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Injury Patterns by Body Mass Index in US High School Athletes

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Background: There are over 7 million US high school athletes and one-third are overweight or obese. Our objective was to examine injury patterns by body mass index (BMI) in high school athletes. ***Methods:*** Certified athletic trainers (ATCs) at 100 nationally representative US high schools submitted exposure and injury information during the 2005 to 08 school years via High School RIO (Reporting Information Online). We retrospectively categorized injured athletes as underweight (≤15th percentile), normal weight (15th–85th percentile), overweight (85th–95th percentile), or obese (≥95th percentile). ***Results:*** ATCs reported 13,881 injuries during 5,627,921 athlete-exposures (2.47 injuries per 1000 athlete-exposures). Nearly two-thirds (61.4%) of injured high school athletes were normal weight. The prevalence of overweight and obesity was highest among injured football athletes (54.4%). Compared with normal weight athletes, obese athletes sustained a larger proportion of knee injuries (Injury Proportion Ratio [IPR] = 1.27, 95% CI: 1.14 to 1.42) and their injuries were more likely to have resulted from contact with another person (IPR = 1.31, 95% CI: 1.26 to 1.37). Compared with normal weight athletes, underweight athletes sustained a larger proportion of fractures (IPR = 1.45, 95% CI: 1.10 to 1.92) and a larger proportion of injuries resulting from illegal activity (IPR = 1.59, 95% CI: 1.03 to 2.46). ***Conclusions:*** Injury patterns differ by BMI. BMI-targeted preventive interventions should be developed to help decrease sports injury rates.

Keywords: epidemiology, overweight, obesity, underweight

Following a 37% increase over the past 3 decades, United States (US) high school sports had more than 7 million participants during the 2006–07 school year.[1] During the same time, US obesity rates have more than doubled among adolescents.[2] Almost one-third of US adolescents were overweight or obese during 2003–06.[3] Evidence indicates that high school athletes are not immune to this obesity epidemic, as high school athletes have similar or higher proportions of overweight and obesity as the general adolescent population.[4,5]

Overweight and obese children are at increased risk for numerous adverse physical and mental health conditions.[2] Although overweight or obese individuals appear at increased risk for injury,[6–11] studies examining this relationship among athletes have been inconclusive. Some found no statistically significant differences in sports injury rates or patterns by body mass index (BMI; kilogram/meter^2).[12–17] Other studies found that higher-BMI athletes participating in football[18–21] and rugby[22] had an increased injury risk. However, most previous studies were limited to a specific sport[13–15,18–20,22] or to specific injuries.[18,20,21] To date, no study has examined injury patterns by BMI in a nationally representative sample of US high school athletes across multiple sports.

The study objective was to examine injury patterns by BMI in a nationally representative sample of US high school athletes participating in 9 sports during the 2005–08 school years. The specific aims were to 1) describe BMI patterns among injured high school athletes, 2) compare injury patterns by BMI, and 3) examine whether BMI injury patterns differed by sport or gender. Providing sports medicine professionals with evidence-based comparisons of injury patterns by BMI will help them determine whether BMI-targeted injury prevention interventions are needed.

Methods

Data Collection

The National High School Sports-Related Injury Surveillance Study gathers data via High School RIO (Reporting Information Online). This surveillance study's methods have been reported previously.[23] Briefly, high schools with ≥1 National Athletic Trainers' Association-affiliated certified athletic trainers (ATCs) with a valid e-mail

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address were invited to participate. Willing participants were categorized into 8 strata based on school population (enrollment ≤1000, or >1000 students) and US Census geographic location.[24] From these 8 strata, 100 high schools were randomly chosen to participate. If a high school dropped out of the study, a replacement school from the same stratum was selected to maintain the 100-school study population. ATCs from participating high schools logged onto the High School RIO website weekly throughout the school year to report injury incidence and athlete exposure (AE) information for 5 boys' sports (football, soccer, basketball, wrestling, and baseball) and 4 girls' sports (soccer, volleyball, basketball, and softball).

Definition of Injury and Exposure

An AE was 1 athlete participating in 1 athletic practice or competition. A reportable injury had to 1) occur as a result of participation in an organized practice or competition, 2) require medical attention, and 3) result in a restriction of the student's athletic participation for ≥1 days. For each injury, ATCs completed a detailed injury report that described characteristics of the injured player (eg, height, weight, etc.), the injury (eg, body site, diagnosis, etc.), and the event leading to injury (activity, mechanism, etc.). Throughout the study, ATCs were able to view all data they submitted and update reports as needed.

