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Football Players' Head-Impact Exposure After Limiting of Full-Contact Practices

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Context: Sporting organizations limit full-contact football practices to reduce concussion risk and based on speculation that repeated head impacts may result in long-term neurodegeneration.

Objective: To directly compare head-impact exposure in high school football players before and after a statewide restriction on full-contact practices.

Design: Cross-sectional study.

Setting: High school football field.

Patients or Other Participants: Participants were varsity football athletes from a single high school. Before the rule change, 26 athletes (age = 16.2 ± 0.8 years, height = 179.6 ± 6.4 cm, weight = 81.9 ± 13.1 kg) participated. After the rule change, 24 athletes (age = 15.9 ± 0.8 years, height = 178.3 ± 6.5 cm, weight = 76.2 ± 11.6 kg) participated. Nine athletes participated in both years of the investigation.

Main Outcome Measure(s): Head-impact exposure was monitored using the Head Impact Telemetry System while the athletes participated in football games and practices in the seasons before and after the rule change. Head-impact frequency, location, and magnitude (ie, linear acceleration, rotational acceleration, and Head Impact Telemetry severity profile [HITsp], respectively) were measured.

Results: A total of 15 398 impacts (592 impacts per player per season) were captured before the rule change and 8269 impacts (345 impacts per player per season) after the change. An average 42% decline in impact exposure occurred across all players, with practice-exposure declines occurring among linemen (46% decline); receivers, cornerbacks, and safeties (41% decline); and tight ends, running backs (including fullbacks), and linebackers (39% decline). Impact magnitudes remained largely unchanged between the years.

Conclusions: A rule change limiting full-contact high school football practices appears to have been effective in reducing head-impact exposure across all players, with the largest reduction occurring among linemen. This finding is likely associated with the rule modification, particularly because the coaching staff and offensive scheme remained consistent, yet how this reduction influences concussion risk and long-term cognitive health remains unknown.

Key Words: concussions, traumatic brain injuries, protective equipment

Key Points

- When full-contact high school practices were restricted to no more than 2 days per week, head impacts declined by 42%.
- The decline varied by player position; linemen experienced the largest reduction.
- The coaching staff and offensive scheme remained unchanged, so the rule change is likely responsible for the decline in head impacts.

Repetitive concussive and nonconcussive head impacts are speculated to result in long-term neurodegenerative disease.[1] The proposed model suggests that each impact results in the deposition of phosphorylated τ protein in the depths of the cerebral sulci that accumulates over time, causing impaired cognitive functioning. Many conclusions have been drawn from observational data, and American football has attracted the most attention, leading sporting organizations to implement rule changes in an effort to reduce head-impact exposure. For example, the most recent contract between players and owners in the National Football League limits contact practices to 1 day per week during the regular season.[2] At the collegiate level, the National Collegiate Athletic Association limits all member institutions to 2 live-contact practices per week during the regular season, mimicking the policies put in place by the Ivy League and Pac-12 conferences.[3] Pop Warner Football placed restrictions on contact practices at the youth level,[4] yet state or high school conference regulations are sparse, despite the participation of more than 1 million youngsters annually.

Head-impact biomechanics research has a long history, and several groups[5–7] have reconstructed concussive head impacts in laboratory settings. The advent of wireless devices that estimate head center-of-mass acceleration postimpact now allows for the on-field, in vivo measurement of concussive and nonconcussive impacts. These sensors have been used for football players as young as 7 years old, with the average player sustaining 161 impacts in a given season.[8] In another investigation,[9] 9- to 13-year-old players experienced 154 impacts in a season. Slightly older athletes (10–13 years old) received 193 head impacts,[10] whereas a team of similarly aged players (ages 11–13 years) sustained 252 impacts over the course of 27 practice and 9 game sessions[11] (7 impacts per session). Head-impact exposure in a similar cohort of 12- to 14-year-old players was nearly identical, with the average player experiencing 210 to 275 impacts during 5 games and 27 practices (6.5 impacts per session).[12,13]

