more likely to reduce SRCs in females than males due to females' weaker necks [1, 38, 41–44]. Multiple neck strengthening programs have been proposed that show promise [39, 45]. However, further research is required on the benefit of neck strengthening on concussion prevention during actual play.

Rule Changes

Question: How effective have rule changes been in reducing the number of concussions? Is there a difference in the effectiveness from sport to sport?

Rule changes intended to reduce collisions that often result in concussion have been proposed and implemented in several sports. The difficulty in coming up with new rules is finding a balance between limiting the number of head collisions while maintaining the game's integrity. Additionally, rule changes in specific sports cannot be generally applied across all levels of play from youth to the elite level.

Football

Football has implemented several safety-related rule changes in an effort to reduce SRCs and other injuries. In 2011, the NFL moved the kickoff line forward by 5 yards in an attempt to prevent concussions. That rule change was intended to increase rates of touchbacks on kickoffs, a play involving high-speed collisions in which a disproportionate number of SRCs have been found to occur. In 2016, the Ivy League, a Division I National Collegiate Athletic Association conference, moved the kickoff and touchback lines up to the 40-yard and 25-yard lines, respectively, for the same reasons. A 2018 study found these rule changes reduce the average annual concussion rate in Ivy League football by more than 68% [46].

Certain youth football leagues have postponed tackling until a certain age and/or reduced the number of contact practices [47].The NFL also adopted a rule beginning in the 2018–2019 season making it a foul for a player to lower his head to initiate and make contact with his helmet against an opponent [48].

Hockey

Body checking and fighting, which are associated with higher risk of SRCs, are hot button, safety-related issues debated in hockey. Until the 2010–2011 season, a body check to an opponent's head as the primary point of contact was legal in the National Hockey League ("NHL"). Beginning that season, in an effort to prevent SRCs and other head injuries, the NHL adopted Rule 48.1, which made *targeting* an opponent's head from the blind side illegal. An independent study released in July 2013 found no decrease in concussion incidence among NHL players following implementation of Rule 48 [49].[1]

Removing body checking at the youth level has also gained popularity [37]. Since 2011, USA Hockey, the American youth hockey governing board, has prohibited all body checking in players 12 and younger [37]. In Canada, the age at which body checking is allowed has also increased to 13 years old [37]. A 2011 Canadian study found that eliminating body checking under age 13 lead to significant reduction in SRCs among youth 13 and under compared to SRCs among similarly aged youth playing in leagues that allowed checking [50]. Opponents of the youth body checking ban were concerned that such a ban would increase the risk of injury, including SRCs, to young players by depriving them of the chance to learn proper body checking technique once they grew and joined leagues in which body checking is permissible. The authors of this chapter are not aware of any research that substantiates this concern and the same 2011 Canadian study specifically refuted it [37, 50]. Disallowing body checking has also been incorporated into older age groups in non-elite levels, but the impact on concussions in these groups requires further investigation [51].

In an effort to reduce fighting, beginning the 2016–17 season, the American Hockey League adopted Rule 23.7, which provides an automatic one-game suspension after a player incurs ten fighting major penalties during the regular season [52]. The Ontario Hockey League adopted a similar rule in 2011 [53].

Other Sports

Other sports have also instituted rule changes in an effort to reduce SRCs. For example, since 2014, Major League Baseball has banned avoidable collisions between catchers and base runners at home plate by initiating a rule that disallows runners attempting to score from deviating from his direct pathway to the plate [54].

[1] Rule 48 has been revised several times since the 2010–2011 and season and currently to define an illegal check to the head as "a hit resulting in contact with an opponent's head where the head was the main point of contact and such contact to the head was *avoidable*." http://www.nhl.com/nhl/en/v3/ext/rules/2018-2019-NHL-rulebook.pdf; https://www.cbc.ca/sports-content/hockey/opinion/2013/09/30-thoughts-nhl-clarifies-illegal-check-to-head-rule.htm

In 2015, US Soccer, the soccer governing body in the United States, banned heading among players younger than age 10 and limited the amount of heading in practice among players ages 11–13 [55, 56].

Rule Enforcement

Question: How effective have rule changes been in reducing illegal play?

While the rules of play form the basis of safer play, athletes, coaches, and officials need to adhere to the rules in order for them to make a difference [37]. In high school athletes, illegal activity contributed to over 10% of injuries in boys and girls soccer and basketball, and concussions made up the greatest percentage of those injuries [57]. The injuries related to illegal play are even greater in other leagues and have been reported to be as high as 50% [57, 58]. Promoting fair and safer play requires an attitude shift and modeling by coaches, parents, officials, and managers in addition to the athletes. In ice hockey, fair play rules, a program developed to reward teams with good sportsmanship, has contributed to a significant reduction in injuries including concussions [37]. Additionally, the zero tolerance to head contact rule change in the NHL has led to a 36% reduction in concussion risk [49]. In soccer, stricter enforcement of red cards for high elbows during heading duals has led to a slightly reduced risk of concussion [3, 59].

Legislation

Question: Have states implemented legislation to protect children from SRCs?