BMI Categorization

For each injured athlete, BMI was calculated using ATC-reported weight and height. Once BMI was calculated, an age- and gender-specific BMI percentile was assigned to each athlete, using guidelines developed by the Centers for Disease Control and Prevention.[25] These percentiles rank an adolescent's BMI among the entire US population for their age and gender. For example, if a 16-year old male has a BMI percentile of 60%, then their BMI is higher than approximately 60% of all other 16-year old US males. Athletes were then categorized as underweight (≤15th percentile), normal weight (15th-85th percentile), overweight (85th-95th percentile), or obese (≥95th percentile).[26]

Statistical Analysis

Data were analyzed using SAS, version 9.1 (SAS Institute Inc., Cary, NC). Injury rates were calculated as injury counts per 1000 AEs. Rate ratios (RR) and injury proportion ratios (IPR) were calculated with 95% confidence intervals (CI), with CI not including 1.00 considered statistically significant. For example, competition and practice injury rates were compared as follows:

$$\text{RR} = \frac{(\#\text{ competition injuries} / \#\text{ competition AE}) \times 1000}{(\#\text{ practice injuries} / \#\text{ practice AE}) \times 1000}$$

Because it was not feasible for ATCs to report AE separately for all athletes in each sport, injury rates by BMI were not calculated. Instead, injury patterns were compared by BMI using IPRs, with normal weight athletes used as the referent category. For example, the comparison of the proportion of fractures between underweight and normal weight athletes was calculated as follows:

$$\text{IPR} = \frac{\#\text{ fractures among underweight athletes} / \text{total }\#\text{ injuries among underweight athletes}}{\#\text{ fractures among normal weight athletes} / \text{total }\#\text{ injuries among normal weight athletes}}$$

National injury incidence was estimated by assigning a sample weight to each reported injury. The sample weight was based on the inverse probability of the school's selection into the study (based on the total number of US high schools in each of the 8 sampling strata). Unless otherwise specified, results present unweighted injury counts. This study was approved by the Institutional Review Board at The Research Institute at Nationwide Children's Hospital.

Results

Overall Injury Rates and Incidence

During the 2005 to 08 school years, participating ATCs reported 13,881 injuries during 5,627,921 AE (2.47 injuries per 1000 AE) (Table 1). The injury rate was higher in competition (4.65 per 1000 AE) compared with practice (1.65 per 1000 AE) RR = 2.82, 95% CI: 2.73 to 2.92). Injury rates were highest in football (4.32 per 1000 AE), wrestling (2.43 per 1000 AE) and girls' soccer (2.40 per 1000 AE). Injury rates were lowest in baseball (1.13 per 1000 AE), softball (1.19 per 1000 AE), and volleyball (1.39 per 1000 AE). These 13,881 reported injuries represent an estimated 4,339,247 injuries sustained nationally during the 2005–08 school years, for an average of 1,446,416 injuries sustained annually.

Table 1 Injury Rates per 1000 Athlete-Exposures by Sport and Type of Exposure, National High School Sports-Related Injury Surveillance Study, US 2005–08 School Years

	Overall	Competition	Practice	Rate ratio[a] (95% Confidence Interval)
All sports, n[b] = 13,881	2.47	4.65	1.65	2.82 (2.73–2.92)
Boys' sports, n = 10,575	2.82	5.68	1.87	3.03 (2.92–3.15)
Football, n = 6507	4.32	12.8	2.56	5.01 (4.77–5.26)
Soccer, n = 1133	2.12	4.03	1.29	3.12 (2.77–3.51)
Basketball, n = 1119	1.66	2.66	1.25	2.13 (1.90–2.40)
Wrestling, n = 1219	2.43	3.83	1.95	1.97 (1.76–2.21)
Baseball, n = 597	1.13	1.72	0.80	2.13 (1.82–2.50)
Girls' sports, n = 3306	1.76	3.04	1.15	2.64 (2.47–2.83)
Soccer, n = 1149	2.40	5.25	1.19	4.40 (3.90–4.97)
Basketball, n = 1059	1.91	3.52	1.23	2.86 (2.54–3.23)
Volleyball, n = 624	1.39	1.56	1.30	1.20 (1.02–1.41)
Softball, n = 474	1.19	1.86	0.82	2.27 (1.90–2.72)

[a] Practice serves as the referent category in rate ratios.

