Increasing Lower Extremity Injury Rates Across the 2009-2010 to 2014-2015 Seasons of National Collegiate Athletic Association Football: An Unintended Consequence of the "Targeting" Rule Used to Prevent Concussions?

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Am J Sports Med 2016 44: 3230 originally published online August 10, 2016
DOI: 10.1177/0363546516659290

Increasing Lower Extremity Injury Rates Across the 2009-2010 to 2014-2015 Seasons of National Collegiate Athletic Association Football

An Unintended Consequence of the ''Targeting'' Rule Used to Prevent Concussions?

Robert W. Westermann,*† MD, Zachary Y. Kerr,‡ PhD, MPH,
Peter Wehr,† MD, and Annuziato Amendola,§ MD
Investigation performed at the University of Iowa Hospitals and Clinics, Iowa City, Iowa, USA

Background: Sports-related concussions (SRCs) have gained increased societal interest in the past decade. The National Collegiate Athletic Association (NCAA) has implemented legislation and rule changes to decrease the incidence and risk of head injury impacts. The ''targeting'' rule forbids initiating contact with the crown of a helmet and targeting defenseless players in the head and neck area; however, there are concerns that this rule change has unintentionally led to an increased incidence of lower extremity injuries.

Purpose/Hypothesis: The purpose of this study was to evaluate the change in lower extremity injury rates in NCAA football during the 2009-2010 to 2014-2015 seasons. We hypothesized that the lower extremity injury rate has increased across the time period.

Study Design: Descriptive epidemiology study.

Methods: Sixty-eight NCAA football programs provided 153 team-seasons of data to the NCAA Injury Surveillance Program. Lower extremity injuries (ie, hip/groin, upper leg/thigh, knee, lower leg/Achilles, foot/toes) and SRCs sustained during NCAA football games were examined. We calculated injury rates per 1000 athlete-exposures (AEs) for lower extremity injuries and SRCs. Rate ratios (RRs) compared injury rates between the 2009-2010 to 2011-2012 and 2012-2013 to 2014-2015 seasons.

Results: Overall, 2400 lower extremity injuries were reported during the 2009-2010 to 2014-2015 seasons; most were to the knee (33.6%) and ankle (28.5%) and caused by player contact (59.2%). The lower extremity injury rate increased in 2012-2013 to 2014-2015 compared with 2009-2010 to 2011-2012 (23.55 vs 20.45/1000 AEs, respectively; RR, 1.15; 95% CI, 1.06-1.25). This finding was retained when restricted to injuries due to player contact (RR, 1.19; 95% CI, 1.07-1.32) but not for injuries due to noncontact/overuse (RR, 0.96; 95% CI, 0.80-1.14). When examining player contact injury rates by anatomic site, only ankle injuries had an increase (RR, 1.36; 95% CI, 1.13-1.64). The SRC rate also increased in 2012-2013 to 2014-2015 compared with 2009-2010 to 2011-2012 (3.52 vs 2.63/1000 AEs, respectively; RR, 1.34; 95% CI, 1.08-1.66).

Conclusion: The lower extremity injury rate has increased in NCAA football athletes. Similarly, SRC rates have increased, although this may be caused by concurrent policies related to better education, identification, and management. Targeting rule changes may be contributing to increased rates of player contact–related ankle injuries. Alongside continued surveillance research to examine longitudinal time trends, more in-depth individual-level examinations of how targeting rule changes influence coaching and player behaviors are warranted.

