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Introduction

Injuries involving the head and neck represent a significant proportion of sports-related trauma incurred by youth athletes. Approximately 6.5 % of over 2.6 million children ≤ 19 years treated for sport and recreation-related injuries in an emergency department setting between 2001 and 2009 had sustained traumatic brain injuries or concussions [1]. In this chapter, we will review the history of protective equipment; evidence supporting the utilization of head, face, and neck protective gear in contact/collision sports; the role protective equipment plays in injury reduction; attitudes among players, medical staff, and coaches toward the use of protective equipment; issues pertaining to enforcement and mandated use of protective gear; advertising and marketing claims regarding protective equipment; and future directions and research regarding head and neck protective equipment.

History of Protective Equipment and Evidence of Effectiveness

Helmets and Headgear

Protective headgear initially was designed for combat due to the vulnerability of the head in wartime operations. With the advent of sophisticated weapons and twentieth-century manufacturing technological advances, mass production of standard-issue head protection became available for soldiers. Significant morbidity and mortality in American football sparked the adoption of modern head protection

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in sport. The first documented use of a leather football helmet occurred during the 1893 Army-Navy game. In 1905, 18 deaths and 129 serious injuries occurred in American football, prompting President Theodore Roosevelt to call a conference with representatives of several Ivy League schools, resulting in the formation of the Intercollegiate Athletic Association, the predecessor to the National Collegiate Athletic Association (NCAA) [2, 3]. Helmet technology continued to evolve in the early twentieth century, with leather padding gradually being replaced by metal and plastic components. However, leather helmets continued to be developed and utilized routinely in American football through the 1940s. Mandatory helmet use in American football did not occur until 1939 in the NCAA and 1943 in the National Football League (NFL). Unfortunately, serious head injuries including intracranial hemorrhages and skull fractures remained prevalent in American football throughout the mid-twentieth century, prompting rule changes, coaching changes, and, ultimately, the formation of the National Operating Committee on Standards for Athletic Equipment (NOCSAE) in 1969, which ultimately implemented the first football helmet safety standards in 1973 [4, 5].

American Football

Since the development of modern-day sports concussion assessment and management guidelines [6–8], few studies regarding helmet effectiveness in reducing head injury in American football have been published. Studies conducted prior to the Prague/Zurich era tended to underreport concussive injuries, reported only the most severe concussive injuries, and relied on coach and certified athletic trainer (ATC) diagnosis [4, 9, 10]. Collins et al. performed a prospective cohort study during the 2002–2004 seasons comparing concussion rates and recovery times for 2141 high school football players. Nearly half the sample wore newer helmet technology (Riddell Revolution), and the remainder used traditional helmet designs from various manufacturers. Over the course of the study, the concussion rate of the Revolution helmet group was 5.3 % compared to 7.6 % in the traditional helmet group ($p < 0.03$) [11]. However, this study was limited by lack of randomization of helmets among study participants, mean chronologic age discrepancies among study groups, and variability in age of the helmets, as the Revolution helmets were brand new while traditional helmets were reconditioned. Additionally, impact exposure was not accounted for.

Rowson et al. performed a retrospective analysis of head impact data collected from 1833 Division I collegiate football players between 2005 and 2010 utilizing helmet-mounted accelerometers, in an effort to determine whether helmet design reduces the incidence of concussion. Concussion rates were compared between two helmet models: the Riddell VSR4 and the Riddell Revolution. The Revolution helmet had a greater offset and 40 % thicker foam than the VSR4 helmet. The number of head impacts each player experienced were controlled for. ATCs or team physicians diagnosed 64 concussions by from a total of 1,281,444 recorded head impacts. Players wearing the Revolution helmets had a 53.9 % reduction in concussion risk compared to players wearing the VSR4 helmet. When each player's exposure to head impact was controlled for, a statistically significant difference was found

between concussion rates for players wearing VSR4 and Revolution helmets ($\chi^2=4.7, p=0.04$). Players wearing VSR4 helmets had a per-impact concussion rate more than twice as high as players wearing Revolution helmets (8.4 vs. 3.9 concussions per 100,000 head impacts, respectively). Additionally, players wearing VSR helmets experienced higher acceleration impacts more frequently, regardless of the position they played. The authors concluded that differences in the ability to reduce concussion risk between helmet models in American football indeed exist [12]. Limitations of this study included lack of randomization of helmets among study participants and widespread underreporting of concussion in Division I college football during the study period.