High school football athletes (14–18 years old) have also been evaluated, with impacts totaling 340 in a given season[14] and 652 per year in a 4-year investigation.[15] Impact frequency at the player level among high school athletes, however, varies based on a number of factors. Receivers, cornerbacks, and safeties typically sustain the fewest impacts each season, with an average of 372 per player. Conversely, linemen typically receive 868 impacts per season, but a single player may sustain more than 2000 per season.[15] In addition, the style of play adopted by the coaching staff influences impact exposure. For example, athletes playing on a team with a "run-first" offensive scheme sustained 456 impacts per season, whereas those on teams that used a "pass-first" offensive scheme experienced 304 impacts per season, or 33.3% fewer.[16]

Recently, investigators[17] speculated on how limiting contact practices would influence head-impact exposure among high school athletes. The authors proposed that limiting contact practices to 1 day per week would reduce head-impact exposure by 18% across all positions. The elimination of all contact sessions would further reduce head-impact exposure by 39% across all positions. In that model, linemen would benefit the most, with a 22% to 48% reduction in head impacts relative to 1 or 0 contact sessions, whereas quarterbacks would see the least change, with a 4% to 8% decline in head impacts under the same conditions.[17] This report is supported by a study of youth football athletes (9–12 years old) that demonstrated a 37% reduction in head contacts when contact practices were restricted to one-third of the total practice time.[9] To date, a direct measure of head-impact exposure with contact practice restrictions at the high school level has not been conducted, but it represents an important next step. Therefore, the primary intent of our research was to evaluate how impact exposure in high school football players was affected by a statewide rule change limiting full-contact football sessions. A secondary aim was to explore the changes in impact magnitude and location during the same time period.

METHODS

As part of a larger multiyear investigation on the association of head-impact exposure and cognitive health, male interscholastic varsity level American football athletes from a single school were enrolled in this investigation (N = 41, age = 16.1 ± 0.8 years at the time of enrollment). Each athlete was issued a new or reconditioned Revolution Speed helmet (Riddell, Elyria, OH) equipped with a Head Impact Telemetry (HIT) System (Riddell) encoder before the start of the season. Each athlete then participated in football practices and games without intervention from the research team. Walkthroughs and scrimmages were coded as practice sessions. The project was approved by the university's institutional review board. All participants provided informed assent and their parent or guardian provided informed consent before data collection.

Rule Change

In 2013, the Michigan High School Athletic Association had no rules regulating the number or duration of regular-season contact practice sessions, which occurred approximately 3 days per week. In 2014, the Association implemented the following rule: "After the first regular-season game, teams may conduct no more than 2 collision practice days in any week."[18] The rule regarding preseason contact practices states: "Before the first regular-season game, schools may not schedule more than 1 'collision' practice in a day," and was unchanged between 2013 and 2014.[18] *Collision practices* are defined by the Michigan High School Athletic Association as "live, game-speed, player versus player contact in pads involving any number of players."[18]

Head Impact Telemetry System

The HIT System has been described elsewhere in detail.[19] Briefly, the system comprises a sideline computer and antenna that receive and record data in real time from players instrumented with an encoder. Each encoder contains 6 single-axis accelerometers that estimate the head's center-of-mass acceleration after impact. Acceleration values are continuously monitored, and data recording begins when any single accelerometer exceeds 6 bits (approximately 14.4*g*) of unfiltered, unprocessed data. The sideline computer then processes the impact event, and the software filters out all impacts below 10.0*g* of resultant head acceleration. The 10*g* threshold is preset by the manufacturer, as events below this magnitude were thought to be more common without impact (eg, jumping up and down, running).

Data Analysis

We calculated descriptive measures of frequency and central tendency (mean and standard deviation) for head impacts during practices and games, head-impact location, and impact magnitude (ie, the resultant linear and rotational acceleration and Head Impact Telemetry severity profile [HITsp], respectively). In addition, because concussion risk is associated with the highest-magnitude impacts, we evaluated the top 5%, 1%, and 0.5% of impact magnitudes for linear and rotational acceleration and HITsp. Each variable was evaluated for the entire study and for each year and player position. Consistent with previous investigations,[15,17] players were grouped into the following positions: linemen; quarterbacks; receivers, corners, safeties; and tight ends, running backs (including fullbacks), and linebackers.