Keywords: concussion; knee; ankle injury; football; rule change

Recent data estimate that over 10,000 sports-related concussions (SRCs) are sustained annually in National Collegiate Athletic Association (NCAA) athletes.[30] Of these, one-third are sustained during participation in football.[16,30] Because of growing societal concerns,[10,11] in 2014, the Institute of Medicine (IOM) recommended the scientific study of SRC incidence among youth, adolescents, and young adults aged 5 to 21 years as well as the effectiveness of rule changes in reducing head injuries and sequelae.[10]

Rule changes to keep football players safe have been implemented over the past century. The forward pass

The American Journal of Sports Medicine, Vol. 44, No. 12
DOI: 10.1177/0363546516659290

was introduced after the 1905 season in which an estimated 20 deaths occurred during competition.[3,18] The NCAA made helmets mandatory in 1939.[2] Tackling rules that forbid "spearing" to improve the head position of defensive players led to dramatic decreases in the incidence of spinal cord injuries in the late 1970s.[26]

Given concerns about the potential risk of SRCs due to player contact, the NCAA instituted a "targeting" rule to reduce the rate of head injuries in NCAA football.[22] Initiating contact with the crown of a helmet (Rule 9-1-3) and targeting defenseless players in the head and neck area (Rule 9-1-4) became punishable actions by personal foul penalty in 2008. Consequences for the latter penalty were increased in 2013, with targeting resulting in automatic ejection from the game.[23]

When injury prevention interventions such as rule changes are made, follow-up efficacy studies are prudent and recommended.[10] In addition, it is important to consider the unintentional consequences of such interventions. When players act to avoid head and neck contact, lower extremities may be left as open targets for injury. Football players have reported that lower extremity injuries are of more concern to them than SRCs[1] and are worried that targeting rule changes may encourage dangerous low hits.[25] The need to examine this potentially unintended consequence of the targeting rule is important as lower extremity injuries in football populations have been associated with posttraumatic osteoarthritis disability among retired National Football League (NFL) players.[8] To our knowledge, no study has assessed the change in the incidence of head or lower extremity injury rates since the targeting rule change was implemented. Therefore, this study evaluates the change in lower extremity injury rates in NCAA football during the 2009-2010 to 2014-2015 seasons. We hypothesized that the lower extremity injury rate would have increased during the study period.

METHODS

The study was approved by the University of Iowa's Institutional Review Board and the NCAA. The NCAA Injury Surveillance Program (NCAA-ISP) database was queried for injuries reported during the 2009-2010 to 2014-2015 seasons in games. The NCAA-ISP is a prospective injury surveillance program managed by the Datalys Center for Sports Injury Research and Prevention. The methodology of the NCAA-ISP has been previously described in depth.[15,30] Data collected before the 2009-2010 season are available but were not utilized as methodological differences that could potentially bias time trend analyses.

Data Collection

The NCAA-ISP utilized a sample of NCAA varsity football programs. During the 2009-2010 to 2014-2015 seasons, 68 NCAA football programs provided data on 153 team-seasons. Football programs originated from all 3 divisions, with 30 Division I Football Bowl Subdivision programs providing 58 team-seasons, 10 Division I Football Championship Subdivision programs providing 18 team-seasons, 9 Division II programs providing 28 team-seasons, and 19 Division III programs providing 49 team-seasons. Certified athletic trainers (ATs) who worked with participating programs were present at each school-sanctioned game or practice and were responsible for reporting injury and exposure data. As part of ATs' day-to-day clinical practice, when injuries occurred, they were recorded electronically through each institution's electronic health record (EHR) application in real time. Injury data collected by the ATs included anatomic site, diagnosis, circumstances of the injury including the mechanism (ie, player contact, surface contact, noncontact, etc), and event type (ie, practice or competition). ATs could also return to injury records and update them as needed, such as for entering the return to full participation date. Further, ATs reported the total numbers of athletes participating in each event. For this study, we included only injury and exposure data collected from games.

De-identified common data elements (CDEs) from the injury and exposure data were extracted from the EHRs of each participating program. All certified EHRs had to successfully undergo a data validation process to be certified. The CDEs were stripped of any identifiers and encrypted before export to the central aggregate research database. Exported data passed through an automated verification process that conducted a series of range and consistency checks. Data were reviewed and flagged for invalid values. The AT and data quality assurance staff were notified and worked together to resolve the issue. Data that passed the verification process were then placed into the aggregate research dataset.

