# Body Mass Index, Playing Position, Race, and the Cardiovascular Mortality of Retired Professional Football Players

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**Concern exists about cardiovascular disease (CVD) in professional football players. We examined whether playing position and size influence CVD mortality in 3,439 National Football League players with ≥5 pension-credited playing seasons from 1959 to 1988. Standardized mortality ratios (SMRs) compared player mortality through 2007 to the United States population of men stratified by age, race, and calendar year. Cox proportional hazards models evaluated associations of playing-time body mass index (BMI), race, and position with CVD mortality. Overall player mortality was significantly decreased (SMR 0.53, 95% confidence interval [CI] 0.48 to 0.59) as was mortality from cancer (SMR 0.58, 95% CI 0.46 to 0.72), and CVD (SMR 0.68, 95% CI 0.56 to 0.81). CVD mortality was increased for defensive linemen (SMR 1.42, 95% CI 1.02 to 1.92) but not for offensive linemen (SMR 0.70, 95% CI 0.45 to 1.05). Defensive linemen's cardiomyopathy mortality was also increased (SMR 5.34, 95% CI 2.30 to 10.5). Internal analyses found that CVD mortality was increased for players of nonwhite race (hazard ratio 1.69, 95% CI 1.13 to 2.51). After adjusting for age, race, and calendar year, CVD mortality was increased for those with a playing-time BMI ≥30 kg/m$^2$ (hazard ratio 2.02, 95% CI 1.06 to 3.85) and for defensive linemen compared to offensive linemen (hazard ratio 2.07, 95% CI 1.24 to 3.46). In conclusion, National Football League players from the 1959 through 1988 seasons had decreased overall mortality but those with a playing-time BMI ≥30 kg/m$^2$ had 2 times the risk of CVD mortality compared to other players and African-American players and defensive linemen had higher CVD mortality compared to other players even after adjusting for playing-time BMI. Published by Elsevier Inc. (Am J Cardiol 2012;109:889–896)**

In 1990 the National Football League (NFL) Players Association requested that the National Institute for Occupational Safety and Health (NIOSH) investigate the rate and causes of death of NFL players because of concerns about player longevity and excess cardiovascular disease (CVD) mortality. In 1994 the NIOSH[1] reported that players from the 1959 through 1988 seasons experienced decreased overall mortality, but CVD mortality was higher in linemen compared to nonlinemen and in players with an increased playing-time body mass index (BMI) compared to other players. Subsequent studies of retired and active professional players have documented higher rates of CVD risk factors—including hypertension, increased left atrial size, and metabolic syndrome—in relation to player position and size.[2–6] The 1994 report on NFL mortality was based on a small number of cardiovascular deaths (38) owing to the relatively short vital status follow-up period. We report on 16 additional years of follow-up, expanding our understanding of players' mortality as they age beyond their status as elite athletes.

## Methods

A cohort of 3,439 NFL players was constructed from a 1990 NFL pension fund database and included all pension-vested players (≥5 pension-credited playing seasons) from the 1959 through 1988 seasons. The pension fund database includes each player's name, Social Security number, date of birth, and year of each credited season. Player race was collected because of known racial differences in United States mortality. Race was determined based on players' self-identification using standard racial categories on a response form accompanying a letter introducing the study sent to players' last known address. For nonrespondents (48%) race was assigned using available pictures in yearly media guides.[1] Position played and height and weight during the last season played were assigned using data reported annually by the NFL teams and compiled in a commercial publication.[7] BMI (weight in kilograms divided by height in meters squared) was categorized using standard cutpoints: normal (18.5 to <25 kg/m$^2$), overweight (25 to <30 kg/m$^2$), and obese (≥30 kg/m$^2$).[8] Player position was categorized based on physiologic studies of college and professional players demonstrating differences in size, body composition, strength, and endurance: category I (defensive back, punter, kicker, quarterback, and wide receiver), category II (fullback, halfback, linebacker, running back, and tight end), and category III (linemen).[9,10] Because of our interest in linemen, we performed additional analyses on the 2 major subgroups, offensive and defensive linemen.

