

Body Size Changes Among National Collegiate Athletic Association New England Division III Football Players, 1956–2014: Comparison With Age-Matched Population Controls

Kayla R. Elliott, MBS, BA*; Jerold S. Harmatz, BA†; Yanli Zhao, BS†; David J. Greenblatt, MD*†

*Master of Science in Biomedical Science Program and †Program in Pharmacology and Experimental Therapeutics, Tufts University School of Medicine, Boston, MA

Context: Collegiate football programs encourage athletes to pursue high body weights.

Objective: To examine position-dependent trends over time in body size characteristics among football players in the National Collegiate Athletic Association Division III New England Small College Athletic Conference (NESCAC) from 1956 to 2014 and to compare the observed absolute and relative changes with those in age-matched male population controls.

Design: Descriptive laboratory study.

Setting: Medical school affiliated with a NESCAC institution.

Patients or Other Participants: Football team rosters from the 10-member NESCAC schools, available as public documents, were analyzed along with body size data from general population males aged 20 to 29 years from the National Health and Nutrition Examination Survey (NHANES).

Main Outcome Measure(s): Body weight, height, and calculated body mass index were evaluated using analysis of variance, linear regression, and nonlinear regression to determine the distribution features of size variables and changes associated with time (year), school, and position.

Results: Among NESCAC linemen, absolute and relative changes over time in body weight and body mass index exceeded corresponding changes in the NHANES population controls. New England Small College Athletic Conference offensive linemen body weights increased by 37.5% from 1956 to 2014 (192 to 264 lb [86.4 to 118.8 kg]), compared with a 12% increase (164 to 184 lb [73.8 to 82.8 kg]) since 1961 in the NHANES population controls. Body mass index changed in parallel with body weight and exceeded 35 kg/m² in more than 30% of contemporary NESCAC offensive linemen. Among skill players in the NESCAC group, time-related changes in body size characteristics generally paralleled those in the NHANES controls.

Conclusions: High body weight and body mass indices were evident in offensive linemen, even among those in Division III football programs with no athletic scholarships. These characteristics may be associated with adverse cardiovascular and metabolic outcomes. We need approaches to encourage risk modification in the postfootball lifestyles of these individuals.

Key Words: body weight, body mass index, obesity, Division III football, offensive linemen

Key Points

- In a Division III collegiate football league in New England, the mean weights of offensive linemen increased by 38% from 1956 to 2014, which significantly exceeds the rate for age-matched controls in the general population over the same period. Findings for defensive linemen and defensive ends were similar.
- For players in skill positions, the mean weight changes over time were similar to those in the control population.
- The increased prevalence of high body weight and body mass index values among contemporary college football linemen, even at the Division III level, is concerning because of their risk factors for adverse health consequences.

Body sizes among the North American and northern European populations have increased progressively since World War II,^{1–9} with consequent concern regarding the increasing prevalence of obesity and the accompanying health complications that include lipid disorders, diabetes, hypertension, and other cardiovascular diseases.^{2,3} Among a number of specific subpopulations, concerns relating to body size and body habitus might be greater than in the general population. American football players are a subgroup of obvious interest because size and strength are requisites for competitive success. Most of the epidemiologic and biomedical research involving football

players has focused on National Collegiate Athletic Association Division I players and the relatively few who go on to become professional players. In Division I, football players have generally been preselected for size, strength, and talent, with further physical development in college encouraged through diet and resistance training. Most athletes receive partial or full scholarship support, and their college life focuses on football. For this group of Division I players, the data consistently show progressive increases since the 1950s in mean body weight, body mass index (BMI) and, to a lesser extent, height.^{10–14} The greatest increases are seen in offensive and defensive linemen.

Table 1. Schools Participating in the New England Small College Athletic Conference

Name	Location	Entering Class Size ^a	Proportion of Males in Entering Class, % ^a
Amherst College	Amherst, MA	461	52.7
Bates College	Lewiston, ME	517	49.0
Bowdoin College	Brunswick, ME	501	50.5
Colby College	Waterville, ME	493	45.7
Hamilton College	Clinton, NY	475	48.0
Middlebury College	Middlebury, VT	602	48.5
Trinity College	Hartford, CT	611	52.0
Tufts University	Medford, MA	1309	47.7
Wesleyan University	Middletown, CT	808	50.2
Williams College	Williamstown, MA	545	49.0

^a Data for class of 2018 or 2019 gathered from school's Web site or collegesimply.com.

Among offensive linemen on Division I collegiate teams, body weights in excess of 300 lb (136 kg) and BMI values in excess of 35 kg/m² are typical^{15–18} and are accompanied by objective risk factors for the development of metabolic syndrome and cardiovascular disease.^{19–22} The body size and risk factor trends among National Football League players—most of whom came from Division I collegiate programs—are even greater.^{23–26}

Little information is available on body size trends among players in Division III football programs.^{22,27,28} Unlike Division I, there are no athletic scholarships as such in Division III programs. Scholarship support is based on financial need and is not modified or forfeited if a player elects to discontinue participation in the football program. Limited data suggest that body sizes have also increased among Division III players—particularly offensive and defensive linemen—but apparently to a lesser extent than in Division I.^{22,27,28} It is unusual for a Division III player to move on to professional football, and few have aspirations to that end.

