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High Prevalence of Hypertension Among Collegiate Football Athletes

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Abstract

Background—The prevalence of hypertension among collegiate football athletes is not well described.

Methods and Results—A retrospective cohort of all male athletes who participated in varsity athletics at a National Collegiate Athletic Association Division I university between 1999–2012 was examined through chart review. Mandatory annual preparticipation physical examinations included blood pressure, body mass index, medication use, and supplement use. Prevalence of hypertension was compared between football and non-football athletes. A mixed-effects linear regression model examined change in blood pressure over time. 636 collegiate athletes, including 323 football players, were identified. In the initial year of athletic participation, 19.2% of football athletes had hypertension and 61.9% had prehypertension. The prevalence of hypertension was higher among football athletes than non-football athletes in their initial (19.2% vs. 7.0%, $P < 0.001$) and final (19.2% vs. 10.2%, $P = 0.001$) years of athletic participation. In adjusted analyses, the odds of hypertension was higher among football athletes in the initial year (AOR 2.28, 95% CI 1.21 to 4.30) but not the final year (AOR 1.25, 95% CI 0.69 to 2.28). Over the course of their collegiate career, football athletes had an annual decrease in systolic blood pressure (−0.82 mmHg, $P = 0.002$), while non-football athletes did not (0.18 mmHg, $P = 0.58$).

Conclusions—Hypertension and prehypertension were common among collegiate football athletes, and football athletes were more likely to have hypertension than male non-football athletes. This presents a potential cardiovascular risk in a young population of athletes. Strategies for increasing awareness, prevention and treatment are needed.

Keywords

blood pressure; epidemiology; hypertension; physical exercise; athletes

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Introduction

In the 2011–2012 academic year, an estimated 261,150 male college students at National Collegiate Athletic Association (NCAA) member schools participated in varsity athletics and 69,643 of these students played American football.¹ Routine physical activity is an established means of blood pressure reduction and provides many cardiovascular health benefits. However, football players may have increased cardiovascular risks. One study of professional athletes found that National Football League (NFL) players had a higher prevalence of hypertension (13.8%) than age-matched men in the general US population (5.5%).² The higher prevalence of hypertension persisted even after adjusting for body mass index (BMI) and race.²

The prevalence of hypertension among collegiate football athletes has not been well established. Several small studies have suggested that collegiate football athletes have a high prevalence of hypertension. Recently, it was reported that first-year football athletes have an increase in blood pressure during their initial season of collegiate football participation. In this cohort, 14% had hypertension at the end of their initial year of athletic participation.³ However these studies have been limited by small sample sizes, blood pressure measurement during a single season, comparisons to non-athletes, or inability to assess potential confounders such as BMI, race, medication use, and supplement use.^{3–10} Information about the change in blood pressures among football athletes over the course of an entire collegiate career is lacking.

Our aim was to determine the prevalence of hypertension among collegiate football athletes and to compare hypertension among football athletes to non-football athletes during collegiate athletic participation. We also sought to compare the change in systolic blood pressure of these 2 groups of athletes over the course of their collegiate careers. Our hypothesis was that football athletes would have a higher prevalence of hypertension and a greater increase in systolic blood pressure over the course of a collegiate career than non-football athletes.

Methods

Study Design and Population

We assembled a retrospective cohort of 678 collegiate athletes who participated in varsity athletics at a private NCAA Division I university in the Southeastern Conference. We selected all male athletes listed on varsity rosters whose final year of athletic participation was in the 2003–2004 academic year through those participating in the 2011–2012 academic year. Because athletes started at the university up to 5 years before their final year of participation, data was collected between 1999–2012. Data were collected from the athletic training room medical record, which contains athletic-specific medical documentation, for each year that the athlete participated in varsity athletics. Because some students do not participate in athletics for their entire 4-year NCAA eligibility period while other athletes did not use their eligibility in contiguous years, each athlete had data collected from between 1 and 5 years of athletic participation.

Male athletes were excluded if they reported a history of a cardiac or renal abnormality or surgery, did not have at least one preparticipation physical evaluation available for review, or did not have an initial blood pressure recorded. The Institutional Review Board at Vanderbilt University approved the study with a waiver for informed consent.

