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Fewer US Adolescents Playing Football and Public Health: A Review of Measures to Improve Safety and an Analysis of Gaps in the Literature

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Abstract

Physical activity during adolescence is associated with positive health outcomes, yet only 26% of US middle and high school students report daily physical activity. Moreover, the number of high school students playing a sport is declining, with the largest decline in football. One reason for this decline in playing football may be increased attention to the risk of head injury. For public health, the decline is alarming because football offers a physical activity opportunity for millions of young people every year. In response, efforts have been made to institute measures to enhance the safety of football. The objective of this topical review was to review these measures and the data supporting their effectiveness. We conducted a search of scientific literature supplemented by a web search to identify safety measures. We used the Indiana University library electronic database, PubMed, and web browser searches with specific search terms. In addition to peer-reviewed studies, we searched news stories and reports from sport-related organizations. We summarized the measures and evaluations of effectiveness and categorized the measures by type (game rules, practice guidelines, equipment innovations, strategic initiatives) and target age group (elementary/middle school, high school, college, professional). We found that attempts are being made to improve the safety of football at all levels. However, many measures lack scientific evidence to support their effectiveness. Therefore, researchers need to systematically evaluate safety measures. By implementing evidence-based interventions, we can balance the public health risk of playing football versus the public health risk of continued declines in participation.

Keywords

adolescents, concussion, football, physical activity, safety

Physical activity during childhood and adolescence is associated with many positive health outcomes (eg, improved weight status, bone health, cardiorespiratory and muscular fitness, cardiometabolic health, cognition, reduced risk of depression),[1] yet only 26% of US middle and high school students report daily physical activity.[2] Moreover, only 56% of US middle and high school students are on a sports team,[2] and the total number of high school students playing a sport declined for the first time in 30 years during the 2018-2019 school year.[3] The steepest decline in participation was in football, possibly because of concerns about head injuries and their potential long-term consequences.[4] Despite the heated debate about whether football should be played, it is the most popular sport in the United States[5] and provides a platform for millions of adolescents to engage in physical activity. It is, therefore, important to identify how to improve the safety of the sport instead of banning football altogether. The literature on efforts to enhance the safety of football is

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growing, but to our knowledge, these efforts have not been summarized and reviewed. The main objective of our topical review was to address this knowledge gap. Summarizing and reviewing the literature is an important step in increasing the safety of football, thus reversing the downward trend in football participation and increasing physical activity levels for more adolescents, which is an important public health goal.

The decline in football participation rates is concerning, because in addition to providing opportunities to engage in physical activity, participation in organized team sports offers other benefits, including better academic and cognitive performance, enhanced development of life skills, enhanced development of social and interpersonal skills, better mental health, and decreased likelihood of engaging in risky behaviors, compared with nonparticipation.[6] Despite these well-established benefits, many possible factors can explain the low rates of sports participation, including cost,[7,8] early age of sports specialization that can lead to injury and burnout,[9] schools eliminating athletic programs because of budget cuts,[10] and parental concerns about the risk of injury from participating in contact sports.[11]

Studies have demonstrated high rates of head injuries among football players[12-25] and high rates of injuries associated with body checking among hockey players aged 11-14.[26,27] Moreover, a recent review concluded that repetitive head impacts among male participants of contact sports are associated with microstructural and functional changes in the brain.[28] Media reports of chronic traumatic encephalopathy among former professional football players and the 2015 movie *Concussion* have likely added to parental concerns about the perceived risks of football. As a possible consequence, the largest decline in high school sports participation has been in football. Participation in high school football declined for the fifth consecutive year to 1 006 013 during 2018-2019, the lowest level since 1999-2000.[3] From a public health perspective, this decline is alarming because football offers a physical activity opportunity for the largest number of adolescents of all high school sports. Of course, football is not the only physical activity option for adolescents, and the sport has been played almost exclusively by males. Although participation in all sports involves some risk of injury, several sports (eg, soccer) may offer a safer physical activity opportunity for adolescents of all genders. Nevertheless, football is the most popular sport in the United States, and an estimated 5 million children and adolescents play football annually.[5]

