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Tackling in Youth Football

COUNCIL ON SPORTS MEDICINE AND FITNESS

abstract

American football remains one of the most popular sports for young athletes. The injuries sustained during football, especially those to the head and neck, have been a topic of intense interest recently in both the public media and medical literature. The recognition of these injuries and the potential for long-term sequelae have led some physicians to call for a reduction in the number of contact practices, a postponement of tackling until a certain age, and even a ban on high school football. This statement reviews the literature regarding injuries in football, particularly those of the head and neck, the relationship between tackling and football-related injuries, and the potential effects of limiting or delaying tackling on injury risk.

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INTRODUCTION

With more than 1.1 million players, American football remains one of the most popular sports for male high school athletes.[1] In addition, there are approximately 250 000 youth football players 5 to 15 years of age in Pop Warner leagues alone, making football one of the most popular sports for younger athletes as well.[2] The injuries sustained during football, especially those to the head and neck, have been a topic of intense interest recently in both the public media and the medical literature. Concerns about the number of head and neck injuries, especially concussions and catastrophic injuries, have led some athletes to stop playing football.[3] More recently, the cumulative effects of concussions and the potential for a cumulative effect of subconcussive blows to the head, defined as those that do not cause symptoms of concussion, have been hypothesized as a causative risk factor for chronic traumatic encephalopathy (CTE). The recognition of these injuries and the potential for long-term sequelae have led some physicians to call for a reduction in the number of contact practices, a postponement of tackling until a certain age, and even a ban on high school football.[4–6]

Others, however, have argued that football is a generally safe sport that carries with it the substantial benefits of regular exercise on health[7,8] as well as social and academic outcomes[9–11] that outweigh the risks involved, pointing out that the risk of catastrophic injury is low, that most concussions resolve within a few days or weeks, and that there are

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substantial limitations to the current understanding of CTE. Some have expressed concerns about limiting contact practices or delaying the age at which tackling is introduced for fear that inadequate training may lead to unintended consequences once contact is allowed, such as increased forces of impact and more concussions.

The purpose of this statement is to review the literature regarding injuries in football, particularly those of the head and neck, the relationship between tackling and football-related injuries, and the potential effects of limiting or delaying tackling on injury risk. For purposes of this statement, unless otherwise defined, an athletic exposure (AE) refers to 1 athlete participating in 1 game or 1 practice.

INCIDENCE OF INJURIES IN YOUTH FOOTBALL

The most commonly injured body parts in football at all ages are the knee,[12–20] ankle,[12–21] hand,[21] and back.[12–16] The head and neck sustain a relatively small proportion of overall injuries, ranging from 5% to 13%.[12–18] Fortunately, most injuries are contusions, musculotendinous strains, and ligamentous sprains.[12,13,15,17,18]

Available data suggest that both the overall incidence and the severity of injuries sustained by younger football players are lower than those sustained by older players,[12–16,18,19,21–25] although this finding is not universally consistent.[21] Some studies suggest that the incidence of overall injuries in football is similar to other sports,[19,21] although the incidence of serious injuries appears to be greater for football than many other team sports.[21,26] Although data regarding the most common injuries sustained by football players at the professional, collegiate, and high school level are more readily available, data regarding younger players is limited. The overall incidence of injury varies between studies, depending on how an injury was defined and how data were gathered (Table 1).

Cumulative and Catastrophic Head and Neck Injuries in Football

Although the risk of catastrophic injuries to the head and neck in football is low, with yearly estimates between 0.19 and 1.78 for every 100 000 participants,[27–29] it appears higher in football than most other team sports.[28] The risk of catastrophic injury during participation in football is, however, comparable to the risk in gymnastics and lower than the risk in ice hockey.[28] The risk appears lower for youth players than for high school players and lower for high school players than for college players.[27,29] The annual risk of quadriplegia is approximately 0.52 per 100 000 football participants and, again, appears lower for high school football players (0.50/100 000 participants) than collegiate players (0.82/100 000 participants). Spear tackling, or leading with the crown of the helmeted head while tackling by defensive players, continues to be the predominant mechanism of injury causing quadriplegia.[29]

The cumulative effects of concussion have been documented both in athletes and those outside the realm of organized sports.[30–34] Some former athletes who participated in sports that involve purposeful collisions and repetitive blows to the head have suffered from mood disorders, behavior problems, cognitive difficulties, gait abnormalities, headaches, and Parkinsonism later in life. At autopsy, these athletes had pathologic changes to the brain, including ventriculomegaly, cerebral atrophy, β-amyloid deposits, and phosphorylated τ deposits, an entity now commonly known as CTE.[35–49] These case reports and case series have led to the hypothesis that repetitive blows to the head, whether concussive or subconcussive, result in the pathologic changes noted above and that these pathologic changes are associated with certain neurobehavioral characteristics. Whether the pathologic findings are solely attributable to the blows to the head and whether the pathologic changes are significantly associated with the neurobehavioral correlates is debated because these hypotheses remain to be tested by case-control and cohort studies.[50–54] Some have argued that these effects may be attributable to confounding variables, such the use of drugs, alcohol, or performance-enhancing substances. It should be noted, however, that animal models of repetitive concussive brain injury have shown a decrease in cognitive function in the absence of such potential confounding variables.[55–57]

"Second impact syndrome" is a term used to describe a devastating brain injury associated with cerebral edema that occurs after an often minor blow to the head is sustained before full recovery from a concussion.[58–61] Although second impact syndrome is often associated with football, it has been observed in other sports, such as ice hockey, boxing, and skiing.[58] Nearly all athletes with this diagnosis in the literature are younger than 20 years old. Given the rarity of this injury, its incidence in football is unknown. Furthermore, whether second impact syndrome is a unique entity, as opposed to cerebral edema attributable to a solitary blow to the head, remains debated.[62–65]

INJURIES ASSOCIATED WITH TACKLING

Injuries are common during contact and tackling in particular.[14,16–18] A higher proportion of injuries result from contact than noncontact mechanisms.[14,16,17,23,66] Tackling, specifically, is the most common player activity at the time of injury[20] and at the time of severe injury.[26] Being tackled and tackling account for about half of high school and college football-related injuries.[17,18]