Data collection

All athletes were required to undergo a preparticipation physical examination by a Sports Medicine physician prior to annual athletics participation. A clinical nurse, certified athletic trainer, or physician took at least 1 standardized resting blood pressure measurement at each preparticipation physical evaluation. Attention was given to use of an appropriately sized blood pressure cuff, and a repeat blood pressure measurement was typically assessed if the initial value was abnormal. In cases of multiple blood pressure measurements, the lowest measurement recorded during the preparticipation physical evaluation was conservatively used for analysis. The athletic training room medical record also included a standardized demographic history form completed once at matriculation containing: birth date, medical history, tobacco use, family medical history, and zip code. A standardized preparticipation physical evaluation form contained repeated (annual) assessment of: height, weight, medications (including over the counter medications), and supplement use. Study data were collected using a chart abstraction form by 5 trained reviewers from the Vanderbilt Survey Research Shared Resource core within the Vanderbilt Epidemiology Center. In addition, the institutional Athletics Compliance Office provided athlete's self-reported race, sport, positions played, and scholarship status. All data was managed using REDCap (Research Electronic Data Capture).

Exposure: Classification of Sport

Athletes whose primary or secondary sport was football were classified as football athletes. Athletes whose primary or secondary sport was not football were classified as non-football athletes. There were 2 athletes who played both a primary and secondary sport. Both of these athletes played football and basketball, and were considered as football athletes only.

Outcomes: Hypertension Prevalence and Systolic Blood Pressure

Blood pressures were collected at each annual preparticipation physical evaluation. Blood pressure classifications from The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC 7) were used.¹² Normal blood pressure was defined as a systolic blood pressure <120 mmHg and a diastolic blood pressure <80 mmHg. Prehypertension was defined as a systolic blood pressure of 120 to 139 mmHg or a diastolic blood pressure of 80 to 89 mmHg. The primary outcome was the prevalence of hypertension in the initial and final year of athletic participation, defined as a systolic blood pressure \geq 140 mmHg, or a diastolic blood pressure \geq 90 mmHg, or a self-reported history of hypertension, or use of an antihypertensive medication with no alternative reason documented. The secondary outcome was the mean systolic and diastolic blood pressure at the 2 time points. We also examined the change in systolic blood pressure over the course of the collegiate career.

Covariates

Covariates abstracted from the training room medical record included: age, BMI, parental history of hypertension, medication use, supplement use, tobacco use, and estimated parental income derived from zip code. Medications were reviewed and classified (A.R.K. and C.L.R.) as blood pressure increasing or non-blood pressure increasing based on the primary effects or common side effects of the medication with reference to Epocrates®. Supplements were self-reported separately from medications. The most common supplements were vitamins and protein supplements. Assessment of tobacco use was not added to the demographic history form until 2005. Athletes were considered to be scholarship athletes if they received a scholarship during at least half of their years of athletic participation. Parental income was estimated using the 2011 median household income in 2011 inflation-

adjusted dollars for the zip code tabulation area of each athlete's residence immediately prior to matriculation.¹³

Statistical analysis

Statistical analyses were performed using Stata/SE version 12.0 (Stata Corp, College Station, Texas) and R 2.15.2 (<http://www.R-project.org>). Using descriptive statistics, we examined the distribution of demographics, covariates, and systolic and diastolic blood pressure outcomes in football and non-football athletes. We compared the prevalence of hypertension and prehypertension in the initial and final years of athletic participation between football and non-football athletes using chi-squared analyses and calculated 95% confidence intervals (CI) for binomial proportions using Wilson's formula.¹⁴ We used multivariable logistic regression models to estimate the odds of hypertension vs. non-hypertension (prehypertension and normal blood pressure) in football athletes and non-football athletes in the initial and the final years of athletic participation adjusted for the following covariates: age (continuous), race (White, Black, or other), BMI (continuous), parental history of hypertension (present/absent), blood pressure increasing medication use (present/absent), supplement use (present/absent), tobacco use (present/absent), scholarship status (present/absent), and estimated parental income (continuous).

For the secondary outcome, we examined systolic and diastolic blood pressure as continuous measures at the initial and final years of athletic participation. We used multivariable linear regression models to estimate systolic blood pressure in football athletes and non-football athletes adjusting for the same covariates as described above.

For longitudinal analyses, we used a mixed-effects linear regression model to examine the change in systolic blood pressure over time and mixed-effects logistic regression model to examine change in hypertension over time for football athletes and non-football athletes with random intercepts to account for within-subject correlation. BMI, medication use, and supplement use were included in the model as time-varying covariates and the other covariates were time-invariant. We also included the number of years played and an athletic status (football vs. non-football) x number of years played interaction term in these models.