McGuine et al. performed a prospective cohort study of 2081 high school football players during the 2012 and 2013 seasons to determine whether the type of protective equipment and player characteristics affect the incidence of sports-related concussion (SRC). There were 211 SRCs sustained by 206 players (9 % of included athletes), for an incidence of 1.6 SRCs per 1000 athletic-exposures. No difference in incidence of SRC for players wearing Riddell, Schutt, or Zenith helmets was identified. Additionally, helmet age and recondition status did not affect the incidence of SRC [13]. Limitations of this study included lack of randomization of helmets among study participants and lack of collection of impact exposure data.

Ice Hockey

Similar to American football, ice hockey protective headgear underwent technological advances, beginning with leather and felt construction in the 1950s and the introduction of plastic shells and foam liners in the 1970s which could absorb energy and provide a comfortable fit. In 1979, the National Hockey League (NHL) adopted head protection 11 years following a fatal head injury during NHL play [2]. Despite the widespread use of helmets at both amateur and professional levels, brain injuries remain a serious concern [14]. Recent literature has focused on the role that facial protection plays in modifying head injury risk in ice hockey and will be discussed in a later section.

Cycling

Early bicycle helmets were very rudimentary, constructed from strips of leather sewn together and reinforced with padding. Such designs were largely ineffective in reducing head injury and were replaced in the 1970s with a hard shell and expanded polystyrene (EPS) liner. Over the past several decades, this hard shell has waned in popularity and has been replaced by a thin microshell covering an EPS liner [2]. Wearing a properly fitted helmet has been shown to decrease head injuries by 63–88 % in cyclists of all ages [15]. While the debate and dispute over mandatory helmet use legislation continue, currently only two countries mandate bicycle helmet use for all cyclists: Australia and New Zealand.

Amoros et al. performed a retrospective case-control study utilizing a road trauma registry in France between 1998 and 2008. Thirteen thousand seven hundred ninety-seven cyclist injuries involving the head, face, or neck were identified. The control group consisted of cyclist injuries below the neck. Authors adjusted for age,

gender, type of crash, injury severity, and crash location (road type, urban/rural). For head injury of any severity, the crude odds ratio (OR) for helmeted cyclists was estimated at 0.8 (95 % CI 0.7–0.9), whereas the crude OR for serious head injury was estimated at 0.4 (95 % CI 0.2–0.7). When adjusted for confounders, ORs were lower for both injury subgroups. Authors concluded that bicycle helmet use resulted in a decreased risk of head injury regardless of severity, with a greater decrease for risk of serious head injuries [16].

Bambach et al. performed a retrospective case-control study using linked police-reported road crash, hospital admission, and mortality data in Australia during 2001–2009. One of the primary objectives of the study was to assess the effectiveness of bicycle helmets in preventing head injuries (HIs) among cyclist crashes involving motor vehicles (CCMVs). Cases were those cyclists who sustained HIs and weren't admitted to hospital, while controls were those admitted/not admitted to hospital without HIs. A total of 6745 CCMVs were identified where helmet use was known, and the overall helmet wearing rate was 75.4 %. Of the 639 cyclists with HIs, 42.9 % sustained intracranial injury, 18.5 % sustained skull fracture, and 14.4 % sustained open wounds. Helmet use was associated with up to 74 % reduced risk of HIs in CCMVs. Cyclists not wearing a helmet had 3.9 (95 % CI 2.2–6.8) times higher odds of sustaining moderate, serious, or severe head injuries, with $p < 0.0001$ for all three injury severities. Nearly 50 % of children and adolescents 19 years and younger in the study were not wearing a helmet [17].