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Table 1
Characteristics of National Football League players cohort, overall and by position category (1960 to 2007)

| Variable | Overall (n = 3,439) | Position Category* | | | |
|---|---|---|---|---|---|
| | | I (n = 1,180) | II (n = 1,097) | III—Defensive (n = 498) | III—Offensive (n = 664) |
| Race | | | | | |
| White | 2,070 (60%) | 631 (53%) | 606 (55%) | 291 (58%) | 542 (82%) |
| African-American | 1,355 (39%) | 548 (46%) | 486 (44%) | 203 (41%) | 118 (18%) |
| Other | 14 (<1%) | 1 (<1%) | 5 (<1%) | 4 (1%) | 4 (1%) |
| Vital status as of December 31, 2007 | | | | | |
| Alive | 3,105 (90%) | 1,095 (93%) | 998 (91%) | 422 (85%) | 590 (89%) |
| Dead | 334 (10%) | 85 (7%) | 99 (9%) | 76 (15%) | 74 (11%) |
| First credited season | | | | | |
| Median (range) | 1973 (1950–1984) | 1973 (1950–1984) | 1974 (1950–1984) | 1972 (1950–1984) | 1972 (1950–1984) |
| Before 1980 | 2,685 (78%) | 912 (77%) | 847 (77%) | 398 (80%) | 528 (80%) |
| 1980 and after | 754 (22%) | 268 (23%) | 250 (23%) | 100 (20%) | 136 (20%) |
| Age (years) at first credited season† | | | | | |
| Median (range) | 22 (19–34) | 22 (19–34) | 22 (21–28) | 23 (21–28) | 22 (21–28) |
| ≤21 | 789 (23%) | 248 (21%) | 258 (24%) | 112 (22%) | 171 (26%) |
| 22 | 1,614 (47%) | 572 (48%) | 532 (48%) | 214 (43%) | 296 (45%) |
| 23 | 701 (20%) | 245 (21%) | 215 (20%) | 106 (21%) | 135 (20%) |
| ≥24 | 335 (10%) | 115 (10%) | 92 (8%) | 66 (13%) | 62 (9%) |
| Number of credited seasons‡ | | | | | |
| Median (range) | 8 (5–25) | 8 (5–25) | 7 (5–17) | 8 (5–20) | 8 (5–17) |
| Age (years) at death | | | | | |
| Median (range) | 54 (27–81) | 54 (27–80) | 53 (28–78) | 53 (31–81) | 55 (29–76) |
| Age (years) at date last observed—nondeceased | | | | | |
| Median (range) | 57 (45–88) | 57 (45–88) | 56 (45–82) | 58 (45–84) | 57 (45–83) |
| <50 | 633 (20%) | 218 (20%) | 212 (21%) | 84 (20%) | 119 (20%) |
| 50–54 | 738 (24%) | 267 (24%) | 263 (26%) | 82 (19%) | 126 (21%) |
| 55–59 | 565 (18%) | 197 (18%) | 162 (16%) | 90 (21%) | 116 (20%) |
| 60–69 | 890 (29%) | 309 (28%) | 282 (28%) | 120 (28%) | 179 (30%) |
| ≥70 | 279 (9%) | 104 (9%) | 79 (8%) | 46 (11%) | 50 (8%) |
| Body mass index (kg/m$^2$) | | | | | |
| Median (range) | 29 (22–39) | 26 (22–34) | 29 (24–34) | 31 (24–37) | 31 (25–39) |
| 18.5–<25 | 342 (10%) | 337 (29%) | 4 (<1%) | 1 (<1%) | 0 (0%) |
| 25–<30 | 1,944 (57%) | 841 (71%) | 897 (82%) | 114 (23%) | 92 (14%) |
| 30–<35 | 1,125 (33%) | 2 (<1%) | 196 (18%) | 372 (75%) | 555 (84%) |
| ≥35 | 28 (1%) | 0 (0%) | 0 (0%) | 11 (2%) | 17 (3%) |

Data are reported as number (percentage). Percentages may not sum to 100% because of rounding.

* Player position was categorized into 3 broad position categories: category I (defensive back, n = 549; punter/kicker, n = 79; punter, n = 49; quarterback, n = 192; and wide receiver, n = 311), category II (fullback, n = 89; halfback, n = 55; linebacker, n = 513; offensive end, n = 4; running back, n = 252; and tight end, n = 184), and category III (defensive positions: defensive end, n = 238; defensive lineman, n = 41; defensive tackle, n = 174; nose guard, n = 7; and nose tackle, n = 38; offensive positions: center, n = 126; offensive guard, n = 234; offensive lineman, n = 62; and offensive tackle, n = 242).

