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American Football Sets Players' Body Mass Index

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Abstract

Objectives. Document American football, National Football League (NFL), Lean State (LS) or Heavy State (FS) Public High School (PHS), sets similar player position mean body mass indexes (BMI). Review health risks related to BMI. *Methods*. Public accessible 2014-2015 football rosters were used to calculate individual player's BMI for four PHS teams about each LS and FS Capital City and 32 NFL teams. Mean BMI were compared for male player positions: quarterback (Q), backfield (B), and line (L) players. *Results*. Q, B, and L mean BMI were not significantly different for LS and FS PHS and NFL, but mean BMI was significantly ($P < .01$) different for Q or B versus L. *Conclusion*. Football sets similar BMI for player positions with PHS line prone to obese BMI (considered healthy for NFL players) regardless of regional BMI trends. We propose PHS football set player BMI upper limit 30 to support public health and sports safety goals.

Keywords

body mass index, BMI, exertional heat illness, American Football, high school sports, adolescent obesity

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American football remains a popular participatory sport among high school males whether of lean, average, or obese weight as participation is often inspired by professional National Football League (NFL)–supported events. The National Federation of State High School Associations reports 1 057 382 American high school male athlete participants in football for the 2016-2017 academic year.[1] However, among high school sports, American football is associated with the highest morbidity and mortality for high school male athletes, 4.36 injuries per 1000 athlete exposures in the 2005-2006 Centers for Disease Control and Prevention (CDC) grant supported report.[2,3] High school and college football have estimated 12 fatalities annually among which most common causes are cardiac failure, brain injury, and exertional heat illness or stroke (EHI, EHS).[4]

Body mass index (BMI; reported in kg/[height in meter]^2) is generally accepted to define childhood (nonprofessional athlete) obesity and to be a marker for obesity-associated health risks: cardiovascular disease, impaired glucose tolerance and diabetes mellitus type 2, sleep apnea and asthma, and joint and musculoskeletal discomfort.[5] Obesity is also a risk factor for EHI of particular concern during preseason training.[6] Choate et al[7] reported that 51.4% of all high school football players are overweight or obese, and Cooper et al[8] reported that 64.7% of football players who experienced EHI to be obese and 88% of EHI occurred in August in Southeast United States. Although physical exercise is important for successful weight control, high school football appears to offer little by way of BMI improvement. When contrasted with other high school sports, several studies support a positive (postseason weight gain rather than loss) association with BMI for participating adolescent males.[9-11]

Obesity is recognized as a national health care concern with CDC data and statistics presenting alarming prevalence and trends for US childhood obesity. From 2011 to 2014, prevalence of childhood obesity remained stable at 17% overall, about 12.7 million children and adolescents aged 2 to 19 years, higher among Hispanics

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Table 1. Public High School (PHS) Student Body Composition.

Lean state (LS) four distinct PHS
Total students in each PHS: 1106, 1379, 1447, 1414; average 1300 ± 135 (SD)[a]
Male students in each PHS: 633, 693, 775, 719; average 705 ± 51
Male students in PHS football (percent of all males): average 5.7 ± 0.5%
Heavy state (FS) four distinct PHS
Total students in each PHS: 1003, 1347, 1234, 876; average 1075 ± 186 (SD)
Male students in each PHS: 510, 737, 624, 448; average 580 ± 111
Male students in PHS football (percent of all males): average 14 ± 3.8%

[a]SD, standard deviation of the sample population about the mean.

(21.9%) and non-Hispanic blacks (19.5%) than among non-Hispanic whites (14.7%).[12] A subset of interest is adolescent boys participating in Public High School (PHS) football aspiring to play in the NFL.

We performed this public health surveillance study to test our hypothesis that the game of American football from PHS to NFL level of play throughout the United States sets player position BMI limits. Recognition of player position BMI limits regardless of regional population BMI trends could then set a rational health criterion to identify PHS boys who should achieve healthy weight reduction prior to participation in high school football.

Methods

Our public health surveillance study did not require institutional review board approval (all information was freely accessible within the public domain). Individual height, weight, and positions played from PHS and NFL rosters were available for free public internet access for the 2014-2015 football seasons. We located four complete PHS football rosters for each Lean State (LS) and Heavy State (FS) capital city area (Denver, CO, and Jackson, MS) and 32 full NFL (16 American Football Conference [AFC] and 16 National Football Conference [NFC]) team rosters.[13,14] Individual player names and ages were de-identified prior to data analysis of individual football player assigned position-associated height and weight.