Soccer

Headgear use in soccer is a relative newcomer to the landscape of protective equipment in contact sports. Federation International de Football Association (FIFA), the global governing body of soccer, began permitting its use in 2003. Most headgear is comprised of a thin layer of shock-absorbing foam fit between outer layers of fabric. American Society for Testing and Materials (ASTM) International set a performance standard for headgear in 2006; currently, five headgear products meet this standard [18].

Withnall et al. conducted controlled laboratory testing utilizing a human volunteer and test dummy headforms in an effort to determine whether soccer headgear had an effect on head impact responses. Impact attenuations of three commercial headgears during ball impact speeds of 6–30 m/s and in head-to-head contact with a closing speed of 2–5 m/s were measured. For ball impacts, none of the headgear provided attenuation over the full range of impact speeds. Head responses with or without headgear were not significantly different ($p > 0.05$) and remained well below levels associated with mild traumatic brain injury. The authors concluded that while headgear provided a measurable benefit during head-to-head impact (both linear and rotational acceleration were reduced by nearly 33 % for all three headgear in head-to-head contacts), the headgear models tested did not provide any benefit during ball impact, likely due to the large amount of ball deformation relative to the headband thickness [19].

Delaney et al. performed a retrospective online survey of 278 Canadian youth soccer players aged 12–17 years old in an effort to assess the role of headgear on

concussion symptoms. Respondents were asked how many concussions they had experienced in the prior season, as well as how many times they had experienced concussion-specific symptoms in response to a collision. 7.2 % of players reported at least one concussion, while 7.8 % reported experiencing concussion symptoms at least once in the prior season. Players self-selected on the decision to wear headgear, and those players who had suffered a previous concussion were more likely to wear headgear. Players who did not wear headgear were 2.6 times more likely to sustain a concussion compared to those players who did [20]. Limitations of this study include the lack of randomization of headgear use and recall bias as information in this retrospective study was collected from athletes at the conclusion of the season.

Facemasks and Face Shields

Ice Hockey

Variable standards are imposed at different levels of ice hockey with regard to the use of face shields. Full-face shields cover the entire face and can either be made of impact-resistant plastic or metal cages, while half-face shields or visors cover only the upper half of the face. The National Federation of State High School Associations (NFHS) and the NCAA require all players to wear full-face shields, while USA Hockey only requires the use of full-face shields until the adult level [21]. Asplund et al. found that wearing facemasks significantly reduced the occurrence of facial, ocular, and dental injuries in hockey [14]. Lemaire and Pearsall demonstrated that ice hockey helmets with full-face shields produce lower post-impact peak acceleration (10–100 g) than do helmets alone (100–130 g), consequently concluding that facial protector use may lower the incidence as well as severity of head injuries by decreasing post-impact head acceleration [22].

Reduction of facial injuries by facemasks should not be confused with evidence for the reduction of concussions in ice hockey. Injury data obtained from the NHL ($n=787$ players) during the 2001–2002 season found that players wearing half visors were not less likely to sustain concussions than those players without face shields. Visors were shown to prevent eye injuries and significantly reduce non-concussion head injuries. The data provided by the NHL is representative of the visor trends throughout North American and European hockey leagues [23]. Similarly, at the amateur level, Asplund et al. found no difference in the concussion rates between players who wear half vs. full-face shields [14]. Although there is a lack of evidence that visors and full-face shields prevent concussions, there is evidence demonstrating that the use of visors and face shields reduces the recovery time from a concussion. In a study by Benson et al., concussed hockey players wearing visors missed over twice as many practices and games compared to those wearing a full-face shield (4.1 vs. 1.7 sessions; 95 % CIs 3.5–4.7 and 1.3–2.2, respectively) [24]. Despite this, NHL players have claimed that wearing a visor shows lack of toughness, making them a prime target for the opposing team [23, 25].