Definitions

An injury was defined as any injury that required attention from the team physician or AT and occurred during participation in a school-sanctioned game. A time loss injury was defined as an injury that resulted in participation restriction time of at least 24 hours. A severe injury was defined as an injury that resulted in participation restriction time of over 21 days.[4] An athlete-exposure

*Address correspondence to Robert W. Westermann, MD, Department of Orthopaedic Surgery, University of Iowa Hospitals and Clinics, 200 Hawkins Drive, 01008 JPP, Iowa City, IA 52242, USA (email: robert-westermann@uiowa.edu).
†University of Iowa Hospitals and Clinics, Iowa City, Iowa, USA.
‡Datalys Center for Sports Injury Research and Prevention, Indianapolis, Indiana, USA.
§Duke University, Durham, North Carolina, USA.
Presented at the interim meeting of the AOSSM, Orlando, Florida, March 2016.
One or more of the authors has declared the following potential conflict of interest or source of funding: The National Collegiate Athletic Association (NCAA) Injury Surveillance Program data were provided by the Datalys Center for Sports Injury Research and Prevention. The Injury Surveillance Program was funded by the NCAA. The content of this report is solely the responsibility of the authors and does not necessarily reflect the views of the NCAA. Dr Amendola receives intellectual property royalties from Arthrex Inc, Arthrosurface, and Smith & Nephew; has stock or stock options in First Ray Inc; and is a paid consultant for Arthrex Inc.

TABLE 1
Lower Extremity Injuries in NCAA Football Games by Season and Severity: 2009-2010 to 2014-2015 Seasons[a]

Season and Severity	No. of Injuries	Injuries per 1000 AEs (95% CI)
2009-2010 to 2011-2012		
All injuries	1175	20.45 (19.28-21.62)
Time loss injuries only	587	10.22 (9.39-11.04)
Severe injuries only	185	3.22 (2.76-3.68)
2012-2013 to 2014-2015		
All injuries	1225	23.55 (22.23-24.87)[b]
Time loss injuries only	644	12.38 (11.42-13.34)[b]
Severe injuries only	178	3.42 (2.92-3.92)
Overall		
All injuries	2400	21.92 (21.05-22.80)
Time loss injuries only	1231	11.25 (10.62-11.87)
Severe injuries only	363	3.32 (2.97-3.66)

[a]AE, athlete-exposure; NCAA, National Collegiate Athlete Association.
[b]Injury rate higher during the 2012-2013 to 2014-2015 seasons versus 2009-2010 to 2011-2012.

(AE) was defined as 1 student-athlete's participation in 1 game in which he was exposed to a potential injury.

Lower Extremity Injuries and SRCs

Lower extremity injuries in the present study were defined as any injury to 6 regions as defined by the NCAA-ISP: hip/groin, upper leg/thigh, knee, lower leg/Achilles, ankle, and foot/toes. We did not provide a definition of an SRC, as we relied on the medical expertise of the professionals providing the data, although they were encouraged to follow the definition provided by the Consensus Statement on Concussion in Sport.[20] All SRCs were assessed by the ATs and/or physicians.

Statistical Analysis

Data analysis was conducted using SAS Enterprise Guide software (version 4.3; SAS Institute Inc). During the study period, 6 football seasons took place. Data were analyzed to compare rates of injury between the first 3 (2009-2010, 2010-2011, 2011-2012) and last 3 (2012-2013, 2013-2014, 2014-2015) seasons; this pooling of season data was performed to control for season-by-season random variation. Injury rates were calculated per 1000 AEs for all injuries and then restricted to first, time loss injuries, and second, severe injuries. Rates were also calculated for each specific anatomic site and injury mechanism. Rate ratios (RRs) with 95% CIs compared injury rates between the 2 time periods. All RRs with 95% CIs not including 1.00 were considered statistically significant.

