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National Athletic Trainers' Association Position Statement: Reducing Intentional Head-First Contact Behavior in American Football Players

Erik E. Swartz, PhD, ATC*; Johna K. Register-Mihalik, PhD, LAT, ATC†; Steven P. Broglio, PhD, ATC‡; Jason P. Mihalik, PhD, ATC†; Jay L. Myers, PhD*; Kevin M. Guskiewicz, PhD, ATC†; Julian Bailes, MD§; Merril Hoge, BA||

*Department of Physical Therapy and Kinesiology, University of Massachusetts, Lowell; †Matthew Gfeller Center, Department of Exercise and Sport Science, University of North Carolina, Chapel Hill; ‡Michigan Concussion Center, University of Michigan, Ann Arbor; §NorthShore University HealthSystem, Evanston, IL; ||Find A Way, Fort Thomas, KY

Objective: To provide evidence-based recommendations for reducing the prevalence of head-first contact behavior in American football players with the aim of reducing the risk of head and neck injuries.

Background: In American football, using the head as the point of contact is a persistent, well-documented, and direct cause of catastrophic head and cervical spine injury. Equally concerning is that repeated head-impact exposures are likely to result from head-first contact behavior and may be associated with long-term neurocognitive conditions such as dementia, depression, and chronic traumatic encephalopathy.

Conclusions: The National Athletic Trainers' Association proposes 14 recommendations to help the certified athletic trainer, allied health care provider, coach, player, parent, and broader community implement strategies for reducing the prevalence of head-first contact in American football.

Key Words: catastrophic injury, sport injury, helmet, concussion, chronic traumatic encephalopathy

Key Points

- Head-first contact behavior during tackling and blocking in American football persists and is associated with an increased risk of head and neck injury.
- We developed 14 recommendations based on the scientific literature and expert consensus to help address the behavior of initiating contact with the head in American football.
- High-level, empirical evidence to support strategies for reducing head-first contact behavior is lacking, highlighting the continuing need to conduct rigorous research (eg, randomized controlled trials).
- Lower-level evidence, combined with education and rule changes, shows promise for reducing injuries stemming from head-first contact.

In 2004, the National Athletic Trainers' Association (NATA) position statement "Head-Down Contact and Spearing in Tackle Football" presented recommendations to decrease the incidence of cervical spine and head injury risk in football participants using head-down tackling techniques.[1] *Head-down tackling* uses the top or crown of the helmet to initiate contact, and *spearing* is the deliberate and intentional use of a head-down contact technique.[2] The original 24 recommendations were aimed at reducing the risky behaviors that can lead to cervical spine fractures and dislocations, as well as traumatic brain injuries.[3] At that time, head-down tackling remained a persistent behavior in football players despite a decades-old rule prohibiting spear tackling. Even with new rules and contemporary educational programs on tackling intended to protect the head, head-first contact behavior remains commonplace in tackle football today and, therefore, necessitates a renewed focus. For the purposes of this position statement, *head-first contact behavior* refers to players initiating contact with their heads, regardless of where that impact is initiated (top or front of helmet) or what they are doing when exhibiting that head-first contact technique (tackling, blocking, or carrying the ball).

Research[4–12] has revealed that head impacts in American football, at all levels of play, are frequent and of varying severity. Technologies permitting in vivo head-impact measurements indicated that players can experience a high frequency of head impacts each season, with crown-related impacts resulting in the highest accelerations (ie, impact force).[4,7] These impacts pose particular risk for both head and neck injuries, as evidenced in 2011 with the initial in vivo biomechanical data of a head-first tackle that resulted in a cervical spine fracture and concussion.[13] These data highlight an increasing concern that head impacts can cause not only cervical spine injuries but also acute[3] and chronic[14–17] brain injuries. Since 2004, investigators[3,18–20] have continued to document the prevalence and incidence of head and neck injuries in epidemiologic studies. For example, data from the 2011–2012 and 2013–2014 athletic seasons showed that US high school football players had the highest sport-related concussion rate.[18] Most impacts that result in concussion among high school football players occur at the front of the helmet; the largest proportion of those involving loss of consciousness occur at the top of the head.[21] Not only is using the head as the point of contact in American football a direct cause of catastrophic head and spine injuries, but accumulated head-impact exposures are thought to contribute to the risk for long-term neurocognitive conditions such as dementia, depression, and chronic traumatic encephalopathy,[22–25] emphasizing the importance of reducing head impacts in football, regardless of the force or association with acute injury.

Therefore, it is essential to update the 2004 position statement and address the persistent behavior of head-first contact in American football players. Our purpose was to present recommendations that encompassed (1) education and administration, (2) skill development and behavior modification, (3) rules and regulations, and (4) technology and scientific research as they relate to decreasing head impacts in football.

RECOMMENDATIONS

Through its members, the NATA has provided foundational leadership, research, and education for the prevention, management, and care of athletic injuries. Highlighting these key principles is the NATA position statement on preventing sudden death in sports.[26] Thus, the NATA continues to seek collaborations and interprofessional initiatives to improve the safety of sport at all levels by reducing injuries and illnesses. Football players must learn, execute, and maintain head-protective behaviors. However, we should not expect players to independently and spontaneously learn these complex behaviors[27,28] or transfer them to the unpredictable context and emotions of competition.[29] The responsibility for implementing these recommendations should not fall solely on an athletic trainer (AT). Rather, where appropriate, the AT may be part of a multidisciplinary team that can help implement these best practices cohesively within the organizational structure. All stakeholders should commit to working together to use strategies that enhance football player health and safety by reducing head-first impacts and limiting both intentional and unintentional head contact.

The NATA advocates that the following recommendations be carefully considered as part of an overall prevention strategy to reduce the prevalence of head-first contact in tackle football. The recommendations are rated using the letters *A*, *B*, or *C* in association with the Strength of Recommendation Taxonomy (SORT) developed by the American Academy of Family Physicians.[30,31] Although some methods for reducing head-first contact in football have been outlined,[32,33] few data from controlled trials' research designs have supported the effectiveness of such measures. Nevertheless, the epidemiologic and case study literature, in addition to models from other sports and expert consensus, inform the recommendations that lack high-level evidence.

Education and Administration

1. Develop and require consistent, contemporary education for players on the dangers of head-first contact in football as it pertains to the risk for head and neck injury.[34] *Strength of Recommendation (SOR): C*
2. Develop and require documented education for coaches at all levels of play, including youth, on the dangers of teaching, instructing, or allowing head-first contact in football as it pertains to the risk for head and neck injury.[34] *SOR: C*
3. Develop and require education for officials at all levels of play on the mechanisms and dangers of head-first contact in football and how they pertain to officiating scrimmages and games.[1,34] *SOR: C*
4. Organizational bodies that involve minors should communicate with parents and legal guardians on a regular basis to describe the strategies used to reduce head-first contact behavior and its potentially risky outcomes. *SOR: C*
5. Encourage coaches, strength and conditioning specialists, administrators, ATs, team physicians, and athletics or league directors to meet regularly and work together to discuss, implement, and review strategies (including the recommendations in this document) that reduce head-first contact behavior by football players.[1,26,34] *SOR: C*

Skill Development and Behavior Modification

6. Introduce evidence-based, progressive techniques for avoiding head-first contact behavior[33,35–38] during ball carrying, tackling, and blocking before the first exposure to tackle football (ie, first-time participants, preseason). *SOR: B*
7. Teach until mastery is achieved and reinforce the maintenance of appropriate tackling and blocking skills that explicitly deter head-first contact behavior[3,33,35,38] in football at all levels of play. *SOR: B*

Rules and Regulations

8. Because full-contact practice sessions (ie, live tackling, taking the opponent to the ground) increase the opportunities for head-first behavior, regulate the time devoted to such sessions each week[39,40] to ensure sufficient focus on age-appropriate instruction, maintenance, and mastery of proper tackling and blocking skills. *SOR: B*
9. Adapt the practice structure by eliminating or modifying football drills that do not reinforce proper and safe tackling and blocking behaviors or techniques.[41–43] *SOR: B*
10. Consistently enforce the penalties or fines (or both) for head-first contact behavior, spearing, or targeting at all levels of play for all player positions.[3,44] *SOR: C*