Baseball/Softball

In baseball and softball, catchers are required to wear a facemask, and for good reason: a 2010 study showed that facemask wear reduced the resultant post-impact peak acceleration by 85 %, from a range of 140–180 to a range of 16–30 g. Not only did the catcher's mask reduce the peak acceleration post-impact, but it was also shown to reduce the head injury criterion number from 93–181 without a mask to 3–13 with a mask, as well as the severity index from 110–210 to 3–15 with a mask [26]. Recent discussions have focused on the idea of requiring headgear and face-masks for pitchers, who have suffered rare albeit serious injuries from receiving baseballs to the head.

Marshall et al. analyzed data from over 6.7 million player-seasons when studying the effectiveness of faceguards in youth baseball. They found that the use of faceguards reduced the risk of facial injury (adjusted rate ratio, 0.7, 95 % CI 0.4–1.0) [27].

Lacrosse

Lincoln et al. studied 507,000 high school and 649,573 collegiate lacrosse players of both genders to find the most common occurrences of head, face, and eye injuries. At the high school level, the rate of head, face, and eye injuries for girls was significantly higher than that for boys (0.5 vs. 0.4 per 1000 AEs, respectively). The same trend was found among college athletes, with women having a higher injury rate than men (0.8 vs. 0.4 per 1000 AEs, respectively). Of these injuries, boys and men were more likely to sustain concussions (73 % for boys, 85 % for men vs. 40 % for girls and 41 % for women), while girls and women presented higher rates of face injuries. The majority of concussions for men were the result of direct contact with another player, whereas female concussions were usually due to stick, ball, or ground contact [28]. It remains unclear, from such striking evidence, why helmets and protective gear are required for men's but not women's lacrosse. As in all contact sports, there is a concern that players who wear more protective equipment will play more aggressively and possibly incur injury more frequently. However, studies of the implementation of additional protective equipment in ice hockey and field hockey do not support such claims [29, 30].

Protective Eyewear

Sports are responsible for a third of eye injuries in the United States that lead to blindness [31]. Recent studies reviewing data from the National Electronic Injury Surveillance System reveal that 208,517 sports-related eye injuries were treated in US emergency departments between 2001 and 2009. Data from the National Eye Trauma System show that sports account for 13 % of all penetrating ocular injuries. While eye injury trends declined from 2001 to 2005, recent data show increasing injury rates from 2007 to 2009 [32, 33]. Despite policy and position statements that strongly recommend certified protective eyewear from organizations including the American Academy of Ophthalmology and the American Academy of Pediatrics [34], few youth sports organizations mandate protective eyewear, and few studies have been published which demonstrate the effectiveness of protective eyewear in reducing eye injuries.

Lincoln et al. performed a prospective cohort study involving American female high school lacrosse players during the 2000–2009 seasons, comparing eye injury rates before and after implementation of a protective eyewear mandate during the 2004 season. The study population included 9430 player-seasons over the study period. ATCs recorded all injury and athletic exposure data. Eye injury rates were reduced from 0.1 injuries per 1000 AEs in 2000–2003 to 0.02 injuries per 1000 AEs in 2004–2009. Injuries to the eyelid, eyebrow, eye orbit, and eye globe were virtually eliminated after mandated use of eyewear, with the exception of injuries that occurred when standard eyewear was not being worn [35].