We evaluated time trends in body size characteristics among football players in the New England Small College Athletic Conference (NESCAC), a Division III conference consisting of 11 colleges and universities located in New England and New York State. Ten of the NESCAC schools have football programs.

For contrast, we also evaluated contemporary body sizes among football players in the Ivy League, 2 Division I football conferences, and offensive linemen participating in the 2014 National Football League Combine as well as those on the roster of the 2014 New England Patriots. For comparison with men of similar ages in the general population, we used data from the National Health and Nutrition Examination Survey (NHANES), an ongoing national survey of health data sponsored by the Centers for Disease Control and Prevention's National Center for Health Statistics.^{2–9}

METHODS

This study was performed at Tufts University School of Medicine, which is part of the Health Sciences Campus of Tufts University.

New England Small College Athletic Conference Data

The 10 NESCAC participant schools with football programs, their locations, and their enrollments are shown in Table 1. With 1 exception (Tufts University), entering undergraduate

class enrollments range from 461 to 808 students. All NESCAC schools are coeducational, with a male : female ratio of close to 50:50. The football schedule consists of 8 games, all within the conference, and no postseason play.

Beginning with 1956, football team rosters for the 10 NESCAC schools were accessed in 5-year intervals to 2006 and then in 2011–2012 and 2014. Sources were public documents and included Internet-available rosters or archived football game programs (from individual collections or kindly made available by school officials). In 9 instances (out of 129), data for the target year were not available, in which case roster data from the nearest year above or below the target were substituted. With only 1 exception (1961), all 10 NESCAC teams were represented for each sampling time. The total number of players in the survey was 7880.

Roster information on body weight, height, and position were digitized, and BMI was calculated from height and body weight. Data management and interpretation were influenced by time-related changes in football rules and in NESCAC school operations. Two-platoon rules were instituted in 1965, subsequently yielding larger rosters and increased specialization by offensive and defensive positions. Up to 1966, rosters did not distinguish offensive and defensive players, so we categorized players in that era as offensive line, tight ends, or running backs. Beginning in 1972, freshmen eligibility for varsity play had the general effect of increasing roster sizes. Four NESCAC schools had been coeducational dating back to the 19th century, but 6 others were male only until coeducation was instituted between 1969 and 1978. This had the effect of reducing the net number of male students available for football participation, though this might have been partially offset by increased enrollment numbers in general. Finally, NESCAC rosters are now capped at 75, explaining the relatively constant mean roster sizes since 1996.

Data From Ivy League and Division I Colleges

We accessed Internet-available 2011–2012 football roster data from the Ivy League (Brown University, Columbia University, Cornell University, Dartmouth University, Harvard University, Princeton University, Yale University), the Atlantic Coast Conference (Boston College, Clemson University, Duke University, Florida State University, Georgetown University, Georgia Institute of Technology, North Carolina State University, University of Maryland, University of Miami, University of North Carolina, University of Virginia, Wake Forest University), and the Big 10 (Michigan State University, Northwestern University, Ohio State University, Pennsylvania State University, Purdue University, University of Illinois, Indiana University, University of Iowa, University of Michigan, University of Minnesota, University of Nebraska, University of Wisconsin).

Data From Professional Football Offensive Linemen

Internet-available data for offensive linemen were accessed for the National Football League 2014 Combine and for the 2014 New England Patriots.

National Health and Nutrition Examination Survey Data

Survey data were available as public documents,^{2–8} provided in intervals as follows: 1960–1962, 1971–1974, 1976–1980, 1988–1994, 1999–2002, 2003–2006,

Table 2. New England Small College Athletic Conference Body Size Data by Position, 1956–2014: Mean Body Weight (lb [kg]) per Year

Position	Year											Slope, lb (kg) per Decade	Slope Versus NHANES Slope (P Value)
	1956	1961	1966	1971	1976	1981	1986	1991	1996	2001	2006	2011–2012	2014
Offensive line	192 (86.4)	197 (88.7)	197 (88.7)	195 (87.8)	205 (92.3)	206 (92.7)	217 (97.7)	226 (101.7)	240 (108.0)	252 (113.4)	264 (118.8)	260 (117.0)	264 (118.8)
Defensive line ^a				207 (93.2)	207 (93.1)	209 (94.1)	216 (97.2)	226 (101.7)	236 (106.2)	236 (106.2)	238 (107.1)	237 (106.7)	241 (108.5)
Tight end	180 (81.0)	183 (82.4)	186 (83.7)	187 (84.2)	194 (87.3)	195 (87.8)	198 (89.1)	210 (94.5)	214 (96.3)	226 (101.7)	229 (103.1)	224 (100.8)	222 (99.9)
Defensive end ^a				187 (84.2)	193 (86.9)	195 (87.8)	194 (87.3)	205 (92.3)	214 (96.3)	220 (99.0)	228 (102.6)	229 (103.1)	NA
Wide receiver ^b				171 (77.0)	176 (79.2)	175 (78.8)	174 (78.3)	174 (78.3)	175 (78.8)	180 (81.0)	183 (82.4)	185 (83.3)	185 (83.3)
Linebacker ^a				188 (84.6)	189 (85.1)	196 (88.2)	196 (88.2)	200 (90.0)	202 (90.9)	204 (91.8)	210 (94.5)	206 (92.7)	206 (92.7)
Defensive back ^a				169 (76.1)	173 (77.9)	176 (79.2)	174 (78.3)	177 (79.7)	179 (80.6)	180 (81.0)	184 (82.8)	181 (81.5)	181 (81.5)
Running back	173 (77.9)	175 (78.8)	175 (78.8)	178 (80.1)	180 (81.0)	181 (81.5)	185 (83.3)	185 (83.3)	191 (86.0)	199 (89.6)	198 (89.1)	194 (87.3)	190 (85.5)
Quarterback ^a				174 (78.3)	177 (79.7)	177 (79.7)	179 (80.6)	182 (81.9)	185 (83.3)	193 (86.9)	196 (88.2)	192 (86.4)	195 (87.8)
Kicker ^a				164 (73.8)	178 (80.1)	176 (79.2)	167 (75.2)	173 (77.9)	184 (82.8)	175 (78.8)	185 (83.3)	187 (84.2)	187 (84.2)
Mean roster size	38	39	46	47	59	64	66	67	76	69	73	71	76