Technology and Scientific Research

11. Recognize that helmet and after-market companies that produce helmet add-on products may overstate injury-prevention benefits,[45,46] leading to risk-taking behavior.[47,48,49] *SOR: B*
12. Consider using validated head-impact monitoring systems or video capture[50,51] (or both) as a complementary tool for identifying and correcting head-first contact behavior. *SOR: B*
13. Educate athletes on the influence of protective equipment and techniques related to avoiding head contact.[46] *SOR: C*
14. Engage all stakeholders in the generation of high-level scientific research to test and validate strategies, techniques, or technologies proposed to support the reduction of head-impact exposure in football. *SOR: C*

BACKGROUND AND LITERATURE REVIEW

Education and Administration (Recommendations 1–5)

The need for consensus among stakeholders on the education and administration of head-safe principles is obvious and stems from the 1970s, when the risk of spear tackling was first identified.[44] Players were then instructed to "see what you hit" and encouraged to tackle with the "head up." Thus, the "heads-up tackling" phrase was used in promotional efforts, such as locker room posters. The National Operating Committee on Standards for Athletic Equipment (NOCSAE) included such phrases on helmet shells as a required component of certification. Tracking the direct effectiveness of these educational efforts remains difficult because they coincided with rule changes that made intentional spear tackling illegal. However, after the rule was implemented, the incidence of catastrophic head and neck injuries declined by approximately 50%.[44]

Despite widely accepted knowledge about the axial-load mechanism and risks of head-down tackling,[3] the behavior has not been eliminated, as verified through observational[52,53] and instrumented[4,9,54–56] research. For example, between 2010 and 2019 in high school and collegiate football, a total of 287 catastrophic head and neck injuries were reported, with 40 of these events resulting in fatalities.[57] Although no football injury rates during this timeframe have been published, Boden et al[58] determined that the rate of brain-related injury deaths from 1990 to 2010 was 0.26 per 100 000 athletes (number of fatalities = 62) and 4 deaths resulted from cervical fractures. All deaths were attributed to severe head impact. Justifiably, much effort continues to be directed at educational strategies for participants and other stakeholders to raise awareness and discourage head-first and head-down tackling behaviors. No authors have directly evaluated the effect of player or coach education on head-first contact, but expert consensus is that contemporary education for players and documented education for coaches should be current practices for both governing bodies and institutions.[12]

Table 1. Categories of Educational Programs on Head-Contact and Playing Behaviors in Rugby

Strategies
General education
Safety workshops and practical trainings for stakeholders
Online educational material specific to head, neck, and spine injuries
Athlete education and information
Supportive environment and community information
Medical care and protocols
First aid in rugby
Medical programs and protocols

Even though they were not necessarily aligned with the historical understanding pertaining to spine injury prevention and the focus of the original position statement, USA Football[59] and the US Centers for Disease Control and Prevention[60] developed educational campaigns promoting heads-up tackling to improve awareness and encourage proper tackling and contact training to avoid concussion. Yet, despite this common-sense approach, little to no direct scientific evidence has supported a role of heads-up educational programs in reducing cervical spine and head injuries. However, early researchers who studied the USA Football model proposed that implementation of such a program might reduce head impacts over a season in youth athletes[61] and reduce concussions among high school athletes.[36] Missing from the discussion, analysis, and implementation of educational programs were game officials, who have a significant influence on the field of play. Thus, based on consensus and expert opinion, American football officials should also be part of these educational efforts.[1,34]

American football is not alone in its efforts to reduce the incidence of head and spine injuries. Recommendations 2 and 3 highlight the similarities with rugby in the requisite skill of tackling and associated injuries.[62] Although players sustained multiple impacts during play,[63–65] most of these occurred on the side and back of the head,[63,65] suggesting that intentional head-first contact behaviors were not used in rugby; this was in contrast to American football, in which front and top impacts were most frequent.[4,7,66] Nevertheless, extensive educational efforts using various themes (Table 1) to control the head[62] and spine[67,68] injury risk in rugby demonstrated moderate success. For example, the RugbySmart program in New Zealand[69] required coaches and referees to attend annual workshops to view video and internet resources related to head safety. Educational guidelines focused on physical conditioning, tackling and scrimmaging techniques, and injury-management strategies. The RugbySmart program decreased scrum-related spine injuries and overall injury claims.[70] BokSmart, a similarly designed educational program for rugby in South Africa, reduced the prevalence of catastrophic head and neck injuries between 14% and 24%.[71] A national injury-prevention program for rugby in France, when combined with rule changes to the scrum event, decreased spine injuries from 1.8/100 000 to 1.0/100 000 players, yet spine injuries among players categorized as backs increased.[67] However, when Fraas and Burchiel[72] reviewed 10 reports on rugby educational programs and catastrophic head and neck injuries or concussions, they concluded that little good-quality evidence supported the effectiveness of these programs. Of the articles included, none provided SORT level 1 (good-quality) evidence, and only 2 studies offered level 2 (limited-quality [patient-oriented]) evidence.[72] Although initiatives in rugby can serve as a model for football, further prospective research is needed to establish the long-term efficacy of educational programs in these and other sports involving collisions (eg, ice hockey).

Additionally, for these educational efforts to be effective, coordination of key stakeholders (eg, coaches, strength and conditioning specialists, administrators, ATs, team physicians, officials) is essential to ensure that evidence-based strategies[1,26,34] are part of local football safety efforts. Experts agreed that organizations involving minors should also communicate these evidence-based strategies on a regular basis to parents and guardians, given their role in the child's decision making and participation.[1,34]

Skill Development and Behavior Modification (Recommendations 6, 7)

Tackling and blocking are foundational skills that involve contact or collision, often with subsequent body-to-ground contact. Thus, it is likely unrealistic to prevent all head impacts in American football players, and no threshold has been identified for a safe number of head impacts. Nevertheless, teaching tackling and blocking techniques that help players adopt skills to avoid or significantly limit head impacts provides a conservative platform for the recommendations in this category, especially for young players and those beginning football participation. Because reducing the prevalence of impacts derived from head-first contact behavior is this statement's logical goal, teaching skills with the intent of reducing head impacts is essential.

However, rigorous research models for reducing head-initiated behavior in sports are challenging to design and carry out. This explains the dearth of prospective randomized controlled trials (RCTs) in American football; to date, most studies have been cohort based and nonrandomized in design, which can carry a high risk of bias[73] (Table 2). For example, a laboratory-based investigation[37] demonstrated that football players could adapt techniques to avoid or lessen the magnitude of head impacts after a single training session, but because this work was not conducted in an active football environment, its external validity was limited. Field-based research on a team-level (nonrandomized) intervention using the "Heads Up Football Program" (USA Football) showed a 3.4 impacts/practice reduction in head-impact exposure,[61] and head impacts decreased by approximately 30% after midseason implementation of a tackling training intervention.[35] Other field-based studies resulted in reductions in concussions, both when combined with practice contact restrictions[32] and without.[36] Despite these findings, some research on USA Football's "Heads Up" program indicated it was inconsistently implemented[74] and may be less accessible to communities of lower socioeconomic status.[75] Furthermore, USA Football recently revised the "Heads Up" tackling training system to include "rugby-style" tackling, which emphasizes shoulder contact, but to our knowledge, the newer protocol's effectiveness has not yet been assessed.

The concept of incorporating rugby-style tackling techniques in American football[76] has grown in popularity based on the presumption that it develops safer skills and reduces the chance of using the head as the point of contact. During a properly executed rugby tackle, the defender's head is not the focal point of contact, nor is it intentionally placed in front of the ball carrier.[77] The National Football League (NFL) promotes a modification of rugby-style tackling instruction for American football in the "Hawk Tackling" method[76] associated with the Seattle Seahawks and the team's head coach. Instructional videos remain prevalent online, although no scientific literature to date supports the efficacy of the tackling technique to reduce head-first contact behavior.