RESULTS

Lower Extremity Injury Rates and Severity

During the 2009-2010 to 2014-2015 seasons, 2400 lower extremity injuries were reported in games, of which 1175 (49.0%) occurred during the 2009-2010 to 2011-2012 seasons and 1225 (51.0%) occurred during the 2012-2013 to 2014-2015 seasons (Table 1). Within these 2 time periods, respectively, 50.0% and 52.6% were time loss injuries; in addition, 15.7% and 14.5% were severe injuries, respectively. There was a 15% increase in the lower extremity rate in 2012-2013 to 2014-2015 compared with 2009-2010 to 2011-2012 (23.55 vs 20.45/1000 AEs, respectively; RR, 1.15; 95% CI, 1.06-1.25). This finding was retained when restricted to time loss injuries only (12.38 vs 10.22/1000 AEs, respectively; RR, 1.21; 95% CI, 1.06-1.36) but not when restricted to severe injuries only (3.42 vs 3.22/1000 AEs, respectively; RR, 1.06; 95% CI, 0.87-1.31).

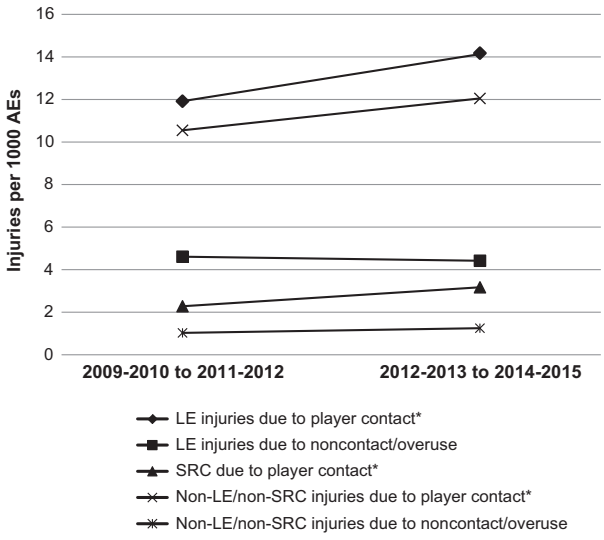

Figure 1. Comparison of injury rates per 1000 athlete-exposures (AEs) between the 2009-2010 to 2011-2012 and 2012-2013 to 2014-2015 seasons. There were significant increases in injury rates for lower extremity (LE) injuries due to player contact, sports-related concussions (SRCs) due to player contact, and non-LE/non-SRC injuries due to player contact. There were no differences found for LE injuries due to noncontact/overuse and non-LE/non-SRC injuries due to noncontact/overuse. *Significant changes between groups compared.

Lower Extremity Injury Rates by Body Part and Player Contact

Most lower extremity injuries were to the knee (33.6%) and ankle (28.5%) and were caused by player contact (59.2%) (Table 2). There were increases in injury rates in 2012-2013 to 2014-2015 compared with 2009-2010 to 2011-2012 for the knee (7.96 vs 6.84/1000 AEs, respectively; RR, 1.16; 95% CI, 1.01-1.34) and ankle (7.21 vs 5.40/1000 AEs, respectively; RR, 1.34; 95% CI, 1.15-1.55) (Table 2). There was also a 19% increase in the lower extremity injury rate because of player contact (14.13 vs 11.92/1000 AEs, respectively; RR, 1.19; 95% CI, 1.07-1.32). No difference in the 2 time periods was found in lower extremity injury rates because of noncontact/overuse (4.42 vs 4.61/1000 AEs, respectively; RR, 0.96; 95% CI, 0.80-1.14) (Figure 1).

TABLE 2
Lower Extremity Injuries in NCAA Football Games by Season, Anatomic Site, and Injury Mechanism: 2009-2010 to 2014-2015 Seasons[a]