De-identified roster assigned offensive and defensive combined American football positions were Microsoft Excel 2016 worksheet tabulated into three definable all male data groups (excluding all kickers who may be female in some PHS) for LS, FS, AFC, and NFC: Quarterbacks (Q), Backfield players (B), and Line players (L). Players listed as playing multiple positions were noted to be playing all Backfield or all Line with Quarterbacks listed as such even when rarely playing multiple Backfield positions and no Quarterbacks played line positions. Individual BMI ± SD were calculated for each Q, B, and L group tabulated for LS, FS, NFC, and AFC players.

Statistical analyses of de-identified data were performed with Microsoft Statistics Package 2016 (Microsoft, Redmond, WA). Statistical comparisons of tabulated Q, B, and L groups for LS, FS, NFC, and AFC were made by analysis of variance (ANOVA) for 2-tailed, unpaired, unequal variance testing of the null hypothesis that was rejected at $P < .01$.

Results

The four distinct PHS that offered complete football rosters located about each capital city, Denver, CO (LS), and Jackson, MS (FS), were comparable in their student body compositions (Table 1). About twice as many male students participated in PHS football in the FS schools than noted to participate in PHS football in the LS schools, supporting the popularity of PHS football within the American Southeast.

American football offense and defense combined identifiable positions Q, B, and L for LS players' and FS players' mean BMI ± SD are shown in Table 2. There were no statistically significant differences for comparisons of corresponding Q, B, and L mean BMI between LS and FS PHS football players. However, Line player mean BMI was significantly elevated when compared with corresponding LS mean BMI for Q or B or with corresponding FS mean BMI for Q or B (Figure 1).

Professional NFL American football offense and defense combined identifiable positions Q, B, and L for AFC players' and NFC players' mean BMI ± SD are also shown in Table 2. There are 3- to 5-fold more players per Q, B, and L positions within the NFL than within PHS that resulted in smaller SD about the NFL player positions mean BMI. Remarkably, there were no statistically significant differences for comparisons of corresponding Q, B, and L mean BMI among LS and FS PHS and AFC and NFC NFL football players. Line player mean BMI was again significantly elevated when compared

Table 2. LS and FS, AFC and NFC American Football Positions.

Combined Offense and Defense, BMI (Mean ± SD)	
Lean State (LS) Player BMI	Heavy State (FS) Player BMI
LS overall players (n = 160) 26.8 ± 4.9 (SD)	FS overall players (n = 318) 26.8 ± 5.6 (SD)
LS quarterback (n = 14) 24.5 ± 2.5	FS quarterback (n = 15) 23.9 ± 2.4
LS backfield (n = 75) 24.0 ± 3.1	FS backfield (n = 184) 24.0 ± 3.1
LS line player (n = 71) 29.9 ± 4.7**	FS line player (n = 119) 31.6 ± 5.7**
AFC Player BMI	NFC Player BMI
AFC overall players (n = 970) 31.7 ± 0.4 (SD)	NFC overall players (n = 961) 31.7 ± 0.4 (SD)
AFC quarterback (n = 47) 27.9 ± 0.6	NFC quarterback (n = 44) 27.8 ± 0.8
AFC backfield (n = 548) 29.0 ± 3.0	NFC backfield (n = 510) 28.7 ± 0.3
AFC line player (n = 375) 36.0 ± 0.6 **	NFC line player (n = 407) 35.8 ± 0.7**

Abbreviations: BMI, body mass index ([kg body weight]/[height in meter]^2); AFC, American Football Conference; NFC, National Football Conference; SD, standard deviation of the sample population about the mean; *P*, probability of null hypothesis being true.
**$P < .01$ significant difference for LS or FS mean BMI L versus mean BMI Q or mean BMI B.