We compared head-impact frequency by season and position and head-impact location and severity before and after the rule change using generalized estimating equations (GEEs) models,[20] which produce robust statistical inferences with potential correlations arising from repeated measures within and between seasons. To quantify differences in head-impact frequency, we used the *event rate ratio* (RR): the number of events per person in 2014 divided by the number of events per person in 2013.

Table 1. Impact Exposure by Player Group for Practices, Competitions, and All Sessions for 2013 (Before Rule Change) and 2014 (After Rule Change) and Percentage Change Between Years

Position	Mean Impact Exposure								
	Practices			Competitions			All Sessions		
	Year, Mean ± SD		Change, %	Year, Mean ± SD		Change, %	Year, Mean ± SD		Change, %
	2013	2014		2013	2014		2013	2014	
Linemen	685 ± 211	371 ± 92[a]	−45.8	383 ± 138	299 ± 110	−22.0	1068 ± 318	670 ± 156[a]	−37.3
Quarterbacks	103 ± NA	75 ± 35	−27.7	237 ± NA	102 ± 130	−57.0	340 ± NA	177 ± 165	−48.1
Receivers, corners, and safeties	161 ± 50	95 ± 36[a]	−40.8	123 ± 62	124 ± 74	0.7	283 ± 84	219 ± 94	−22.8
Tight ends, running backs (including fullbacks), and linebackers	254 ± 108	155 ± 122[a]	−39.0	184 ± 124	172 ± 120	2.0	438 ± 193	327 ± 224	−25.3
All athletes	359 ± 262	169 ± 134[a]	−52.9	233 ± 153	175 ± 199	−24.8	592 ± 391	345 ± 236[a]	−41.8

Abbreviation: NA, not available.

[a] Indicates a decline in impact exposure from 2013 to 2014.

Confidence intervals (CIs) for the RR were produced through log-linear GEEs models with independence working correlation structure; CIs that cross 1.0 were interpreted as providing no evidence for a change in hit frequency. Impact severity was compared using the mean difference ($\bar{X}_D$) for 3 measures—linear acceleration, rotational acceleration, and HITsp—between the years. The CIs for the mean difference were calculated using linear GEEs models with independence working correlation structure; CIs that cross 0.0 indicated no evidence for a change in severity.

RESULTS

In 2013, 26 athletes participated in the investigation (age = 16.2 ± 0.8 years, height = 179.6 ± 6.4 cm, weight = 81.9 ± 13.1 kg), and in 2014, 24 athletes participated (age = 15.9 ± 0.8 years, height = 178.3 ± 6.5 cm, weight = 76.2 ± 11.6 kg). Nine athletes participated in both years of the investigation.

Impact Frequency

Over the course of the study, 23 667 impacts were recorded, consisting of 13 397 during practices (106 sessions) and 10 270 during games (20 sessions). In 2013, 15 398 total impacts were captured: 9335 during practices (55 sessions) and 6063 during games (10 sessions). In 2014, 8269 total impacts were captured: 4062 during practices (51 sessions) and 4207 during games (10 sessions). Data from an additional week of practice and a game collected during the 2013 season were excluded from the analyses to match the 2014 season length. Data on the number of contact and noncontact practice days in each season were not recorded. Eight impacts over the 2 years resulted in diagnosed concussions and were included in the analyses. Head-impact exposure rates for each athlete group are presented in Table 1; the average football athlete sustained 592 ± 391 head impacts during 2013, compared with 345 ± 236 in 2014. Change rates from 2013 to 2014 are also shown in Table 1; overall, head-impact exposure declined by 41.8% between seasons, with a 52.9% decline during practices and a 24.8% decline during games.