TABLE 1 Summary of Studies Describing Incidence of Injuries in American Football

Study	Population	Definition of Injury	Methods	Results
Shankar et al 2007[18]	High school (and college) football players from 100 high schools	Occurred during organized practice or game	Prospective cohort study	Overall injury incidence 4.4/1000 AEs (higher rate observed for college players; 8.6/1000 AEs)
		Required medical attention from athletic trainer or team physician	Injuries reported by athletic trainers	Game time incidence higher than practice (12.0 vs 2.6/1000 AEs)
		Resulted in ≥1 d of restriction beyond day of injury		
Badgeley et al 2013[17]	High school football players from 100 high schools	Occurred during organized practice or game	Prospective cohort study	Overall injury incidence 4.08/1000 AEs
		Required medical attention from athletic trainer or team physician	Injuries reported by athletic trainers	Game time incidence higher than practice (12.61 vs 2.35/1000AEs)
		Resulted in ≥1 d of restriction beyond day of injury		
		Included all fractures, concussions, and dental injuries		
Knowles et al 2006[114]	High school athletes from 100 high schools	Resulted from participation in high school sport	Prospective cohort study	Overall injury incidence rate of 2.08/1000 AEs
		Limited full participation day following injury or required medical attention	Injuries reported by athletic trainers or athletic directors	Football had the highest incidence of injury
		Included all concussions, fractures, and eye injuries		
Turbeville et al 2003[14]	Middle school football players, grades 6–8, aged 10-15 y, N = 646	Resulted in a player missing ≥1 practices/games	Prospective cohort study	Game time incidence of overall injuries higher than practice (8.84 vs 0.97/1000 AEs)
		Included all head injuries resulting in alteration of consciousness requiring the player to leave practice/game	Football coach or athletic trainer reported injuries	Head was site of injury for 2% of all injuries
				Neck/spine was site of injury for 3% of all injuries
				Concussion accounted for 12.5% of all injuries
Dompier et al 2007[15]	Youth football players aged 9–14 y; N = 779	Non–time-loss injuries did not require removal from participation	Prospective cohort study	Overall injury incidence of 17.8/1000 AEs
		Time-loss injuries required removal from session or subsequent session	Athletic trainers present for practices and games, reported injuries	Time-loss injury only incidence 7.4/1000 AEs
		Included all fractures, dental injuries, concussions, and injuries requiring referral		Injury rate increased with grade in school (4.3/1000 AEs for fourth/fifth graders, 14.4/1000 AEs for eighth graders)
				Neck and head were sites of injury for 4.6% and 6.5% of injuries, respectively)
Malina et al 2006[22]	Youth football players	Caused cessation of participation and prevented return to that session	Prospective cohort study	Overall injury incidence 10.4/1000 AEs
	Aged 9–14 y; N = 678	Included all fractures, dental injuries, and concussions	Athletic trainers reported injuries	No significant association between incidence of injury and height, weight, BMI, or estimated maturity status
				Incidence of injury increased with grade in school
Stuart et al 2002[13]	Youth football players, aged 9–13 y; N = 915	Occurred during a game, kept the player out for remainder of game, and required attention of a physician	Injuries reported by orthopedist in medical tent adjacent to the playing field	Game time incidence 8.47/1000 AEs (only assessed game time AEs)
		Included all concussions, dental injuries, eye injuries, and nerve injuries		Older players in the higher grades more susceptible to injuries
				Running backs at highest risk

TABLE 1 Continued

Study	Population	Definition of Injury	Methods	Results
Radelet et al 2002[21]	Youth athletes in several sports, aged 7–13 y; *N* = 1659	Brought coach on the field to check condition of a player, required removal from play, or required first aid	Coaches kept records, contacted weekly by researchers	Overall injury incidence in football was 15/1000 AEs
				Overall injury incidence comparable to baseball and boys' soccer, but lower than girls' soccer
				Authors note, however, the reporting of injuries may have differed by sport, possibly underreported in football
				8- to 10-y-old players injured more frequently than 5- to 7-y-old and 11- to 13-y-old players
Kontos et al 2013[23]	Youth football players aged 8–12 y, *N* = 468	Concussion defined as any mild closed head injury involving altered cognitive functioning or signs or symptoms or brief loss of consciousness after a blow to the head	Prospective cohort study	Concussion incidence was 1.8/1000 AEs
			Coaches referred suspected concussions to medical professional for diagnosis	Game time incidence higher than practices (6.2 vs 0.24/1000 AEs)
				Concussion incidence rate lower for the 8- to 10-y-old players than 11- to 12-y-old players (0.93 vs 2.53/1000 AEs)
Linder et al 1995[24]	High school football players, aged 11–15 y; *N* = 340	"Any sports-related mishap" occurring during practice or games, resulting in removal from practice or game and/or missing subsequent practice or game	Injuries recorded by coaches; data collected weekly by authors	16% of participants were injured
				Proportion of participants injured increased with Tanner stage

The majority of concussions result from tackling or being tackled.[17] Head-to-head contact is one of the leading causes of concussions sustained by youth football players.[18,23]

Badgeley et al studied the mechanisms leading to injury in a cohort of high school students playing football.[17] Players in the older division had higher overall rates of injury than players in younger divisions. The leading mechanism of injury was player-to-player contact, with tackling/being tackled accounting for nearly half (46.2%) of all injuries. Similar findings have been reported in studies of youth football. In an observational cohort study of 208 Pop Warner football teams from New England, Goldberg et al reported on injuries sustained by players between the ages of 5 and 15 years that required restricted participation for more than 1 week.[16] The vast majority (88%) of injuries occurred during contact with another player; 41% resulted directly from tackling. Players in the older division (Bantam) had higher overall rates of injury than players in younger divisions.