Randomized controlled trials have been conducted to determine the effectiveness of a progressive helmetless-tackling training (HuTT) program in reducing head-impact exposures.[33,38] The HuTT technique also models rugby in that the skill progression and behavioral development require athletes to complete training without a helmet. Doing so makes use of inherent reflexes[78,79] that remove the unprotected head as a point of contact. This is a manifestation of risk compensation theory,[80–82] whereby protective measures, such as a helmet, can sometimes result in unintended consequences or increase risky behavior. For instance, spear-tackling behavior originated and persisted because of the advent of helmets with hard outer shells, which gave players a false sense of security.[83] This conduct may be countered by time spent in helmetless training. Early results at the collegiate level showed a 30% reduction in head-impact exposure throughout the season when training drills were implemented twice per week in the preseason and once per week in the regular season.[33] At the high school level, more frequent training sessions primarily reduced head impacts during games at midseason time points.[38] Although more examination is warranted, this training method holds promise as an intervention for reducing head-impact behavior and cumulative exposure. Details on these interventions published in the research thus far can be found in Table 2.

Rules and Regulations (Recommendations 8–10)

Historically, the first measures taken to influence player behavior were updating policies and rules. The landmark 1976 rule change to eliminate intentional spear tackling or using the head as a weapon is one such example. Even though this change decreased catastrophic head and spine injuries, nearly 80% of high-magnitude head impacts resulted from leading with the head.[66] This indicates a continuing need to emphasize policies and develop innovative health and safety interventions to further reduce

Table 2. Characteristics of Intervention Studies for Reducing Head-Impact Exposure in American Football Players Continued on Next Page

Research Study	Study Design	Strength of Recommendation Taxonomy Study Quality[30]	Sample, n	Intervention	Relevant Findings
Kerr et al (2015), "Comprehensive Coach Education Reduces Head Impact Exposure in American Youth Football"[60]	Cohort	2	70 (HU = 38, NHU = 32)	Educational: preseason, HU teams received didactic and demonstration instruction in tackling techniques, drill development, and ↓ player contact. Top-down instruction provided by "master trainers" to PSCs and then team coaches and players.	• ↑ Impacts in NHU (62%, n = 4637) vs HU (38%, n = 2841) group • 6 concussions, all in NHU, but no difference between HU and NHU • Age 8 to 11 y: ↑ practice impacts/individual in NHU (9.1 ± 3.3) vs HU (5.5 ± 3.2; difference = 3.6; 95% CI = 2.9, 4.3) • Age 12 to 15 y: ↑ practice impacts/individual in NHU (8.7 ± 2.9) vs HU (5.7 ± 2.5; difference = 3.0; 95% CI = 2.3, 3.7) • At 10*g*, 20*g* thresholds: no difference between game impacts/individual • 10*g* threshold: ↓ practice impacts/individual in HU (5.6 ± 2.9) vs NHU (8.9 ± 3.1; difference = 3.4; 95% CI = 0.9, 3.9); difference varied at 20*g* threshold but remained significant (difference = 1.0; 95% CI = 0.7, 1.3)
Schussler et al (2018), "The Effect of Tackling Training on Head Accelerations in Youth American Football"[37]	Controlled laboratory	3	24 (age = 11.5 ± 0.6 y)	Behavioral: 1-d training on tackling technique using tackling dummy. Subgroup completed additional 2 d of training and 48-h retention test.	• ↓ Peak linear head accelerations >10*g* and peak rotational head accelerations >1885°/s² in dummy tackling after 1- and 3-d training regimens; tackling form score changed between pretest and posttest (*P* = .004).
Shanley et al (2019), "Heads Up Football Training Decreases Concussion Rates in High School Football Players"[36]	Prospective cohort	2	2514 (HU = 1818, NHU = 696)	Behavioral: preseason, ≥1 coach/team received HU training from USA Football. Coaching technique, player instruction monitored randomly ×3 during season to ensure program compliance.	• Risk of SRC = 1.5× (95% CI = 1.1, 2.1) or 32% ↓ for HU vs NHU (4.1 vs 6.0/100 players) • Entire cohort: game (61) vs practice (56) rate ratio difference not significant (1.1; 95% CI = 0.73, 1.5) • ↑ Practice SRCs in NHU vs HU (RR = 1.9; 95% CI = 1.1. 3.2)
Swartz et al (2015), "Early Results of a Helmetless-Tackling Intervention to Decrease Head Impacts in Football Players"[33]	RCT	2	50 (intervention = 25, control = 25)	Behavioral: progressive tackling instruction, drills (HuTT) without shoulder pads and helmet 2×/wk preseason, 1×/wk in-season	• End of season 1: intervention → 28% ↓ in head-impacts/AE (9.99 ± 6.10); control unchanged (13.84 ± 7.27. *P* = .009) • Intervention: 30% ↓ impacts/AE (9.99 ± 6.10) vs control (14.32 ± 8.45, *P* = .045)
Swartz et al (2019), "A Helmetless-Tackling Intervention in American Football for Decreasing Head Impact Exposure: A Randomized Controlled Trial"[38]	RCT	1	180 enrolled, 115 completed study (WoH = 59, control = 56)	Behavioral: progressive tackling, blocking instruction and drills without shoulder pads and helmet; 4×/wk preseason, 2×/wk in-season over 2 y	• WoH: 26%–33% ↓ game ImpAEs at 2 identical time points across seasons; also ↓ game ImpAEs vs control at wk 4 (season 1 *P* = .0001, season 2 *P* = .0005) and 7 in both seasons (*P* = .0001) and ↓ ImpAEs in wk 7 during training vs control in-season 1 (*P* = .015)

Table 2. Continued From Previous Page

Research Study	Study Design	Strength of Recommendation Taxonomy Study Quality[30]	Sample, n	Intervention	Relevant Findings
Kerr et al (2016), "Comparison of Indiana High School Football Injury Rates by inclusion of the USA Football 'Heads Up Football' Player Safety Coach"[97]	Cohort	2	390 (PSC = 204, EDU = 186)	Educational: players supervised by PSC certified in concussion program modules ("Heads-Up"), heat and hydration, cardiac arrest, and proper tackling, blocking, and equipment fit	• 17 SRCs = 11.4% of all injuries • Educational = 88.2% (n = 15/17) vs PSC group (11.8%, n = 2/17) • SRCs in practice: IRR ↓ in PSC group (0.09 vs 0.73/1000 AEs; IRR = 0.12; 95% CI = 0.01, 0.94) • SRCs in games: IRR not different in PSC group vs EDU (0.60 vs 4.39/1000 AEs; IRR = 0.14; 95% CI = 0.02, 1.11)
Champagne et al (2019), "Data-Informed Intervention Improves Football Technique and Reduces Head Impacts"[35]	Experimental	2	70 (baseline and postintervention measurements), 19 wore helmet accelerometers	Behavioral: players completed prepractice tackling and blocking drills simulating game-like situations 2×/wk	• 30% ↓ total frequency of practice impacts session in practice 1 mo postintervention • No difference in cumulative rotational velocity (*g*): preintervention = 4047.46 ± 1838.71, postintervention = 3789.98 ± 2170.24 (*P* = .6378) • Average cumulative linear acceleration (*g*) ↓: preintervention = 272.19 ± 112.78, postintervention = 186.10 ± 80.98 (*P* = .0037)

Abbreviations: AE, athlete-exposure; EDU, education-only group; HU, "Heads-Up" participants; HuTT, helmetless-tackling training; ImpAE, impacts per athlete-exposure; IRR, injury rate ratio; NHU, non–"Heads-Up" participants; PSC, player safety coach; RCT, randomized controlled trial; RR, rate ratio; SRC, sport-related concussion; WoH, without-helmet group.

head-first contact behavior, whether via tackling, blocking, or carrying the ball.