Abbreviations: NHANES, National Health and Nutrition Examination Survey; NA, not available.

^a In and before 1966, this position was not designated separately.

^b Before 1966, this position was not designated separately.

^c Indicates slope value is smaller than the slope for NHANES population controls.

Table 3. New England Small College Athletic Conference Body Size Data by Position, 1956–2014: Mean Height (in [cm]) per Year

Position	Year											Slope, in (cm) per Decade	Slope Versus NHANES Slope (P Value)
	1956	1961	1966	1971	1976	1981	1986	1991	1996	2001	2006	2011–2012	2014
Offensive line	71.5 (181.6)	71.8 (181.9)	71.6 (181.9)	71.8 (182.5)	72.5 (184.0)	72.4 (183.8)	73.0 (185.5)	73.1 (185.8)	73.4 (186.5)	74.1 (188.2)	73.8 (187.4)	74.0 (188.0)	74.2 (188.5)
Defensive line ^a				72.1 (183.2)	72.5 (184.0)	72.1 (183.2)	72.6 (184.3)	72.7 (184.8)	72.9 (185.2)	72.9 (185.0)	73.0 (185.5)	73.4 (186.4)	73.9 (187.7)
Tight end	72.4 (184.0)	72.6 (184.4)	72.6 (184.5)	72.8 (185.0)	73.4 (186.5)	73.3 (186.2)	74.19 (188.4)	74.2 (188.6)	74.1 (188.1)	74.4 (189.0)	74.3 (188.7)	75.1 (190.7)	74.9 (190.4)
Defensive end ^a				72.3 (183.7)	73.0 (185.3)	72.6 (184.3)	72.4 (183.9)	72.9 (185.2)	73.4 (186.4)	73.8 (187.5)	73.5 (186.6)	73.3 (186.2)	NA
Wide receiver ^b				71.3 (181.0)	72.1 (183.2)	71.5 (181.5)	71.2 (180.8)	71.8 (182.5)	71.3 (181.0)	71.5 (181.5)	71.6 (181.8)	72.3 (183.7)	72.7 (184.7)
Linebacker ^a				71.2 (180.9)	71.4 (181.4)	71.4 (181.4)	71.5 (181.7)	71.9 (182.6)	71.7 (182.0)	71.8 (182.5)	71.8 (182.4)	72.0 (182.8)	72.0 (182.9)
Defensive back ^a				70.5 (179.1)	70.7 (179.6)	70.7 (179.5)	70.6 (179.3)	70.6 (179.2)	70.8 (179.7)	71.0 (180.2)	70.8 (179.8)	70.9 (180.0)	70.7 (179.6)
Running back	70.3 (178.5)	70.3 (178.5)	70.3 (178.5)	70.0 (177.8)	70.5 (179.0)	70.0 (177.9)	70.4 (178.8)	70.1 (178.1)	70.3 (178.5)	70.7 (179.6)	70.2 (178.4)	70.1 (178.0)	69.7 (180.0)
Quarterback ^a				71.7 (182.2)	71.7 (182.1)	71.0 (180.3)	72.1 (183.0)	72.4 (184.0)	72.6 (184.5)	73.1 (185.7)	73.5 (186.6)	72.9 (185.2)	73.2 (186.0)
Kicker ^a				69.8 (177.3)	71.3 (181.2)	71.1 (180.6)	70.4 (178.7)	71.3 (181.1)	70.4 (178.8)	70.0 (177.8)	71.7 (182.2)	72.3 (183.6)	71.1 (180.5)
Mean roster size	38	39	46	47	59	64	66	67	76	69	73	71	76

Abbreviations: NHANES, National Health and Nutrition Examination Survey; NA, not available.

^a In and before 1966, this position was not designated separately.

^b Before 1966, this position was not designated separately.

^c Indicates slope value is smaller than the slope for NHANES population controls.