In all models, missing data for race (n=3), BMI (n=6), tobacco use (n=192), scholarship status (n=3), and income (n=54) were imputed using multiple imputation, incorporating predictive mean matching and flexible additive imputation models, as implemented in the *aregImpute* function available in the Hmisc package in R. In the initial models it appeared BMI was strongly predictive of the association between football and hypertension as well as football and systolic blood pressure. Thus, in a *post hoc* analysis we report additional models showing the effect of all covariates except BMI.

Sample Size calculation

We calculated that including 178 football athletes and 178 non-football athletes, assuming a 24% prevalence of hypertension among football athletes,⁹ an 11% prevalence of hypertension among non-football athletes,¹⁵ and a type I error rate of 0.05, based on a 2-sample comparison of proportions, would provide 90% power to detect a difference in the prevalence of hypertension.

Sensitivity and subgroup analyses

In sensitivity analyses, we used the mean of all blood pressures recorded during the preparticipation physical evaluation, rather than the lowest measurement obtained that day. We also performed sensitivity analyses excluding athletes' who self-reported a history of hypertension as part of the definition of hypertension. We performed subgroup analyses

restricting the population to football athletes and comparing offensive and defensive linemen (offensive lineman, center, offensive guard, offensive tackle, defensive lineman, defensive tackle, and defensive end) to non-linemen football athletes.

Results

We identified 678 male athletes on varsity athletic rosters. We excluded 42 athletes (6%) for the following reasons: history of cardiac or renal abnormality or surgery (n=13), no preparticipation physical evaluation available for review (n=17), or no initial blood pressure recorded (n=12) (Figure 1). The remaining 636 males, 323 (50.8%) football athletes and 313 (49.2%) non-football athletes, were included in the study.

Athletes participated in baseball, basketball, cross-country, football, golf, soccer, and tennis (Table 1). All sports were offered each year other than soccer, which was only available until 2006. Football and non-football athletes were similar in age, medication use, and tobacco use. Compared to non-football athletes, football athletes were more likely to be Black ($P<0.001$), have a higher initial BMI ($P<0.001$), and have a parental history of hypertension ($P=0.03$). Football athletes reported more initial supplement use ($P<0.001$), more scholarships ($P=0.003$), lower parental incomes ($P<0.001$), and more years of athletic participation ($P<0.001$) than non-football athletes.

Primary Outcome: Prevalence of Hypertension

The prevalence of hypertension among football athletes was 19.2% (95% CI 15.3% to 23.8%) in the initial year of athletic participation and 19.2% (95% CI 15.3% to 23.8%) in the final year of athletic participation (Table 2). Compared to non-football athletes, the prevalence of hypertension was higher among football athletes in both the initial year (19.2% vs. 7.0%; $P<0.001$) and final year (19.2% vs. 10.2%; $P=0.005$) of athletic participation (Figure 2). Athletes met criteria for hypertension in the initial year for: elevated blood pressure measurement (93%), history of hypertension (9.5%), and use of anti-hypertensive medication (1.2%). Athletes met criteria for hypertension in the final year for: elevated blood pressure measurement (90%), history of hypertension (8.5%), and use of anti-hypertensive medication (4.3%). The prevalence of prehypertension among football athletes was 61.9% (95% CI 56.5% to 67.0%) in the initial year of athletic participation and 59.8% (95% CI 54.3% to 65.0%) in the final year of athletic participation.

In the initial year, the adjusted odds of hypertension was higher among football athletes (AOR 2.28, 95% CI 1.21 to 4.30; $P=0.01$) than non-football athletes. However, in the final year, the adjusted odds of hypertension did not differ between football athletes (AOR 1.25, 95% CI 0.69 to 2.28; $P=0.47$) and non-football athletes. BMI was an important confounder in each model (Figure 3). Race as a confounder did not contribute to the overall effect. In a longitudinal analysis, the odds of having hypertension decreased by 8.2% with each additional year for football athletes (95% CI, -12.0% to 24.7%, $P=0.401$) and increased by 21.7% for non-football athletes (95% CI -11.2% to 66.8%, $P=0.222$).