	No. of Injuries (Injuries per 1000 AEs)							
	Contact							
Season and Anatomic Site	Player Contact	Surface Contact	Other Contact	Total	Noncontact	Overuse	Other/ Unknown	Total
2009-2010 to 2011-2012								
Hip/groin	45 (0.78)	16 (0.28)	2 (0.03)	63 (1.10)	34 (0.59)	11 (0.19)	10 (0.17)	118 (2.05)
Upper leg/thigh	81 (1.41)	3 (0.05)	2 (0.03)	86 (1.50)	57 (0.99)	3 (0.05)	9 (0.16)	155 (2.70)
Knee	256 (4.46)	40 (0.70)	0	296 (5.15)	56 (0.97)	7 (0.12)	34 (0.59)	393 (6.84)
Lower leg/Achilles	57 (0.99)	4 (0.07)	0	61 (1.06)	20 (0.35)	0	10 (0.17)	91 (1.58)
Ankle	200 (3.48)	29 (0.50)	0	229 (3.99)	48 (0.84)	2 (0.03)	31 (0.54)	310 (5.40)
Foot/toes	46 (0.80)	23 (0.40)	0	69 (1.20)	19 (0.33)	8 (0.14)	12 (0.21)	108 (1.88)
Total	685 (11.92)	115 (2.00)	4 (0.07)	804 (13.99)	234 (4.07)	31 (0.54)	106 (1.85)	1175 (20.45)
2012-2013 to 2014-2015								
Hip/groin	50 (0.96)	15 (0.29)	1 (0.02)	66 (1.27)	30 (0.58)	4 (0.08)	5 (0.10)	105 (2.02)
Upper leg/thigh	70 (1.35)	3 (0.06)	0	73 (1.40)	43 (0.83)	2 (0.04)	8 (0.15)	126 (2.42)
Knee	273 (5.25)	50 (0.96)	0	323 (6.21)[b]	66 (1.27)	3 (0.06)	22 (0.42)	414 (7.96)[b]
Lower leg/Achilles	62 (1.19)	2 (0.04)	0	64 (1.23)	19 (0.37)	1 (0.02)	9 (0.17)	93 (1.79)
Ankle	247 (4.75)[b]	55 (1.06)[b]	1 (0.02)	303 (5.83)[b]	45 (0.87)	2 (0.04)	25 (0.48)	375 (7.21)[b]
Foot/toes	33 (0.63)	38 (0.73)[b]	1 (0.02)	72 (1.38)	11 (0.21)	4 (0.08)	25 (0.48)	112 (2.15)
Total	735 (14.13)[b]	163 (3.13)[b]	3 (0.06)	901 (17.32)[b]	214 (4.11)	16 (0.31)	94 (1.81)	1225 (23.55)[b]
Overall								
Hip/groin	95 (0.87)	31 (0.28)	3 (0.03)	129 (1.18)	64 (0.58)	15 (0.14)	15 (0.14)	223 (2.04)
Upper leg/thigh	151 (1.38)	6 (0.05)	2 (0.02)	159 (1.45)	100 (0.91)	5 (0.05)	17 (0.16)	281 (2.57)
Knee	529 (4.83)	90 (0.82)	0	619 (5.65)	122 (1.11)	10 (0.09)	56 (0.51)	807 (7.37)
Lower leg/Achilles	119 (1.09)	6 (0.05)	0	125 (1.14)	39 (0.36)	1 (0.01)	19 (0.17)	184 (1.68)
Ankle	447 (4.08)	84 (0.77)	1 (0.01)	532 (4.86)	93 (0.85)	4 (0.04)	56 (0.51)	685 (6.26)
Foot/toes	79 (0.72)	61 (0.56)	1 (0.01)	141 (1.29)	30 (0.27)	12 (0.11)	37 (0.34)	220 (2.01)
Total	1420 (12.97)	278 (2.54)	7 (0.06)	1705 (15.58)	448 (4.09)	47 (0.43)	200 (1.83)	2400 (21.92)

[a]AE, athlete-exposure; NCAA, National Collegiate Athlete Association.
[b]Injury rate higher during the 2012-2013 to 2014-2015 seasons versus 2009-2010 to 2011-2012.

When examining player contact injury rates by anatomic site, only ankle injuries had a significant increase in 2012-2013 to 2014-2015 compared with 2009-2010 to 2011-2012. (4.75 vs 3.48/1000 AEs, respectively; RR, 1.36; 95% CI, 1.13-1.64). Contact-related knee injuries increased by 18%, but this finding was not statistically significant (5.25 vs 4.46/1000 AEs, respectively; RR, 1.18; 95% CI, 0.99-1.40) (Table 2). When examining player contact injury rates by more specific mechanisms, no differences in the 2 time periods were found in injuries due to blocking (RR, 1.26; 95% CI, 0.95-1.66), tackling (RR, 1.10; 95% CI, 0.89-1.37), being blocked (RR, 1.19; 95% CI, 0.95-1.49), and being tackled (RR, 1.00; 95% CI, 0.78-1.29).