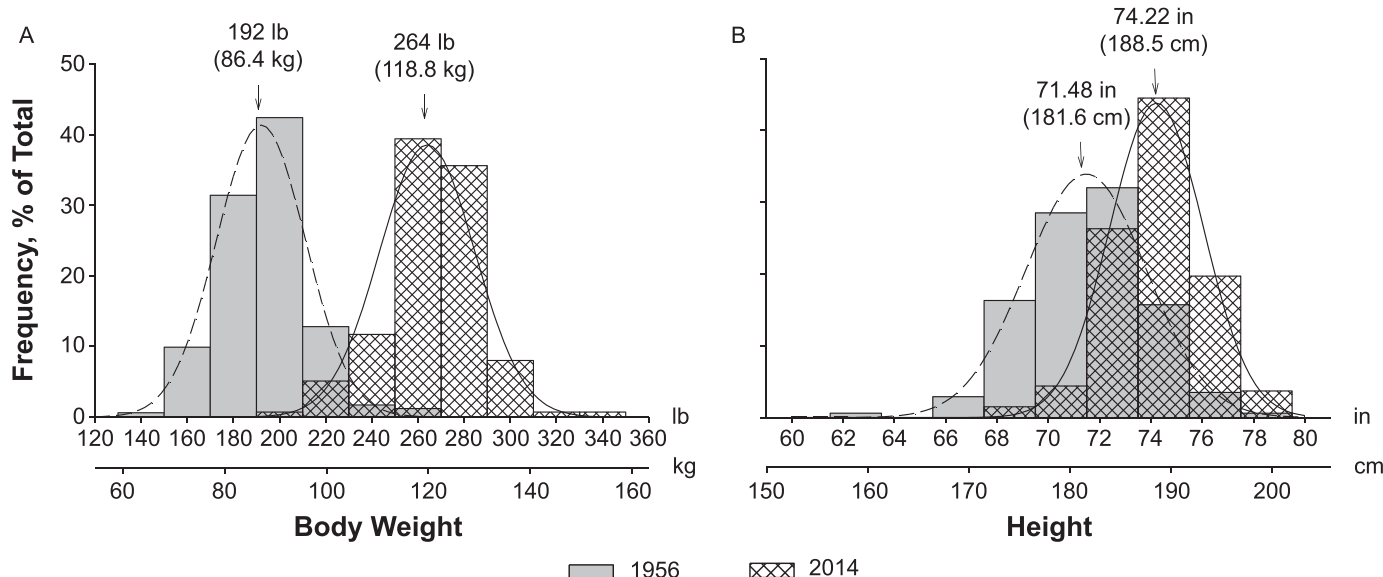


Figure 1. Frequency distributions for A, Body weight and B, Height among New England Small College Athletic Conference offensive linemen for the years 1956 ($n = 174$) and 2014 ($n = 137$). Lines indicate the functions of best fit based on a normal probability distribution. Values above the arrows indicate the arithmetic mean values.

2007–2010, and 2011–2012. For men aged 20 to 29 years, the mean (and standard error) values of height, body weight, and BMI were analyzed as presented.

Statistical Procedures

For the NESCAC data, we calculated descriptive statistics (arithmetic mean, standard deviation, and coefficient of variation) for body weight, height, and BMI at each time point, at each position, and for each school. Roster sizes were also determined. For the Division I football conference (2011–2012) and for the 2014 National Football League offensive linemen, descriptive statistics were calculated. For NHANES data, mean values of body weight, height, and BMI for each survey interval were presented as descriptive statistics and also used for subsequent analysis of changes over time.

The initial statistical analysis evaluated differences in body size among the 10 NESCAC schools. Within each sampling time (year) and at each position, 1-way analysis of variance (ANOVA) was performed for each of the size variables (body weight, height, and BMI) using the 10 schools as the independent groups. This analysis indicated that school differences were either not statistically significant or were small in magnitude (see Results). Accordingly, body size values for each position at each time point were averaged across the 10 schools and used for subsequent analysis.

Changes in body size variables over time from the NESCAC data base were evaluated by 2 methods. The first approach was a 1-way ANOVA using the 13 sampling time points as the independent groups. This was done for each position and for each of the 3 size measures.

The second approach evaluated rates of change over time in mean size within each position. Because the most appropriate model to describe time-related changes in this context has not been established, we assumed a linear model was the most straightforward approach and applied linear regression analysis. The independent variable was

time (year), and the dependent variable was the mean value of the body size characteristic at each position. Each analysis yielded a quantitative value of the slope (overall rate of change with time), along with the strength of the association (the r^2 value) and the statistical significance of the r^2 value.

The same linear regression analysis was performed on the NHANES data for men aged 20 to 29 years,^{2–8} with the time (year) values represented as the midpoint of the survey interval. The statistical significance of the difference in regression slope (rate of change with time) between the NHANES population controls and the NESCAC players at each position was evaluated using a general linear model to determine the statistical interaction of group assignment (NHANES versus NESCAC) in relation to time. This analysis yielded test statistics and inferences that were essentially identical to those derived from comparison of the slopes using the Student t test for independent groups.

For the NESCAC data, we also evaluated the characteristics of the distributions of body size. Within each position for each year, the consistency of the distributions with normal and log-normal statistical distribution patterns was evaluated using the Kolmogorov-Smirnov and Shapiro-Wilk tests.