[b] n = number of injuries.

Body Mass Index

Of the 13,881 injury reports, 11,918 (85.9%) provided the athlete's age, height, and weight and thus were included in this study. Almost two-thirds of these injured high school athletes had a BMI considered normal weight (61.4%). The remainder were overweight (19.6%), obese (16.4%), or underweight (2.6%) (Figure 1). Although there was little difference by gender within gender-comparable sports (ie, soccer, basketball, and baseball/softball), sport-specific differences existed.

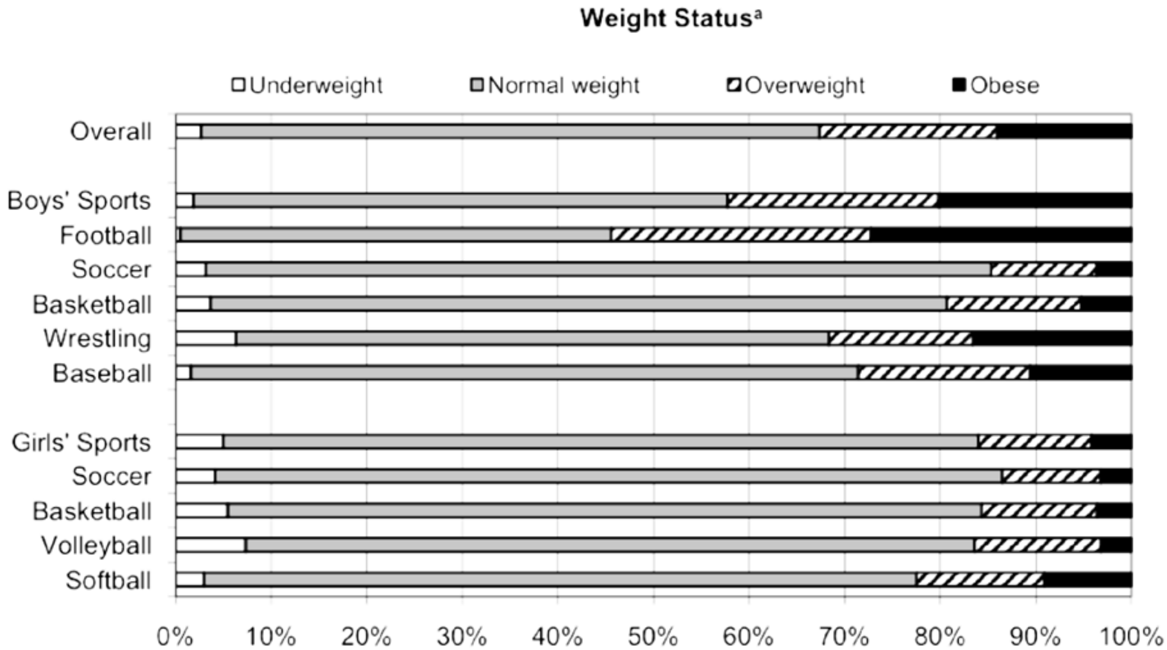
The prevalence of overweight or obesity was markedly higher among injured football players (54.4%) than among athletes of any other sport. Sport-specific overweight and obesity prevalence was also high in wrestling (31.7%), baseball (28.6%), and boys' basketball (19.3%). Conversely, injured girls' soccer athletes were least likely to be overweight or obese (13.5%). In football, the majority of injured defensive tackles (65.2%), offensive tackles (64.7%), centers (63.1%), and offensive guards (58.4%) were obese (Table 2). Other sport-specific positions with large proportions of obese athletes included first basemen in baseball (20.5%) and softball (17.2%).