Secondary Outcome: Mean Systolic and Diastolic Blood Pressures

In both the initial and final year of athletic participation, football athletes had higher mean systolic (initial: 126.4 ± 11.0 vs. 122.5 ± 9.8 mmHg; $P<0.001$; final: 125.1 ± 11.0 vs. 123.4 ± 10.0 mmHg; $P=0.05$) and diastolic (initial: 75.3 ± 9.9 mmHg vs. 72.3 ± 9.0 mmHg; $P<0.001$; final: 76.8 ± 9.3 vs. 73.8 ± 8.2 mmHg; $P<0.001$) blood pressures than non-football athletes (Table 2). In adjusted analyses, football athletes had higher systolic blood pressures than non-football athletes in the initial year, by 2.62 mmHg (95% CI 0.59 to 4.66 mmHg; $P=0.01$). However, in the final year of athletic participation, their mean systolic blood

pressure was not different from non-football athletes (-1.23 mmHg, 95% CI -3.30 to 0.84 mmHg; $P=0.24$) (Figure 3). In a longitudinal analysis, football athletes had an annual decrease in systolic blood pressure over the course of their collegiate career (-0.82 mmHg; $P=0.002$) while non-football athletes did not have a change in systolic blood pressure over time (0.18 mmHg; $P=0.58$) (Figure 4).

In 2 sensitivity analyses, using the mean of all blood pressure measurements, and excluding athletes' history of hypertension as part of the definition of hypertension, results were similar. In subgroup analyses of football athletes ($n=323$), the prevalence of hypertension was similar between linemen ($n=100$) and non-linemen ($n=223$) in the initial year (23.0% vs. 17.5%; $P=0.25$) and final year (24.0% vs. 17.0%; $P=0.14$) of athletic participation.

Discussion

In this study, 76% of all collegiate male athletes had prehypertension or hypertension. In unadjusted analyses, football athletes had a higher prevalence of hypertension and higher mean systolic blood pressures than non-football male athletes in both initial and final years of athletic participation. Some, but not all, of this increase in hypertension and systolic blood pressure was explained by a higher BMI among football athletes. In longitudinal analyses, football athletes had a non-significant decrease in the risk of developing hypertension over the course of a collegiate athletic career. The systolic blood pressure of football athletes decreased slightly over the course of a collegiate athletic career while systolic blood pressure remained unchanged for non-football athletes. Similar to others, we found that football linemen had a similar prevalence of hypertension as non-linemen.^{2, 16, 17}

We found a high prevalence of hypertension (19.2%) among collegiate football athletes in both the initial year and final year of athletic participation. The prevalence of hypertension in our sample of collegiate male football athletes is much greater than the 2.2% prevalence of hypertension reported among 18–24 year old males¹⁸ and the 9.1% prevalence of hypertension reported among 20–34 year old males in the general U.S. population.¹⁹ The results are similar to a prior report that described 85 collegiate football athletes with a 23.5% prevalence of hypertension in their initial year of athletic participation.⁹ However, it is somewhat greater than the 14% prevalence of hypertension reported in 113 football athletes after the initial year of athletic participation.³ Additionally, the mean blood pressure of collegiate football athletes in our sample was in the prehypertensive range in both the initial year (126/75 mmHg) and the final year (125/77 mmHg) of athletic participation. This is consistent with past reports of collegiate football^{4–9} and NFL athletes,² but remains higher than the estimated mean blood pressure among 18–39 year old men in the general population (119/70 mmHg).²⁰

Although football athletes had a higher prevalence of hypertension in the initial year of athletic participation when adjusting for BMI and other covariates, in the final year of athletic participation there was no difference. It is possible that participation in high school football may be an independent risk factor for hypertension that is responsible for the initial difference. Alternatively, the increase in BMI experienced by non-football athletes between their initial and final years of athletic participation may have a larger effect on blood pressure than the increase in BMI experienced by football athletes. More research is needed in this area.

We also found a high prevalence of prehypertension and hypertension, and elevated mean systolic blood pressures, in the non-football collegiate male athletes. These findings may raise concern about whether blood pressure was measured properly in this population who tend to be larger and more muscular than the general population. However, our providers

were trained to use large cuffs and have a standardized approach to blood pressure measurement. The high blood pressure measurements may also call into question our application of standard definitions for normal blood pressure from the general population to the population of male athletes. Current blood pressure guidelines do not provide alternate definitions for hypertension for athletes.

If these measurements are a true reflection of blood pressure in this population, then collegiate male athletes, and football athletes in particular, may have an increased cardiovascular risk that should be more robustly addressed. Possible factors that may increase the risk of hypertension among football athletes, include frequent use of non-steroidal anti-inflammatory drugs,²¹ high salt intake,²² strength and resistance training^{23–25} the psychosocial pressures of competition,²⁶ stimulant use,²⁷ or supplement use.²⁸ These factors should continue to be investigated.