Limiting contact practices and modifying practice structures may be beneficial in reducing the magnitude and frequency of head impacts. In 2011, the NFL Players' Association collective bargaining agreement restricted full-contact practices by limiting the total to 14 per year, with 11 allowable in the first 11 weeks of the season (1 per week). The agreement influenced the 2016 National Collegiate Athletic Association (NCAA) policy change that limited full-contact practices to 1 per week with players dressed in full equipment or shells (helmet and shoulder pads only). The Ivy League schools went so far as to ban tackling from practice altogether.[84]

Youth football participants can experience an average of 100 to 200 head impacts in a season,[10,11,85] whereas high school players may sustain more than 400 impacts.[86,87] The increase in head-impact frequency with age contradicts the typical improvement in skill that correlates with increased experience. To mitigate head-impact exposure, some states and leagues have limited the number of allowable full-contact practice days per week or, as in youth football, prohibited tackling in practice. Pop Warner practice guidelines eliminate drills in which players are more than 2.7 m (3 yd) apart,[88] though these efforts have been driven primarily by the risk for concussion. When full-contact high school football practices were reduced from 3 to 2 per week, head-impact instrumentation captured a 42% overall reduction in head-impact exposure, with a greater decrease during practices than during games.[40] However, too few concussions occurred to evaluate a change in that risk. Similar findings were noted among youth athletes when contact practices were restricted.[89] In addition, eliminating certain drills known to encourage head-first contact behavior (eg, the Oklahoma Drill) or limiting full-contact practice sessions decreased the risk of sustaining a catastrophic spine injury or concussion.[40] Yet adopting changes that restrict practice in a full-contact environment prompts questions about how these measures might inhibit skill development or reduce a team's competitive edge. In other words, because the game requires full contact, how much of the introduction, rehearsal, and mastery of these skills can be suppressed before the participant's safety is affected? This conundrum has been studied in ice hockey regarding the risk of injury due to body checking,[90] a collision-specific skill that is similar to tackling or blocking in football. Compared with youth hockey players who lacked body-checking experience, those who had 2 years of such experience displayed a 33% decrease in overall severe injuries (more than 7 days of time loss) but no differences in concussion rates or severity.[91] Nevertheless, the authors pointed out that this finding needs to be considered in the context of the 70% reduction in severe injuries among Pee Wee players in leagues that prohibited body checking.[90] In other words, the benefits and consequences of rule changes for tackling must be assessed in totality to determine the best overall preventive model for decreasing head-impact exposure in American football players. To our knowledge, this work has not yet been done.

At higher levels of play, leagues have changed rules for game play, particularly kickoffs, which had the highest incidence of concussions and severe injuries.[92,93] Notable changes by the NFL were the ban on wedge-formation blocking by the receiving team (2004, 2018), moving the line of scrimmage from the 30- to the 35-yard line and minimizing the running start of the kicking team to 4.57 m (5 yd [2011]), restricting contact to within 13.72 m (15 yd) of the kickoff spot (2018), and eventually eliminating the running start by the kicking team (2018). The NCAA followed suit with wedge and line-of-scrimmage changes and added a fair-catch option for the receiving team (2018). These rule changes resulted in a reduction in concussions of 8.88/1000 plays during kickoffs at the collegiate level.[93–95] Updates to the National Federation of State High School Associations (NFHS) rules include infractions for *blind-side blocking* (ie, contact with an opponent other than the runner who does not see the block coming) and banning *pop-up kicks* (a form of onside kick in which the ball is kicked so that it pops it up in the air; 2018). The receiving player's upward gaze and concentration during the pop-up kick leaves him vulnerable to injury. Pop Warner Youth Football was the first league to ban kick-offs for its youngest divisions (2016).

In addition, the NCAA and NFHS have elevated the consequences for head-down tackling in situations deemed to be targeting. Specifically, targeting and making forcible contact with the crown of the helmet (NCAA Rule 9-1-3) or the head or neck area of a defenseless player (NCAA Rule 9-1-4) both result in immediate disqualification from competition.[2] The NCAA describes *targeting* as an infraction stemming from a player "taking aim at an opponent for the purposes of attacking with forcible contact going beyond that which is required to make a legal tackle or a legal block."[2] The NFHS uses similar language and punitive results.[96]

Ultimately, although policies aimed at reducing full-contact time or practices have merit for lowering the general head-impact risk,[8,89] they fall short in addressing head-first contact behavior. Use of the "Heads-Up" coaching strategy and limiting contact in practice decreased both head-impact exposures and concussions in youth football.[97] However, further study is needed to understand when introducing tackling and blocking is appropriate. For example, researchers[98] attempted to address a similar question about the injury risk from body checking among youth ice hockey teams, considering rule and policy changes, and this work could serve as a model for American football.

Rule and policy changes may create controversies due to social pressures in the sport (eg, football highlights often center on "big hits"). These changes may put pressure on coaches and players to modify training techniques, develop new skills while eliminating high-risk maneuvers, and limit the amount of contact exposure and potentially the opportunities for skill rehearsal. Greater still is the pressure on game officials. Consistent and vigorous enforcement of rules for protecting players' safety, especially the use of the head and helmet when making contact, is subjective at best and may influence the outcome of a game. Despite these concerns and pressures, rule changes have been demonstrated to improve athlete safety. As more evidence becomes available, they should be implemented to enhance the health and safety of athletes.

Technology and Scientific Research (Recommendations 11–14)

Helmets remain the best—and yet still incomplete—solution for mitigating forces generated by single or multiple direct head impacts. As a result, attention has focused on designing better protective headgear and the emergence of independent quality assessments to validate these enhancements (eg, Virginia Tech's Summation of Tests for the Analysis of Risk [STAR] rating,[99] National Football League helmet testing[100]). At its outset, the STAR system identified a single helmet as qualifying for 5 stars (the highest rating); more recently, 16 helmets spread over 5 brand labels have received top ratings.[101] Given these independent appraisals, which exceed the minimum certifying standards set forth by NOCSAE, manufacturers have developed helmets that are better able to mitigate head-impact forces. Despite persistent concussion rates,[102] the football helmet has likely never been better able to absorb deleterious contact forces and protect the head from acute trauma (eg, skull fracture, hemorrhage), its original intention.[103]

Helmets are not designed to reduce head-first contact behavior, so ATs and other key stakeholders should remain vigilant in their efforts to do so. This vigilance may include ATs educating other stakeholders about recent evidence, as unintended behavioral changes and subsequent injury outcomes follow a pattern associated with the use of protective equipment.[80,104,105] Risk compensation theory explains similar consequences for behavioral changes in other sport or physical activities (eg, helmet use in alpine skiing and cycling) and activities of daily living (eg, seatbelt use and motor vehicle crashes).[80] History informs us that as helmets evolved, from a leather cover to a solid outer shell in the 1950s to 1960s and the inclusion of a face mask and various iterations of interior padding or air bladders in the 1970s to 1980s,[103] a documented change in player behavior took place. Alarmingly and at a time coinciding with helmet innovation,[44] head and neck injuries in American football at all levels of play resulted in 204 deaths between 1965 and 1974, with 36 deaths in the 1968 football season alone[3] and 99 permanent cervical cord injuries in a 4-year span from 1971 to 1975.[83]

To mitigate the unintended consequence of head-first contact behavior associated with helmet usage, head-impact monitoring systems may be useful. These instruments are commercially available as research-grade equipment (most expensive) and more consumer-friendly models (least expensive). The devices are primarily intended to detect head accelerations resulting from impacts during sport participation. Head-impact biomechanical data are computed as linear acceleration (g), rotational velocity (rad/s), rotational acceleration (rad/s^2), Head Injury Criterion, Gadd Severity Index (GSI), or other measures of interest. Some also triangulate the head-impact location. These data may be minimally useful as a means of biofeedback or, more importantly, as trackable outputs in the study of behavioral interventions. With recent advances in technology (eg, smaller equipment at lower costs), a growing market of head-impact monitors is available. These monitoring systems may be beneficial for obtaining real-time head-impact data, but their clinical utility has been questioned.[50,106] The science surrounding head-impact biomechanics continues to evolve and, thus, the data provided by these systems are likely affected by external (eg, sport) and internal (eg, age, behavioral) factors. Devising a product that performs perfectly in the field is not tenable, even when the product demonstrates good performance in controlled laboratory environments. The literature is divided on this topic: some researchers[107] noted system inaccuracies, whereas others[108] supported these tools as useful in furthering our knowledge of concussion and head-impact biomechanics. Notwithstanding the known limitations of these devices, accelerometer-based head-impact monitoring is useful for characterizing the head kinematics and kinetics associated with concussion[50] and the play-related circumstances believed to increase the concussion risk (eg, anticipating collisions,[109] special teams plays[110]). Although these systems may provide additional information for identifying and correcting drills or practice strategies that result in leading with the head, it is important to point out that impact-monitoring systems and video capture are not appropriate clinical tools for diagnosing a concussion,[56,106,111] nor should they be used in place of an on-site health care professional for football.