Injury Patterns by Body Mass Index

Body Site. The most commonly injured body sites were the ankle/foot (22.6%), knee (15.2%), head/face/neck (15.0%), shoulder/upper arm/elbow (12.6%), forearm/wrist/hand (11.0%), and hip/thigh/upper leg (9.4%). Across all sports, obese athletes sustained a higher proportion of knee injuries compared with normal weight athletes (18.3% versus 14.3%; IPR = 1.27, 95% CI: 1.14 to 1.42) (Table 3). Specifically, obese athletes sustained a larger proportion of knee injuries compared with normal weight athletes in softball (24.3% versus 11.3%; IPR = 2.16, 95% CI: 1.13 to 4.14), girls' basketball (33.3% versus 17.5%; IPR = 1.90, 95% CI: 1.15 to 3.16), and football (18.3% versus 13.2%;IPR = 1.38, 95% CI: 1.20 to 1.60).

Other sport-specific differences also existed. Obese athletes sustained higher proportions of ankle/foot injuries compared with normal weight athletes in wrestling (15.8% versus 6.4%; IPR = 2.46, 95% CI: 1.56 to 3.87), volleyball (64.7% versus 37.8%; IPR = 1.71, 95% CI: 1.18 to 2.49), and football (18.8% versus 16.0%; IPR = 1.18, 95% CI: 1.03 to 1.35). In boys' basketball, obese athletes sustained a higher proportion of trunk injuries (17.3% versus 6.7%; IPR = 2.59, 95% CI: 1.35 to 4.96). In girls' basketball, obese athletes sustained a lower proportion of head/face/neck injuries (3.0% versus 16.8%; IPR = 0.18, 95% CI: 0.03 to 1.25).

Diagnosis. The most common injury diagnoses were incomplete ligament sprains (28.2%), incomplete muscle strains (14.0%), contusions (13.2%), fractures (9.8%), and concussions (9.2%). Overall, underweight athletes sustained a larger proportion of fractures compared with normal weight athletes (IPR = 1.45, 95% CI: 1.10 to 1.92) (Table 3), particularly in boys' basketball (27.8% versus 10.5%; IPR = 2.65, 95% CI: 1.50 to 4.66). Although this pattern was also seen in boys' soccer (25.5% versus 8.4%), baseball (37.5% versus 13.8%), girls' soccer (14.6% versus 6.7%), girls' basketball (10.0% versus 7.6%), and football (14.3% versus 11.8%), these sport-specific differences were not statistically significant. Obese athletes also sustained a larger proportion of fractures compared with normal weight



[a]Weight status was calculated using age- and gender-specific BMI charts developed by the Centers for Disease Control and Prevention. Underweight (≤15th percentile), normal weight (15th-85th percentile), overweight (85th-95th percentile), and obese (≥95th percentile).[25]

Figure 1 — Weight status of injured athletes by sport, National High School Sports-Related Injury Surveillance Study, US 2005–08 school years.

athletes in boys' basketball (25.0% versus 10.5%; IPR = 2.38, 95% CI: 1.42 to 3.98). Obese athletes sustained a larger proportion of incomplete ligament sprains in volleyball (64.7% versus 42.0%; IPR = 1.54, 95% CI: 1.07 to 2.23) and football (28.1% versus 23.1%; IPR = 1.22, 95% CI: 1.09 to 1.36).

Severity. Half of all injured players resumed their sport in 1 to 2 days (22.7%) or 3 to 6 days (27.6%). The remainder missed 7 to 9 days (14.7%), 10 to 21 days (14.8%), or >21 days (17.0%; 3.2% sustained an unknown time loss) (Table 3). Overall, underweight athletes sustained a slightly larger proportion of injuries resulting in >21 days time loss compared with normal weight athletes (20.3% versus 17.2%; IPR = 1.18, 95% CI: 0.94 to 1.48) (Table 3), although there were no statistically significant differences by sport. Obese football athletes sustained a larger proportion of injuries resulting in 1 to 2 days time loss compared with normal weight athletes (25.4% versus 20.4%; IPR = 1.25, 95% CI: 1.11 to 1.40).

One in twenty (5.9%) injured athletes required surgery (Table 3). Although there were no significant differences overall, a larger proportion of underweight football players required surgery compared with normal weight players (14.3% versus 5.2%; IPR = 2.87, 95% CI: 1.14 to 7.22) and a higher proportion of obese softball players required surgery compared with normal weight athletes (13.5% versus 4.1%; IPR = 3.40, 95% CI: 1.27 to 9.11).