Our study was strengthened by our ability to evaluate blood pressures in a large cohort of athletes from 14 consecutive years at multiple time points over the course of a collegiate athletic career while considering many important covariates. However, we were limited by the retrospective use of medical records at a single private institution, which affects the generalizability of our results. Additionally, although BMI is commonly used in clinical practice, it may overestimate obesity in football athletes with increased muscle mass.^{9, 29} We were not powered to detect a difference in the prevalence of hypertension between linemen and other football athletes. There may have been a social desirability bias leading athletes to under-report medication, supplement, or tobacco use. Finally, we were unable to measure other factors that could influence blood pressure, such as alcohol use, banned-substance use, salt intake, or psychosocial stressors.

In summary, collegiate male athletes have a markedly high prevalence of prehypertension and hypertension, and football athletes have a higher prevalence of hypertension and higher systolic blood pressures than male non-football athletes. Some, but not all, of the elevation in blood pressure is related to the higher BMI of football athletes. The increased prevalence of hypertension and higher systolic blood pressures of football athletes upon matriculation to college suggests the need for further investigation of hypertension in pre-college football athletes. Additionally, we should continue to investigate the etiologies of these higher blood pressures. Regardless of the cause, the high prevalence of prehypertension and hypertension in all collegiate male athletes supports the need for increased awareness, prevention, and treatment of elevated blood pressures in athletes.

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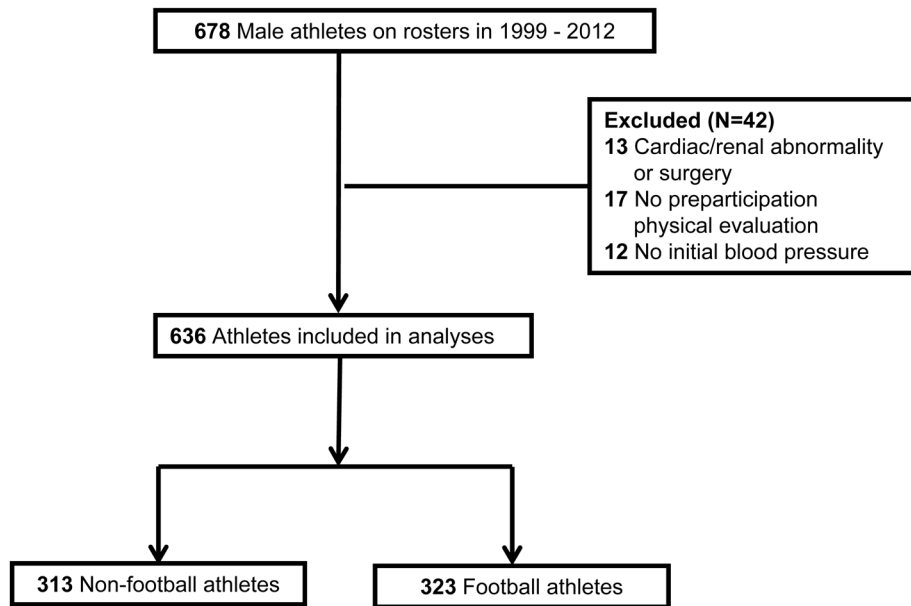


Figure 1.
Flow of Study Participant Selection.