Several commercially available products attempt to address the safety-related needs of players, and many are advertised as after-market add-ons to football helmets for impact-force mitigation. Such products often take the form of more soft or conforming exterior padding and come with little to no independent scientific evidence to support their efficacy in reducing impact forces during play. The current evidence describes no benefit. For example, investigators[45] assessed the ability of the Guardian Cap helmet cover to reduce linear acceleration and the GSI score. Using 2 styles of helmets and the NOCSAE drop-testing method, they found that the Guardian Cap failed to improve the helmets' ability to mitigate impact forces at all but 2 rear helmet locations. Football helmets must meet an industry standardization process. Though several processes exist, NOCSAE certification is required of all helmets worn in professional and amateur football. No standards or certifications are required for after-market helmet add-ons. Because of this limited product oversight, stakeholders are encouraged to use due diligence before investing in marketed products. In most cases, after-market helmet add-ons will compromise the NOCSAE certification obtained by protective equipment manufacturers.[112]

Finally, an overarching primary injury-prevention recommendation is to continue rigorous epidemiologic monitoring and experimental research where possible to provide evidence-informed strategies related to head-safe behaviors. It is paramount that American football stakeholders use observational and empirical data to evaluate, propose, and direct head-safe behaviors. Ideally, head and cervical spine trauma in football players should be more fully understood before rules and policies are proposed to further mitigate the injury risk. Athletic trainers who already work closely with coaches and strength specialists can reinforce the importance of teaching appropriate skills and monitoring practice structures in a way that reduces head-first contact behavior.[26] Athletic trainers should be primary stakeholders on committees that assess and direct policy. For example, identifying and then eliminating or modifying specific drills or practice maneuvers that increase the concussion risk is one such approach.[113] The benefit of this approach is eliminating injuries, allowing for greater participation by all involved athletes.

CONCLUSIONS

The recommendations outlined in this position statement and discussed in the existing literature are aimed at decreasing the prevalence of head-first contact behavior and the associated risk for serious head and cervical spine injury, in addition to reducing the accumulation of head impacts over time. Although these recommendations provide a host of potentially effective strategies for reducing head impacts in football, it is concerning that the scientific-medical community has little to no high-level (SOR A) evidence for a mechanism that entails a potentially catastrophic outcome. Critically needed are rigorous studies (ie, RCTs) and validation of existing and future strategies intended to address head-first contact behavior in American football players. It is worth noting that participation in any sport comes with an inherent risk of injury, and our profession should take collective action to reduce the injury risks for athletes participating in all sports. The potential risks of participation should be mitigated by options that enable young athletes to develop skills and sustain physically active lifestyles. With respect to American football, we must continue to identify strategies that decrease football-related head, neck, and spine injuries and the associated behaviors that increase the injury incidence, given the very high level of interest in participating in the sport.

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REFERENCES

1. Heck JF, Clarke KS, Peterson TR, Torg JS, Weis MP. National Athletic Trainers' Association position statement: head-down contact and spearing in tackle football. *J Athl Train*. 2004;39(1):101–111. (Level of evidence [LOE]: 3)
2. 2016 and 2017 NCAA football rules and interpretation. National Collegiate Athletic Association. Published 2016. Accessed October 14, 2021. https://www.ncaapublications.com/p-4430-2016-and-2017-ncaa-football-rules-and-interpretations.aspx (LOE: 3)
3. Kucera KL, Yau RK, Register-Mihalik J, et al. Traumatic brain and spinal cord fatalities among high school and college football players – United States, 2005–2014. *MMWR Morb Mortal Wkly Rep*. 2017;65(52):1465–1469. doi:10.15585/mmwr.mm6552a2 (LOE: 3)
4. Broglio SP, Sosnoff JJ, Shin S, He X, Alcaraz C, Zimmerman J. Head impacts during high school football: a biomechanical assessment. *J Athl Train*. 2009;44(4):342–349. doi:10.4085/1062-6050-44.4.342 (LOE: 2)
5. Crisco JJ, Fiore R, Beckwith JG, et al. Frequency and location of head impact exposures in individual collegiate football players. *J Athl Train*. 2010;45(6):549–559. doi:10.4085/1062-6050-45.6.549 (LOE: 2)
6. Greenwald RM, Gwin JT, Chu JJ, Crisco JJ. Head impact severity measures for evaluating mild traumatic brain injury risk exposure. *Neurosurgery*. 2008;62(4):789–798. doi:10.1227/01.neu.0000318162.67472.ad (LOE: 2)
7. Mihalik JP, Bell DR, Marshall SW, Guskiewicz KM. Measurement of head impacts in collegiate football players: an investigation of positional and event-type differences. *Neurosurgery*. 2007;61(6):1229–1235. doi:10.1227/01.neu.0000306101.83882.c8 (LOE: 2)
8. Broglio SP, Martini D, Kasper L, Eckner JT, Kutcher JS. Estimation of head impact exposure in high school football: implications for regulating contact practices. *Am J Sports Med*. 2013;41(12):2877–2884. doi:10.1177/0363546513502458 (LOE: 2)
9. Crisco JJ, Wilcox BJ, Machan JT, et al. Magnitude of head impact exposures in individual collegiate football players. *J Appl Biomech*. 2012;28(2):174–183. doi:10.1123/jab.28.2.174 (LOE: 2)
10. Daniel RW, Rowson S, Duma SM. Head impact exposure in youth football. *Ann Biomed Eng*. 2012;40(4):976–981. doi:10.1007/s10439-012-0530-7 (LOE: 2)
11. Daniel RW, Rowson S, Duma SM. Head impact exposure in youth football: middle school ages 12–14 years. *J Biomech Eng*. 2014;136(9):094501. doi:10.1115/1.4027872 (LOE: 2)
12. Munce TA, Dorman JC, Thompson PA, Valentine VD, Bergeron MF. Head impact exposure and neurologic function of youth football players. *Med Sci Sports Exerc*. 2015;47(8):1567–1576. doi:10.1249/MSS.0000000000000591 (LOE: 2)
13. Broglio SP, Swartz EE, Crisco JJ, Cantu RC. In vivo biomechanical measurements of a football player's C6 spine fracture. *N Engl J Med*. 2011;365(3):279–281. doi:10.1056/NEJMc1102689 (LOE: 3)
14. Di Battista AP, Rhind SG, Richards D, Churchill N, Baker AJ, Hutchison MG. Altered blood biomarker profiles in athletes with a history of repetitive head impacts. *PLoS One*. 2016;11(7):e0159929. doi:10.1371/journal.pone.0159929 (LOE: 2)
15. Kawata K, Rubin LH, Lee JH, et al. Association of football subconcussive head impacts with ocular near point of convergence. *JAMA Ophthalmol*. 2016;134(7):763–769. doi:10.1001/jamaophthalmol.2016 (LOE: 2)
16. Kawata K, Rubin LH, Wesley L, et al. Acute changes in plasma total tau levels are independent of subconcussive head impacts in college football players. *J Neurotrauma*. 2018;35(2):260–266. doi:10.1089/neu.2017.5376 (LOE: 2)
17. Montenigro PH, Alosco ML, Martin BM, et al. Cumulative head impact exposure predicts later-life depression, apathy, executive dysfunction, and cognitive impairment in former high school and college football players. *J Neurotrauma*. 2017;34(2):328–340. doi:10.1089/neu.2016.4413 (LOE: 2)