In a community survey by Radelet et al, the incidence of injuries sustained by children ages 7 to 13 years playing football (0.15 per 1000 AEs) was similar to, and in fact slightly lower than, that of baseball (0.17 per 1000 AEs) and boys' soccer (0.17 per 1000 AEs).[21] This finding was unexpected, but the authors noted that the results may have been affected by underreporting and differences in the interpretation of the definition of injury. The percentage of injuries that were defined as serious (fractures, dislocations, and concussions) was higher in football (13%) than other sports (0%–3%). Furthermore, the frequency of injury per team per season was 5 to 7 times higher in football than in baseball, soccer, or softball. The most common method of injury was contact with another player, although the authors did not report the nature of contact; therefore, the proportion of injuries attributable to tackling as opposed to blocking or incidental person-to-person contact is unknown. As with many other studies,[17,18,67] their results showed a higher rate of injuries during football games (0.43 per 1000 AEs) than practices (0.07 per 1000 AEs).[21]

Head Injuries and Impacts Associated With Tackling

The study by Badgeley et al suggests that during high school football, the majority (64.3%) of concussions occur when an athlete is tackling or being tackled,[17] a finding consistent with previous work performed by some of the same investigators showing that tackling/being tackled accounted for half of all high school football injuries.[18] During football played by younger athletes, Kontos et al showed that head-to-head contact was the most common mechanism of concussion, but whether head-to-head contact occurred during tackling, as opposed to blocking or incidental contact, is not discussed.[23]

In a study of 42 varsity high school football players, Broglio et al used accelerometers to record head impacts resulting >14.4 *g* of linear acceleration and found a mean of 774 impacts per player during a single season. The mean number of impacts varied by player position, with linemen sustaining a higher number of impacts. Games were associated with a higher incidence of impacts than practices. Contact practices were associated with a higher incidence of impacts than noncontact practices.[68]

In a single-season study of 7 football players aged 7 and 8 years, Daniel et al used accelerometers to record the cumulative number of impacts to the head.[69] The authors examined both linear acceleration and rotational acceleration with blows to the front, side, rear, and top of the head. The average number of impacts per player was 107, with more impacts occurring during practices (59% of recorded impacts) than games (41% of recorded impacts). A greater number of high-force impacts (>95th percentile for acceleration) occurred during practices than games. The number of impacts experienced by these youth players was lower than that reported for high school and college players and more heavily weighted toward lower levels of impact. As might be expected, the number of impacts increased with increasing level of play, likely because of the increased size and strength of older players. The authors argued that restructuring practices might lead to a lower number of head impacts.[69] This study was limited by a small sample size.

Neck Injuries Associated With Tackling

Fortunately, most neck injuries that occur during football are strains, sprains, and contusions.[12,15] Cervical spine fractures and spinal cord injuries do occur, however, and some lead to permanent neurologic damage.[15,16]

Catastrophic Head and Neck Injuries Associated With Tackling

Although the rates of catastrophic injury in football are low, most of the cases that occur are sustained during tackling.[29,70–73] Most cases of quadriplegia occur while the injured player is making a tackle.[29] A majority of brain and cervical spine injury–related fatalities result from tackling or being tackled.[67,74,75]

Brain injury–related fatalities account for approximately 69% of all football fatalities.[67] Subdural hemorrhages are the most common injury associated with brain injury–related fatalities; tackling and being tackled[67,74–76] are the most frequent activities when subdural hemorrhages occur.[67] The annual incidence of catastrophic head injuries sustained by football players appears higher for high school athletes than college players (0.67 vs 0.21 per 100 000 participants).[29] The majority are sustained by an athlete who is tackling or being tackled.[29]

Football players are among the team sport athletes at highest risk for catastrophic cervical spine injuries.[71] The annual incidence of catastrophic cervical spine injuries appears higher for collegiate players than for high school players (4.72 vs 1.10 per 100 000 participants).[77] Most catastrophic cervical spine injuries occur during tackling, often when improper technique is used. Specifically, most spinal cord injuries are caused by axial loading of the cervical spine during head-down contact, often as a result of "spear tackling," a method in which the athlete lowers his head, thereby lining up the vertebral bodies, and uses his body as a battering ram to deliver a blow to another player with the crown of his head.[19,70,72,73] Fortunately, the incidence of catastrophic cervical spine injuries decreased after the banning of spear tackling in 1976.[71,72] Catastrophic spine injuries still occur, however, and spear tackling remains a problem despite the ban.[19,29,70,73]

THE EFFECT OF DECREASING CONTACT PRACTICES ON INJURY INCIDENCE

Given the association of player-to-player contact with incidence of injury, decreasing the number of contact practices has been proposed as a method of decreasing injury risk, particularly concussions. Although the incidence of concussion is lower during practice than it is during games, there are far more practices than games. Because most impacts to the head occur during practices, decreasing the number of contact practices has been shown to decrease the overall number of head impacts that occur during the course of a season, thereby reducing the risk of any potential cumulative effects of such exposures.[23,68,69,78] Some argue this may also lead to a decrease in the number of concussions.[79]

Other authors, however, note that the risk of concussion is higher during games than it is during practices and argue that decreasing the number of contact practices is unlikely to reduce the number of concussions. In fact, they propose that the decrease in time spent practicing proper tackling technique may lead to an increase in the magnitude of impacts during games and an increase in the risk of concussion.[23,68] Therefore, some authors have suggested that if contact practices are to be reduced as a means of decreasing overall head impact exposures, then extra emphasis should be placed on teaching appropriate tackling technique to avoid an increased risk during games.[68] Other authors have also cautioned that a lack of proper training may increase risk of injury.[18,24]

In a study of high school varsity football players, Broglio et al reported that limiting the number of contact practices to 1 per week would result in an 18% decrease in the number of impacts, whereas eliminating contact practices entirely would result in a 39% decrease in the number of impacts.[68] That same study showed that games resulted in both a significantly higher number of impacts than practices as well as higher magnitude impacts than practices. The authors cautioned that limiting contact practices may increase the risk of high-magnitude impacts and concussions that occur during game time, especially if additional efforts are not made to teach proper tackling and techniques for safely absorbing tackles.[68]

As opposed to high school and collegiate players,[68] preliminary evidence suggests younger players may sustain higher magnitude impacts during practices as opposed to games.[69] Thus, for younger players, limiting full contact practices while simultaneously teaching fundamental skills required for proper tackling and properly absorbing tackles may reduce the overall exposure to head impacts and high magnitude impacts. If CTE proves to be the result of cumulative impacts to the head, including subconcussive impacts, then limiting contact practices should decrease the risk of CTE.[68,69,80]

A recent report from the Institute of Medicine concluded that although the concept of limiting the number of head impacts is sound, setting a limit on number of impacts or the magnitude of impacts per week or per season is without scientific basis.[81]

The Effect of Delaying Tackling Until a Certain Age

Some physicians have recently argued that because the brain is in a rapid period of development during youth, contact should be eliminated from football until a certain age.[4,6] Others have argued, however, that eliminating contact at a young age would prevent young athletes from learning the skills required to tackle, absorb a tackle, and fall to the ground safely. Then, when contact is later introduced, athletes will be ill prepared and forced to learn these skills at an age where they are bigger, faster, stronger, more coordinated, and capable of delivering more forceful blows. Some have suggested that this might increase the risk of injury[23] and have argued the correct contact techniques should be taught at the earliest organized level.[72,81] A previous study of high school football players in Wisconsin suggested that previous tackling experience is not independently associated with the risk of sustaining a sport-related concussion.[82] Further investigation into the effects of delaying the introduction of tackling until a certain age must be conducted before informed recommendations can be made.