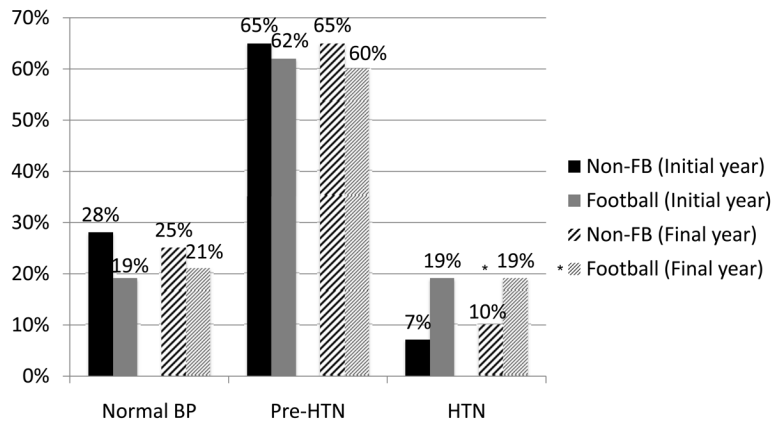
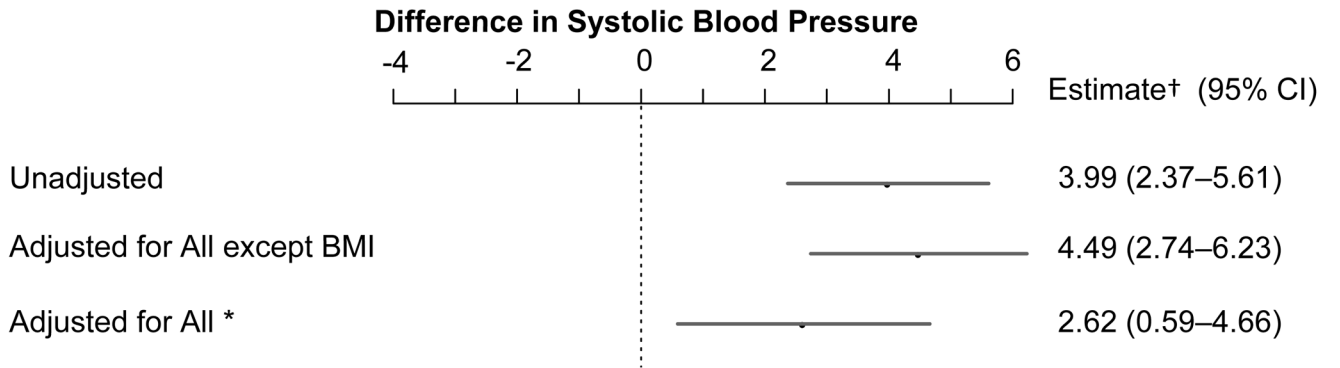
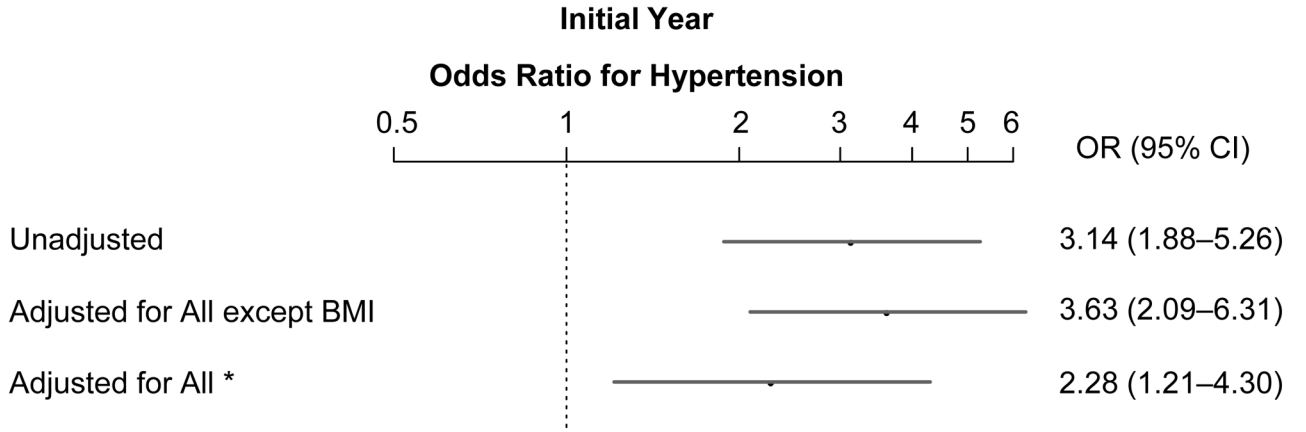


Figure 2.
Prevalence of Normal Blood Pressure, Prehypertension, and Hypertension Among Collegiate Football Athletes and Non-football (Non-FB) Athletes in the Initial Year and Final Year of Athletic Participation.
* $P < 0.05$