Kriz et al. performed a prospective cohort study involving American female high school field hockey players during two seasons of play immediately before (fall 2009 and fall 2010) and immediately after (fall 2011 and fall 2012) a national mandate for protective eyewear in girls' field hockey was exercised by the National Federation of High School Associations. Eye injury incidence rates were compared between players competing in US states that mandated protective eyewear (MPE), players competing in states with no protective eyewear mandate (no MPE), and the postmandate group. Players from 16 of the 19 states that sanctioned high school field hockey at the time of the study were represented. Four hundred fifteen eye/orbital, head, and facial injuries were recorded during 624,803 AEs. The incidence of eye/orbital injuries was significantly higher in states without MPE (0.080 injuries per 1000 AEs) than in states with MPE (before the 2011/2012 mandate) and the postmandate group (0.025 injuries per 1000 AEs) (odds ratio 3.20, 95 % CI 1.47–6.99, $p=0.003$). There was no significant difference in concussion rates for the two groups (odds ratio 0.77, 95 % CI 0.58–1.02, $p=0.068$), challenging a perception in contact/collision sports that increased protective equipment yields increased injury rates [30]. After the 2011/2012 MPE, severe eye/orbital injuries (time loss >21 days) were reduced by 67 %, and severe/medical disqualification head/face injuries were reduced by 70 %. Limitations of this study included lack of randomization as enrollment in MPE and non-MPE groups was predetermined by individual state interscholastic league mandates.

Mouthguards

The first sport to require mouthguards was professional boxing in the 1920s. Decades later, in 1962, mouthguards became mandatory in high school football. Currently, both the NFHS and the NCAA require the use of mouthguards in football, ice hockey, field hockey, and lacrosse [36]. When properly fitted, mouthguards can greatly reduce the severity of dental and maxillofacial injuries [21]. In a 2007 study by Knapik et al., athletes who did not wear mouthguards were 1.6–1.9 times more likely to receive an oral-facial injury than those wearing mouthguards [36].

There are three main types of mouthguards: stock, boil-and-bite, and custom made. Stock mouthguards are ready to wear, while boil-and-bite mouthguards must first be heated and then can be molded to the teeth while cooling. Custom mouthguards must be made by a dental professional and offer the best fit [21].

There has been great debate as to the effectiveness of mouthguards in preventing concussions. It has been postulated that mouthguards may be able to absorb some of the shock that would otherwise reach the brain [36]. Studies of hits to the underside of the jaw of a mechanical skull have demonstrated that mouthguards reduce deformations and fractures to the jaw by 54.7 % and significantly decrease the acceleration of the head by 18.5 % [21]. In a number of other impact studies, it has been shown that mouthguards do reduce the injury to teeth and dampen impact forces [36]. However, due to ethical concerns, these studies were not done on live humans, putting into question the ability to generalize the results to athletes.

In other studies, comparisons were made between concussion occurrences in athletes who wear mouthguards vs. those who do not [37–39]. In all three studies, no significant difference was found between those who used mouthguards and those who did not. There also is no evidence that custom-fit mouthguards provide superior protection compared to stock and boil-and-bite models.

Despite the lack of clear evidence as to the effectiveness of mouthguards in the prevention of concussions, the NFHS remains steadfast that mouthguards are necessary for safe participation in sports. The NFHS has determined that prior to the use of mouthguards and facemasks, over 50 % of football injuries were oral-facial. That number has been reduced to 1 % with the use of mouthguards [40].

Neck Straps

Neck guards are most commonly seen in ice hockey, yet they are not a required piece of equipment in most hockey programs. In 2008, following the neck laceration of an NHL player, Stuart et al. conducted a retrospective Internet-based survey and follow-up of 328,821 registered USA Hockey players, inquiring about personal experience with a neck laceration during hockey or their witnessing of such an injury. Of 26,589 responses received, only 485 (1.8 %) had sustained a neck laceration. In more than one quarter (27 %) of the incidents, the player was wearing a neck guard [41]. The survey had a number of limitations, including a response rate of only 5.8 %. Nevertheless, USA Hockey's position statement continues to recommend the use of neck guards by all hockey players.

Lloyd et al. evaluated the effectiveness of different neck guards against skate lacerations. They reviewed 46 samples of 14 different types of neck guards with both low force and high force tests at differing skate orientations (45° and 90°). The authors found that neck lacerations were more likely to occur when the skate blade was angled at 45° compared with 90°. They also concluded that neck guards containing Spectra® fibers were the most resistant to lacerations [42].