RESULTS

New England Small College Athletic Conference Data

The mean body weight, height, and BMI for players in the 10 NESCAC schools at each time point (year) are shown in Tables 2 through 4. Within each position, differences in body size characteristics among the 10 schools in any given year were either not statistically significant ($P > .05$ from ANOVA) or were quantitatively small. Data for the 10 schools were therefore aggregated by year and position in Tables 2 through 4 and for subsequent analysis.

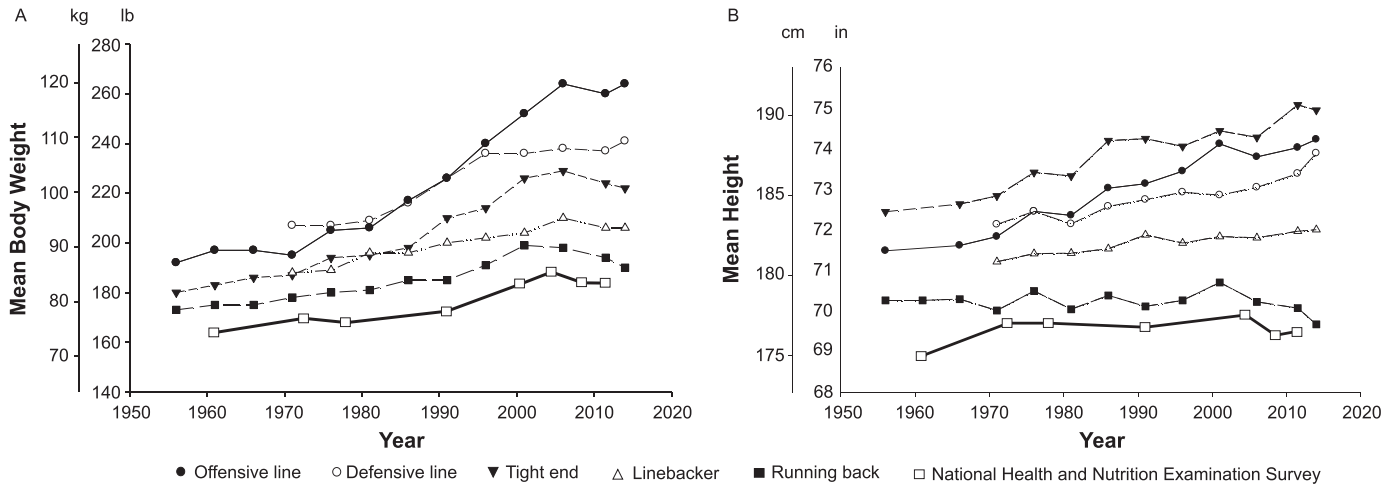


Figure 2. Changes over time in mean values for A, Body weight and B, Height among New England Small College Athletic Conference offensive linemen, defensive linemen, tight ends, linebackers, and running backs. Data for all positions are available in Tables 2 and 3. Shown for comparison purposes are corresponding mean body weights and heights among the general population of men aged 20 to 29 years based on the National Health and Nutrition Examination Survey.

Mean roster sizes increased from 38 per team in 1956 to 76 per team in 1996 (Tables 2 through 4). Thereafter, rosters stabilized in the range of 69 to 76 through 2014.

Body size variables were distributed unimodally (examples shown in Figure 1). In the majority of cases, the pattern was consistent with a normal distribution or with a log-normal distribution that was slightly positively skewed. With only a few exceptions, coefficients of variation (the arithmetic standard deviation divided by the arithmetic mean, expressed as a percentage) did not exceed 10% for body weight and BMI and did not exceed 5% for height.

Changes across time in mean body weight and height among NESCAC players at selected positions (see also Tables 2 and 3) are provided in Figure 2. Also shown in Figure 2 are mean values for the NHANES population control men aged 20 to 29 years (which will be discussed further in the article). Body weights among the NESCAC players changed significantly with time for all positions (Table 2, Figure 2). The r^2 values from linear regression exceeded 0.73 for all positions ($P < .001$) except kickers ($r^2 = 0.62$, $P < .03$). The largest increase was seen among the offensive linemen, with an overall increase of 14.20 lb (6.4 kg) per decade. Rates of increase were also high for defensive ends, defensive linemen, and tight ends (11.40, 9.00, and 8.90 lb [5.1, 4.1, and 4.0 kg] per decade, respectively). For the other positions, rates of increase were not different from or were actually smaller than those for men aged 20 to 29 years in the NHANES control population (Table 2). Maximum mean body weights in the NESCAC data set were reached in 2006, with no further increases through 2014.

Changes in height with time were significant for offensive and defensive linemen, tight ends, defensive ends, and quarterbacks (Table 3, Figure 2). For other positions, changes with time were not significant. The relative increases in height were far less than the increases in body weight. Among offensive linemen, for example, mean height increased from 71.5 in (181.6 cm) in 1956 to 74.2 in (188.5 cm) in 2014, a change of 3.8%. However, mean body weight increased from 192 to 264 lb (86.4 to

118.8 kg) during the same interval, a 37.5% change (Figures 1 and 2).