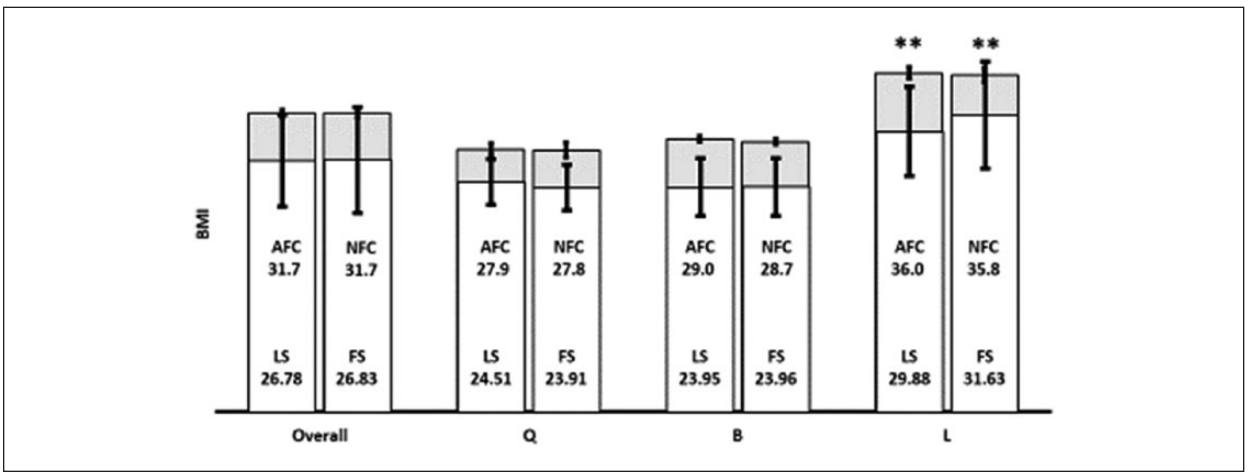

Figure 1. Public High School (PHS) for Lean State (LS) or Heavy State (FS), NFL American Football Conference (AFC) or National Football Conference (NFC) football position comparisons (quarterback [Q], backfield [B], line [L] players).
LS or FS BMI (mean ± SD) ☐ or AFC or NFC BMI (mean ± SD) ☐ + ▬
**$P < .01$ significant difference for LS mean BMI L versus Q or B or for FS mean BMI L versus Q or B.

with corresponding AFC BMI for Q, B or corresponding NFC BMI for Q, B (Figure 1).

Comparison of the ranges in heights, weights, and BMI for LS and FS PHS teams, AFC and NFC NFL teams show considerable overlap of values at corresponding Q, B, and L positions. Heights of PHS school players 5 feet to 6 feet 6 inches, anticipated to be completing their puberty growth into adult heights, are nearly as tall as the adult NFL players 5 feet 6 inches to 6 feet 9 inches. For all players, the PHS Line players are of particular concern as they are less well trained athletes yet have similar maximum 300 to 362 lb body weights compared with well-trained professional athletes in the NFL with maximum 350 to 364 lb body weights.

Discussion

Despite current political discourse and hazards associated with American football at all levels of play, participation in this sport remains a priority for many PHS males. Public Internet website accessible team rosters from PHS to professional NFL level of play permit calculation of individual player BMI from their reported heights and weights. Comparable player position tasks allow corresponding offensive and defensive positions to be combined into 3 groups: quarterbacks, backfield players, and line players.[15] Roster-designated quarterbacks are placed in the Q group as they rarely rotate to fill B positions and never fill L positions. Line players

are identified by their proximity to the line of scrimmage along which the ball is spotted for the next game play. All offensive and defensive line players (offensive center and guard, offensive tackle and defensive tackle and nose tackle, offensive tight end, and defensive end and linebackers) are placed in the L group. All other players are placed in the B group.

Professional football player's performance (reflected in game time played and income) is dependent on body composition. While performance is focused on winning for the team, media attention to American football has attracted society's interest in football players' long-term health as contributing to population health care concerns. Over several decades professional football players' heights have changed little while their weights have increased, especially for line players whose BMI have increased nearly 25% since 1972.[15] Professional football player body composition assessments by dual-energy X-ray absorptiometry and air-displacement plethysmography (Bod Pod) confirm major increases in BMIs occurred primarily in line players and support grouping offensive and defensive players in positions that mirror each other having similar body composition.[15-17]

Remarkably, we find mean BMI of Q, B, and L groups are similar for the 2014-2015 season corresponding groups at PHS and NFL levels of play regardless of regional LS or FS population BMI trends (obesity by BMI prevalence about 20% CO vs 35% MS).[12] Similar to other reports, we note L mean BMI are significantly ($P < .01$) higher than Q or B mean BMI and similar for corresponding player positions at the PHS and NFL levels of play. This raises concern for PHS line players' health risks associated with body fatness, metabolic syndrome, and BMI over 30 contributing to football injuries, not only physical trauma but also cardiovascular risk and environmental EHI and EHS morbidity and mortality.