† Age at first credited season is age on July 1 of the year of the first credited season of play.

‡ Number of credited seasons does not necessarily equal the number of seasons played.

Vital status was ascertained from multiple sources: NFL pension fund death records, Social Security Administration Death Master File, and Internal Revenue Service records. Players were matched to the National Death Index from 1979, when the National Death Index began, through the study end date, December 31, 2007. The National Death Index provided underlying causes of death coded to the revision of the *International Classification of Diseases* in effect at the time of death. When death information was not provided by the National Death Index, hardcopy death certificates were obtained from state vital statistics offices and were coded by a certified nosologist.

NFL player mortality was compared to the general United States population using the NIOSH life-table analysis system.[11] Because all cohort members had a minimum of 5 credited seasons, a risk begin date was determined as the approximate date at the end of the fifth credited season (assigned as February 1). Each cohort member accumulated person-years at risk for each year of life from the risk begin date until the date of death or the study end date, whichever came first. To calculate the expected number of deaths, person-years at risk were stratified into 5-year intervals by age and calendar time and then multiplied by the appropriate United States race- and cause-specific mortality rates for

Table 2
Observed and expected number of deaths and standardized mortality ratios, National Football League players cohort (1960 to 2007)

| Underlying Cause of Death* | Observed | Expected | SMR† | 95% CI |
|---|---|---|---|---|
| All causes | 334 | 625.2 | 0.53 | 0.48–0.59 |
| All cancers | 85 | 146.8 | 0.58 | 0.46–0.72 |
| Digestive organs and peritoneum | 33 | 39.0 | 0.85 | 0.58–1.19 |
| Respiratory system | 16 | 52.0 | 0.31 | 0.18–0.50 |
| Genital organs | 6 | 6.4 | 0.93 | 0.34–2.03 |
| Urinary organs | 5 | 6.8 | 0.74 | 0.24–1.72 |
| Other and unspecified sites | 12 | 22.5 | 0.53 | 0.28–0.93 |
| Neoplasms of lymphatic and hematopoietic tissue | 13 | 15.3 | 0.85 | 0.45–1.45 |
| Hodgkin disease | 3 | 1.0 | 2.99 | 0.62–8.73 |
| Tuberculosis and diseases related to human immunodeficiency virus | 4 | 28.8 | 0.14 | 0.04–0.36 |
| Diseases of blood and blood-forming organs | 2 | 2.6 | 0.78 | 0.09–2.82 |
| Diabetes mellitus | 7 | 16.5 | 0.42 | 0.17–0.87 |
| Mental, psychoneurotic, and personality disorders | 4 | 11.7 | 0.34 | 0.09–0.87 |
| Diseases of nervous system and sense organs | 12 | 9.7 | 1.24 | 0.64–2.16 |
| Cardiovascular disease | 126 | 186.2 | 0.68 | 0.56–0.81 |
| Diseases of heart | 113 | 149.8 | 0.75 | 0.62–0.91 |
| Coronary heart disease | 79 | 110.8 | 0.71 | 0.56–0.89 |
| Cardiomyopathy | 14 | 9.9 | 1.42 | 0.77–2.38 |
| Other diseases of circulatory system | 13 | 36.4 | 0.36 | 0.19–0.61 |
| Diseases of respiratory system | 6 | 31.9 | 0.19 | 0.07–0.41 |
| Diseases of digestive system | 9 | 34.0 | 0.27 | 0.12–0.50 |
| Diseases of musculoskeletal and connective tissue | 5 | 1.7 | 3.00 | 0.97–7.00 |
| Diseases of genitourinary system | 4 | 8.7 | 0.46 | 0.13–1.18 |
| Symptoms and ill-defined conditions | 3 | 10.0 | 0.30 | 0.06–0.88 |
| Transportation injuries | 19 | 32.3 | 0.59 | 0.35–0.92 |
| Falls | 3 | 4.4 | 0.68 | 0.14–2.00 |
| Other injury | 19 | 28.2 | 0.67 | 0.41–1.05 |
| Violence | 13 | 48.3 | 0.27 | 0.14–0.46 |
| Intentional self-harm | 9 | 21.8 | 0.41 | 0.19–0.78 |
| Assault and homicide | 4 | 26.4 | 0.15 | 0.04–0.39 |
| Other causes | 9 | 21.1 | 0.43 | 0.19–0.81 |
| Unknown cause of death | 4 | — | — | — |

* International Classification of Diseases codes were mapped to cause-of-death categories as tabulated on the National Institute for Occupational Safety and Health Web site (http://www.cdc.gov/niosh/ltas/rates.html). Categories omitted because no deaths occurred include cancers of the buccal cavity and pharynx, cancers of the breast, benign and unspecified nature neoplasms, and diseases of the skin and subcutaneous tissue.