Although there does not appear to be any study to date showing the effect of delaying the age at which tackling is introduced to football on risk of injury, data from other sports suggest that eliminating tackling would decrease the risk of certain injuries for athletes participating at ages for which tackling would be prohibited.[83,84] In a study of Canadian youth ice hockey players, Emery et al showed that the risk of injury, severe injury, concussion, and severe concussion was higher in leagues that allowed body checking than in leagues that did not allow body checking,[83] confirming previous work that had demonstrated an association between body checking and the incidence of concussion.[85] In a follow-up study, however, the same investigators reported that, once exposed to body checking, players who were not introduced to body checking until a later age were at significantly higher risk of severe injuries than those exposed to body checking at an earlier age.[86] The risk of sport-related concussion was also higher in those previously unexposed to body checking, although the findings were not statistically significant.[86] Other studies of youth ice hockey players have shown no significant difference in the incidence of injury between those exposed to body checking at differing ages. However, a previous study by MacPherson et al showed that hockey players exposed to body checking at a younger age had a significantly higher odds of suffering a checking injury than those exposed to checking at a later age.[85]

OTHER STRATEGIES FOR REDUCING INJURIES

Teaching Proper Tackling Technique

Initiating contact with the shoulder while the head is up is believed to be the safest way to tackle in football. Most experts recommend that proper technique be learned and practiced regularly as a means of reducing the risk of injury.[17,18,71,72,79] A recent initiative by USA Football emphasizes keeping the head up during tackling to prevent catastrophic injuries as well as concussions, although this new coaching method needs further study.

Rule Changes

In addition to changing practice regimens and teaching proper tackling techniques, some have proposed changes to the rules of football as a means of reducing head and neck injuries. Indeed, the 1976 banning of spear tackling has been widely credited with reducing the numbers of cervical spinal injuries resulting in quadriplegia.[70–73,77,87,88] Unfortunately, spear tackling has persisted even since the 1976 rule change, and cervical spine injuries continue to occur.[73,88,89] Modification and consistent enforcement of the rules may lead to a further decrease in the risk of injury, including catastrophic injuries.[73,79,89]

Protective Equipment

The introduction of helmets to football and the updating of helmet design is widely credited for playing a role in the reduction of head injuries, particularly catastrophic head injuries and brain injury–related fatalities.[67,90,91] Therefore, athletes participating in football should wear undamaged, properly fitted helmets with secured chin straps. By protecting the scalp from the discomfort of blows to the vertex of the head, however, helmets are considered, in part, to have led to an increase in the number of cases of quadriplegia by encouraging the use of the head as the point of impact.[92] This trend was fortunately reduced by the banning of spear tackling, as noted previously. The role of helmets in preventing concussions is less clear. Although some studies suggest that helmet design might play a role in reducing the incidence of concussion,[93,94] many experts refute such a claim.[82,95,96] In a recent study of more than 2000 high school football players, McGuine et al reported that helmet model had no significant effect on the incidence of sport-related concussion.[82] As of now, there is little reliable evidence that concussions can be prevented or mitigated by any of the currently available helmet designs.[95–97]

Mouth guards are effective at reducing the incidence of dental injuries.[97,98] Although some studies have suggested an effect of mouthguard type on the incidence of concussion,[82,99,100] there are few reliable data suggesting that any currently available mouth guards are effective at preventing or reducing the incidence of concussion.[95,96,101–103]

Although there is some evidence that neck rolls and cowboy collars can reduce movement of the head and neck, there is limited evidence regarding their effect on the incidence of burners or stingers, injuries to the nerve of the upper arm that result in a burning or stinging sensation.[104–106] Because neck rolls limit extension of the neck, they may, theoretically, interfere with the ability of the proper head-up tackling technique.

Neck Muscle Strengthening

Neck muscle strengthening has been recommended by the National Athletic Trainers' Association as a means of decreasing neck fatigue, thereby allowing for maintenance of the head-up position associated with proper tackling technique and decreasing the risk of burners and stingers.[72] Furthermore, weak neck musculature has been proposed as a risk factor for concussion.[107–109] Acceleration of a struck object is inversely proportional to its mass. Because concussion results from a rotational acceleration of the brain, it has been suggested that increasing the effective mass of the head might result in a decreased acceleration of the brain after impact. The head becomes more firmly bonded to the rest of the body when the neck muscles are contracted, thereby increasing the effective mass of the head and decreasing the resultant acceleration after impact.[109] This increase in effective mass is thought to explain the decreased risk of concussion when collisions are anticipated.[108,109] Thus, by increasing cervical muscle strength, athletes might decrease their risk of concussion.[108,110] Preliminary evidence supports this hypothesis.[111] Other preliminary studies suggest that it may be cervical stiffness, as opposed to strength alone, that is associated with risk of injury.[112]

CONCLUSIONS AND RECOMMENDATIONS

Most injuries sustained during participation in youth football are minor, including injuries to the head and neck. The incidences of severe injuries, catastrophic injuries, and concussion, however, are higher in football than most other team sports and appear to increase with age. Player-to-player contact results in an increase in the number of subconcussive impacts that occur during football. Concussion is associated with player-to-player contact and tackling, in particular. Severe and catastrophic injuries, particularly those of the head and neck, are associated with tackling, often when improper and illegal technique, such as spear tackling, is used. Efforts should be made to improve the teaching of proper tackling technique and enforce existing rules prohibiting the use of improper technique.