SRC Rates

During the 2009-2010 to 2014-2015 seasons, 334 SRCs were reported in games, of which 151 (45.2%) were reported during the 2009-2010 to 2011-2012 seasons and 183 (54.8%) were reported during the 2012-2013 to 2014-2015 seasons (Table 3). There was a 34% increase in the SRC rate in 2012-2013 to 2014-2015 compared with 2009-2010 to 2011-2012 (3.52 vs 2.63/1000 AEs, respectively; RR, 1.34; 95% CI, 1.08-1.66). This finding was retained when restricted to SRCs due to player contact only (3.17 vs 2.28/1000 AEs, respectively; RR, 1.39; 95% CI, 1.11-1.75).

Rates for Other Injuries

During the 2009-2010 to 2014-2015 seasons, 1805 injuries that were not lower extremity injuries or SRCs were reported in games, of which 893 (49.5%) were reported during the 2009-2010 to 2011-2012 seasons and 912 (50.5%) were reported during the 2012-2013 to 2014-2015 seasons (Table 3). There was a 13% increase in the non–lower extremity/non-SRC injury rate in 2012-2013 to 2014-2015 compared with 2009-2010 to 2011-2012 (17.53 vs 15.54/1000 AEs, respectively; RR, 1.13; 95% CI, 1.03-1.24). This finding was retained when restricted to injuries due to player contact only (12.05 vs 10.55/1000 AEs, respectively; RR, 1.14; 95% CI, 1.02-1.28). However, when restricted to time loss injuries only, nonsignificant findings were found for both all injury mechanisms (5.90 vs 5.41/1000 AEs, respectively; RR, 1.09; 95% CI, 0.93-1.28) and player contact injuries only (4.21 vs 3.78/1000 AEs, respectively; RR, 1.11; 95% CI, 0.92-1.34). In addition, no difference in the 2 time periods was found in rates of non–lower extremity/non-SRC injuries due to noncontact/overuse

TABLE 3
SRCs and Non–Lower Extremity/Non-SRC Injuries in NCAA Football Games by Season and Severity: 2009-2010 to 2014-2015 Seasons[a]

	No. of Injuries (Injuries per 1000 AEs)			
	All Injury Mechanisms		Player Contact–Related Only	
Season and Severity	SRC	Non–Lower Extremity/Non-SRC	SRC	Non–Lower Extremity/Non-SRC
2009-2010 to 2011-2012				
All injuries	151 (2.63)	893 (15.54)	131 (2.28)	606 (10.55)
Time loss injuries only	140 (2.44)	311 (5.41)	122 (2.12)	217 (3.78)
2012-2013 to 2014-2015				
All injuries	183 (3.52)[b]	912 (17.53)[b]	165 (3.17)[b]	627 (12.05)[b]
Time loss injuries only	173 (3.33)[b]	307 (5.90)	155 (2.98)[b]	219 (4.21)
Overall				
All injuries	334 (3.05)	1805 (16.49)	296 (2.70)	1233 (11.26)
Time loss injuries only	313 (2.86)	618 (5.65)	277 (2.53)	436 (3.98)

[a]AE, athlete-exposure; NCAA, National Collegiate Athlete Association; SRC, sports-related concussion.
[b]Injury rate higher in during the 2012-2013 to 2014-2015 seasons versus 2009-2010 to 2011-2012.

(1.25 vs 1.03/1000 AEs, respectively; RR, 0.82; 95% CI, 0.58-1.17) (Figure 1).