Injury Mechanism. Half of all injuries were sustained following contact with another person (49.3%). Other frequent injury mechanisms were contact with the playing surface (17.7%) and noncontact mechanisms (ie, rotation around a planted foot/hand, etc.) (16.8%). Across all sports, obese athletes sustained a larger proportion of injuries following contact with another person than normal weight athletes (IPR = 1.31, 95% CI: 1.26 to 1.37) (Table 4). Although there was little difference overall (Table 4), in wrestling (IPR = 3.02, 95% CI: 1.01 to 8.99) and girls' basketball (IPR = 2.90, 95% CI: 1.36 to 6.20) injured underweight athletes sustained a larger proportion of overuse/chronic injuries than normal weight athletes.

Although only 6.4% of all injuries occurring in competition were related to illegal activity, underweight athletes sustained a higher proportion of injuries during a play ruled as illegal activity compared with normal weight athletes (IPR = 1.59, 95% CI: 1.03 to 2.46) (Table 4). Other sport-specific patterns also existed. In

Table 2 Weight Status by Position and Sport,[a] National High School Sports-Related Injury Surveillance Study, US 2005–08 School Years

	Underweight	Normal weight	Overweight	Obese	Total
Sport					
Football[b]					
Running back (n[c] = 865)	0.5%	50.8%	36.0%	12.8%	100%
Linebacker (n = 794)	0.4%	37.9%	37.9%	23.8%	100%
Wide receiver (n = 622)	1.8%	81.0%	13.8%	3.4%	100%
Defensive tackle (n = 497)	0.0%	11.1%	23.7%	65.2%	100%
Offensive tackle (n = 462)	0.0%	10.6%	24.7%	64.7%	100%
Offensive guard (n = 459)	0.2%	13.1%	28.3%	58.4%	100%
Cornerback (n = 411)	1.2%	80.5%	13.9%	4.4%	100%
Defensive end (n = 355)	0.0%	37.2%	37.8%	25.1%	100%
Boys' soccer					
Midfield (n = 375)	4.3%	85.9%	6.9%	2.9%	100%
Forward (n = 289)	2.1%	86.5%	9.0%	2.4%	100%
Defense (n = 208)	3.9%	76.0%	18.3%	1.9%	100%
Goalkeeper (n = 98)	1.0%	70.4%	16.3%	12.2%	100%
Girls' soccer					
Midfield (n = 349)	4.0%	85.7%	8.3%	2.0%	100%
Forward (n = 273)	5.5%	85.0%	7.3%	2.2%	100%
Defense (n = 252)	2.8%	82.9%	10.3%	4.0%	100%
Goalkeeper (n = 99)	5.1%	65.7%	22.2%	7.1%	100%
Volleyball					
Outside hitter (n = 194)	7.2%	78.4%	9.8%	4.6%	100%
Middle blocker (n = 131)	13.7%	67.2%	16.8%	2.3%	100%
Setter (n = 96)	3.1%	80.2%	13.5%	3.1%	100%
Diagonal player (n = 48)	4.2%	81.2%	14.6%	0.0%	100%
Libero (n = 34)	0.0%	94.1%	5.9%	0.0%	100%
Boys' basketball					
Guard (n = 453)	4.6%	83.0%	10.4%	2.0%	100%
Forward (n = 405)	2.5%	76.1%	14.6%	6.9%	100%
Center (n = 122)	4.1%	57.4%	26.2%	12.3%	100%
Girls' basketball					
Guard (n = 453)	5.3%	81.5%	11.3%	2.0%	100%
Forward (n = 325)	6.5%	78.2%	10.8%	4.6%	100%
Center (n = 116)	3.5%	70.7%	19.0%	6.9%	100%
Baseball[b]					
Pitcher (n = 100)	1.0%	75.0%	16.0%	8.0%	100%
Base runner (n = 59)	1.7%	76.3%	11.9%	10.2%	100%
Center field (n = 47)	0.0%	70.2%	19.2%	10.6%	100%
Catcher (n = 42)	0.0%	69.1%	23.8%	7.1%	100%
Left field (n = 41)	0.0%	70.7%	19.5%	9.8%	100%
First base (n = 39)	2.6%	53.9%	23.1%	20.5%	100%
Third base (n = 39)	0.0%	59.0%	28.2%	12.8%	100%
Batter (n = 38)	2.6%	71.1%	15.8%	10.5%	100%
Shortstop (n = 33)	3.0%	75.8%	15.2%	6.1%	100%
Second base (n = 32)	3.1%	78.1%	15.6%	3.1%	100%