† United States referent rates.

men in 119 cause-of-death categories. For each cause of death the expected numbers of deaths were summed across the strata and the ratio of observed to expected number of deaths was expressed as the standardized mortality ratio (SMR). Ninety-five percent confidence intervals (CIs) were obtained using exact methods when the observed number of deaths was $\leq 10$ or approximate methods when the observed number of deaths was $>10$. SMRs were also calculated by position category and for the offensive and defensive linemen subgroups.

Internal analyses compared mortality across player position categories. Because stratified SMRs are generally not comparable, directly standardized rate ratios and 95% CIs for each position category relative to category I were obtained using the life-table analysis system.[11] We also used Cox proportional hazards regression models to evaluate the association of position category and BMI with CVD mortality (*International Classification of Diseases, Tenth Revision* codes I00 through I78). Attained age was used as the time scale; consequently, age was controlled for in the models. BMI was treated as a categorical variable using standard cutpoints but additional models treating BMI as a continuous variable were evaluated. In addition to position category and BMI, other covariates included race (white/Hispanic, African-American/all other races), era of play (play ended before vs in 1980 [median] or later), and time since last played ($<10$ vs $\geq 10$ years). We also controlled

Table 3
Mortality for selected causes of death stratified by position category, National Football League players cohort (1960 to 2007)

| Underlying Cause of Death and Position Category* | No. of Deaths | SMR† (95% CI) | SRR (95% CI) |
|---|---|---|---|
| All causes | | | |
| Category I | 85 | 0.38 (0.30–0.47) | 1 (reference) |
| Category II | 99 | 0.52 (0.42–0.63) | 1.37 (1.02–1.83) |
| Category III | 150 | 0.72 (0.61–0.85) | 1.89 (1.44–2.47) |
| Defensive‡ | 76 | 0.80 (0.63–1.00) | 2.13 (1.55–2.91) |
| Offensive | 74 | 0.65 (0.51–0.82) | 1.74 (1.25–2.43) |
| All cancers (C00–C97)§ | | | |
| Category I | 15 | 0.29 (0.16–0.47) | 1 (reference) |
| Category II | 30 | 0.69 (0.46–0.98) | 2.29 (1.23–4.28) |
| Category III | 40 | 0.79 (0.56–1.08) | 2.77 (1.52–5.04) |
| Defensive | 20 | 0.89 (0.54–1.37) | 3.04 (1.55–5.97) |
| Offensive | 20 | 0.71 (0.43–1.10) | 2.25 (1.13–4.49) |
| All cardiovascular disease (I00–I78) | | | |
| Category I | 32 | 0.48 (0.33–0.67) | 1 (reference) |
| Category II | 29 | 0.52 (0.35–0.74) | 1.03 (0.62–1.71) |
| Category III | 65 | 1.03 (0.80–1.32) | 2.14 (1.39–3.30) |
| Defensive | 41 | 1.42 (1.02–1.92) | 3.07 (1.92–4.92) |
| Offensive | 24 | 0.70 (0.45–1.05) | 1.50 (0.85–2.66) |
| Coronary heart disease (I20–I22, I24–I25, I51.3, I51.6) | | | |
| Category I | 20 | 0.51 (0.31–0.78) | 1 (reference) |
| Category II | 19 | 0.58 (0.35–0.90) | 1.04 (0.55–1.96) |
| Category III | 40 | 1.04 (0.74–1.41) | 1.83 (1.06–3.14) |
| Defensive | 22 | 1.27 (0.80–1.93) | 2.51 (1.36–4.65) |
| Offensive | 18 | 0.84 (0.50–1.33) | 1.39 (0.72–2.66) |
| Cardiomyopathy (I42) | | | |
| Category I | 3 | 0.82 (0.17–2.40) | 1 (reference) |
| Category II | 2 | 0.64 (0.08–2.33) | 0.83 (0.14–5.04) |
| Category III | 9 | 2.89 (1.32–5.49) | 4.44 (1.19–16.6) |
| Defensive | 8 | 5.34 (2.30–10.5) | 8.74 (2.30–33.2) |
| Offensive | 1 | 0.62 (0.02–3.45) | 1.42 (0.15–13.7) |