Because of the popularity of football, and in response to the elevated risk of injury and resulting decline in football participation, efforts have been made to institute measures to enhance the safety of football by reducing the incidence of head trauma. The primary objective of this topical review was to examine these measures and the data supporting their effectiveness. To our knowledge, no comprehensive review of measures to reduce head injury at all levels of football has been published to date. Furthermore, substantial gaps remain in our knowledge about the positive and negative outcomes that result from playing football for multiple years during childhood and adolescence. Therefore, a secondary objective of our review was to present gaps in the science that need to be addressed. If future policies and guidelines put into place to improve player safety are data-based, public health policies can be implemented to provide a safe environment for student athletes to engage in physical activity and reduce the risk associated with a sedentary lifestyle during adolescence.

Measures Implemented to Reduce Head Injuries

We conducted a search of the scientific research literature, coverage by the news media, and reports from sport-related organizations to identify an exhaustive list of football safety measures that have been implemented. We used the Indiana University library electronic database, PubMed, and web browser searches with the following search terms to identify articles published in 2010 or later: football concussions, football rule changes, football safety, football tackling guidelines, football subconcussive head impacts, football equipment innovations, and football policy. We also searched the reference list of the articles located to identify additional relevant articles. In addition to peer-reviewed studies, we searched reports from sport-related organizations and elements of popular culture, such as news stories. We used this approach because a wide range of information sources influence this rapidly evolving topic. Policy makers and parents use news articles and other non–peer-reviewed reports and websites as sources of information to make decisions about their children playing football. These sources provided valuable information about football safety measures that have been implemented to supplement the peer-reviewed literature. When we examined news stories, we did not use the story as the sole information source about a safety measure for our review. Rather, we conducted additional searches to locate either the peer-reviewed article or the report that described the safety measure and any evaluation of its effectiveness. We categorized measures by type (game rules, practice guidelines, equipment innovations, and strategic initiatives) and target age group (elementary/middle school, high school, college, and professional) (Table). The safety measures were not a priori categories decided on before we conducted the review. Game rule changes were more common at the college and professional levels, whereas coach education programs were more common at the elementary/middle school and high school levels. Attempts at advancements in helmet design and other technologies have taken place across age groups.

Game Rules

Several rule changes at the elementary/middle school, high school, college, and professional football levels have been implemented in recent years. Kickoffs have been completely eliminated for some young age groups; for college, rules were changed from 2016 to 2019 to make touchbacks and fair catches more common to reduce the number of high-speed collisions

Table. Measures implemented to reduce the incidence and magnitude of head injuries in football, by implementing entity, year implemented, target group, and evaluation results, among various levels of players, United States, 1985-2020