Football Collars

Football collars are commonly employed in American football to reduce the incidence of burners and stingers by limiting extremes of cervical motion. However, their use and purported effectiveness are based largely on empiric data [43–45].

Up to 65 % of collegiate players experience a burner during their careers with recurrence rates approaching 85 % [46], resulting in widespread implementation of preventive strategies that includes neck and shoulder conditioning, learning proper blocking and tackling technique, and utilization of protective equipment. Gordon et al. conducted a laboratory study to evaluate the effectiveness of 3 football collars in reducing cervical range of motion in 15 Division I collegiate football players. Cervical hyperextension and lateral flexion (both active and passive) were measured with video analysis. All three collars reduced hyperextension when compared to helmet and shoulder pads alone ($p < 0.05$). Additionally, the Cowboy collar was superior to a traditional foam neck roll in reducing hyperextension ($p < 0.05$). No collar reduced passive lateral flexion when compared to helmet and shoulder pads alone; however, the foam neck roll permitted significantly less active lateral flexion than the other collars ($p < 0.01$). From these results, the authors concluded that (1) cervical hyperextension could be controlled in a laboratory setting using various cervical collars and (2) cervical lateral flexion could not be controlled by any of the cervical collars tested, and foam collars may reduce active lateral flexion while providing no additional protection during cervical loading [45]. Study limitations included testing in a laboratory setting rather than during live, full contact play. Additionally, as football collars collectively appear to reduce active motion without an accompanying reduction in passive motion, clinicians and athletic trainers should question the use of any piece of protective equipment which limits function without providing protective benefits.

Attitudes of Players, Medical Staff, and Coaches Toward Protective Equipment Use

In a number of contact and collision sports, certain protective equipment including mouthguards, protective eyewear, face shields/visors, and athletic cups for genital protection is recommended but not mandatory. In certain sports or levels of participation, such protective equipment is mandatory, but compliance is low due to suboptimal enforcement. Factors that can affect utilization in these circumstances can include discomfort; interference with vision, breathing, speech, or running/movement; poor esthetics; peer perceptions; lack of instruction/advice on usage; and lack of education regarding injuries associated with disuse. Oftentimes, indifferent attitudes of players, parents, and/or coaching staffs can contribute to suboptimal compliance with various sports protective equipment. In other circumstances, sport tradition or culture can dictate utilization. For instance, American football players tend to demonstrate high compliance with mouthguard use but rarely choose to wear athletic cups [47]. Conversely, male ice hockey players demonstrate poor compliance with proper mouthguard use but demonstrate high compliance with athletic cup use.

Raaij et al. conducted a cross-sectional survey of 180 Canadian travel hockey players aged 9–12 years who participated in leagues allowing bodychecking and mandating mouthguard use, in an effort to determine if youth hockey players engage in proper mouthguard wear. A 12-question written questionnaire ascertained what

types of mouthguards were worn, whether mouthguards were worn at all, worn properly, and reasons for noncompliance. Sixty-eight percent of players reported “always” wearing mouthguards, but only 31.7 % wore them properly during games and 51.1 % during practice. Custom mouthguards were most likely to be worn properly, followed by boil-and-bite and stock-type guards. Younger players wore mouthguards more consistently than older players ($p < 0.01$). Incidentally, many mouthguards were noted to be worn out from chewing, which significantly altered their protective function [48].

Hawn et al. performed a survey of 104 NCAA ATCs who covered men’s varsity ice hockey to determine enforcement patterns and athlete compliance with a rule requiring mouthguard wearing during the collegiate season. Key questions inquired about attitudes of coaching and medical staff toward mouthguard use, enforcement of mouthguard use, percentage of players wearing mouthguards in competition, and estimated number of penalties incurred secondary to mouthguard violations. The overall response rate was 82 % (104/127 programs). ATCs reported 63 % of athletes consistently wore mouthguards in competition, with significantly higher compliance at the Division II/III level compared to Division I (82 % vs. 65 %, respectively). Twenty-six percent of ATCs reported that neither the ATC nor the coach enforced mouthguard wear, despite 93 % of ATCs reporting they believed mouthguards play a role in injury prevention. Overall, only 19 mouthguard violation penalties (14/19 in Division III) were reported during the 1997 season [49].