DISCUSSION

The IOM has recommended the examination of SRCs and their sequelae among patients aged 5 to 21 years as well as the effectiveness of rule changes and policies aiming to reduce the incidence and severity of SRCs.[10] As rule changes are implemented, rule efficacy in promoting player safety should be rigorously evaluated. This is the first study that has evaluated the interplay between SRC and lower extremity injury rates since the implementation of the targeting rule, which aimed to decrease head trauma in NCAA football players. Our findings suggest that over the past 6 seasons, the rates of SRCs and lower extremity injuries have increased, particularly because of increases in player contact–related injuries. These findings warrant further discussion of how to better protect the safety and health of collegiate athletes.

Prior rule changes in football have been effective in reducing the incidence of specific injuries. In 1976, the NCAA banned "spearing" from gameplay, which produced a decrease in the incidence of cervical spine injuries resulting in quadriplegia (5 observed cases in 1984 compared with 34 in 1976).[26] A follow-up study highlighted further decreases in later years.[13] Our study determined that the reported SRC rate has increased across recent NCAA football seasons, which is similar to previous findings. Lincoln et al[19] observed an 8% annual increase in SRC rates in high school football athletes from the 1997 to 2008 seasons. However, as the authors noted, findings may not reflect an annual increased incidence of SRCs but rather an increase in awareness by coaches and health care personnel responsible for high school players; those less severe SRCs that may have been undetected in the past may be better detected today.

Likewise, in the current study, findings may reflect an increase in the reporting rate and not a true increase in the SRC incidence. In April 2010, the NCAA Executive Committee adopted a concussion policy that mandated that each school's concussion management plan include (1) annual concussion education to athletes, (2) immediate removal from play if a concussion is suspected, (3) elimination of same-day return to play in a concussed athlete, and (4) a process for clearance by a medical professional.[21] The reporting and true incidence rates could be distinguished if the postconcussion protocol had stayed the same during the study period. However, it appears that more SRCs are being diagnosed, and concussed athletes are being held out of sports participation for longer periods of time.[27] As better education and awareness allow researchers to better identify all concussive events, time trends related to the true incidence of SRCs can be ascertained.

There are concerns that the targeting rule change may unintentionally result in an increased risk of lower extremity injuries.[1,25] Our findings suggest that lower extremity injury rates may have increased over the past 6 NCAA football seasons. The changes are most pronounced in ankle and knee injuries, particularly those that result from player contact. In contrast, the rates of lower extremity injuries resulting from noncontact/overuse did not change. Thus, although the targeting rule change in NCAA football aims to reduce the incidence and severity of head trauma, it may also have produced unintended consequences, many of which were initially noted by NFL players.[1,25]

Risk compensation theory[12] suggests that people adjust their behavior according to a perceived risk and may be less cautious with respect to other risks. As it relates to our study, SRCs and head-to-head contact during play are the perceived risks, and players may be adjusting their behavior, perhaps changing tackling form, which may be leading to increases in lower extremity injury rates. Examples of risk compensation have been demonstrated previously in sport. In professional and amateur rugby, it was noted that injuries increased after the implementation of protective gear including padded helmets, gloves, mouth

guards, padded clothing, shin guards, and ankle braces.[7] Following this report, the use of protective equipment was repealed until its effect on player safety could be assessed. Injury rates in skiers may also be higher with helmet use.[12,24] Unintended consequences of rule changes should be screened for and thoroughly evaluated.

However, it is important to consider that our study was not able to track injury rates before the initial implementation in 2008, as data collection methodologies for the NCAA-ISP before the 2009-2010 season differed and may bias time trend analyses.[15] Also, the intended and unintended effects of other policy changes must be considered. For example, in 2012, the NCAA moved the kickoff up to the 35-yd line (previously at the 30-yd line) and moved touchbacks up to the 25-yd line (previously at the 20-yd line). This was intended to decrease the rates of contact-related injuries and resulted in decreasing the number of kickoffs returned. Interestingly, we determined that there was an increase in player contact–related lower extremity injuries during this rule change. Given the change in kickoff rules that occurred concurrently during our study, it is possible that we are underestimating the true change in the rate of lower extremity injuries and concussions that would be directly associated with the targeting rule change. This study also did not account for additional confounders. Several reports have noted that an artificial playing surface has been associated with increased lower extremity injuries.[5,6,14] It is plausible that studies reporting increased injury rates on an artificial surface may be reporting this same trend, without mention. More artificial playing surfaces are used with every new season. Older injury data with low injury rates indicated play predominantly on grass fields, while more recent data with an elevated rate of injuries indicated play more commonly on artificial fields.[6,9,29] Although the playing surface may be a potential confounder, our study found that noncontact/overuse injuries did not increase; it would be these injuries that would be more directly related with changes in the playing surface. At the same time, surveillance data such as those from the NCAA-ISP do not account for athlete- and team-level factors such as player and coaching behaviors. Thus, more in-depth examinations of policy, environmental, team, and individual factors are warranted when evaluating the association of targeting rule changes and injury rates.