Measure	Implementing entity	Year implemented	Target group	Evaluation results
Game rules				
Elementary/middle school				
Players not allowed to position themselves on the line with their hand on the ground (eg, in a 3-point stance) before the snap. Instead, they must either be upright or in a modified squat position with their hands on their legs.	Pop Warner	2019	Children aged 5-10	No evaluation
No kickoffs at the Pee Wee level.	Pop Warner	2019	Children aged 9-11	No evaluation
No kickoffs; offensive possession will start at the 35-yd line.	Pop Warner	2016	Children aged 5-10	No evaluation
High school				
Onside kick rule changed to eliminate "pop-up" onside kicks.	NFHS	2017	High school	No evaluation
Expanded definition of a "defenseless player" to protect players in vulnerable positions: a defenseless player is one who, because of his/her physical position and focus of concentration, is especially vulnerable to injury.	NFHS	2017	High school	No evaluation
Elimination of blindside blocks: executing blindside blocks generally is not improper, and the rules do not preclude their use altogether. Instead, to enhance player safety and minimize the risk of injury, the rules prohibit a specific type of blindside block: one that is forceful, is not initiated with open hands, and occurs outside the free-blocking zone.	NFHS	2017	High school	No evaluation
Free-blocking zone and legal blocking: attempt to clarify the free-blocking zone and legal blocking to properly officiate blocks below the waist and in the back.	NFHS	2019	High school	No evaluation
College				
Targeting review and suspension: every targeting foul is now reviewed to confirm or overturn.	NCAA Rules Committee	2019	College	No evaluation
Blindside blocking: banned forcible contact in blindside blocks.	NCAA Rules Committee	2019	College	No evaluation
Banned 2-person kickoff return wedge.	NCAA Rules Committee	2019	College	No evaluation
NCAA fair-catch line adjustment: any fair-catch call on a kickoff that is made between the goal line and 25-yd line to be treated as a touchback.	NCAA	2018	College	Kick returns down 20% in the first year of the rule change.[29]
Kickoffs moved from 35- to 40-yd line and touchbacks moved from 25- to 20-yd line.	Ivy League	2016	College: Ivy League	The mean annual concussion rate per 1000 plays during kickoff plays was 10.9 before the rule change and 2.0 after (difference, −8.9; 95% CI, −13.7 to −4.1). The difference-in-differences analysis showed that 7.5 fewer concussions (95% CI, −12.9 to −2.1) occurred for every 1000 kickoff plays after vs before the rule change.[30]
Professional				
Moved kickoff line from 35- to 30-yd line.	NFL	2011	Professional	Incidence of head injuries decreased by approximately 3 times during kickoff plays, primarily due to the increased frequency of touchbacks.[31]
Health and safety rule changes[32]	NFL	1985-2019	Professional	NA

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Table. (continued)

Measure	Implementing entity	Year implemented	Target group	Evaluation results
Summary: since 2002, the NFL has made 50 rule changes intended to eliminate potentially dangerous tactics and reduce the risk of injuries.[33]	NFL	As of May 2018	Professional	NA
Practice guidelines				
Elementary/middle school				
Practice guidelines to limit player-to-player practice time.	Pop Warner	2012	Pop Warner	No evaluation
Ban of full-speed, head-on blocking or tackling drills where players are lined up more than 3 yd apart.	Pop Warner	2012	Pop Warner	No evaluation
Contact restriction to 25% of practice time.	Pop Warner	2016	Pop Warner	No evaluation
USA Football National Practice Guidelines	USA Football	2014	Elementary/middle school and high school	Increased cumulative head impact exposure as the USA Football level of contact increased[34]
Elimination of "2-a-day" contact practices.	USA Football	Unclear	Elementary/middle school	No evaluation
High school				
Data-informed, targeted football drills placed into a team's practice routine with a goal of improving players' technique and reducing exposure to subconcussive head impacts. Testing was used to inform the design of prepractice intervention.	Queen's University researchers	2019	High school	Significant improvements in blocking and tackling techniques were observed after intervention. Better techniques were observed when evaluated in new game-like situations providing evidence of acquisition and generalizability of safer habits. Frequency of head impacts (>15*g*) were significantly reduced by about 30% after 1 month of training.[35]
Emphasizing one offensive scheme over another.	Martini et al[36]	2013	High school	In a study of 2 teams with different offensive schemes, athletes in the run-first offense sustained an average of 456 head impacts per season (41 practices and 9 games), whereas the pass-first offense athletes sustained an average of 304 head impacts per season (44 practices and 9 games). The pass-first offense, however, sustained significantly higher impact magnitudes than the run-first offense across a season.[36]
Helmetless tackling intervention	Swartz et al[37]	2019	High school	The experimental group had fewer impacts during games than the control group. Tackling and blocking drills performed without helmet and shoulder pads during training reduced the frequency of head impacts during play, especially during games. However, the differences disappeared by the end of the season.[37]
Rule to limit the amount and duration of full-contact activities: competition/full contact was not allowed in the first week and was limited to 75 minutes per week in week 2 (excluding scrimmage) and 60 minutes per week in week 3 and beyond.	Wisconsin Interscholastic Athletic Association	2014	High school	Sport-related concussions decreased by 57% in the season after the rule change.[38]
Michigan statewide restriction on full-contact practices: "After the first regular-season game, teams may conduct no more than 2 collision practice days in any week." The rule about preseason contact practice states: "Before the first regular season game, schools may not schedule more than 1 'collision' practice in a day," and was unchanged from 2013 to 2014. "Collision practices" are defined by the Michigan High School Athletic Association as "live, game speed, player versus player contact in pads involving any number of players."	Michigan High School Athletic Association	Decision made in 2013, rule implemented in 2014	High school	Number of head impacts per play declined by 42%.[39]