* Player position was categorized into 3 broad position categories: category I (defensive back, punter/kicker, punter, quarterback, and wide receiver), category II (fullback, halfback, linebacker, offensive end, running back, and tight end), and category III (defensive positions: defensive end, defensive lineman, defensive tackle, nose guard, and nose tackle; offensive positions: center, offensive guard, offensive lineman, and offensive tackle).

† United States referent rates.

‡ Category III group was further divided into offensive and defensive positions.

§ Underlying cause of death (*International Classification of Diseases, Tenth Revision* codes).

SRR = standardized rate ratio (within-cohort comparison).

for the calendar year of follow up (by decades) because recent studies have found that age-adjusted CVD mortality has been decreasing over time.[12] Because BMI and position category are strongly associated, in our models we first examined the independent effect of BMI on CVD mortality. Additional models examined the added effect of position category on CVD mortality while adjusting for the role of BMI.

The proportional hazards assumption for BMI was tested using a time-dependent interaction term between age ($<55$ vs $\geq 55$ years) and BMI category. To examine the impact of possible racial misclassification we conducted additional stratified analyses comparing findings for players with self-reported versus observationally assigned race. All regression modeling used the SAS 9.2 procedure PHREG (SAS Institute, Cary, North Carolina). A 2-sided p value $<0.05$ was considered statistically significant. The study protocol was approved by the NIOSH institutional review board.

## Results

The initial cohort included 3,732 NFL players but 292 players with unknown race and 1 "player" who was actually a trainer were excluded. By the end of follow-up in 2007, the final cohort of 3,439 players contributed 104,776 person-years at risk and 334 deaths. On average the cohort was followed for 26.8 ± 8.7 years (mean ± SD) after retirement from the NFL. For players still alive, the median age at the study end date was 57 years; 60% of the players were white (including 15 Hispanics) and 39% were African-American (Table 1). Players were evenly distributed among the 3 position categories and 10% of the cohort had a BMI $<25$ kg/m$^2$ and 34% had a BMI $\geq 30$ kg/m$^2$. BMI varied across position categories with $<1\%$ of category I, 18% of category II, and 82% of category III players having a BMI $\geq 30$ kg/m$^2$. Demographically, the players were similar across the position categories except a larger proportion of category III players were of white race. Within category III offensive

Table 4
Cox proportional hazards regression models for cardiovascular disease mortality with body mass index at last season played, National Football League players cohort (1960 to 2007)

| Term | No. of Deaths | Hazard Ratio (95% CI) | | | |
|---|---|---|---|---|---|
| | | Model 1* | Model 2† | Model 3‡ | Model 4§ |
| Body mass index (kg/m$^2$) | | | | | |
| 18.5–<25 | 11 | 1 (reference) | 1 (reference) | 1 (reference) | 1 (reference) |
| 25–<30 | 53 | 0.82 (0.43–1.58) | 0.85 (0.45–1.64) | 0.80 (0.39–1.65) | 0.80 (0.39–1.65) |
| ≥30 | 62 | 1.85 (0.98–3.52) | 2.02 (1.06–3.85) | 1.54 (0.64–3.71) | 1.58 (0.66–3.78) |
| Race | | | | | |
| White | 84 | | 1 (reference) | 1 (reference) | 1 (reference) |
| Nonwhite | 42 | | 1.69 (1.13–2.51) | 1.71 (1.15–2.55) | 1.57 (1.05–2.36) |
| Calendar year | | | | | |
| Before 1980 | 9 | | 1 (reference) | 1 (reference) | 1 (reference) |
| 1980–1989 | 24 | | 0.76 (0.33–1.72) | 0.77 (0.34–1.74) | 0.78 (0.35–1.78) |
| 1990–1999 | 42 | | 0.43 (0.18–1.01) | 0.44 (0.19–1.03) | 0.45 (0.19–1.07) |
| 2000 and after | 51 | | 0.26 (0.10–0.64) | 0.27 (0.11–0.66) | 0.28 (0.12–0.71) |
| Player position□ | | | | | |
| Category I | 32 | | | 1 (reference) | 1 (reference) |
| Category II | 29 | | | 1.02 (0.58–1.81) | 1.01 (0.57–1.78) |
| Category III | | | | 1.38 (0.72–2.64) | |
| Defensive | 41 | | | | 1.86 (0.96–3.62)¶ |
| Offensive | 24 | | | | 0.90 (0.43–1.86) |
| Model fit | | | | | |
| −2 log likelihood | | 1,792.11 | 1,775.01 | 1,773.60 | 1,765.48 |
| Akaike information criterion | | 1,796.11 | 1,787.01 | 1,789.60 | 1,783.48 |
| Schwarz Bayesian criterion | | 1,801.78 | 1,804.02 | 1,812.30 | 1,809.00 |
| Likelihood-ratio test | | vs null model | vs model 1 | vs model 2 | vs model 2 |
| Chi-square (degrees of freedom) | | 18.86 (2) | 17.10 (4) | 1.40 (2) | 9.53 (3) |
| p Value | | <0.001 | 0.002 | 0.50 | 0.02 |