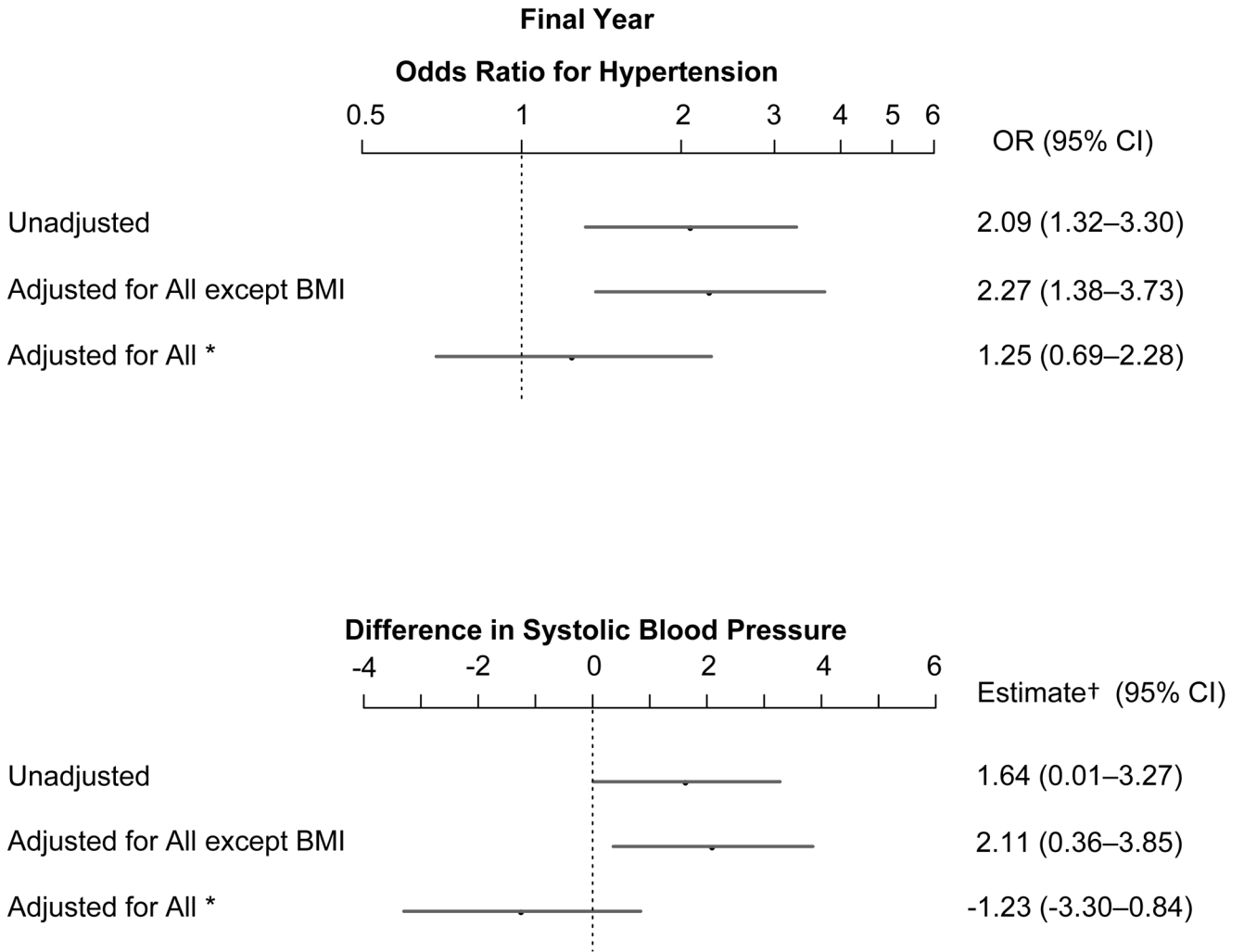


Figure 3. Results of Multivariable Logistic Regression of Hypertension and Multivariable Linear Regression of Systolic Blood Pressure for Collegiate Football Athletes vs. Non-football Athletes in the Initial Year and Final Year of Varsity Athletic Participation.
 * All covariates included age, race, BMI, parental history of hypertension, medication use, supplement use, tobacco use, scholarship status, and parental income.
 † Estimate for difference in systolic blood pressure in mmHg.