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Measure	Implementing entity	Year implemented	Target group	Evaluation results
USA Football Heads Up Football player safety coach (PSC)	USA Football	2015	High school	Findings support the PSC as an effective method of injury mitigation in high school football. Lower injury and concussion rates were found in PSC group compared with online coaching education–only group.[40]
Biomechanic data-driven behavior modification to reduce concussion risk in high school football athletes.	Matthew Gfeller Sport-Related Traumatic Brain Injury Research Center at University of North Carolina–Chapel Hill	2019	High school	N = 220 (143 intervention, 77 control). Mentoring effects were modest. On average, the proportion of top-of-head impacts dropped 2.8% in mentored players and 2.0% in nonmentored players. The proportion of head impacts classified as high-magnitude (>60*g*) dropped 1.1% from pre- to post-intervention among mentored players. There was minimal (<1%) change in high-magnitude impacts among nonmentored players. In postseason exit surveys, most mentored players agreed (n = 18, 69%) that their playing behaviors improved because of the study. Most intervention team coaches thought the study was effective (n = 31, 97%).[41]
College				
NCAA eliminated 2-a-day practices while maintaining total number of practice sessions.	NCAA	2017	College	Despite the elimination of 2-a-day practices, the number of preseason contact days increased in 2017, with an increase in average hourly impact exposure, resulting in a significant increase in total head impact burden (+26%) for the 2017 season. Thus, the NCAA ruling was not effective at reducing head impact burden.[42]
NCAA decreased the number of preseason on-field team activities for Division I teams from 29 to 25.	NCAA	2018	College	Among all athletes, the total preseason head impact burden was unchanged from 2017 to 2018. However, there were significant team-by-team differences.[43]
Elimination of tackling in practice.	Ivy League	2016	College	No evaluation
Limit of 2 live-contact practices per week during the regular season.	NCAA (mimicking Ivy League and Pac-12)	2017	College	No evaluation
Equipment innovations				
All levels				
Comparison of concussion characteristics between new and reconditioned helmets and common brands and models in high school football players.	Collins et al[44]	2008-2013	High school	Multiyear epidemiologic study of high school football players found no differences in concussion characteristics between new and refurbished helmets and across common manufacturers and models.[44]
Comparison of concussion rates between different helmet designs among college football players.	Rowson et al[45]	2005-2010	College	Multiyear epidemiologic study of college football players found a significant difference in concussion rates between 2 models of 1 brand of football helmet.[45]
NFL Helmet Challenge ($3 million)	NFL	HeadHealthTECH $2 million grant in 2020, $1 million NFL award in 2021	Professional	The HeadHealthTECH Challenge series is operated on behalf of Football Research, Inc, by Duke University's Clinical and Translational Science Institute and aims to create incentives for helmet manufacturers, small businesses, entrepreneurs, universities, and others to develop and commercialize new and improved protective equipment, including helmets.[46]