(continued)

Table 2 *(continued)*

	Underweight	Normal weight	Overweight	Obese	Total
Softball[b]					
Catcher (n = 52)	0.0%	75.0%	11.5%	13.5%	100%
Pitcher (n = 48)	2.1%	70.8%	18.8%	8.3%	100%
Base runner (n = 46)	2.2%	76.1%	6.5%	15.2%	100%
Second base (n = 37)	5.4%	78.4%	13.5%	2.7%	100%
Third base (n = 33)	0.0%	69.7%	18.2%	12.1%	100%
Left field (n = 31)	9.7%	74.2%	16.1%	0.0%	100%
Center field (n = 31)	3.2%	74.2%	9.7%	12.9%	100%
First base (n = 29)	0.0%	62.1%	20.7%	17.2%	100%
Shortstop (n = 25)	0.0%	84.0%	16.0%	0.0%	100%
Right field (n = 25)	4.0%	92.0%	0.0%	4.0%	100%

[a] Weight status was calculated using age- and gender-specific BMI charts developed by the Centers for Disease Control and Prevention. Underweight (≤15th percentile), normal weight (15th–85th percentile), overweight (85th–95th percentile), and obese (≥95th percentile).[25]

[b] For football, baseball, and softball, only positions accounting for at least 5% of injuries are listed.

[c] n = number of injuries.

Table 3 Body Site, Diagnosis, Time Loss, and Need for Surgery by Weight Status,[a] National High School Sports-Related Injury Surveillance Study, US 2005–08 School Years

	Underweight n[b] = 310	Normal weight n = 7318	Overweight n = 2335	Obese n = 1955
Body site				
Ankle/foot	26.8%	23.9%	20.6%	19.7%
Head/face/neck	15.5%	15.7%	14.7%	12.4%
Knee	14.2%	14.3%	15.3%	18.3%
Shoulder/upper arm/elbow	12.6%	11.5%	14.6%	14.3%
Forearm/wrist/hand	9.0%	10.9%	11.1%	11.2%
Hip/thigh/upper leg	7.7%	9.9%	9.3%	8.0%
Trunk	7.4%	6.7%	7.2%	7.7%
Lower leg	3.9%	5.1%	4.6%	5.1%
Other/unknown	2.9%	1.8%	2.6%	3.4%
Total	100%	100%	100%	100%
Diagnosis				
Incomplete ligament sprain	26.1%	28.2%	28.3%	28.3%
Incomplete muscle strain	13.5%	14.1%	13.8%	14.0%
Contusion	11.0%	12.8%	13.6%	14.8%
Fracture	14.5%	10.0%	8.8%	9.5%
Concussion	8.1%	9.7%	8.8%	7.7%
Dislocation	4.2%	3.0%	3.5%	3.7%
Complete ligament sprain	2.3%	2.7%	2.7%	2.3%
Other/unknown	20.3%	19.4%	20.5%	19.6%
Total	100%	100%	100%	100%
Time loss				
1–2 days	23.5%	22.2%	23.2%	23.8%
3–6 days	26.5%	27.4%	27.8%	28.1%
7–9 days	12.6%	15.2%	14.2%	13.8%
10-21 days	13.9%	14.9%	15.4%	13.7%
>21 days	20.3%	17.2%	16.0%	17.3%
Other/unknown	3.2%	3.1%	3.4%	3.3%
Total	100%	100%	100%	100%
Need for Surgery				
Yes	8.0%	6.0%	6.1%	5.1%
No	92.0%	94.0%	93.9%	94.9%
Total	100%	100%	100%	100%

[a] Weight status was calculated using age- and gender-specific BMI charts developed by the Centers for Disease Control and Prevention. Underweight (≤15th percentile), normal weight (15th–85th percentile), overweight (85th–95th percentile), and obese (≥95th percentile).[25]

[b] n = number of injuries.