Among all player positions, the average number of impacts sustained during a season of practices and games per individual in 2014 was lower (RR = 0.58, 95% CI = 0.40, 0.84) than in 2013. A player-position analysis of impact exposure for games and practices indicated a decline among the linemen (37.3% decline, RR = 0.63; 95% CI = 0.48, 0.83) but not among the receivers, corners, and safeties (22.8% decline, RR = 0.77, 95% CI = 0.53, 1.13) and tight ends, running backs (including fullbacks), and linebackers (25.3% decline, RR = 0.75, 95% CI = 0.48, 1.17). The RR for quarterbacks was 0.52, but with only 1 such athlete in 2013 and 2 such athletes in 2014, CI estimates are not valid and, thus, not presented here or in the other analyses. When practice and game impact exposures were evaluated independently, we noted a decrease in practice impacts from 2013 to 2014 among all players (RR = 0.47, 95% CI = 0.31, 0.71), with a 53% rate reduction during the 2014 season, while game impact frequency remained statistically unchanged (RR = 0.75, 95% CI = 0.52, 1.08). The statistical decline in practice impact exposures was apparent among linemen (45.8% decline, RR = 0.54, 95% CI = 0.41, 0.72); receivers, corners, safeties (40.8% decline, RR = 0.59, 95% CI = 0.41, 0.85); and tight ends, running backs, and linebackers (39.0% decline, RR = 0.61, 95% CI = 0.37, 0.99) but not quarterbacks (RR = 0.72). No position group demonstrated a decline in impact exposures during games (ie, all CIs crossed 1.0).

Impact Magnitude

Impact magnitude was evaluated on 2 levels. The first evaluation was measures of central tendency, which are presented in Table 2. During the 2013 season, the average impact magnitude was 27.3*g*, 1204.9 rad/s/s, and 16.3 HITsp. In 2014, the average impact magnitude was 27.5*g*, 1217.2 rad/s/s, and 16.7 HITsp. Because a large portion of head impacts that occur during football are of low magnitude and mask the most severe blows, we report the top 5%, 1%, and 0.5% of impacts for each player position in Table 3. When all athletes were evaluated, the top 0.5% of impacts was higher at 98.6*g*, 4461.1 rad/s/s, and 57.4 HITsp in 2013 than the 108.6*g*, 4779.4 rad/s/s, and 60.0 HITsp in 2014.

Table 2. Impact Magnitudes for Each Player Position for Each Year of the Investigation

Position	Variable	Year, Mean ± SD 2013	Year, Mean ± SD 2014
Linemen	Linear acceleration, *g*	28.4 ± 15.8	28.3 ± 16.6
	Rotational acceleration, rad/s/s	1196.8 ± 713.7	1165.7 ± 738.8
	HITsp value	16.4 ± 8.1	16.0 ± 7.6
Quarterbacks	Linear acceleration, *g*	28.4 ± 20.3	30.0 ± 21.0
	Rotational acceleration, rad/s/s	1179.0 ± 868.9	1421.4 ± 1115.0
	HITsp value	16.1 ± 9.3	18.2 ± 12.8
Receivers, corners, and safeties	Linear acceleration, *g*	25.9 ± 16.8	25.0 ± 15.8
	Rotational acceleration, rad/s/s	1215.3 ± 916.7	1165.2 ± 889.8
	HITsp value	15.6 ± 8.9	15.7 ± 8.2
Tight ends, running backs (including fullbacks), and linebackers	Linear acceleration, *g*	25.8 ± 15.4	27.5 ± 17.0
	Rotational acceleration, rad/s/s	1217.4 ± 771.9	1251.2 ± 840.5
	HITsp value	16.3 ± 8.3	17.4 ± 43.3
All athletes	Linear acceleration, *g*	27.3 ± 16.0	27.5 ± 16.9
	Rotational acceleration, rad/s/s	1204.9 ± 760.5	1217.2 ± 833.2
	HITsp value	16.3 ± 8.3	16.7 ± 30.5

Abbreviation: HITsp, Head Impact Telemetry severity profile.