Loopholes

Despite the existence of mandates pertaining to protective equipment in youth sports, circumstances exist in youth sports which circumvent universal compliance with these protective mandates. In the United States, the NFHS enacted a mandate regarding protective eyewear in field hockey, effective with the 2011–2012 season [50]. However, enforcement of this mandate is only applicable to public high school and interscholastic leagues that sanction field hockey. High school-age players participating in private/independent schools and leagues, as well as club teams, showcases, tournaments, and instructional camps do not have to comply with this mandate, and subsequently protective eyewear is not required for play but can be worn on a voluntary basis. The NCAA and USA Field Hockey, the governing body of field hockey in the USA, allow but do not require protective eyewear [51, 52].

Advertising/Marketing

As the focus on sports-related concussion has recently expanded to include prevention, sporting goods manufacturers have been aggressively marketing helmets, headgear, and mouthguards to youth sport participants and their parents, often with advertising campaigns that include performance test results conducted by the manufacturer. Consequently, these campaigns have been misleading to the general population as the advertising appears scientific and convincing. In 2010, Cascade Sports marketed the

M11 hockey helmet, which was endorsed by a former professional ice hockey player. The National Advertising Division of the Council of Better Business Bureaus inquired into the manufacturer's claims and ultimately recommended that Cascade Sports modify or discontinue certain advertising campaigns, after Cascade claimed the M11 helmet provided "maximum protection" and reduced the risk of concussions [53]. In 2012, the Federal Trade Commission reached a settlement with Brain-Pad, Inc., prohibiting the company from claiming that its mouthguards can reduce risk of concussions [54]. In 2014, the US Senate Committee on Commerce, Science, and Transportation passed the Youth Sports Concussions Act (S. 1014), which increased potential penalties for using false injury prevention claims to sell youth sports equipment [55].

Future Research and Direction

Current evidence pertaining to the effectiveness of protective equipment in youth sports is limited by study design, study setting, study population, standardization of reporting, sample size/power constraints, bias and confounding, ethical considerations (e.g., control group in helmeted collision sports), and expense, as longitudinal studies are costly in time and resources. Future research pertaining to youth sport protective equipment—specifically mouthguards, headgear/helmets, facial protection, and neck protection—should ideally: be prospective; be performed in natural experimental sport settings; utilize pediatric/adolescent populations; include adequate sample sizes/be sufficiently powered; utilize validated injury surveillance systems and standardized measurements, definitions (e.g., of injury and exposure), and reporting; and utilize multivariate analyses which adjust for covariates [56].

Conclusion

Protective equipment use in contact/collision sports has undergone substantial technological advancement over the past half century, resulting in significant reduction of morbidity and mortality in athletes participating in these activities. However, as more youth play competitive sports and engage in sport-specific training including strength and conditioning programs, they can resultantly generate high-magnitude impacts—forces previously thought to be achieved only by college and professional athletes. There is a collective effort by youth sports organizations, medical, safety, and scientific communities to reduce injury risk in young athletes, specifically injuries to the head and neck. Contact and collision sports have inherent safety risks that will remain despite protective equipment advances and rule modifications. Current literature demonstrates a lack of evidence regarding the role that protective equipment plays in injury reduction of youth athletes. There is a need for well-designed, prospective studies enrolling pediatric and adolescent participants utilizing standardized, validated data collection and clinical assessment tools to ultimately provide research that can guide the medical, scientific, and youth sport organization communities in establishing protective equipment regulations that ultimately make contact and collision sports safer for their participants.

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