1. Officials and coaches must ensure proper enforcement of the rules of the game. A significant number of concussions and catastrophic injuries occur because of improper and illegal contact, such as spear tackling. There is a culture of tolerance of head first, illegal hits. This culture has to change to one that protects the head for both the tackler and those players being tackled. Stronger sanctions for

contact to the head, especially of a defenseless player, should be considered, up to and including expulsion from the game. The culture should change to one of zero tolerance of illegal, head-first hits.

2. Removing tackling from football altogether would likely lead to a decrease in the incidence of overall injuries, severe injuries, catastrophic injuries, and concussions. The American Academy of Pediatrics recognizes, however, that the removal of tackling from football would lead to a fundamental change in the way the game is played. Participants in football must decide whether the potential health risks of sustaining these injuries are outweighed by the recreational benefits associated with proper tackling.
3. The expansion of nontackling leagues for young athletes who enjoy the game of football and want to be physically active but do not want to be exposed to the collisions currently associated with the game should be considered by football leagues and organizations. This would allow athletes to choose to participate in football without tackling and its associated risks, even after the age at which tackling is introduced.
4. Although the effect of subconcussive blows on long-term cognitive function, incidence of CTE, and other health outcomes remains unclear, repetitive trauma to the head is of no clear benefit to the game of football or the health of football players. If subconcussive blows to the head result in negative long-term effects on health, then limiting impacts to the head should reduce the risk of these long-term health problems. Thus, efforts should be made by coaches and officials to reduce the number of impacts to the head that occur during participation in football. Further research is needed in this area.
5. Delaying the age at which tackling is introduced to the game would likely decrease the risk of these injuries for the age levels at which tackling would be prohibited. Once tackling is introduced, however, athletes who have no previous experience with tackling would be exposed to collisions for the first time at an age at which speeds are faster, collision forces are greater, and injury risk is higher. Lack of experience with tackling and being tackled may lead to an increase in the number and severity of injuries once tackling is introduced. Therefore, if regulations that call for the delaying of tackling until a certain age are to be made, they must be accompanied by coaches offering instruction in proper tackling technique as well as the teaching of the skills necessary to evade tackles and absorb being tackled. It is unclear whether such techniques and the neuromuscular control necessary for performing them can be adequately learned in the absence of contact.
6. Although definitive scientific evidence is lacking, strengthening of the cervical musculature will likely reduce the risk of concussions in football by limiting the acceleration of the head after impact. Physical therapists, athletic trainers, or strength and conditioning specialists, with expertise in the strengthening and conditioning of pediatric athletes, are best qualified to help young football players achieve the neck strength that will help prevent injuries.
7. Given their importance in the medical management of sport-related injuries and preliminary evidence suggesting an association between athletic trainers presence and a decreased incidence of sport-related injuries,[113] efforts should be made by football teams to have athletic trainers at the sidelines during organized football games and practices.

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ABBREVIATIONS

AE: athletic exposure
CTE: chronic traumatic encephalopathy

REFERENCES

1. Frollo J. Football remains number 1 among high school participation. 2011. Available at: http://usafootball.com/news/coaches/football-remains-no-1-among-high-school-participation. Accessed March 14, 2014
2. Alves WM, Rimel RW, Nelson WE. University of Virginia prospective study of football-induced minor head injury: status report. *Clin Sports Med*. 1987;6(1):211–218