Is medical clearance needed prior to returning to sports following a concussion?

Concussion management in youth sports is subject to a state-by-state patchwork of laws and regulations [60, 61]. The most well-known of these laws is Washington State's Lystedt Law [62]. The Lystedt Law was enacted in 2009 in the aftermath of the tragic death of Zackery Lystedt who suffered multiple concussions in a single game resulting in intracranial hemorrhage and severe traumatic brain injury. The Lystedt Law has three main components: (1) removal; (2) medical clearance for return-to-play; and (3) education [60, 62]. Since the Lystedt Law's enactment, all 50 states have enacted some form of legislation to protect children from SRCs. Many of these are patterned on the Lystedt Law but significant differences exist.

Several studies have looked at the impact of the Lystedt Law in Washington State and similar laws in other states on concussions in high school athletes [61, 63–65]. Studies have found an increase both in the frequency of concussions and the mean number of days during which concussed youths are held out of play. This is likely due to the increased awareness of concussions in addition to the need for medical clearance prior to returning to play. In regards to implementation, high school football and soccer coaches in Washington State endorsed receiving appropriate concussion education 3-years after the Lystedt Law was passed [66]. However, there is still a lot that must be done to in regards to implementation of the laws [61, 63]. One study found that after enacting a concussion law in Ohio the rate of follow-up after an initial ED visit for concussion increased from 44% pre-law to 58% post-law, which means that nearly 40% of concussed players did not receive appropriate follow-up and therefore clearance [61, 64].

Education

Question: Do formal concussion education programs improve concussion knowledge? Does education decrease the rate of concussions?

Several formal education programs have been established that focus on both primary and secondary prevention strategies with specific information geared towards the athletes, coaches/staff, parents, healthcare providers, and/or the public. There is consensus among policies, guidelines, and consensus statements on school sport injury prevention that education is the mainstay of concussion prevention [24]. A large component of programs is teaching improved identification and reporting of concussions to protect against athletes the potential consequences of playing with concussions. Most also emphasize strict adherence to return to play guidelines (refer to chapter on return to play). Programs also aim to educate on the short and long-term consequences of suffering a concussion with the hope of changing attitudes on the playing field to prevent risky behaviors that may lead to concussions. While several educational programs have been developed and most show increased rates of concussion knowledge after the programs, further research into whether they actually decrease the rates of concussions is required. The specific education method or program should be tailored to each individual group to optimize learning. Table 12.1 lists several education programs and resources that currently exist.

The annual pre-participation physical exam (PPE) can be very useful in identifying athletes who have a history of concussion and who may be at increased risk for concussion due to involvement in contact sports. The PPE provides an excellent educative opportunity to inform athletes and their parents of the significance of concussions [51]. The medical professional performing the exam should ask concussion-related questions including past history of concussion, duration of

Table 12.1 Education programs and resources

Program	Target audience	Website
Barrow Brainbook	High school athletes	https://concussion.barrowneuro.org
Brain 101: The Concussion Playbook	Coaches Educators Parents Teen athletes	http://brain101.orcasinc.com/1000/
Concussion Legacy Foundation Team Up against Concussions Advanced Concussion Training	Schools, community centers, and athletic programs with youth in grades 4–12 Families, coaches, teachers, medical professionals, and athletes beyond high school	https://concussionfoundation.org/programs/education
The Center for Disease Control and Prevention's Heads Up	Coaches Parents Athletes School professionals Healthcare provider	www.cdc.gov/headsup/index.html
Heads Up Football	Coaches	usafootball.com/programs/heads-up-football/
National Federation of State High School Associations' Concussion for Students	High school athletes	https://nfhslearn.com/courses?searchText=Concussion
NCAA Concussion Educational Resources	College athletes Coaches Athletic trainers Team physicians Athletic directors	http://www.ncaa.org/sport-science-institute/concussion-educational-resources
Rugbysmart	Coaches Referees	www.rugbysmart.co.nz
ThinkFirst About Concussion	Youth and teens	http://thinkfirst.org/concussion

Note: This table is not exhaustive

symptoms, and the presence of mood, learning attention, or migraine disorders, which have been shown to complicate the diagnosis and management of concussed athletes [1]. However, there is no evidence that pre-existing mood or learning disorders predisposes athletes to concussions.

Conclusion

Researchers have made considerable progress over the past 20 or so years in determining the causes of SRCs but have made fewer inroads in determining how to prevent them. There is no cure-all to prevent SRCs. This much is known.

Nevertheless, much of the existing research is imprecise and/or unsatisfying and questions abound. More research is required, and until such research becomes available, PCPs are left to endorse SRC prevention strategies based largely on intuition and anecdotal evidence.

Key Points

- Investigating the effect of helmets to reduce SRC has proven to be challenging and requires on-going research.
- Teaching proper technique in sports activities such as sport-specific techniques to reduce head acceleration may help to reduce concussions.
- Rule changes intended to reduce collisions that often result in concussion have been proposed and implemented in several sports.
- More research is required and until such research becomes available, PCPs are left to endorse SRC prevention strategies based largely on intuition and anecdotal evidence.

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