18. O'Connor KL, Baker MM, Dalton SL, Dompier TP, Broglio SP, Kerr ZY. Epidemiology of sport-related concussions in high school athletes: National Athletic Treatment, Injury and Outcomes Network (NATION), 2011–2012 through 2013–2014. *J Athl Train*. 2017;52(3):175–185. doi:10.4085/1062-6050-52.1.15 (LOE: 3)
19. Pfister T, Pfister K, Hagel B, Ghali WA, Ronksley PE. The incidence of concussion in youth sports: a systematic review and meta-analysis. *Br J Sports Med*. 2016;50(5):292–297. doi:10.1136/bjsports-2015-094978 (LOE: 2)
20. Zuckerman SL, Kerr ZY, Yengo-Kahn A, Wasserman E, Covassin T, Solomon GS. Epidemiology of sports-related concussion in NCAA athletes from 2009–2010 to 2013–2014: incidence, recurrence, and mechanisms. *Am J Sports Med*. 2015;43(11):2654–2662. doi:10.1177/036354651559963 (LOE: 3)
21. Kerr ZY, Collins CL, Mihalik JP, Marshall SW, Guskiewicz KM, Comstock RD. Impact locations and concussion outcomes in high school football player-to-player collisions. *Pediatrics*. 2014;134(3):489–496. doi:10.1542/peds.2014-0770 (LOE: 2)
22. Alosco ML, Kasimis AB, Stamm JM, et al. Age of first exposure to American football and long-term neuropsychiatric and cognitive outcomes. *Transl Psychiatry*. 2017;7(9):e1236. doi:10.1038/tp.2017.197 (LOE: 2)
23. Mez J, Daneshvar DH, Kiernan PT, et al. Clinicopathological evaluation of chronic traumatic encephalopathy in players of American football. *JAMA*. 2017;318(4):360–370. doi:10.1001/jama.2017.8334 (LOE: 2)
24. Rabinovici GD. Advances and gaps in understanding chronic traumatic encephalopathy: from pugilists to American football players. *JAMA*. 2017;318(4):338–340. doi:10.1001/jama.2017.9353 (LOE: 2)
25. Tharmaratnam T, Iskandar MA, Tabobondung TC, Tobbia I, Gopee-Ramanan P, Tabobondung TA. Chronic traumatic encephalopathy in professional American football players: where are we now? *Front Neurol*. 2018;9:445. doi:10.3389/fneur.2018.00445 (LOE: 2)
26. Casa DJ, Guskiewicz KM, Anderson SA, et al. National Athletic Trainers' Association position statement: preventing sudden death in sports. *J Athl Train*. 2012;47(1):96–118. doi:10.4085/1062-6050-47.1.96 (LOE: 3)
27. Farrow D, Buszard T. Exploring the applicability of the contextual interference effect in sports practice. *Prog Brain Res*. 2017;234:69–83. doi:10.1016/bs.pbr.2017.07.002 (LOE: 2)
28. Macnamara BN, Moreau D, Hambrick DZ. The relationship between deliberate practice and performance in sports: a meta-analysis. *Perspect Psychol Sci*. 2016;11(3):333–350. doi:10.1177/1745691616635591 (LOE: 2)
29. Broadbent DP, Causer J, Williams AM, Ford PR. Perceptual-cognitive skill training and its transfer to expert performance in the field: future research directions. *Eur J Sport Sci*. 2015;15(4):322–331. doi:10.1080/17461391.2014.957727 (LOE: 2)
30. Ebell MH, Siwek J, Weiss BD, et al. Strength of Recommendation Taxonomy (SORT): a patient-centered approach to grading evidence in the medical literature. *J Am Board Fam Pract*. 2004;17(1):59–67. doi:10.3122/jabfm.17.1.59 (LOE: 3)
31. Yeargin S, Lopez RM, Snyder Valier AR, DiStefano LJ, McKeon PO, Medina McKeon JM. Navigating athletic training position statements: the Strength of Recommendation Taxonomy System. *J Athl Train*. 2020;55(8):863–868. doi:10.4085/1062-6050-240-19 (LOE: 3)
32. Kerr ZY, Yeargin SW, Valovich McLeod TC, et al. Comprehensive coach education and practice contact restriction guidelines result in lower injury rates in youth American football. *Orthop J Sports Med*. 2015;3(7):2325967115594578. doi:10.1177/2325967115594578 (LOE: 2)
33. Swartz EE, Broglio SP, Cook SB, et al. Early results of a helmetless-tackling intervention to decrease head impacts in football players. *J Athl Train*. 2015;50(12):1219–1222. doi:10.4085/1062-6050-51.1.06 (LOE: 2)
34. Parsons JT, Anderson SA, Casa DJ, Hainline B. Preventing catastrophic injury and death in collegiate athletes: interassociation recommendations endorsed by 13 medical and sports medicine organisations. *Br J Sports Med*. 2020;54(4):208–215. doi:10.1136/bjsports-2019-101090 (LOE: 3)
35. Champagne AA, Distefano V, Boulanger MM, et al. Data-informed intervention improves football technique and reduces head impacts. *Med Sci Sports Exerc*. 2019;51(11):2366–2374. doi:10.1249/MSS.0000000000002046 (LOE: 2)
36. Shanley E, Thigpen C, Kissenberth M, et al. Heads up football training decreases concussion rates in high school football players. *Clin J Sport Med*. 2021;31(2):120–126. doi:10.1097/JSM.0000000000000711 (LOE: 2)
37. Schussler E, Jagacinski RJ, White SE, Chaudhari AM, Buford JA, Onate JA. The effect of tackling training on head accelerations in youth American football. *Int J Sports Phys Ther*. 2018;13(2):229–237. (LOE: 2)
38. Swartz EE, Myers JL, Cook SB, et al. A helmetless-tackling intervention in American football for decreasing head impact exposure: a randomized controlled trial. *J Sci Med Sport*. 2019;22(10):1102–1107. doi:10.1016/j.jsams.2019.05.018 (LOE: 1)
39. Pfaller AY, Brooks MA, Hetzel S, McGuine TA. Effect of a new rule limiting full contact practice on the incidence of sport-related concussion in high school football players. *Am J Sports Med*. 2019;47(10):2294–2299. doi:10.1177/0363546519860120 (LOE: 2)
40. Broglio SP, Williams RM, O'Connor KL, Goldstick J. Football players' head-impact exposure after limiting of full-contact practices. *J Athl Train*. 2016;51(7):511–518. doi:10.4085/1062-6050-51.7.04 (LOE: 2)
41. Kelley ME, Espeland MA, Flood WC, et al. Comparison of head impact exposure in practice drills among multiple youth football teams. *J Neurosurg Pediatr*. 2018;23(3):381–389. doi:10.3171/2018.9.PEDS18314 (LOE: 2)
42. Campolettano ET, Rowson S, Duma SM. Drill-specific head impact exposure in youth football practice. *J Neurosurg Pediatr*. 2016;18(5):536–541. doi:10.3171/2016.5.PEDS1696 (LOE: 2)
43. Asken BM, Brooke ZS, Stevens TC, et al. Drill-specific head impacts in collegiate football practice: implications for reducing "friendly fire" exposure. *Ann Biomed Eng*. 2019;47(10):2094–2108. doi:10.1007/s10439-018-2088-5 2018. (LOE: 2)
44. Torg JS, Vegso JJ, Sennett B. The National Football Head and Neck Injury Registry: 14-year report on cervical quadriplegia (1971–1984). *Clin Sports Med*. 1987;6(1):61–72. (LOE: 3)
45. Breedlove KM, Breedlove E, Nauman E, Bowman TG, Lininger MR. The ability of an aftermarket helmet add-on device to reduce impact-force accelerations during drop tests. *J Athl Train*. 2017;52(9):802–808. doi:10.4085/1062-6050-52.6.01 (LOE: 3)
46. Bachynski KE, Smoliga JM. Pseudomedicine for sports concussions in the USA. *Lancet Neurol*. 2021;20(10):791–792. doi:10.1016/S1474-4422(19)30250-9 (LOE: 3)
47. Schmidt JD, Phan TT, Courson RW, Reifsteck F III, Merritt ED, Brown CN. The influence of heavier football helmet faceguards on head impact location and severity. *Clin J Sport Med*. 2018;28(2):106–110. doi:10.1097/JSM.0000000000000437 (LOE: 2)
48. Swartz E, Register-Mihalik J, Bartlett A, Guskiewicz K. The effect of football helmet facemask styles on perceived player behavior: a pilot study. *Athl Train Sports Health Care*. 2019;11(6):273–279. doi:10.3928/19425864-20190131-01 (LOE: 3)
49. Mok D, Gore G, Hagel B, Mok E, Magdalinos H, Pless B. Risk compensation in children's activities: a pilot study. *Paediatr Child Health*. 2004;9(5):327–330. doi:10.1093/pch/9.5.327 (LOE: 3)