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Measure	Implementing entity	Year implemented	Target group	Evaluation results
Dartmouth's Mobile Virtual Player: MVPdummy.com. $3450 and up; various size options.	Dartmouth–NCAA	Prototypes debut with Dartmouth in 2015 and with other NCAA and NFL teams in 2016. Junior size was launched in 2018.	All levels	Mobile Virtual Player was announced as the winner of the "Training the Athlete" category in the second annual 1st and Future competition, a collaboration between the NFL and the Texas Medical Center (TMC) to award startups focused on driving innovations to advance sports technology and athlete safety. Each of the 3 category winners was awarded $50 000 from the NFL to further develop their innovation, and acceptance into TMC's startup program TMCx.
Q-collar	Gregory Myer and colleagues at Cincinnati Children's Hospital Medical Center	2016	All levels	High school athletes with the Q-collar maintained brain activation while performing memory tasks and did not develop cumulative injury to neuronal axons.[47-50]
Guardian Cap	Breedlove et al[51]	2017	All levels	The Guardian Cap did not mitigate impact severity based on a helmet drop-testing battery using both the Gadd Severity Index and peak linear acceleration as outcomes.[51]
Strategic policy initiatives				
Elementary/middle school				
USA Football's levels of contact[52]: USA Football's youth practice guidelines are the first to earn the endorsement of national and international medical organizations: the American College of Sports Medicine, National Athletic Trainers' Association, and the American Medical Society for Sports Medicine.	USA Football	2014	Children and adolescents aged 6-14	Increased cumulative head impact exposure as the USA Football level of contact increased.[34]
USA Football Heads Up Football injury education program for elementary/middle school coaches.	USA Football	2015	Elementary/middle school	Tested the association between community socioeconomic status and adoption of coach concussion education program and found that, compared with communities with less children living in poverty and a higher percentage of White residents, communities with a higher percentage of children living in poverty and a lower percentage of White residents were less likely to have football coaches with Heads Up Football certification.[53] Survey of elementary/middle school football coaches on how their interaction with a PSC influenced their implementation of the Heads Up Football program: despite a lack of reported interaction with a PSC, coaches self-reported high levels of implementation of the program.[54]
Mandate for coaches to train in USA Football's Heads Up Football program.	Pop Warner	2016	Elementary/middle school	No evaluation
Offers "Rookie Tackle" program to help kids transition from flag football to 11-player tackle football: smaller field, fewer players; flag football > rookie tackle > tackle football.	USA Football and Pop Warner	2017	Elementary/middle school	No evaluation
Providing CrashCourse to teach kids how to better recognize if they or a teammate have suffered a concussion (video-based concussion education).	Pop Warner (developed by TeachAids [Stanford University])	2018	Elementary/middle school	No evaluation

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Measure	Implementing entity	Year implemented	Target group	Evaluation results
The Aspen Institute recommends flag football before age 14.[55]	The Aspen Institute	2018	Children and adolescents aged ≤14	A comparison of injuries between tackle football leagues and a flag football league found fewer injuries in tackle football than in flag football and no difference in severe injuries and concussions.[56]
The Aspen Institute recommendation to begin tackling technique at age 12.	The Aspen Institute	2018	Children and adolescents aged ≥12	No evaluation
First sport concussion policy for young people: any participant removed from play due to a head injury may not return to Pop Warner activities until he/she is evaluated and receives clearance.	Pop Warner	2010	Pop Warner	No evaluation
Elementary/middle school and high school				
Heads Up CDC (different from Heads Up Football): whether you are a parent, youth sports coach, school coach, school professional, or health care provider, this site will help you recognize, respond to, and minimize the risk of concussion or other serious brain injury. • ≥150 million media impressions through print media and television public service announcements • >6 million print materials distributed • >1.5 million coaches completing online trainings • >50 Heads Up products developed • ≥15 000 Facebook fans • ≥85 organizations signed on as participating organizations • Nearly 40 million social-media impressions	CDC	2003–present	Elementary/middle school and high school	No evaluation
Heads Up Football (coaching education program): educational components on equipment fitting, tackling technique, strategies to reduce player contact, and sports medicine topics such as concussion, heat illness, and sudden athlete death.	USA Football	2012	Elementary/middle school and high school	Players who participated in Heads Up Football leagues accumulated fewer head impacts per practice at both the 10*g* and 20*g* thresholds.[57]
Heads Up Football/Pop Warner comprehensive coach education program and practice contact restrictions.	USA Football and Pop Warner	2015	Elementary/middle school and high school	Compared injury rates between leagues that implemented USA Football's Heads Up Football coach education program and/or Pop Warner's contact restrictions: the Heads Up Football and Pop Warner group had lower practice injury rates than the non–Heads Up Football and Pop Warner group.[58]
Football Development Model pilot program (6 pillars)	USA Football	2019	Elementary/middle school and high school	No evaluation
High school				
The free "Concussion in Sports" online education course through the NFHS Learning Center: as of 2019, the course had been taken by >4 million people since 2010 (www.NFHSLearn.com).	NFHS Learning Center	2010–present	High school	No evaluation
Advocacy for these limits on full-contact practice: • No full contact in spring/summer • 6 hours total including scrimmage(s) during preseason • 15 minutes per week in regular season and postseason	PracticeLikePros.com	Founded in 2013	Coaches: bottom-up approach rather than top-down; get in front of coaches at clinics and conferences	No evaluation