* Model 1 hazard ratios for body mass index are adjusted for age only.

† Model 2 hazard ratios for body mass index are adjusted for age, race, and calendar year. Primary era of play and number of years since last played were not significant predictors (i.e., p >0.05) and did not confound the relation between cardiovascular disease mortality and body mass index.

‡ Model 3 hazard ratios for player position are adjusted for age, body mass index, race, and calendar year.

§ In Model 4, position category III was further divided into offensive and defensive positions; hazard ratios for player position are adjusted for age, body mass index, race, and calendar year.

□ Player position was categorized into 3 broad position categories: category I (defensive back, punter/kicker, punter, quarterback, and wide receiver), category II (fullback, halfback, linebacker, offensive end, running back, and tight end), and category III (defensive positions: defensive end, defensive lineman, defensive tackle, nose guard, and nose tackle; offensive positions: center, offensive guard, offensive lineman, and offensive tackle).

¶ Adjusting for age, body mass index, race, and calendar year; the hazard ratio for defensive versus offensive linemen is 2.07 (95% confidence interval 1.24 to 3.46) and the hazard ratio for defensive linemen versus all other positions is 1.97 (95% confidence interval 1.29 to 3.00).

and defensive linemen were similar except offensive linemen were more likely to be of white race and to have a BMI ≥30 kg/m$^2$.

Compared to the United States population, overall mortality and mortality from cancer and CVD were significantly decreased (Table 2). Overall mortality for all 3 position categories was also decreased (Table 3). CVD mortality was significantly decreased for position categories I and II but not for category III. A subgroup analysis showed that defensive but not offensive linemen had increased SMRs for all CVDs and cardiomyopathy. Internal analyses (standardized rate ratios) comparing mortality across position categories also found higher standardized CVD mortality rates for defensive but not for offensive linemen compared to category I positions.

Internal analysis using Cox proportional hazards regression modeling of the 126 CVD deaths (Table 4) compared CVD mortality by position and BMI. Adjusting for age, race, and calendar year, CVD mortality was associated with having a playing-time BMI ≥30 kg/m$^2$ and with being nonwhite. CVD mortality risk decreased from the 1980s through the 2000s. Era of play and years since retirement from professional football were not significant predictors of CVD mortality. After adjusting for BMI, age, race, and calendar year, compared to position category I players, CVD mortality was not increased for category II or III players.

In our subgroup analysis of category III offensive and defensive linemen (model 4; Table 4) CVD mortality for defensive linemen, adjusting for BMI, age, race, and calendar year, was increased compared to offensive linemen (hazard ratio 2.07, 95% CI 1.24 to 3.46) and to all other positions combined (hazard ratio 1.97, 95% CI 1.29 to 3.00). Also, we found a statistically significant interaction between decade of follow-up and defensive linemen position (likelihood ratio, chi-square 8.1, 3 degrees of freedom, p = 0.04). Adjusting for age, race, and BMI, the increased CVD mortality in defensive linemen compared to other players was observed only for follow-up years before 2000 (Figure 1). This pattern was caused by a steeper decrease in

CVD mortality before 2000 for the other players compared to defensive linemen.