Over 1 million PHS athletes compete in interscholastic football each school year.[1] Federal and state agencies gather injury-related data each season to improve guidelines focused on football injury rate reduction. A 2005-2006 epidemiology survey of high school sports randomly selected 100 study schools reporting injuries for boys' football (n = 1880), soccer (n = 372), basketball (n = 412), wrestling (n = 415), and baseball (n = 214); data gathered at Research Institute, Nationwide Children's Hospital, Columbus, OH.[3] This survey comparing practice and competition sustained injuries finds the greatest number of injuries to occur with boys' football (47.2% during practice and 50.3% during competition).[3] Reported injuries (231 782 during practice and 279 560 during competition) affected in order of occurrence: lower extremities (48.3% practice and 46.8% competition), upper extremities (29.0% practice and 29.7% competition), head/face/neck (14.0% practice and 17.1% competition), and trunk (8.7% practice and 6.4% competition). A 2012-2013 football season across 6 states survey of athletic trainers' reported injuries at each practice and competition compiled at Datalys Center for Sports Injury Research and Prevention Inc, Indianapolis, IN, compared with American youth football programs (boys 5-14 years of age) for injury rates in age participation versus age-and-weight participation team competition.[18] The authors conclude neither age only nor age-and-weight criteria for pairing competing teams are associated with lower injury rates among youth football players. However, the authors note their survey sample may not reflect all youth football players' injury risks. This survey and many similar survey results exemplify limitations of using weight comparisons rather than BMI to approximate a level playing field for competing entry level youth football athletes.

BMI as a sports injury risk factor is controversial. A 2017 systematic review of BMI and sports injury literature covered 1907 titles reduced by 2 or 3 independent reviewers to 35 full text articles addressing BMI and lower extremity sports injuries.[19] The majority of these articles report correlation between higher BMI and increased risk for injury, especially ankle and knee injuries likely due to conservation of momentum forces during rapid football movements on BMI challenged joints. None of the reviewed football player studies report low BMI to increase occurrence of knee injuries. However, articles that average overall injury rate per athletic exposure for contact and collision sports do not report BMI to correlate with injury. The authors conclude future studies of athletic exposures to potential injury should direct attention to associating BMI with specific injury in a specific sport.

Sports medicine literature to date associate estimates of physical maturation and bone strength with chronologic age. Human growth investigators recognize an individual's bone age, which can be read from a single hand X-ray per player compared with established bone age standard films, to be a marker for normal reproductive development events in both boys and girls. We suggest PHS sports studies should consider inclusion of individual player bone age to best assess physical maturation and identify presence of growth plates as vulnerable sites for Salter-Harris fractures reported to occur in 15% of childhood fractures.[20,21]

High school and college football player fatalities are rare but tragic, as estimated to average 12 per year or 1 per 100 000 participants. Most common causes of football player fatalities as reviewed from July 1990 through June 2010 relate to player health status, collision

injuries, and environmental stress: cardiac failure (n = 100, 41.2%), brain injury (n = 62, 25.5%), and EHI or EHS (n = 38, 15.6%).[4]

Cardiovascular disease risk is associated with BMI within the general child and adult population as well as NFL players. A comparison study of 504 active NFL players among 12 NFL teams and the CARDIA study of the general US population of 1959 young adult males 23 to 35 years of age reports BMI to be associated with increased low-density lipoprotein cholesterol, increased triglycerides, and decreased high-density lipoprotein cholesterol in the combined populations. This study reports BMI to be significantly ($P < .01$) associated with hypertension and prehypertension more commonly in NFL players than in the CARDIA group.[22,23]

EHI or EHS is of major concern with trainer and coach directed recommendations from the National and State Athletic Associations, particularly for preseason practice occurring during the hottest summer months.[1] A 2015 review of EHI occurrences in football players at all levels of play notes NFL level adjustments have effectively reduced mortality with no EHS deaths since August 2001 but more than 33 EHI-associated deaths have occurred since August 2001 at high school and collegiate football levels of play.[24] Several studies report nonfatal EHS events to occur 10 to 11 times greater in high school football players versus all other sports players combined.[24,25] A majority of EHI affected 2005 to 2009 football players are reported to have had elevated overweight BMI 25 to 29.9 (37.1%) or obese BMI >29.9(27.6%).[6]

Obesity is complex and remains a prime focus for biomedical research as a serious community health and socioeconomic concern. For the general population obesity is defined as BMI at or above 30 for adults or BMI for age and gender 95th percentile or greater for children and adolescents (http://www.cdc.gov/growthcharts), as 95th percentile boys' BMI reach 30 at 19½ years of age. Review of National Health and Nutrition Examination Surveys 1988 to 1994 through 2013 to 2014 for children and adolescents 2 to 19 years of age finds 2013-2014 prevalence of obesity to be 17.0% (95% confidence interval [CI] = 15.5% to 18.6%). Obesity prevalence for those 12 to 19 years of age rose from 10.5% (95% CI = 8.8% to 12.5%) in 1988 to 1994 to 20.6% (95% CI = 16.2% to 25.6%) in 2013 to 2014.[26]