The second evaluation of impact magnitude indicated no change in mean impact magnitude (all players during all sessions) between 2013 and 2014 as measured by linear acceleration ($\bar{X}_D = 0.18g$, 95% CI = –0.56, 0.93), rotational acceleration ($\bar{X}_D = 12.24$ rad/s/s, 95% CI = –16.98, 41.46), and HITsp ($\bar{X}_D = 0.48$, 95% CI = –0.24, 1.19). Nor were there changes in impact magnitudes of the same measures during games (linear acceleration: $\bar{X}_D = 0.11g$, 95% CI = –1.10, 1.31; rotational acceleration: $\bar{X}_D = 17.68$ rad/s/s, 95% CI = –27.93, 63.30; HITsp: $\bar{X}_D = -0.06$, 95% CI = –0.60, 0.48) and practices (linear acceleration: $\bar{X}_D = -0.44g$, 95% CI = –1.21, 0.33; rotational acceleration: $\bar{X}_D = -24.29$ rad/s/s, 95% CI = –57.69, 9.11; HITsp: $\bar{X}_D = 0.69$; 95% CI = –0.66, 2.03). When magnitude by player position was evaluated, quarterbacks showed an increase in rotational acceleration ($\bar{X}_D = 242.48$ rad/s/s, 95% CI = 88.07, 396.89) and HITsp ($\bar{X}_D = 2.09$, 95% CI = 0.34, 3.85), but these values were based on a small sample (n = 2), making clinical interpretation difficult. No other measures of impact severity among the other player positions were significantly different.

Impact Location

We also evaluated impact location with regard to the number of impacts based on the helmet location (ie, front, back, top, or side). Impact rates to the front of the head (42.3% decline, RR = 0.57, 95% CI = 0.38, 0.87), the back of the head (41.0% decline, RR = 0.59, 95% CI = 0.45, 0.77), and the side (right or left) of the head (40.0% decline, RR = 0.60, 95% CI = 0.43, 0.85) were all significantly reduced from 2013 to 2014. The rate of impacts to the top of the head also declined (43.4% decline, RR = 0.57, 95% CI = 0.30, 1.08), but the result was not statistically significant. The Figure depicts head-impact density based on the elevation and azimuth of each blow. Most notable is the decline in impacts to the front of the helmet among the linemen. A closer look at the data shows that linemen had a 38.8% reduction in the concentration of front helmet impacts.

DISCUSSION

Much attention has been drawn to the speculated relationship between repeated head impacts and the

Table 3. Top 5%, 1%, and 0.5% of Impact Magnitudes for Each Player Position for Each Year of the Investigation

Position	Percentage, Top	2013 Linear Acceleration, *g*	2013 Rotational Acceleration, rad/s/s	2013 HITsp	2014 Linear Acceleration, *g*	2014 Rotational Acceleration, rad/s/s	2014 HITsp
Linemen	5	60.1	2460.8	30.4	60.7	2484.5	28.9
	1	84.3	3568.2	47.5	88.7	3646.0	45.2
	0.5	95.2	4066.8	55.5	102.1	4041.2	53.9
Quarterbacks	5	72.2	3125.6	32.1	72.5	3197.7	42.9
	1	114.0	3958.3	57.2	115.3	5717.2	84.0
	0.5	138.7	5052.6	62.4	156.9	9477.0	99.6
Receivers, corners, and safeties	5	59.8	2952.2	30.8	54.6	2776.6	29.9
	1	102.9	4854.5	53.6	87.9	4666.4	52.1
	0.5	110.5	5906.1	66.0	97.4	5312.3	58.2
Tight ends, running backs (including fullbacks), and linebackers	5	56.8	2726.5	30.1	60.3	2865.4	32.2
	Top 1%	84.8	3939.1	47.1	91.1	4263.0	52.9
	Top 0.5%	93.4	4525.3	57.9	112.1	4773.2	67.2
All athletes	Top 5%	59.1	2621.3	30.4	60.5	2729.2	31.4
	Top 1%	86.1	3846.5	48.1	89.7	4161.1	52.1
	Top 0.5%	98.6	4461.1	57.4	108.6	4779.4	60.0

Abbreviation: HITsp, Head Impact Telemetry severity profile.