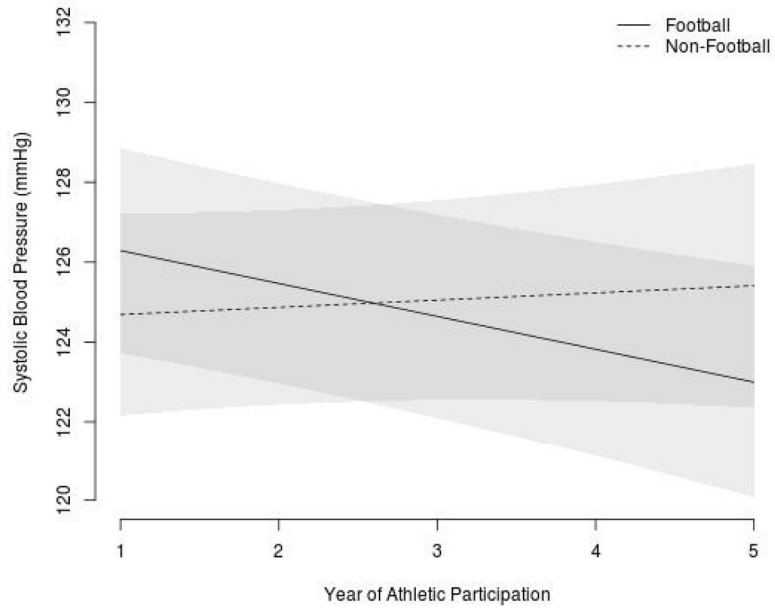


Figure 4. Relationship Between Number of Years of Athletic Participation and Systolic Blood Pressure for Football and Non-Football Athletes Adjusting for Age, Race, BMI, Parental History of Hypertension, Medication Use, Supplement Use, Tobacco Use, Scholarship Status, Parental Income, Number of Years Played, and a Football x Number of Years Played Interaction Term.

Table 1

Characteristics of the Study Cohort.

| | Non-Football N=313 | Football N=323 | P value |
|---|-------------------------------|---------------------------|----------------|
| Age, years (mean ± SD) | 18.8 ± 0.8 | 18.6 ± 0.7 | <0.001 |
| Race (%) | | | |
| White | 62.9 | 44.3 | |
| Black | 12.1 | 39.3 | <0.001 |
| Other | 24.3 | 16.1 | |
| Available (%) | 99.4 | 99.7 | |
| BMI, kg/m² (mean ± SD) | | | |
| Initial year of athletic participation | 23.8 ± 2.6 | 28.4 ± 4.3 | <0.001 |
| Final year of athletic participation | 24.6 ± 2.8 | 29.8 ± 4.3 | <0.001 |
| Parental history of hypertension (%) | 26.5 | 34.7 | 0.03 |
| Medication use (%) | | | |
| Initial year of athletic participation | 29.7 | 29.1 | 0.87 |
| Blood pressure increasing | 10.5 | 8.4 | 0.64 |
| Final year of athletic participation | 19.8 | 18.3 | 0.62 |
| Blood pressure increasing | 8.0 | 7.1 | 0.53 |
| Supplement use (%) | | | |
| Initial year of athletic participation | 22.7 | 37.5 | <0.001 |
| Final year of athletic participation | 8.0 | 14.9 | 0.007 |
| Tobacco use (%) | 11.0 | 11.1 | 0.99 |
| Available (%) | 69.6 | 70.0 | |
| Scholarship (%) | 65.6 | 76.4 | 0.003 |
| Available (%) | 99.4 | 99.7 | |
| Parental income, dollars (median, IQR) | 72,622 (54,690 – 92,948) | 56,568 (44,510 – 83,357) | <0.001 |
| Available (%) | 87.5 | 95.4 | |
| Number of varsity athletic years (mean ± SD) | 2.8 ± 1.1 | 3.2 ± 1.3 | <0.001 |
| Sport (%) | | | |
| Baseball | 39.6 | – | |
| Basketball | 15.3 | – | |
| Cross-country | 12.1 | – | |
| Golf | 8.3 | – | – |
| Soccer | 14.1 | – | |
| Tennis | 10.5 | – | |
| Football | – | 100 | |
| Linemen | | 31.0 | |
| Non-linemen | | 69.0 | |

Table 2

Prevalence of Hypertension and Mean Blood Pressures in Collegiate Football and Non-Football Athletes in Initial Year and Final Year of Athletic Participation.

| | Non-Football N=313 | Football N=323 | P value |
|--|-----------------------|--------------------|---------|
| Hypertension (%) (95% confidence interval) | | | |
| Initial year of athletic participation | 7.0 (4.5 – 10.1) | 19.2 (15.3 – 23.8) | < 0.001 |
| Final year of athletic participation | 10.2 (7.1 – 13.7) | 19.2 (15.3 – 23.8) | 0.001 |
| Prehypertension (%) (95% confidence interval) | | | |
| Initial year of athletic participation | 64.5 (57.1 – 67.6) | 61.9 (56.5 – 67.0) | 0.49 |
| Final year of athletic participation | 64.5 (57.1 – 67.6) | 59.8 (54.3 – 65.0) | 0.21 |
| Systolic blood pressure, mmHg (mean ± SD) | | | |
| Initial year of athletic participation | 122.5±9.8 | 126.4±11.0 | <0.001 |
| Final year of athletic participation | 123.4±10.0 | 125.1±11.0 | 0.05 |
| Diastolic blood pressure, mmHg (mean ± SD) | | | |
| Initial year of athletic participation | 72.3±9.0 | 75.3±9.9 | <0.001 |
| Final year of athletic participation | 73.8±8.2 | 76.8±9.3 | <0.001 |