There was some evidence that the proportional hazards assumption for BMI was violated. The likelihood-ratio test for interaction between age (<55 vs ≥55 years) and categorical BMI was significant (chi-square 7.8, 2 degrees of freedom, $p = 0.02$). After adjusting for race, calendar year, and defensive linemen position, hazard ratios for the 25 to 29- and ≥30-kg/m$^2$ BMI categories were 0.59 (95% CI 0.22 to 1.59) and 1.91 (95% CI 0.73 to 4.98) for follow-up ages <55 years but 0.97 (95% CI 0.41 to 2.31) and 1.08 (95% CI 0.42 to 2.72) for follow-up ages ≥55 years.

BMI was also examined as a continuous variable using log-linear, log-quadratic, threshold, and spline approaches (not shown), and although the categorical model was the best-fitting model, other models produced similar results. For example, the threshold model predicted no increase in risk of CVD mortality until BMI exceeded 28.4 kg/m$^2$ and a hazard ratio of 1.24 for each additional unit increase in BMI.

## Discussion

Overall, retired NFL players from the 1959 through 1988 seasons showed decreased all-cause and CVD mortalities compared to a referent United States population of men. When examining CVD mortality by playing position, defensive linemen had a 42% higher CVD mortality compared to the United States population of men, whereas offensive linemen had no increase. Players with a playing-time BMI ≥30 kg/m$^2$ had 2 times the CVD mortality risk compared to other players. After adjusting for differences in playing-time BMI, African-American players had a higher CVD mortality risk compared to white players and defensive linemen had a higher CVD mortality risk compared to other players including offensive linemen.

Players' overall decreased mortality risk is likely explained by several factors. Previous studies have documented players' low level of cigarette smoking,[2,4] an important contributor to decreasing mortality.[13] Although 90% of players would be classified as overweight or obese based on BMI alone, BMI is likely to overestimate adiposity in athletes who have a larger proportion of muscle mass.[14,15] Players' body composition and high fitness levels[9] likely contribute to their lower than expected overall mortality compared to the general United States population, especially given their increased size.[16]

Our study found a doubling of CVD mortality risk for players with a BMI ≥30 kg/m$^2$ compared to other players. Recent studies of active players have found that many of the largest players, including linemen, had a body fat content >25%, placing them at a higher risk for CVDs.[14] This finding combined with other recent studies demonstrating increased CVD risk factors in active and retired NFL players, especially in linemen and players with higher BMIs, support our findings. Rice et al[6] found higher levels of diastolic blood pressure and fasting glucose and lower high-density lipoproteins in linemen compared to nonlinemen. Tucker et al[4] found no significant difference in rates of hypertension or prehypertension by position but demonstrated an association with BMI. Studies comparing retired linemen to nonlinemen have found an increased risk for metabolic syndrome,[2] greater evidence of sleep disordered breathing,[17] and echocardiographic evidence of greater wall thickness and larger chamber size.[3] Retired players with a mean BMI of 31.5 kg/m$^2$ had a prevalence of carotid artery plaques similar to obese patients in tertiary referral centers of similar age, gender, and BMI and 3 times the prevalence in age- and gender-matched patients from the general population.[5] Our findings and those of these other studies provide increasing evidence that, despite being elite athletes, NFL players with BMI ≥30 kg/m$^2$ are at increased risk for CVD risk factors and CVD mortality like others in the general population with increased BMIs.[18]

In our subgroup analysis of linemen the observed difference in CVD mortality between defensive and offensive linemen was unexpected as was the excess mortality for defensive linemen after adjusting for playing-time BMI. This observed difference resulted from other players having a steeper decrease in CVD mortality from the 1970s through the 1990s compared to the defensive linemen. Our observed decrease in CVD mortality risk over calendar time is consistent with other studies of the general United States population showing decreases in CVD risk factors and CVD mortality attributed to improved medical therapies and public health.[12,19] Differential access to or compliance with these primary and secondary prevention methods between linemen subgroups, especially given linemen's increased size, could contribute to the observed mortality differences and deserves further evaluation. Since 2000 the CVD mortality risk for defensive linemen, after accounting for differences in size, has been similar to other players, perhaps indicating a positive impact from the increased media attention and expanded health promotion campaigns by the NFL and the NFL Players Association since the initial NIOSH report in 1994.[2,4]