Table 4 Mechanism and Presence of Illegal Activity Leading to Injury by Weight Status, National High School Sports-Related Injury Surveillance Study, US 2005–08 School Years[a]

	Underweight n[b] = 310	Normal Weight n = 7318	Overweight n = 2335	Obese n = 1955
Mechanism				
Contact with another person	43.2%	45.4%	53.6%	59.7%
Contact with playing surface	19.7%	19.2%	16.0%	13.8%
No contact	13.5%	18.1%	15.2%	14.1%
Contact with playing apparatus	9.7%	8.0%	6.3%	3.8%
Overuse/chronic	6.5%	4.6%	3.7%	2.5%
Other/unknown	7.4%	4.7%	5.3%	6.2%
Total	100%	100%	100%	100%
	Underweight n = 160	**Normal Weight n = 3882**	**Overweight n = 1199**	**Obese n = 930**
Presence of illegal activity[c]				
Yes	11.9%	7.5%	4.6%	3.5%
No	84.4%	89.1%	92.5%	93.1%
Unknown	3.8%	3.4%	2.9%	3.3%
Total	100%	100%	100%	100%

[a] Weight status was calculated using age- and gender-specific BMI charts developed by the Centers for Disease Control and Prevention. Underweight (≤15th percentile), normal weight (15th–85th percentile), overweight (85th–95th percentile), and obese (≥95th percentile).[25]

[b] n = number of injuries.

[c] Competition injuries only.

football, a higher proportion of underweight athletes were injured following contact with a playing apparatus (eg, ball, goal post, etc.) compared with normal weight athletes (14.3% versus 4.2%; IPR = 3.41, 95% CI: 1.35 to 8.62). A larger proportion of underweight athletes were injured following noncontact mechanisms in boys' soccer (35.5% versus 21.1%; IPR = 1.68, 95% CI: 1.03 to 2.78). Conversely, underweight athletes were injured less frequently following noncontact mechanisms in girls' soccer (4.9% versus 24.2%; IPR = 0.20, 95% CI: 0.052 to 0.78) and volleyball (12.8% versus 28.6%; IPR = 0.45, 95% CI: 0.19 to 1.03), although the latter was statistically insignificant. A higher proportion of obese athletes were injured following contact with the playing surface in girls' basketball (39.4% versus 23.3%; IPR = 1.69, 95% CI: 1.08 to 2.63).

Differences also existed in sport-specific activities leading to injury. In football, obese athletes sustained a larger proportion of injuries while blocking compared with normal weight athletes (28.0% versus 8.2%; IPR = 3.44, 95% CI: 2.95 to 4.02). Obese athletes sustained a larger proportion of injuries goaltending in boys' (19.4% versus 5.3%; IPR = 3.67, 95% CI: 1.77 to 7.58) and girls' (18.8% versus 5.9%; IPR = 3.20, 95% CI: 1.48 to 6.91 soccer. In boys' basketball, obese athletes sustained a larger proportion of injuries while rebounding (40.4% versus 28.0%; IPR = 1.44, 95% CI: 1.02 to 2.05).

Discussion

This study, the first to examine injury patterns by BMI among a nationally representative sample of US high school athletes across several sports, found that over one-third of all injured high school athletes were overweight or obese and that injury patterns differed by BMI. For example, compared with normal weight athletes, underweight athletes sustained a larger proportion of fractures, while obese athletes sustained a larger proportion of knee injuries and a larger proportion of injuries following contact with another person. Given the obesity epidemic in the US, identifying such patterns and developing evidence-based, targeted interventions is crucial for preventing injuries among the changing demographics of high school athletes.

This study found that the prevalence of overweight and obesity among injured males differed greatly by sport. Over half of all injured football athletes were overweight or obese, compared with less than 1 in 3 athletes in wrestling, baseball, boys' basketball, and boys' soccer. Conversely, the prevalence of overweight and obesity differed much less by sport among injured females. In the general population, approximately 31.2% of adolescent males and 30.5% of adolescent females are overweight or obese.[27] With the exception of football, wrestling, and baseball, these results suggest an association between organized high school sports participation and decreased BMI.