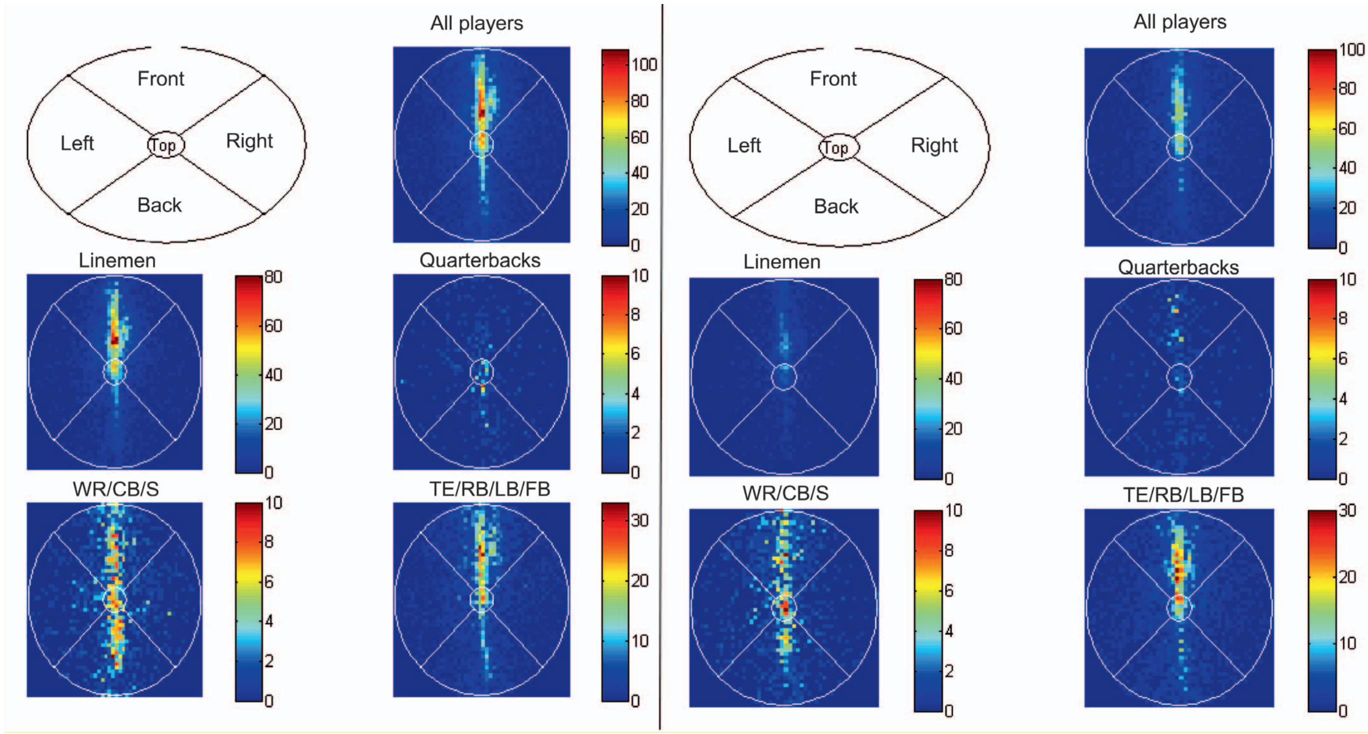

Figure. Heat maps depicting head-impact exposure for all players and position groups in 2013 (left) before the rule change and 2014 (right) after the rule change. Linemen showed the largest reduction in head impacts to the front of the helmet (38.8% reduction). Abbreviations: CB, cornerbacks; FB, fullbacks; LB, linebackers; RB, running backs; S, safeties; TE, tight ends; WR, wide receivers.