Abbreviations: CDC, Centers for Disease Control and Prevention; NA, not applicable; NCAA, National Collegiate Athletic Association; NFHS, National Federation of State High School Associations; NFL, National Football League.

that can occur when a player is attempting to return the ball after the kickoff. Some non–peer-reviewed evidence suggests that the National Collegiate Athletic Association's (NCAA's) kickoff rule change has lowered the number of kickoff returns attempted in college football. One study evaluated the effect of a kickoff rule change implemented by the Ivy League in 2016 for its football games.[30] The study concluded that the rule achieved its intended purpose: the number of touchbacks increased, and the concussion rate decreased 5-fold. Aside from that example, evidence supporting the effectiveness of this rule is sparse.

Practice Guidelines

New practice-related policies recommended in recent years have focused on reducing the amount of time players spend practicing or reducing the amount of practice time in activities that involve contact.[42,43] The intention of these policies is that if the amount of time players spend in practice activities that involve contact is reduced, then the incidence of head impacts will be reduced. For example, the youth football organization Pop Warner implemented a guideline in 2016 that limited activities with contact to no more than 25% of practice time.[59] However, whether that guideline has achieved the intended purpose is unclear based on our review of the available evidence.

Furthermore, USA Football and the NCAA have both eliminated practicing 2 times in the same day (ie, "2-a-days"). Researchers evaluated the implementation of the NCAA policy that discontinued 2-a-day practices in 2017.[42] Their study found that preseason contact days, average hourly head impact exposure, and total burden of head impact (ie, the number of head impacts per day, week, and season) increased despite the elimination of 2-a-day practices. A 2020 study evaluated a related 2018 NCAA policy that decreased the number of preseason on-field team practices for Division I teams from 29 to 25. The study found that, among all college football players, the total burden of preseason head impact was unchanged from 2017 to 2018.[43] However, team-by-team differences were significant. Taken together, the findings of these studies on the NCAA's policies to reduce head trauma by limiting practice sessions are inconclusive, likely due in part to increased contact intensity during preseason practices after the rule changes and wide variation in practice structures and coaching philosophies related to contact intensity during football practices. These inconclusive findings suggest that lowering head injury risk may be better achieved through more clearly defining and reducing the intensity of contact activities as opposed to reducing the total number of contact sessions in a season.

Another category of practice-related guidelines is changes in tackling and blocking techniques to limit exposures to dangerous head impacts. In this type of intervention, coaches are trained on safe techniques, and then they teach the techniques during practice drills. A 2019 study conducted at the high school level found improvements in blocking and tackling techniques and a significant decrease in head impacts after 1 month of training.[35] Similarly, an evaluation of USA Football's 2015 Heads Up Football campaign reported lower rates of concussion and other injuries in the intervention group that used a player safety coach (ie, an extra coach who focuses on teaching safe techniques) compared with the control group that received online coaching education.[58]

Equipment Innovations

Efforts to improve football equipment through advancements in technology have focused on the helmet at all levels of football. Organizations have sponsored competitions, such as the HeadHealth TECH Challenge and the National Football League's (NFL's) 1st and Future Competition, to encourage the development of improved protective equipment.[46] Companies that manufacture football helmets continue to release new helmets with designs and technology intended to reduce the incidence of head injuries.[60] Evidence on the effectiveness of these changes in helmets is limited primarily to laboratory testing environments.[61-65] Two exceptions are large multiyear epidemiologic studies that reported conflicting findings. A study of high school football players found no differences in concussion characteristics among players wearing new and refurbished helmets and no differences across the most common brands and models.[44] In contrast, a study of college football players reported differences in concussion rates between players wearing 2 models of 1 popular helmet brand.[45] These differences illustrate the need for additional research on the effectiveness of helmet innovations conducted during live practices and games among players with different playing styles who play different positions.