3. Fainaru S, Fainaru-Wada M. Youth football participation drops. November 14, 2013. Available at: http://espn.go.com/espn/otl/story/_/page/popwarner/pop-warner-youth-football-participation-drops-nfl-concussion-crisis-seen-causal-factor
4. Cantu RC. *Concussions and Our Kids: America's Leading Expert on How to Protect Young Athletes and Keep Sports Safe*. Boston, MA: Houghton Mifflin; 2012
5. Harris D. High school football ban proposal under attack in New Hampshire. 2012. Available at: http://abcnews.go.com/US/high-school-football-ban-proposal-attack-hampshire/story?id=17559475. Accessed March 14, 2014
6. Robbins L. Let's ban tackle football under age 18. *Real Clear Sports*. December 6, 2012. Available at: http://www.realclearsports.com/articles/2012/12/06/lets_ban_tackle_football_until_age_18_97818.html. Accessed September 4, 2015
7. Goldstein LB, Whitsel LP, Meltzer N, et al; American Heart Association (AHA) Advocacy Coordinating Committee; Council on Cardiovascular Nursing, AHA; Council on the Kidney in Cardiovascular Disease, AHA; Council on Cardiovascular Radiology and Intervention, AHA; Council on Cardiovascular Surgery and Anesthesia, AHA; Council on Clinical Cardiology, AHA; Council on Cardiovascular Disease in the Young, AHA; Council on Cardiopulmonary, Critical Care, Perioperative, and Resuscitation, AHA; Council on Peripheral Vascular Disease, AHA; Council on Arteriosclerosis, Thrombosis and Vascular Biology, AHA; Council on Epidemiology and Prevention, AHA; Council on Nutrition, Physical Activity and Metabolism, AHA; Interdisciplinary Council on Functional Genomics and Translational Biology, AHA. American Heart Association and nonprofit advocacy: past, present, and future. A policy recommendation from the American Heart Association. *Circulation*. 2011;123(7):816–832
8. Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc*. 2007;39(8):1423–1434
9. Bjorklund DF, Brown RD. Physical play and cognitive development: integrating activity, cognition, and education. *Child Dev*. 1998;69(3):604–606
10. Chomitz VR, Slining MM, McGowan RJ, Mitchell SE, Dawson GF, Hacker KA. Is there a relationship between physical fitness and academic achievement? Positive results from public school children in the northeastern United States. *J Sch Health*. 2009;79(1):30–37
11. Donnelly JE, Lambourne K. Classroom-based physical activity, cognition, and academic achievement. *Prev Med*. 2011;52(suppl 1):S36–S42
12. Adickes MS, Stuart MJ. Youth football injuries. *Sports Med*. 2004;34(3):201–207
13. Stuart MJ, Morrey MA, Smith AM, Meis JK, Ortiguera CJ. Injuries in youth football: a prospective observational cohort analysis among players aged 9 to 13 years. *Mayo Clin Proc*. 2002;77(4):317–322
14. Turbeville SD, Cowan LD, Asal NR, Owen WL, Anderson MA. Risk factors for injury in middle school football players. *Am J Sports Med*. 2003;31(2):276–281
15. Dompier TP, Powell JW, Barron MJ, Moore MT. Time-loss and non-time-loss injuries in youth football players. *J Athl Train*. 2007;42(3):395–402
16. Goldberg B, Rosenthal PP, Robertson LS, Nicholas JA. Injuries in youth football. *Pediatrics*. 1988;81(2):255–261
17. Badgeley MA, McIlvain NM, Yard EE, Fields SK, Comstock RD. Epidemiology of 10,000 high school football injuries: patterns of injury by position played. *J Phys Act Health*. 2013;10(2):160–169
18. Shankar PR, Fields SK, Collins CL, Dick RW, Comstock RD. Epidemiology of high school and collegiate football injuries in the United States, 2005–2006. *Am J Sports Med*. 2007;35(8):1295–1303
19. Demorest RA, Landry GL. Prevention of pediatric sports injuries. *Curr Sports Med Rep*. 2003;2(6):337–343
20. Knowles SB, Marshall SW, Bowling MJ, et al. Risk factors for injury among high school football players. *Epidemiology*. 2009;20(2):302–310
21. Radelet MA, Lephart SM, Rubinstein EN, Myers JB. Survey of the injury rate for children in community sports. *Pediatrics*. 2002;110(3). Available at: www.pediatrics.org/cgi/content/full/110/3/e28
22. Malina RM, Morano PJ, Barron M, Miller SJ, Cumming SP, Kontos AP. Incidence and player risk factors for injury in youth football. *Clin J Sport Med*. 2006;16:214–222
23. Kontos AP, Elbin RJ, Fazio-Sumrock VC, et al. Incidence of sports-related concussion among youth football players aged 8–12 years. *J Pediatr*. 2013;163(3):717–720
24. Linder MM, Townsend DJ, Jones JC, Balkcom IL, Anthony CR. Incidence of adolescent injuries in junior high school football and its relationship to sexual maturity. *Clin J Sport Med*. 1995;5(3):167–170
25. Damore DT, Metzl JD, Ramundo M, Pan S, Van Amerongen R. Patterns in childhood sports injury. *Pediatr Emerg Care*. 2003;19(2):65–67
26. Darrow CJ, Collins CL, Yard EE, Comstock RD. Epidemiology of severe injuries among United States high school athletes: 2005–2007. *Am J Sports Med*. 2009;37(9):1798–1805
27. Mueller FO, Cantu RC. Annual survey of catastrophic football injuries 1977–2011. Available at: http://www.unc.edu/depts/nccsi/FBCATReport2011.pdf. Accessed March 7, 2014
28. Zemper ED. Catastrophic injuries among young athletes. *Br J Sports Med*. 2010;44(1):13–20
29. Boden BP, Tacchetti RL, Cantu RC, Knowles SB, Mueller FO. Catastrophic head injuries in high school and college football players. *Am J Sports Med*. 2007;35(7):1075–1081
30. Collins MW, Lovell MR, Iverson GL, Cantu RC, Maroon JC, Field M. Cumulative effects of concussion in high school athletes. *Neurosurgery*. 2002;51(5):1175–1179; discussion 1180–1171
31. Gronwall D, Wrightson P. Cumulative effect of concussion. *Lancet*. 1975;2(7943):995–997
32. Guskiewicz KM, McCrea M, Marshall SW, et al. Cumulative effects associated with recurrent concussion in collegiate

football players: the NCAA Concussion Study. *JAMA*. 2003;290(19):2549–2555

33. Iverson GL, Gaetz M, Lovell MR, Collins MW. Cumulative effects of concussion in amateur athletes. *Brain Inj*. 2004;18(5):433–443

34. Eisenberg MA, Andrea J, Meehan W, Mannix R. Time interval between concussions and symptom duration. *Pediatrics*. 2013;132(1):8–17

35. Corsellis JA, Bruton CJ, Freeman-Browne D. The aftermath of boxing. *Psychol Med*. 1973;3(3):270–303

36. Critchley M. Medical aspects of boxing, particularly from a neurological standpoint. *BMJ*. 1957;1(5015):357–362

37. Jordan BD. Chronic traumatic brain injury associated with boxing. *Semin Neurol*. 2000;20(2):179–185

38. Jordan BD, Matser EJ, Zimmerman RD, Zazula T. Sparring and cognitive function in professional boxers. *Phys Sportsmed*. 1996;24(5):87–98

39. Jordan BD, Relkin NR, Ravdin LD, Jacobs AR, Bennett A, Gandy S. Apolipoprotein E epsilon4 associated with chronic traumatic brain injury in boxing. *JAMA*. 1997;278(2):136–140

40. McKee AC, Cantu RC, Nowinski CJ, et al. Chronic traumatic encephalopathy in athletes: progressive tauopathy after repetitive head injury. *J Neuropathol Exp Neurol*. 2009;68(7):709–735

41. McKee AC, Gavett BE, Stern RA, et al. TDP-43 proteinopathy and motor neuron disease in chronic traumatic encephalopathy. *J Neuropathol Exp Neurol*. 2010;69(9):918–929

42. McKee AC, Stein TD, Nowinski CJ, et al. The spectrum of disease in chronic traumatic encephalopathy. *Brain*. 2013;136(pt 1):43–64

43. Omalu B, Bailes J, Hamilton RL, et al. Emerging histomorphologic phenotypes of chronic traumatic encephalopathy in American athletes. *Neurosurgery*. 2011;69(1):173–183, discussion 183

44. Omalu B, Hammers JL, Bailes J, et al. Chronic traumatic encephalopathy in an Iraqi war veteran with posttraumatic stress disorder who committed suicide. *Neurosurg Focus*. 2011;31(5):E3

45. Omalu BI, Bailes J, Hammers JL, Fitzsimmons RP. Chronic traumatic encephalopathy, suicides and parasuicides in professional American athletes: the role of the forensic pathologist. *Am J Forensic Med Pathol*. 2010;31(2):130–132

46. Omalu BI, DeKosky ST, Hamilton RL, et al. Chronic traumatic encephalopathy in a national football league player: part II. *Neurosurgery*. 2006;59(5):1086–1092; discussion 1092–1083