potential for long-term neurodegeneration.[21–24] Despite a lack of evidence to account for other conditions with similar clinical presentations, bias in the sample populations, and lack of control data,[25–33] sporting organizations have sought to reduce head-impact frequency during football participation. The number of full contact days for football has been restricted at the professional level and to a lesser extent at the collegiate and interscholastic levels, but no studies have directly measured the effect of such rule changes. We found that limiting contact sessions to "no more than 2 collision practice days in any week"[18] resulted in an average 42% reduction in head impacts among all players on a high school football team across a season; the reduction was largely the result of a 53% reduction during practice sessions. Game impacts were also reduced (–25%), possibly as an indirect result of the policy change. The decline in practice impacts was significant for the linemen (37% decline); receivers, corners, and safeties (23% decline); and tight ends, running backs (including fullbacks), and linebackers (25% decline). Quarterbacks also saw a reduction (48% decline), albeit this was nonsignificant.

Although we are the first, to our knowledge, to directly measure head-impact exposure in the same team of high school football athletes before and after a rule change, Kerr et al[34] evaluated changes in head-impact exposure in youth football athletes whose coaches were or were not exposed to the "Heads Up" football program. The coaches' training resulted in the athletes sustaining 3.4 fewer impacts per practice session, with no difference in the game exposure rates. Cobb et al[9] compared head-impact exposure among 2 youth teams, 1 with restricted-contact practice time, and reported a 37% overall reduction. This finding is consistent with our results despite the potential variation in head impacts between teams.[16] In addition, previous authors[17] retrospectively evaluated an existing dataset of high school athletes to estimate how such a rule change would influence head-impact frequencies. Those approximations suggested the average player would experience an 18% reduction, with the greatest reduction among linemen (21.9% reduction); followed by tight ends, running backs, and linebackers (13.2% reduction); receivers, corners, and safeties (11.3% reduction); and quarterbacks (3.7% reduction). The authors[17] also reported that the highest-magnitude impacts (top 0.5%) were greater during noncontact session days than during full-contact days, but those impacts occurred with reduced frequency and were not thought to influence the concussion risk. In our investigation, the average head-impact magnitude remained largely the same during practices and games and when evaluated by player position. The highest-magnitude impacts (ie, the top 0.5%) were greater after the rule change, but the differences were clinically small and likely a result of season-to-season variation.

Head-impact exposure during football participation has garnered significant attention in the previous decade. In part, this is a result of the technology that is now available to record head impacts in the sport, but the sport's popularity also has an influence. Only limited research has been conducted on other sports, such as men's and women's ice hockey, men's and women's soccer, and men's lacrosse. For example, authors using similar instrumentation to ours demonstrated that collegiate hockey athletes sustained 170 to 347 impacts per season[35,36]; high school athletes fell within this range at 223 impacts per season of play.[37] Top-level male soccer athletes are estimated to experience an average of 6.6 impacts per game, or 2000 head balls during games across their careers.[38] The amount of head-ball exposure during practices is unknown in this group. More recent research, however, has shown that collegiate female soccer athletes received a similar number of head balls during games (7 per game) and 3.5 headers during practice sessions.[39] Their high school counterparts sustained significantly fewer impacts of 2.9 per game and 1.7 per practice session.[39] Although these values pale in comparison with impact estimates during a season of football participation at the high school[15] and collegiate[40] levels, additional research is needed in ice hockey, soccer, and other contact-collision sports such as lacrosse, which has not been investigated to date.

Assessing the concussion risk relative to a rule change was not our aim but has been evaluated by Kerr et al,[41] who studied a large cohort of youth football athletes when contact rules and tackling technique drills were introduced simultaneously. Contact sessions were limited to no more than one-third of practice time; full-speed, head-on tackling drills were eliminated; and specific tackling training techniques were implemented. Restrictions on full-contact practice sessions combined with tackling-specific training reduced the concussion risk by 82% during practice sessions compared with those athletes who received no intervention. During our investigation, 3 concussions were diagnosed in 2013 and 5 in 2014. The small case numbers do not allow us to draw conclusions; larger investigations of concussion incidence after a similar rule change are required.