Changes in BMI with time were significant for all groups (r^2 exceeded 0.80, $P < .001$) except for kickers (Table 4). The patterns of change over time paralleled the changes observed in body weight. Among offensive linemen, the mean increase rate was 1.48 kg/m² per decade and reached a mean BMI of 34.13 kg/m² in 2006.

Increases in the percentage of offensive linemen with high BMI values across time were striking (Figure 3). By 2014, more than 90% of NESCAC offensive linemen had BMI values exceeding 30 kg/m², and more than 30% exceeded 35 kg/m² (Figure 3). Among the NHANES control men aged 20 to 29 years in the 2011–2012 survey, 31% had a BMI of 30 kg/m² or greater and 10% had a BMI of 35 kg/m² or greater.³

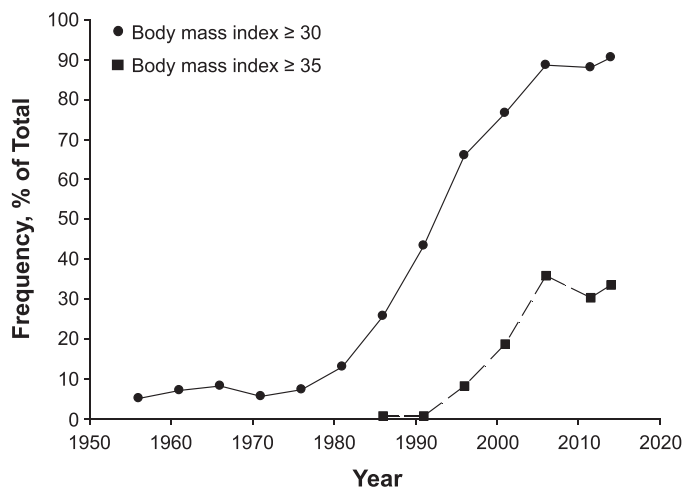


Figure 3. Changes over time in the percentage of New England Small College Athletic Conference offensive linemen who had a body mass index (BMI) ≥ 30 kg/m² or ≥ 35 kg/m². Note that the group with a BMI ≥ 30 kg/m² includes those with a BMI ≥ 35 kg/m².

Table 4. New England Small College Athletic Conference Body Size Data by Position, 1956–2014: Mean Body Mass Index (kg/m²) per Year

Position	Year													Slope, in per Decade	Slope Versus NHANES Slope (P Value)
	1956	1961	1966	1971	1976	1981	1986	1991	1996	2001	2006	2011–2012	2014		
Offensive line	26.36	26.81	27.02	26.56	27.37	27.63	28.67	29.64	31.33	32.22	34.13	33.48	33.80	1.48	<.001
Defensive line ^a				27.91	27.72	28.21	28.85	30.08	31.27	31.25	31.46	31.07	31.58	1.00	.04
Tight end	24.18	24.45	24.73	24.74	25.34	25.47	25.33	26.83	27.51	28.65	29.24	27.96	27.87	0.84	.20
Defensive end ^a				25.09	25.51	26.10	26.04	27.17	27.97	28.36	29.79	30.05	NA	1.30	<.001
Wide receiver ^b				23.68	23.72	24.05	24.14	23.74	24.22	24.82	25.14	24.91	24.96	0.34 ^c	.02
Linebacker ^a				26.00	25.99	26.98	26.87	27.25	27.71	27.84	28.62	28.04	28.05	0.55 ^c	.49
Defensive back ^a				23.84	24.29	24.71	24.54	24.96	25.17	25.11	25.85	25.39	25.47	0.37 ^c	.02
Running back	24.56	24.96	24.95	25.51	25.53	25.92	26.26	26.41	27.13	28.00	28.24	27.88	27.58	0.64	.98
Quarterback ^a				23.82	24.16	24.72	24.29	24.46	24.64	25.38	25.56	25.44	25.61	0.40 ^c	.042
Kicker ^a				23.74	24.50	24.41	23.60	23.99	26.08	25.11	25.29	25.15	26.07	0.45 ^c	.28
Mean roster size	38	39	46	47	59	64	66	67	76	69	73	71	76		

Abbreviations: NHANES, National Health and Nutrition Examination Survey; NA, not available.

^a In and before 1966, this position was not designated separately.

^b Before 1966, this position was not designated separately.

^c Indicates slope value is smaller than the slope for NHANES population controls.

Comparison of NESCAC Data With NHANES Population Controls

Mean body weight and height versus time (year) for NHANES population control men aged 20 to 29 years are illustrated in Figure 2. Mean body weight increased with time ($r^2 = 0.88$, $P < .001$). The overall slope (rate of increase over time) was 4.65 lb per decade (2.1 kg per decade). This slope was significantly smaller than the corresponding slope for NESCAC offensive and defensive linemen and defensive and tight ends (Table 2). For other positions, NHANES and NESCAC slopes were either not different or the NHANES slope was actually larger than the NESCAC slope.

The change in height with time among NHANES controls was small, averaging 0.03 in (0.1 cm) per decade; this was not statistically significant ($r^2 = 0.03$). The slope of height versus time for NESCAC offensive and defensive linemen, tight ends, and quarterbacks was greater than the NHANES slope (Table 3).