Helmet add-ons and nonhelmet technological innovations have also been released in recent years. An example of a helmet add-on is the Guardian Cap, a protective cover that is attached to the exterior surface of the helmet and intended to lessen energy transfer to the head during contact. A laboratory-based study found that the Guardian Cap did not significantly improve the ability of football helmets to mitigate impact forces.[51] In 2016, researchers at the University of Cincinnati Children's Hospital Medical Center developed a jugular compression collar, also known as the Q-collar, to reduce brain movement. Studies have found that athletes with the Q-collar maintained brain activation while performing memory tasks[47,48] and did not develop cumulative injury to neuronal axons.[49,50] Conversely, their counterparts without the Q-collar needed to recruit additional brain areas to execute memory tasks and developed abnormality in neuronal axon structures. Although the Q-collar has shown promise in ameliorating chronic subconcussive effects, no reports have indicated that it can reduce subconcussive incidence or increase brain resiliency to concussive head impacts. Moreover, reliability and generalizability of the study results have not been addressed.

Strategic Policy Initiatives

Primarily in the last decade, organizations have proposed broad-based policy recommendations intended to improve player

safety on a large scale. For example, USA Football's Heads Up Football program[54] trains coaches on multiple aspects of player safety, including tackling and blocking techniques, proper fitting of equipment, and sports medicine. One study compared head impacts between players from leagues that did and did not adopt the Heads Up Football educational program.[57] Practices among players from the Heads Up Football leagues had fewer head impacts above the 10*g* and 20*g* threshold levels, but no differences occurred during games. Another example is USA Football's Levels of Contact guidelines.[52] With these guidelines, coaches limit the amount of practice time that involves full-contact drills and instead incorporate drills at the air (unopposed and without contact), bags (against a bag or soft-contact surface), control (at an assigned speed until the moment of contact), or thud (at competitive speed through the moment of contact) levels that are meant to reduce the number and magnitude of head impacts during practice. Data from a 2019 pilot study suggest that incorporating these levels of contact into practice plans at the high school level could be effective in limiting the number of high-magnitude head impacts.[34] Finally, the Aspen Institute recently put forth recommendations that proper tackling technique should be introduced at age 12 and that young people should play flag football until age 14.[55]

Discussion

With several notable exceptions, we found an overall lack of evidence about the effectiveness of most of the measures that have been put into place purportedly to reduce the incidence and magnitude of head impacts in football. Therefore, a need exists for systematic investigations that test these measures as rigorously as possible. Although randomized controlled trials are considered the gold standard in testing interventions, they are not always feasible in real-world situations. As such, observational studies and quasi-experimental designs can be used as alternatives. Unfortunately, observational studies that rely on surveys are limited by response bias and lack of generalizability of findings. Specifically, football coaches who support the implementation of safety measures are more likely than coaches who do not support the implementation of safety measures to respond to requests to participate in surveys about safety measures.[54] Another weakness of many studies is that they often lack a control group. A notable exception was the evaluation of the effectiveness of incorporating a player safety coach into the coaching staff of high school football teams, where some teams were assigned a player safety coach to ensure proper tackling and blocking techniques and other teams were coached as usual.[40] Although it can be challenging to incorporate control groups into community-based trials of safety interventions, it is critical to think creatively and use designs such as cluster randomized designs and block designs, in which schools or teams are assigned to implement different interventions. These studies should ensure that the schools or teams that initially serve as a control or practice-as-usual group eventually receive the intervention, unless it demonstrates deleterious effects.