50. Brennan JH, Mitra B, Synnot A, et al. Accelerometers for the assessment of concussion in male athletes: a systematic review and meta-analysis. *Sports Med*. 2017;47(3):469–478. doi:10.1007/s40279-016-0582-1 (LOE: 2)
51. O'Connor KL, Rowson S, Duma SM, Broglio SP. Head-impact-measurement devices: a systematic review. *J Athl Train*. 2017;52(3):206–227. doi:10.4085/1062-6050.52.2.05 (LOE: 2)
52. Heck JF. The incidence of spearing by high school football ball carriers and their tacklers. *J Athl Train*. 1992;27(2):120–124. (LOE: 3)
53. Heck JF. The incidence of spearing during a high school's 1975 and 1990 football seasons. *J Athl Train*. 1996;31(1):31–37. (LOE: 3)
54. Daniel RW, Rowson S, Duma SM. Head acceleration measurements in middle school football. *Biomed Sci Instrum*. 2014;50:291–296. (LOE: 2)
55. Duma SM, Manoogian SJ, Bussone WR, et al. Analysis of real-time head accelerations in collegiate football players. *Clin J Sport Med*. 2005;15(1):3–8. doi:10.1097/00042752-200501000-00002 (LOE: 2)
56. Guskiewicz KM, Mihalik JP, Shankar V, et al. Measurement of head impacts in collegiate football players: relationship between head impact biomechanics and acute clinical outcome after concussion. *Neurosurgery*. 2007;61(6):1244–1252; discussion 1252–1253. doi:10.1227/01.neu.0000306103.68635.1a (LOE: 2)
57. Kucera KL, Klossmer D, Colgate B, Cantu RC. Annual survey of football injury research (2020). National Center for Catastrophic Sport Injury Research. Published March 10, 2021. Accessed October 15, 2021. https://nccsir.unc.edu/wp-content/uploads/sites/5614/2021/03/Annual-Football-2020-Fatalities-FINAL.pdf (LOE: 3)
58. Boden BP, Breit I, Beachler JA, Williams A, Mueller FO. Fatalities in high school and college football players. *Am J Sports Med*. 2013;41(5):1108–1116. doi:10.1177/0363546513478572 (LOE: 3)
59. Heads up football. USA Football. Accessed October 15, 2021. https://usafootball.com/programs/heads-up-football/ (LOE: 3)
60. Heads Up resource center. Centers for Disease Control and Prevention. Updated April 16, 2021. Accessed October 15, 2021. https://www.cdc.gov/headsup/resources/index.html. (LOE: 3)
61. Kerr ZY, Yeargin SW, Valovich McLeod TC, Mensch J, Hayden R, Dompier TP. Comprehensive coach education reduces head impact exposure in American youth football. *Orthop J Sports Med.* 2015;3(10):2325967115610545. doi:10.1177/2325967115610545 (LOE: 2)
62. Tee JC, Till K, Jones B. Incidence and characteristics of injury in under-19 academy level rugby league match play: a single season prospective cohort study. *J Sports Sci*. 2019;37(10):1181–1188. doi:10.1080/02640414.2018.1547100 (LOE: 3)
63. King D, Hume P, Gissane C, Clark T. Head impacts in a junior rugby league team measured with a wireless head impact sensor: an exploratory analysis. *J Neurosurg Pediatr*. 2017;19(1):13–23. doi:10.3171/2016.7.PEDS1684 (LOE: 3)
64. King D, Hume PA, Brughelli M, Gissane C. Instrumented mouthguard acceleration analyses for head impacts in amateur rugby union players over a season of matches. *Am J Sports Med*. 2015;43(3):614–624. doi:10.1177/0363546514560876 (LOE: 2)
65. King DA, Hume PA, Gissane C, Clark TN. Similar head impact acceleration measured using instrumented ear patches in a junior rugby union team during matches in comparison with other sports. *J Neurosurg Pediatr*. 2016;18(1):65–72. doi:10.3171/2015.12.PEDS15605 (LOE: 2)
66. Alois J, Bellamkonda S, Campolettano ET, et al. Do American youth football players intentionally use their heads for high-magnitude impacts? *Am J Sports Med*. 2019;47(14):3498–3504. doi:10.1177/0363546519882034 (LOE: 2)
67. Reboursiere E, Bohu Y, Retière D, et al. Impact of the national prevention policy and scrum law changes on the incidence of rugby-related catastrophic cervical spine injuries in French Rugby Union. *Br J Sports Med*. 2018;52(10):674–677. doi:10.1136/bjsports-2016-096122 (LOE: 3)
68. Quarrie KL, Cantu RC, Chalmers DJ. Rugby union injuries to the cervical spine and spinal cord. *Sports Med*. 2002;32(10):633–653. doi:10.2165/00007256-200232100-00003 (LOE: 3)
69. RugbySmart for coaches and referees. New Zealand Rugby. Accessed October 15, 2021. https://www.rugbysmart.co.nz/ (LOE: 3)
70. Gianotti S, Hume PA. Concussion sideline management intervention for rugby union leads to reduced concussion claims. *NeuroRehabilitation*. 2007;22(3):181–189. (LOE: 2)
71. Patricios J. BokSmart – South African rugby's national rugby safety and injury prevention program. *Curr Sports Med Rep*. 2014;13(3):142–144. doi:10.1249/JSR.0000000000000049 (LOE: 3)
72. Fraas MR, Burchiel J. A systematic review of education programmes to prevent concussion in rugby union. *Eur J Sport Sci*. 2016;16(8):1212–1218. doi:10.1080/17461391.2016.1170207 (LOE: 2)
73. Phillips N, Crisco JJ. The effectiveness of regulations and behavioral interventions on head impacts and concussions in youth, high-school, and collegiate football: a systematized review. *Ann Biomed Eng*. 2020;48(11):2508–2530. doi:10.1007/s10439-020-02624-8 (LOE: 2)
74. Kerr ZY, Kroshus E, Lee JGL, Yeargin SW, Dompier TP. Coaches' implementation of the USA Football "Heads Up Football" educational program. *Health Promot Pract*. 2018;19(2):184–193. doi:10.1177/1524839917700398 (LOE: 3)
75. Kroshus E, Kerr ZY, Lee JGL. Community-level inequalities in concussion education of youth football coaches. *Am J Prev Med*. 2017;52(4):476–482. doi:10.1016/j.amepre.2016.12.021 (LOE: 3)
76. 2015 Seahawks tackling. Seattle Seahawks. Published 2015. Accessed June 12, 2020. https://www.seahawks.com/video/2015-seahawks-tackling-124581 (LOE: 3).
77. Hendricks S, Matthews B, Roode B, Lambert M. Tackler characteristics associated with tackle performance in rugby union. *Eur J Sport Sci*. 2014;14(8):753–762. doi:10.1080/17461391.2014.905982 (LOE: 2)
78. Bonnard M, de Graaf J, Pailhous J. Interactions between cognitive and sensorimotor functions in the motor cortex: evidence from the preparatory motor sets anticipating a perturbation. *Rev Neurosci*. 2004;15(5):371–382. doi:10.1515/revneuro.2004.15.5.371 (LOE: 2)
79. Kuramochi R, Kimura T, Nakazawa K, Akai M, Torii S, Suzuki S. Anticipatory modulation of neck muscle reflex responses induced by mechanical perturbations of the human forehead. *Neurosci Lett*. 2004;366(2):206–210. doi:10.1016/j.neulet.2004.05.040 (LOE: 2)
80. Hagel B, Meeuwisse W. Risk compensation: a "side effect" of sport injury prevention? *Clin J Sport Med*. 2004;14(4):193–196. doi:10.1097/00042752-200407000-00001 (LOE: 3)
81. Pless IB, Magdalinos H, Hagel B. Risk-compensation behavior in children: myth or reality? *Arch Pediatr Adolesc Med*. 2006;160(6):610–614. doi:10.1001/archpedi.160.6.610 (LOE: 3)
82. Wilde GJ. Risk homeostasis theory: an overview. *Inj Prev*. 1998;4(2):89–91. doi:10.1136/ip.4.2.89 (LOE: 3)
83. Torg JS, Quedenfeld TC, Burstein A, Spealman A, Nichols C III. National Football Head and Neck Injury Registry: report on cervical quadriplegia, 1971 to 1975. *Am J Sports Med*. 1979;7(2):127–132. doi:10.1177/036354657900700209 (LOE: 3)
84. Belson K. Ivy League moves to eliminate tackling at football practices. *New York Times*. March 1, 2016:B:11. Accessed October 15, 2021. https://www.nytimes.com/2016/03/02/sports/ncaafootball/ivy-league-moves-to-eliminate-tackling-at-practices.html (LOE: 3)