Body mass index increased in the NHANES controls ($r^2 = 0.90$, $P < .001$), from 24.3 kg/m² in 1960–1962 to 27.0 kg/m² in 2011–2012. The overall slope was 0.63 kg/m² per decade. This was significantly smaller than the slope for NESCAC offensive and defensive linemen and defensive ends but either not different from or larger than the slope for other NESCAC positions (Table 4).

Division I and Ivy League Football and Professional Offensive Linemen

Body size variables for players in the 2 Division I football conferences (Atlantic Coast and the Big 10) and the Ivy League are shown in Tables 5 through 7. Division I players were consistently larger than the NESCAC players, and the Ivy League players were in between those groups. Mean body weights for offensive linemen at the professional level were 313 lb (140.9 kg) for the 2014 National Football League Combine and 312 lb (140.4 kg) for the 2014 New England Patriots.

DISCUSSION

Increases in body sizes among American college football players over the last 50 years are well recognized.^{10–14} Also established is the position dependence of the size increases, with the changes being most evident among offensive linemen. Data on this topic have been derived principally from Division I collegiate football programs, with only limited information available from Division III programs.^{22,27,28} We evaluated body size characteristics among players in the NESCAC, a Division III conference located in New England and Eastern New York State, over the last nearly 60 years. Data were obtained from game program rosters or Internet-available rosters (or both), the accuracy of which cannot be fully validated. Nonetheless, the sample

Table 5. Body Weight by Position in 4 American Football Leagues, 2011–2012 (Arithmetic Mean [% Coefficient of Variation])

Position	League, lb (kg [% Coefficient of Variation])			
	New England Small College Athletic Conference	Ivy League	Atlantic Coast Conference	Big 10
Offensive line	264 (118.8 [9])	277 (124.7 [5])	296 (133.2 [7])	295 (132.8 [6])
Defensive line	237 (106.7 [8])	259 (116.6 [8])	283 (127.4 [9])	277 (124.7 [9])
Tight end	224 (100.8 [6])	237 (106.7 [5])	243 (109.4 [6])	244 (109.8 [6])
Defensive end	229 (103.1 [7])	238 (107.1 [5])	252 (113.4 [7])	251 (113.0 [6])
Wide receiver	185 (83.3 [8])	191 (86.0 [7])	191 (86.0 [8])	195 (87.8 [7])
Linebacker	206 (92.7 [7])	217 (97.7 [6])	223 (100.4 [6])	225 (101.3 [5])
Defensive back	181 (81.5 [7])	189 (85.1 [7])	192 (86.4 [8])	192 (86.4 [7])
Running back	194 (87.3 [8])	202 (90.9 [9])	208 (93.6 [11])	213 (95.9 [11])
Quarterback	192 (86.4 [6])	203 (91.4 [9])	209 (94.1 [8])	207 (93.2 [8])
Kicker	187 (84.2 [13])	186 (83.7 [9])	189 (85.1 [9])	193 (86.9 [8])

Table 6. Height by Position in 4 American Football Leagues, 2011–2012 (Arithmetic Mean [% Coefficient of Variation])

Position	League, in (cm [% Coefficient of Variation])			
	New England Small College Athletic Conference	Ivy League	Atlantic Coast Conference	Big 10
Offensive line	74.0 (188.0 [2.6])	75.8 (192.5 [2.1])	76.5 (194.3 [2.2])	76.6 (194.6 [2.3])
Defensive line	73.4 (186.4 [2.5])	74.6 (189.5 [2.1])	74.6 (189.5 [2.1])	75.3 (191.3 [1.8])
Tight end	75.1 (190.7 [1.6])	75.7 (192.3 [1.8])	76.1 (193.3 [1.6])	76.4 (194.1 [1.8])
Defensive end	73.3 (186.2 [1.2])	75.5 (191.8 [2.0])	75.9 (192.8 [2.0])	75.7 (192.3 [2.0])
Wide receiver	72.3 (183.7 [3.4])	72.7 (184.7 [3.1])	72.9 (185.2 [3.2])	73.4 (186.4 [2.9])
Linebacker	72.0 (182.8 [2.5])	73.2 (185.9 [1.9])	73.6 (186.9 [2.1])	73.5 (186.7 [2.0])
Defensive back	70.9 (180.0 [2.7])	71.4 (181.4 [2.4])	72.0 (182.9 [2.7])	71.7 (182.1 [2.5])
Running back	70.1 (178.0 [2.7])	71.0 (180.3 [2.3])	71.0 (180.3 [3.1])	71.5 (181.6 [2.8])
Quarterback	72.9 (185.2 [2.6])	74.1 (188.2 [2.1])	74.4 (189.0 [2.6])	74.3 (188.7 [2.3])
Kicker	72.3 (183.6 [3.5])	71.8 (182.4 [2.0])	72.6 (184.4 [3.3])	73.0 (185.4 [2.4])

size is large enough that the core findings are unlikely to be distorted by measurement or recording inaccuracies.