Although we were unable to calculate injury rates by BMI, the sport-specific overweight and obesity prevalence among injured male athletes in the 5 male sports studied were similar to the sport-specific prevalence of overweight and obesity found in a previous study among male extramural high school athletes that included all athletes, regardless of injury status.[4] This indicates that overweight and obese athletes in our study population likely sustained injuries at similar rates to normal weight athletes. This supports previous research that found no association between higher BMI and increased injury rates in high school athletes.[12,15,17–19]

The alarmingly high prevalence of overweight and obesity among injured football athletes has been noted previously among adolescent,[5] high school,[18,28] collegiate,[29] and professional[30] football players. Although the use of BMI instead of body fat percentage may have classified some very muscular football players as overweight or obese,[29] these findings are consistent with the previously reported epidemic of overweight and obesity in football. Football culture not only accepts but often encourages large body size, particularly among offensive and defensive linemen. Overweight and obese adolescents have an increased likelihood of remaining overweight or obese as adults,[31] which can lead to an increased risk of adverse health outcomes such as heart disease and diabetes.[32] Thus, it is imperative that the football community, particularly at the high school level, begin to focus on promoting the long-term health of their athletes by encouraging physical fitness and healthy eating and discouraging athletes from purposely gaining unhealthy weight.

This study found injured underweight athletes sustained a larger proportion of fractures than normal weight athletes. One possibility is that underweight athletes have decreased bone mass, as adolescents with lower bone mass have an increased risk of fracture.[33] Previous research found that 21.8% of high school female athletes have low bone mineral density,[34] and recent research has also found that disordered eating and menstrual dysfunction exist among 18.2% and 23.5% of high school female athletes, respectively.[34] Underweight athletes may have decreased muscle or adipose tissue, both of which may result in less cushion for absorbing the force of collisions. In addition, underweight athletes may be faster than normal weight athletes and thus may be more likely to be involved in high-speed, high-impact collisions.

Underweight athletes in this study were more likely to have been injured during an event that was either ruled or believed to be illegal activity compared with normal weight athletes. One hypothesis is that referees may be more likely to rule a play as illegal activity when it involves a collision with an underweight athlete. It is also possible that underweight athletes may play positions where illegal activity is more prevalent, or perhaps underweight athletes exhibit higher risk-taking behaviors. Due to the scarcity of sports literature focused on risk factors for illegal activity, this should be an area of focus for future research.

This study found that obese athletes sustained an increased proportion of knee injuries and a higher proportion of injuries following contact with another player. Similarly, previous research found that overweight football athletes had increased rates of lower extremity injuries.[19] Because previous research found that heavier athletes have poorer balance and posture,[35,36] one hypothesis is that obese athletes may have more difficulty maintaining their balance during collisions. Another possibility is that obese athletes may play positions that involve more hitting and physical contact. Additional research is needed to further examine these relationships and determine whether targeted balance interventions among higher BMI players might be beneficial.This study is not without limitations. Only high schools with an NATA-affiliated ATC were eligible for participation. Although this may limit generalizability, using medically-trained personnel helped increase data quality and reporting consistency. It was not possible to calculate injury rates by BMI because it was not feasible for ATCs to attend every practice and competition for all 9 sports to determine how often each athlete participated. However, the comparisons between BMI and injury patterns presented here provide essential insights for developing targeted preventive interventions. Although BMI is not always an accurate indicator of body fat percentage, it was not feasible for ATCs to calculate body fat percentages for all injured athletes and using BMI allowed our findings to be compared with the bulk of previous research which also used BMI. Finally, almost 17% of injury reports did not have valid age, height, or weight information and thus were not included in BMI comparisons. However, as there is no reason to believe that missing age, height, or weight variables were related to BMI, this likely had minimal effect on our results.

This study suggests areas of attention for injury prevention and future research. With high school athletes being bigger and faster today than in previous years, collisions between mismatched athletes may be putting smaller, underweight athletes at greater risk for severe injury. Coaches and ATCs should ensure that all athletes, particularly underweight athletes, are physically capable of withstanding the usual physical contact that occurs during a particular sport without an excess risk of injury before the athlete is allowed to compete. Coaches and ATCs should emphasize the importance of healthy eating habits and should screen all underweight athletes, particularly females, to determine whether any disordered eating habits may exist. Coaches and ATCs should consider implementing balance training and/or ankle disc programs into their conditioning regimens. Finally, although the efficacy of prophylactic knee and ankle bracing may need further testing, coaches and ATCs should consider whether some of their athletes, particularly those who are overweight or obese, might benefit from their use. Future research efforts should also focus on developing interventions to prevent knee and ankle injuries in obese athletes and fractures in underweight athletes. Continued surveillance is warranted to confirm these findings and to monitor patterns over time.

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