The concern of lower extremity injuries is warranted, given findings that suggest that lower extremity injuries, specifically those to the knee and ankle, have been associated with elevated risks of arthritis and disability after retirement from sport. Larsen et al[17] evaluated soccer players 25 years after knee and ankle injuries, noting symptoms of arthritis in 63% and 33% of patients who had sustained knee and ankle injuries, respectively. Golightly et al[8] evaluated the prevalence of arthritis in retired NFL players aged under 60 years; the prevalence of knee arthritis among the sample was over 40%, which was 3.5 times as high as that in the general population. Further, they found a strong association with players who suffered knee injuries during football participation and those who developed early arthritis.[8] These findings are concerning as disability and the inability to work/difficulty working have been detected in 33% of retired football players aged 30 to 49 years and 41% of retirees aged over 50 years.[28] Strides have been made in the past to limit the detrimental effects of lower extremity trauma in football. For example, the NCAA banned "clipping" and "chop-blocking" in 1980[2] in response to concerns of increasing knee injuries. However, the effectiveness of these previous rule changes may be mitigated if targeting rule changes do in fact increase the rate of lower extremity injuries.

Limitations

The present study is not without limitations. While data were collected prospectively, the observational epidemiological study design did not allow for firm conclusions regarding causation. We chose not to assess injury rates in the NCAA-ISP before the principal targeting rule changes were implemented as the collection methodology changed in the 2009-2010 season. The NCAA-ISP relies on a convenience sample of football programs and may not be generalizable to the entire population of NCAA football athletes. Also, we caution that trends in injury rates may be attributable to varying participation on an annual basis. In addition, given that the NCAA-ISP is composed of surveillance data, we could not account for variations that occur by team (eg, coaching behavior, prevention programs and policies), athlete (eg, tackling behavior, protective gear), and game (eg, playing surface). The current training room atmosphere and environment may be more welcoming of player reports of contact injuries that may have been tolerated previously without reporting. Our study focuses on in-game injuries as these are under the direct influence of the rule change; there may have been effects of the rule change in practice situations that were not explored. Finally, although the increase in lower extremity injury rates was mostly attributable to player contact, no specific mechanism (blocking, tackling, etc) was specifically associated with this change; this may be a result of underpowered analyses as smaller subsets of data are explored. These limitations illustrate the need for continued research on football lower extremity injury rates that refines our methodology.

CONCLUSION

The lower extremity injury rates increased in more recent years in NCAA football athletes, particularly among player contact injuries and those sustained to the knee and ankle. Similarly, SRC rates have increased, although this may be caused by concurrent policies related to better education, identification, and management; the increased recognition of SRCs, we believe, is ultimately beneficial to the overall health of the NCAA football population. Targeting rule changes may be contributing to increased rates of player contact–related lower extremity injuries. Further studies are warranted to examine the association of SRC prevention measures with rates of head and lower extremity injuries. Alongside continued surveillance research to examine longitudinal time trends, more in-depth individual-level

examinations of how targeting rule changes influence coaching and player behaviors are warranted.

ACKNOWLEDGMENT

The authors thank the many ATs who have volunteered their time and efforts to submit data to the NCAA-ISP. Their efforts are greatly appreciated and have had a tremendously positive effect on the safety of collegiate athletes.

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