Sizes of the NESCAC players increased progressively and significantly from 1956 to 2014, with the increases being most evident from 1976 to 2006. The quantitative increases and the rates of increase were greatest among offensive linemen, with changes of similar magnitude among defensive linemen, tight ends, and defensive ends. In the context of NHANES data on time-related increases in body weight, height, and BMI over the last 50 years in men of comparable age in the general population, changes seen in this subgroup of NESCAC players substantially exceeded those in the population. For players at other positions, sometimes termed *skill positions*, quantitative size changes and rates of change, though statistically significant in some cases, were comparable with or smaller than those observed in the NHANES population data for men of comparable age.

Three previous reports of body size data for Division III football players (published in 1999,²⁷ 2003,²⁸ and 2008²²) have involved relatively small numbers and only a single time point. In those 3 studies, mean body weights for linemen ranged from 222 to 239 lb (99.9 to 107.6 kg), heights from 71.6 to 72.5 in (181.9 to 184.2 cm), and BMI values from 29.9 to 32.7 kg/m². These are smaller than the corresponding values for the same time periods in the NESCAC data (Table 2).

Contemporary body size data from Ivy League football and from 2 Division I football conferences indicate position-dependent findings similar to those observed for NESCAC players but with quantitative values exceeding

those in the NESCAC. Mean offensive linemen body weights were 264 lb (118.8 kg) in the NESCAC, 277 lb (124.7 kg) in the Ivy League, and 295 lb (132.8 kg) in the 2 Division I conferences. Mean body weights reached 313 lb (140.9 kg) for professional football offensive linemen.

Body mass index boundaries are commonly applied in both clinical and research settings to estimate the incidence of overweight or obesity. The association of BMI with more direct measures of body composition or percentage of body fat (such as hydrostatic weighing, bioelectric impedance analysis, air-displacement plethysmography, or dual-energy x-ray absorptiometry) is not perfect, and BMI may overestimate the degree of obesity in football players and other athletes.^{29–34} Despite these limitations of the BMI value, the findings nonetheless indicate that from 2006 to 2014, close to 90% of NESCAC offensive linemen had BMI values greater than 30 kg/m², and more than one-third exceeded 35 kg/m² (the usual boundary for class II obesity). As recently as 1981, only 13% of offensive linemen exceeded 30 kg/m² in BMI, further indicating that the emergence of linemen with high body weights and high BMIs, as well as their separation from men of comparable age in the general population, occurred over 3 decades or less.

This subgroup of players has developed in response to the competitive requirement for large linemen in contemporary American football, whether at the professional, college, or even high school and youth football level.^{35–37} Height in adults cannot, in principle, be modified by exogenous factors such as training and diet. As such, the heights of tight ends and offensive and defensive linemen, which

Table 7. Body Mass Index by Position in 4 American Football Leagues, 2011–2012 (Arithmetic Mean [% Coefficient of Variation])

Position	League, kg/m ² (% Coefficient of Variation)			
	New England Small College Athletic Conference	Ivy League	Atlantic Coast Conference	Big 10
Offensive line	33.5 (9)	33.9 (6)	35.7 (7)	35.5 (7)
Defensive line	31.1 (10)	32.8 (9)	35.9 (10)	34.5 (9)
Tight end	28.0 (5)	29.2 (6)	29.6 (6)	29.4 (6)
Defensive end	30.1 (7)	29.5 (5)	30.9 (7)	30.8 (7)
Wide receiver	24.9 (6)	25.5 (5)	25.3 (6)	25.6 (6)
Linebacker	28.0 (6)	28.6 (5)	29.0 (6)	29.3 (5)
Defensive back	25.4 (7)	26.1 (6)	26.0 (7)	26.4 (6)
Running back	27.9 (7)	28.2 (7)	29.0 (9)	29.3 (9)
Quarterback	25.4 (6)	26.0 (8)	26.5 (7)	26.4 (7)
Kicker	25.2 (10)	25.4 (8)	25.2 (8)	25.5 (8)

exceed the population mean by 3 in (7.6 cm) or more, are explained by selective recruiting of players with these height characteristics. In contrast, body weight and BMI can be modified, such that the high body weights and BMIs are explained by resistance training, conditioning, and nutritional programs,³⁸ in addition to selective recruiting.

CONCLUSIONS

The high body weights and BMI values among linemen in larger college and professional football programs are associated with an increased risk of adverse cardiovascular and metabolic sequelae. It is reasonable to suspect that similar risks are faced by NESCAC linemen. As such, we need research directed at assessing current and future risks, as well as approaches to modifying risk. This applies to NESCAC and other collegiate football linemen, as well as to collegiate athletes in general.

Programs directed at reversing high body weights and BMIs in players' postcollege lives have the potential to modify a substantial number of the associated risks. Such programs could be designed through the coordinated efforts of athletic trainers and coaching staff, medical personnel, exercise scientists, and nutritionists. These professionals would work with former players to identify attainable goals for body weight and exercise habits and on the design of nutritional and conditioning programs to reach and sustain these objectives to maximize the probability of favorable long-term health outcomes.

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Address correspondence to David J. Greenblatt, MD, Master of Science in Biomedical Science Program and Program in Pharmacology and Experimental Therapeutics, Tufts University School of Medicine, 136 Harrison Avenue, Boston, MA 02111. Address e-mail to dj.greenblatt@tufts.edu.