85. Young TJ, Daniel RW, Rowson S, Duma SM. Head impact exposure in youth football: elementary school ages 7–8 years and the effect of returning players. *Clin J Sport Med*. 2014;24(5):416–421. doi:10.1097/JSM.0000000000000055 (LOE: 2)
86. Broglio SP, Eckner JT, Martini D, Sosnoff JJ, Kutcher JS, Randolph C. Cumulative head impact burden in high school football. *J Neurotrauma*. 2011;28(10):2069–2078. doi:10.1089/neu.2011.1825 (LOE: 2)
87. Urban JE, Davenport EM, Golman AJ, et al. Head impact exposure in youth football: high school ages 14 to 18 years and cumulative impact analysis. *Ann Biomed Eng*. 2013;41(12):2474–2487. doi:10.1007/s10439-013-0861-z (LOE: 2)
88. Limited contact in practice rule. Pop Warner Little Scholars. Published 2013. Accessed October 15, 2021. https://www.popwarner.com/Default.aspx?tabid=1403207 (LOE: 3)
89. Cobb BR, Urban JE, Davenport EM, et al. Head impact exposure in youth football: elementary school ages 9–12 years and the effect of practice structure. *Ann Biomed Eng*. 2013;41(12):2463–2473. doi:10.1007/s10439-013-0867-6 (LOE: 2)
90. Emery C, Palacios-Derflingher L, Black AM, et al. Does disallowing body checking in non-elite 13- to 14-year-old ice hockey leagues reduce rates of injury and concussion? A cohort study in two Canadian provinces. *Br J Sports Med*. 2020;54(7):414–420. doi:10.1136/bjsports-2019-101092 (LOE: 2)
91. Emery C, Kang J, Shrier I, Goulet C, et al. Risk of injury associated with bodychecking experience among youth hockey players. *CMAJ*. 2011;183(11):1249–1256. doi:10.1503/cmaj.101540 (LOE: 2)
92. Yard EE, Comstock RD. Effects of field location, time in competition, and phase of play on injury severity in high school football. *Res Sports Med*. 2009;17(1):35–49. doi:10.1080/15438620802678495 (LOE: 2)
93. Clark MD, Asken BM, Marshall SW, Guskiewicz KM. Descriptive characteristics of concussions in National Football League games, 2010–2011 to 2013–2014. *Am J Sports Med*. 2017;45(4):929–936. doi:10.1177/0363546516677793 (LOE: 3)
94. Ruestow PS, Duke TJ, Finley BL, Pierce JS. Effects of the NFL"s amendments to the Free Kick rule on injuries during the 2010 and 2011 seasons. *J Occup Environ Hyg*. 2015;12(12):875–882. doi:10.1080/15459624.2015 (LOE: 3)
95. Wiebe DJ, D'Alonzo BA, Harris R, Putukian M, Campbell-McGovern C. Association between the experimental kickoff rule and concussion rates in Ivy League football. *JAMA*. 2018;320(19):2035–2036. doi:10.1001/jama.2018.14165 (LOE: 2)
96. 2019 rule book. National Federation of State High School Associations. https://www.nfhs.org/media/1020439/2019-20-nfhs-handbook.pdf (LOE: 3)
97. Kerr ZY, Dalton SL, Roos KG, Djoko A, Phelps J, Dompier TP. Comparison of Indiana high school football injury rates by inclusion of the USA Football "Heads Up Football" player safety coach. *Orthop J Sports Med*. 2016;4(5):2325967116648441. doi:10.1177/2325967116648441 (LOE: 3)
98. Black AM, Macpherson AK, Hagel BE, et al. Policy change eliminating body checking in non-elite ice hockey leads to a threefold reduction in injury and concussion risk in 11- and 12-year-old players. *Br J Sports Med*. 2016;50(1):55–61. doi:10.1136/bjsports-2015-095103 (LOE: 2)
99. Rowson S, Duma SM. Development of the STAR evaluation system for football helmets: integrating player head impact exposure and risk of concussion. *Ann Biomed Eng*. 2011;39(8):2130–2140. doi:10.1007/s10439-011-0322-5 (LOE: 3)
100. 2019 helmet laboratory testing performance results. National Football League. Published August 26, 2019. Accessed October 15, 2021. https://www.nfl.com/playerhealthandsafety/equipment-and-innovation/equipment-testing/2019-helmet-laboratory-testing-performance-results (LOE: 3)
101. Helmet ratings.Virginia Tech. Accessed October 15, 2021. https://www.helmet.beam.vt.edu/varsity-football-helmet-ratings.html (LOE: 3)
102. Kerr ZY, Chandran A, Nedimyer AK, Arakkal A, Pierpoint LA, Zuckerman SL. Concussion incidence and trends in 20 high school sports. *Pediatrics*. 2019;144(5):e20192180. doi:10.1542/peds.2019-2180 (LOE: 3)
103. Viano DC, Halstead D. Change in size and impact performance of football helmets from the 1970s to 2010. *Ann Biomed Eng*. 2012;40(1):175–184. doi:10.1007/s10439-011-0395-1 (LOE: 3)
104. Gamble T, Walker I. Wearing a bicycle helmet can increase risk taking and sensation seeking in adults. *Psychol Sci*. 2016;27(2):289–294. doi:10.1177/0956797615620784 (LOE: 2)
105. Kontos AP. Perceived risk, risk taking, estimation of ability and injury among adolescent sport participants. *J Pediatr Psychol*. 2004;29(6):447–455. doi:10.1093/jpepsy/jsh048 (LOE: 2)
106. Mihalik JP, Lynall RC, Wasserman EB, Guskiewicz KM, Marshall SW. Evaluating the "threshold theory": can head impact indicators help? *Med Sci Sports Exerc*. 2017;49(2):247–253. doi:10.1249/MSS.0000000000001089 (LOE: 2)
107. Jadischke R, Viano DC, Dau N, King AI, McCarthy J. On the accuracy of the Head Impact Telemetry (HIT) system used in football helmets. *J Biomech*. 2013;46(13):2310–2315. doi:10.1016/j.jbiomech.2013.05.030 (LOE: 3)
108. Duma SM, Rowson S. Re: On the accuracy of the Head Impact Telemetry (HIT) system used in football helmets. *J Biomech*. 2014;47(6):1557–1558. doi:10.1016/j.jbiomech.2013.08.022 (LOE: 3)
109. Mihalik JP, Moise KF, Ocwieja KM, Guskiewicz KM, Register-Mihalik JK. The effects of player anticipation and involvement on head impact biomechanics in college football body collisions. In: Ashare A, Ziejewski M, eds. *Mechanism of Concussion in Sports*. ASTM Selected Technical Papers, STP1552; 2014:41–55. doi:10.1520/STP1S5220120108 (LOE: 2)
110. Ocwieja KE, Mihalik JP, Marshall SW, Schmidt JD, Trulock SC, Guskiewicz KM. The effect of play type and collision closing distance on head impact biomechanics. *Ann Biomed Eng*. 2012;40(1):90–96. doi:10.1007/s10439-011-0401-7 (LOE: 2)
111. McCaffrey MA, Mihalik JP, Crowell DH, Shields EW, Guskiewicz KM. Measurement of head impacts in collegiate football players: clinical measures of concussion after high- and low-magnitude impacts. *Neurosurgery*. 2007;61(6):1236–1243; discussion 1243. doi:10.1227/01.neu.0000306102.91506.8b (LOE: 2)
112. Certification to NOCSAE standards and add-on helmet products. National Operating Committee on Standards for Athletic Equipment. Published May 8, 2018. Accessed October 15, 2021. https://nocsae.org/certification-to-nocsae-standards-and-add-on-helmet-products/ (LOE: 3)
113. Kelley ME, Kane JM, Espeland MA, et al. Head impact exposure measured in a single youth football team during practice drills. *J Neurosurg Pediatr*. 2017;20(5):489–497. doi:10.3171/2017.5.PEDS16627 (LOE: 2)

Address correspondence to Erik E. Swartz, PhD, ATC, Department of Physical Therapy and Kinesiology, University of Massachusetts, Lowell, 113 Wilder Street, Suite 300, Lowell, MA 01854. Address email to Erik_Swartz@uml.edu.