47. Omalu BI, DeKosky ST, Minster RL, Kamboh MI, Hamilton RL, Wecht CH. Chronic traumatic encephalopathy in a National Football League player. *Neurosurgery*. 2005;57(1):128–134, discussion 128–134

48. Roberts GW, Allsop D, Bruton C. The occult aftermath of boxing. *J Neurol Neurosurg Psychiatry*. 1990;53(5):373–378

49. Tokuda T, Ikeda S, Yanagisawa N, Ihara Y, Glenner GG. Re-examination of ex-boxers' brains using immunohistochemistry with antibodies to amyloid beta-protein and tau protein. *Acta Neuropathol*. 1991;82(4):280–285

50. Randolph C. Is chronic traumatic encephalopathy a real disease? *Curr Sports Med Rep*. 2014;13(1):33–37

51. Wortzel HS, Shura RD, Brenner LA. Chronic traumatic encephalopathy and suicide: a systematic review. *BioMed Res Int*. 2013;2013:424280

52. Tator CH. Chronic traumatic encephalopathy: how serious a sports problem is it? *Br J Sports Med*. 2014;48(2):81–83

53. Iverson GL. Chronic traumatic encephalopathy and risk of suicide in former athletes. *Br J Sports Med*. 2014;48(2):162–165

54. Gardner A, Iverson GL, McCrory P. Chronic traumatic encephalopathy in sport: a systematic review. *Br J Sports Med*. 2014;48(2):84–90

55. Mannix RM, Meehan WP III, Mandeville J, et al. Clinical correlates in an experimental model of repetitive mild brain injury. *Ann Neurol*. 2013;74(1):65–75

56. DeFord SM, Wilson MS, Rice AC, et al. Repeated mild brain injuries result in cognitive impairment in B6C3F1 mice. *J Neurotrauma*. 2002;19(4):427–438

57. Meehan WP III, Zhang J, Mannix R, Whalen MJ. Increasing recovery time between injuries improves cognitive outcome after repetitive mild concussive brain injuries in mice. *Neurosurgery*. 2012;71(4):885–891

58. Cantu RC. Second impact syndrome: a risk in any contact sport. *Phys Sportsmed*. 1995;23(6):27–34

59. Cantu RC. Second-impact syndrome. *Clin Sports Med*. 1998;17(1):37–44

60. Cantu RC, Gean AD. Second-impact syndrome and a small subdural hematoma: an uncommon catastrophic result of repetitive head injury with a characteristic imaging appearance. *J Neurotrauma*. 2010;27(9):1557–1564

61. Saunders RL, Harbaugh RE. The second impact in catastrophic contact-sports head trauma. *JAMA*. 1984;252(4):538–539

62. McCrory P. Does second impact syndrome exist? *Clin J Sport Med*. 2001;11(3):144–149

63. McCrory P, Davis G, Makdissi M. Second impact syndrome or cerebral swelling after sporting head injury. *Curr Sports Med Rep*. 2012;11(1):21–23

64. McCrory PR, Berkovic SF. Second impact syndrome. *Neurology*. 1998;50(3):677–683

65. Wetjen NM, Pichelmann MA, Atkinson JL. Second impact syndrome: concussion and second injury brain complications. *J Am Coll Surg*. 2010;211(4):553–557

66. Zoch TW, Cleveland DA, McCormick J, Toyama K, Nordstrom DL. Football injuries in a rural area. *Wis Med J*. 1996;95(8):570–573

67. Cantu RC, Mueller FO. Brain injury-related fatalities in American football, 1945-1999. *Neurosurgery*. 2003;52(4):846–852; discussion 852–843

68. 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

69. Daniel RW, Rowson S, Duma SM. Head impact exposure in youth football. *Ann Biomed Eng*. 2012;40(4):976–981

70. Banerjee R, Palumbo MA, Fadale PD. Catastrophic cervical spine injuries in the collision sport athlete, part 1:

epidemiology, functional anatomy, and diagnosis. *Am J Sports Med*. 2004;32(4): 1077–1087

71. Erlanger D, Kaushik T, Cantu R, et al. Symptom-based assessment of the severity of a concussion. *J Neurosurg*. 2003;98(3):477–484

72. 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

73. Rihn JA, Anderson DT, Lamb K, et al. Cervical spine injuries in American football. *Sports Med*. 2009;39(9): 697–708

74. Mueller FO. Fatalities from head and cervical spine injuries occurring in tackle football: 50 years' experience. *Clin Sports Med*. 1998;17(1):169–182

75. Mueller FO, Blyth CS. Fatalities from head and cervical spine injuries occurring in tackle football: 40 years' experience. *Clin Sports Med*. 1987;6(1): 185–196

76. Forbes JA, Zuckerman S, Abla AA, Mocco J, Bode K, Eads T. Biomechanics of subdural hemorrhage in American football: review of the literature in response to rise in incidence. *Childs Nerv Syst*. 2014;30(2):197–203

77. Boden BP, Tacchetti RL, Cantu RC, Knowles SB, Mueller FO. Catastrophic cervical spine injuries in high school and college football players. *Am J Sports Med*. 2006;34(8):1223–1232

78. 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

79. Harmon KG, Drezner JA, Gammons M, et al. American Medical Society for Sports Medicine position statement: concussion in sport. *Br J Sports Med*. 2013;47(1):15–26

80. Wong RH, Wong AK, Bailes JE. Frequency, magnitude, and distribution of head impacts in Pop Warner football: the cumulative burden. *Clin Neurol Neurosurg*. 2014;118:1–4

81. Graham RRF, Ford MA, Spicer CM. Sports-Related Concussions in Youth: Improving the Science, Changing the Culture. Washington, DC: Institute of Medicine and National Research Council of the National Academies; 2014

82. McGuine TA, Hetzel S, McCrea M, Brooks MA. Protective equipment and player characteristics associated with the incidence of sport-related concussion in high school football players: a multifactorial prospective study. *Am J Sports Med*. 2014;42(10):2470–2478

83. Emery CA, Kang J, Shrier I, et al. Risk of injury associated with body checking among youth ice hockey players. *JAMA*. 2010;303(22):2265–2272