Racial disparities in CVD risk factors, morbidity, and mortality are well documented in the general population[20] and are partly explained by racial differences in socioeconomic status.[21] The racial disparity in CVD mortality in NFL players is notable given players' more similar socioeconomic status during their playing career and the absence of racial differences in the prevalence of hypertension or prehypertension in active NFL players.[4] Recent initiatives such as the American College of Cardiology's Coalition to Reduce Racial and Ethnic Disparities in Cardiovascular Disease Outcomes (CREDO)[22] are providing tools to clinicians based on evidence-based practices to decrease racial disparities in clinical practice and could potentially contribute to decreasing racial disparities in players' CVD mortality.

The increased mortality from cardiomyopathy in linemen is of interest but limited by the lack of confirmatory autopsy or other medical records data and deserves further study. Croft et al[3] examined echocardiographic changes in retired players and found left ventricular and left atrial enlargement in linemen. Obesity may lead to myocardial changes including heart failure independent of the cardiac effects of obesity-related hypertension, obstructive sleep apnea, and coronary artery disease.[23,24] Also, isometric training, which is an important component of linemen's training regimen, has been shown to

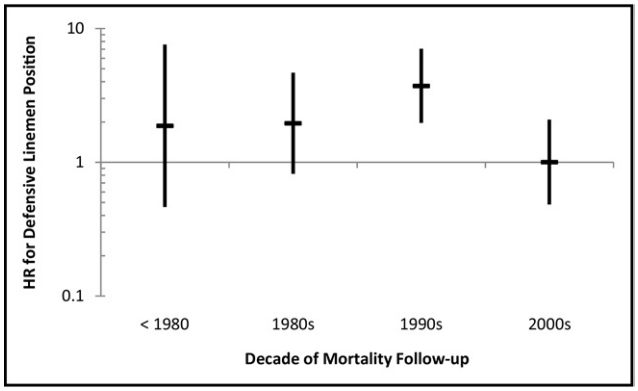


Figure 1. Cardiovascular disease mortality hazard ratios (HRs) and 95% confidence intervals for defensive linemen position category versus all other position categories combined by decade of mortality follow-up adjusted for age, race, and body mass index.

result in significant structural remodeling of the heart in a roughly dose-dependent way.[25] Anabolic androgenic steroid use in athletes has been associated with various adverse cardiovascular outcomes including altered lipid profiles, atherosclerosis, and increased left ventricular dimensions and could contribute to CVD mortality in NFL players.[26] A survey of 3,683 retired players found 9% reported anabolic steroid use while playing but offensive and defensive linemen were most likely to report use (16.3% and 14.8%, respectively). Reported usage for all players peaked in the 1980s at 20%.[27]

Our study is limited by our lack of data on important CVD risk factors including smoking, family history of heart disease, cholesterol levels, and diabetes. We also lack information on changes in players' fitness and weight after retirement, especially because playing-related co-morbidities such as arthritis[28] and other injury-related musculoskeletal disorders[29] may compromise players' ability to remain active. Our finding that the proportional hazards assumption for BMI with age was violated may reflect limitations in assigning BMI category based on playing-time BMI if, as players age, nonlinemen also become obese, thus increasing their risk for CVD mortality. This is supported by the findings of Miller et al[2] who studied players an average of 25 years after retirement and found that 85% of linemen and 50% of nonlinemen had a BMI $\geq$30 kg/m$^2$ and 67.7% of linemen and 27% of nonlinemen had a mean body fat content $\geq$28%, a level considered excess adiposity.[15]

Our methods for assigning race, which used a mixture of player self-identification and observation from photographs, could result in misclassification. However, additional analysis that stratified on race source (self-report vs observed) was consistent with the pooled results (data not shown). Also, our data on cause of death for deceased players relied on information recorded on death certificates, which has some inherent limitations, especially for CVD outcomes.[30] Because the NFL pension database did not include records for all nonvested players, our study was restricted to players with $\geq$5 credited seasons. We were therefore unable to evaluate the impact of duration of playing time on mortality or determine if our findings are representative of shorter-term players.

**Disclaimer:** The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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