Even in light of the head-impact exposure decline we report, the evidence surrounding long-term cognitive health as related to head impacts remains inconclusive. In a large study of cognitive function in high school athletes with or without a concussion history, no differences in Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) test performance were noted, although reports of increased symptoms were correlated with concussion history.[42] These results are similar to those using computer-based measures among collegiate[43] and high school and amateur athletes.[44] Traditional pencil-and-paper batteries in soccer athletes[45] provided similar results. In addition, an investigation of former high school football athletes demonstrated no increased risk for dementia, Parkinson disease, or amyotrophic lateral sclerosis when compared with band, glee club, and choir members of similar ages and in similar geographic areas.[46] The football athletes participated between 1946 and 1956, an era of poorer-quality equipment, medical knowledge, and care for players with concussive injuries.

Conversely, collegiate football athletes with 2 or more previous concussions had worse performance on baseline cognitive evaluations relative to those with no injury history or only 1 injury.[47] Similar results were reported among jockeys with a concussion history.[48] Researchers using more sophisticated measures in high school[49] and collegiate[50] athletes have shown altered neurophysiologic performance in the absence of a diagnosed concussion. Indeed, a high school football athlete cohort demonstrated altered dorsolateral prefrontal cortex activation patterns that were linked to head impacts.[49] Collegiate-level football athletes had decreased fractional anisotropy and mean diffusivity when preseason diffusion tensor images were compared with immediate postseason and 6-month post-season evaluations.[50] Both sets of investigators[49,50] linked these findings to impaired performance on a common computer-based cognitive evaluation, but the known false-positive rate on those assessments limits the ability to draw conclusions between head-impact exposure and cognitive health.[51] Thus, the consequences of cellular-level changes on long-term (ie, 30 years later) cognitive health remain unknown.

Our findings in this investigation are associated with limitations that affect the interpretation in the larger context. Importantly, the number of practice sessions varied slightly between the 2 years, with 4 fewer practices in 2014. Previous research suggests that a single contact practice session accounts for approximately 12 impacts,[15] so each 2014 player might have sustained 48 additional impacts over the season if the number of practice sessions had been identical. However, even if these additional practices had occurred, the overall head-impact exposure would have remained lower for the 2014 season. In addition, the numbers of contact and noncontact sessions between years were not recorded. The number of games remained the same between the years, but the opponent teams varied slightly. As such, it is conceivable that different offensive schemes of the opposing teams may have influenced head-impact counts for our participants.[16] Although 9 athletes were involved in both years of the investigation, a substantial number of athletes differed from 2013 to 2014, and individual playing styles may have influenced head-impact exposure. An estimation of impacts by exposure (ie, game or practice) or playing time may answer that question, but those data are not available. Additionally, these results are promising, but they are generated from a single team, and a number of factors remained outside our control. For example, players entered the study with undetermined playing styles that may have influenced their head-impact exposure. Furthermore, seasonal variations and changes in the roster over time may have led to variations in playing styles and impact exposure. Lastly, the rule change was implemented simultaneously statewide, prohibiting the inclusion of a control team and precluding prospective research with a large number of schools.

CONCLUSIONS

Despite a lack of clarity surrounding the relationship between repeated head impacts in high school athletes and long-term neurocognitive dysfunction, sport governing bodies have begun to place restrictions on full-contact football participation. We identified an average 42% decline in head impacts when full-contact football practices were limited to no more than 2 days per week. The decline varied by player position, with the linemen showing a statistically significant decline between the seasons. The rule modification may have been the cause of this decrease, as head impacts were significantly reduced during practice sessions, while the coaching staff and offensive scheme remained consistent. How head impacts among other teams changed as a result of the rule implementation and whether the decrease may influence concussion risk and long-term cognitive function were beyond the scope of this investigation, but these areas require future attention.

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