84. Brooks A, Loud KJ, Brenner JS, et al; Council on Sports Medicine and Fitness. Reducing injury risk from body checking in boys' youth ice hockey. *Pediatrics*. 2014;133(6):1151–1157

85. Macpherson A, Rothman L, Howard A. Body-checking rules and childhood injuries in ice hockey. *Pediatrics*. 2006; 117(2). Available at: www.pediatrics.org/cgi/content/full/117/2/e143

86. Emery CA, Kang J, Schneider KJ, Meeuwisse WH. Risk of injury and concussion associated with team performance and penalty minutes in competitive youth ice hockey. *Br J Sports Med*. 2011;45(16):1289–1293

87. Boden BP. Direct catastrophic injury in sports. *J Am Acad Orthop Surg*. 2005; 13(7):445–454

88. Chao S, Pacella MJ, Torg JS. The pathomechanics, pathophysiology and prevention of cervical spinal cord and brachial plexus injuries in athletics. *Sports Med*. 2010;40(1):59–75

89. Heck JF. The incidence of spearing during a high school's 1975 and 1990 football seasons. *J Athl Train*. 1996; 31(1):31–37

90. Levy ML, Ozgur BM, Berry C, Aryan HE, Apuzzo ML. Birth and evolution of the football helmet. *Neurosurgery*. 2004;55 (3):656–661; discussion 661–652

91. Levy ML, Ozgur BM, Berry C, Aryan HE, Apuzzo ML. Analysis and evolution of head injury in football. *Neurosurgery*. 2004;55(3):649–655

92. Torg JS, Truex R Jr, Quedenfeld TC, Burstein A, Spealman A, Nichols C III. The National Football Head and Neck Injury Registry. Report and conclusions 1978. *JAMA*. 1979;241(14): 1477–1479

93. Collins M, Lovell MR, Iverson GL, Ide T, Maroon J. Examining concussion rates and return to play in high school football players wearing newer helmet technology: a three-year prospective cohort study. *Neurosurgery*. 2006;58(2): 275–286, discussion 275–286

94. Zemper ED. Analysis of cerebral concussion frequency with the most commonly used models of football helmets. *J Athl Train*. 1994;29(1):44–50

95. Benson BW, Hamilton GM, Meeuwisse WH, McCrory P, Dvorak J. Is protective equipment useful in preventing concussion? A systematic review of the literature. *Br J Sports Med*. 2009;43 (suppl 1):i56–i67

96. McCrory P, Meeuwisse WH, Aubry M, et al. Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. *Br J Sports Med*. 2013;47(5):250–258

97. Trojian TH, Mohamed N. Demystifying preventive equipment in the competitive athlete. *Curr Sports Med Rep*. 2012;11(6):304–308

98. Newsome PR, Tran DC, Cooke MS. The role of the mouthguard in the prevention of sports-related dental injuries: a review. Int J Paediatr Dentistry. 2001;11(6):396–404

99. Winters J, DeMont R. Role of mouthguards in reducing mild traumatic brain injury/concussion incidence in high school football athletes. *Gen Dent*. 2014;62(3):34–38

100. Singh GD, Maher GJ, Padilla RR. Customized mandibular orthotics in the prevention of concussion/mild traumatic brain injury in football players: a preliminary study. *Dent Traumatol*. 2009;25(5):515–521

101. Barbic D, Pater J, Brison RJ. Comparison of mouth guard designs and concussion prevention in contact sports: a multicenter randomized controlled trial. *Clin J Sport Med*. 2005; 15(5):294–298

102. Wisniewski JF, Guskiewicz K, Trope M, Sigurdsson A. Incidence of cerebral concussions associated with type of mouthguard used in college football. *Dent Traumatol*. 2004;20(3):143–149

103. Mihalik JP, McCaffrey MA, Rivera EM, et al. Effectiveness of mouthguards in

reducing neurocognitive deficits following sports-related cerebral concussion. *Dent Traumatol*. 2007;23(1): 14–20

104. Gorden JA, Straub SJ, Swanik CB, Swanik KA. Effects of football collars on cervical hyperextension and lateral flexion. *J Athl Train*. 2003;38(3):209–215
105. Rowson S, McNeely D, Duma S. Lateral bending biomechanical analysis of neck protection devices used in football. *Biomed Sci Instrum*. 2007;43:200–205
106. Rowson S, McNeely DE, Brolinson PG, Duma SM. Biomechanical analysis of football neck collars. *Clin J Sport Med*. 2008;18(4):316–321
107. Benson BW, McIntosh AS, Maddocks D, Herring SA, Raftery M, Dvorák J. What are the most effective risk-reduction strategies in sport concussion? *Br J Sports Med*. 2013;47(5):321–326
108. Viano DC, Casson IR, Pellman EJ. Concussion in professional football: biomechanics of the struck player—part 14. *Neurosurgery*. 2007;61(2): 313–327; discussion 327–318
109. Mihalik JP, Blackburn JT, Greenwald RM, Cantu RC, Marshall SW, Guskiewicz KM. Collision type and player anticipation affect head impact severity among youth ice hockey players. *Pediatrics*. 2010;125(6). Available at: www.pediatrics.org/cgi/content/full/125/6/e1394
110. Tierney RT, Sitler MR, Swanik CB, Swanik KA, Higgins M, Torg J. Gender differences in head-neck segment dynamic stabilization during head acceleration. *Med Sci Sports Exerc*. 2005;37(2):272–279
111. Collins CL, Fletcher EN, Fields SK, et al. Neck strength: a protective factor reducing risk for concussion in high school sports. *J Prim Prev*. 2014;35(5): 309–319
112. Schmidt JD, Guskiewicz KM, Blackburn JT, Mihalik JP, Siegmund GP, Marshall SW. The influence of cervical muscle characteristics on head impact biomechanics in football. *Am J Sports Med*. 2014;42(9):2056–2066
113. LaBella C, Henke N, Collins C, Comstock RD. A comparative analysis of injury rates and patterns among girls' soccer and basketball players at schools with and without athletic trainers from 2006/07–2008/09. American Academy of Pediatrics National Conference and Exhibition; October 20–23, 2012; New Orleans, LA
114. Knowles SB, Marshall SW, Bowling JM, et al. A prospective study of injury incidence among North Carolina high school athletes. *Am J Epidemiol*. 2006; 164(12):1209–1221

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