Despite advances in concussion research during the past 2 decades on acute and chronic effects on neurophysiology, diagnostics, and the recovery process, research on subconcussive impacts is in its early stage, and key knowledge gaps remain. First, longitudinal studies are needed at all levels of contact sports to better understand the long-term implications of subconcussive and concussive head impacts. Although studies have demonstrated negative microstructural and functional brain outcomes associated with repetitive head impacts among male participants in contact sports, those studies assessed the outcomes based only on 1 season of participation. Therefore, research with longer follow-up periods is needed to determine whether these negative outcomes are temporary or permanent.[28] From a public health perspective, these studies are particularly important at the elementary/middle school, high school, and collegiate levels, because these levels have the highest participation rates.

Second, previous studies on brain health outcomes from repetitive head impacts were limited by small sets of neurological assessments. Studies are needed that capitalize on multimodal neural assessment that is sensitive to subtle changes from repetitive subconcussive head impacts. Specifically, studies should include blood biomarkers, measures of neuro-ophthalmologic function, and neuroimaging assessments to test disruption in white matter microstructure and changes in resting-state functional magnetic resonance imaging activation and cerebral perfusion.

Third, research suggests that policy initiatives that have attempted to reduce the incidence of head impacts by restricting practice time are ineffective.[42,43] Deeper exploration into the reasons for these findings is warranted. For example, have coaches adjusted their practice plans to compensate for fewer practice sessions? Are policy interventions that reduce the number of drills or the number of practice repetitions feasible and more likely than guidelines to reduce practice sessions to achieve the desired outcome of reducing head impacts? What is the impact of padded summer workouts and team camp participation? Have increases in the number of summer practices replaced the fewer in-season practice sessions? Have the levels of contact been uniformly implemented by coaches and programs? Are there differences by player position that affect contact? Are changes that are found to be effective for one age group effective across other age groups? An example is the elimination of the 3-point stance for football among children aged ≤10, which has not yet been adopted for older age groups.

Public Health Implications

Attempts are being made to improve the safety of football at all levels by changing rules, implementing new practice

guidelines, enhancing equipment through innovative engineering, and implementing broad-based strategic initiatives. However, most of these measures lack rigorous scientific evidence to support their effectiveness. Therefore, researchers need to systematically evaluate these and other safety measures to inform policy. By implementing evidence-based policies, we can balance the public health risk of participating in tackle football against the public health risk of continued declines in participation or eliminating football as an organized activity altogether. The development and universal application of evidence-based guidelines can enhance the safety of football and lead to an increase in participation and the accompanying public health benefits.

In addition to increasing football participation rates overall, future research-based policy recommendations should address disparities in participation. Girls (vs boys), racial/ethnic minority adolescents (vs White adolescents), young people from households of low socioeconomic status (vs from households of high socioeconomic status), young people living in rural areas (vs urban and suburban areas), and young people with disabilities (vs without disabilities) are less likely to be physically active and play sports.[1,7,65] A safer game of football can be more accessible to even larger numbers of young people who stand to reap the benefits of playing. However, a concerted effort must be made to implement effective football safety measures in all communities. As demonstrated by Kroshus et al,[53] football coach education programs were less likely to be adopted in lower socioeconomic status communities than in higher socioeconomic status communities and in communities with a greater proportion of racial/ethnic minority residents compared with communities with a greater proportion of White residents.

Our review focused on primary prevention, because most safety measures and evaluations of the measures have been oriented toward strategies to reduce the incidence and magnitude of head impacts. Secondary and tertiary prevention strategies also can play a critical role in improving the safety of football. For example, better screening strategies for concussion (and subconcussion) symptoms can identify when players should be temporarily removed from participation to avoid adverse long-term consequences. In addition, improved management of concussed players can facilitate rapid recovery and return to play. Although a thorough review of these and other secondary and tertiary prevention measures was beyond the scope of our review, it is an area for future research.

Important gaps in knowledge remain, but a concerted multidisciplinary approach to addressing those gaps has the potential to result in a new era of football. Although risks will never be completely eliminated, minimizing the risks is an important step that can ultimately result in substantial public health benefits.

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