PHS football players' maximum BMI 42.4 to 47.9 parallel NFL players' maximum BMI 44.3 to 45.0 for corresponding Q, B, and L player positions. However, professional football players' 6% to 13% estimated body fat is relatively healthier than entry level PHS football players' likely 18% to 25% or greater body fat with increased risk for morbidity and mortality when their BMI exceed 30.[6,23-25,27] Federal and state programs are legislated and funded to increase physical activity, improve nutrition, reduce injury and obesity among American children. These programs can be more efficiently utilized with an appreciation of a BMI upper limit for PHS football participation as health care professionals are encouraged to promote healthy weight-control practices in young athletes.[28]

Our study is limited by the number of publically accessible PHS football team rosters and the accuracy of measuring and reporting player heights, weights, and positions played. As team rosters at all levels of play do not report BMI, a player position bias toward a desirable mean BMI is not evident. Similarities of mean BMIs for player positions are seen at all levels of play and reasonably attributable to limits set by the game of American football itself. Our public health surveillance study does not include body fat content assessment, but sports medicine literature support the reduced and healthier body fat content of well-trained professional athletes relative to increased health risks for the higher body fat content of PHS males of similar BMI.

Conclusions

American football continues to attract participation of PHS males despite publicized risks for injury leading to long-term disability and even fatality. Despite American regional population obesity by BMI criteria ranging from about 20% in the "leanest" state (LS) to 35% in the "heaviest" state (FS), the results of our public health surveillance study support our hypothesis that the game of American football itself sets similar BMI limits for player positions at all levels of play. PHS line players are particularly prone to have obese BMI over 30 generally considered unhealthy for their body fat content often more than twice that of well-trained professional athletes of similar BMI. BMI over 30 also associate with more severe football injuries and EHI and EHS contributing to the majority of estimated 12 fatalities annually among PHS and college football players.

Our results encourage an appreciation of healthy physical exercise participation that can reasonably include setting a BMI upper limit of 30 for PHS football applicants. PHS obesity is clearly a national health care concern and a big budget item to establish local obesity management programs that could benefit PHS football applicants with BMI over 30. By implementing a BMI 30 limit, a similar 22% (vs 15% or less for weight limits set at 250 lb or greater) of PHS football players whether in LS or FS regions would be diverted to participate in obesity management programs prior to active PHS football participation (Figure 2). A BMI upper limit of 30 for PHS football applicants should significantly contribute

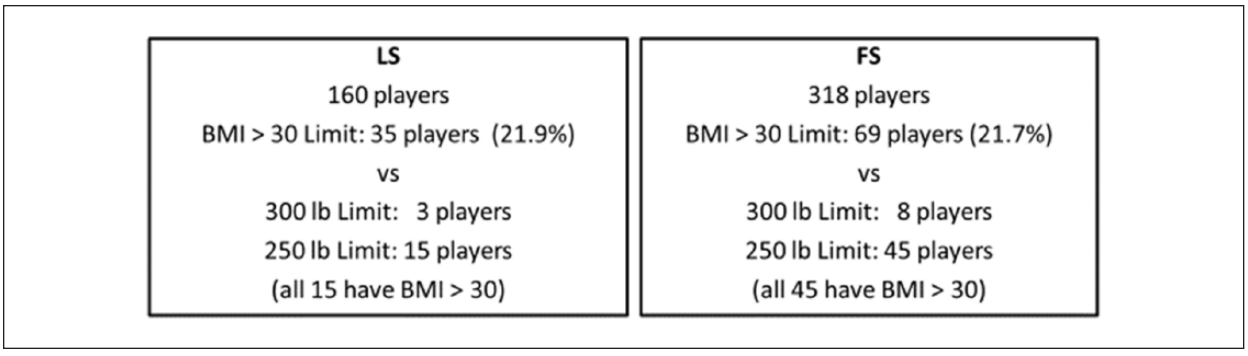

Figure 2. Football PHS 2014-2015 season lean state (LS) comparison with heavy state (FS) proposed BMI versus weight cutoffs.

to reduction in PHS football injuries and success of local PHS obesity management programs that are available and affordable through cooperative agreements and funding between state health departments and CDC Division of Nutrition, Physical Activity, and Obesity as well as private funding sources such as the Robert Wood Johnson Foundation.

Authors' Note

George Moll completed University of Mississippi Medical Center IRB Intranet Self-Certification form that the activity described here does not require IRB review as it is a Public Health Surveillance: "A series of ongoing systematic activities, including collection, analysis, and interpretation of health-related data."

Author Contributions

KM: Contributed to conception and design; contributed to analysis and interpretation; critically revised manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy.
GM: Contributed to conception and design; contributed to acquisition, analysis, and interpretation; drafted manuscript; critically revised manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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