Epidemiology

Ascending Aortic Dimensions in Former National Football League Athletes

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Background—Ascending aortic dimensions are slightly larger in young competitive athletes compared with sedentary controls, but rarely >40 mm. Whether this finding translates to aortic enlargement in older, former athletes is unknown.

Methods and Results—This cross-sectional study involved a sample of 206 former National Football League (NFL) athletes compared with 759 male subjects from the DHS-2 (Dallas Heart Study-2; mean age of 57.1 and 53.6 years, respectively, P<0.0001; body surface area of 2.4 and 2.1 m², respectively, P<0.0001). Midascending aortic dimensions were obtained from computed tomographic scans performed as part of a NFL screening protocol or as part of the DHS. Compared with a population-based control group, former NFL athletes had significantly larger ascending aortic diameters (38±5 versus 34±4 mm; P<0.0001). A significantly higher proportion of former NFL athletes had an aorta of >40 mm (29.6% versus 8.6%; P<0.0001). After adjusting for age, race, body surface area, systolic blood pressure, history of hypertension, current smoking, diabetes mellitus, and lipid profile, the former NFL athletes still had significantly larger ascending aortas (P<0.0001). Former NFL athletes were twice as likely to have an aorta >40 mm after adjusting for the same parameters.

Conclusions—Ascending aortic dimensions were significantly larger in a sample of former NFL athletes after adjusting for their size, age, race, and cardiac risk factors. Whether this translates to an increased risk is unknown and requires further evaluation. (Circ Cardiovasc Imaging. 2017;10:e006852. DOI: 10.1161/CIRCIMAGING.117.006852.)

Key Words: aorta ■ athletes ■ body surface area ■ football ■ hypertension

The term athlete’s heart refers to a constellation of structural, functional, and electric cardiac adaptations that can occur as a result of intensive, regular exercise over a prolonged period of time.1,2 According to the Morganroth theory,3 the type and extent of these cardiac adaptations are dependent on the sport pursued. Endurance training, characterized by prolonged increases in cardiac output, results in 4-chamber enlargement, eccentric left ventricular hypertrophy, and normal diastolic function. Conversely, strength training, characterized by brief but dramatic increases in afterload, is proposed to result in concentric left ventricular hypertrophy. Although this adaptive response has not been consistently shown in strength athletes, American Style football players have been shown to develop concentric hypertrophy.24 Theoretically, these hemodynamic loads would be expected to result in enlargement of the aorta and indeed, alterations in the elastic properties of the aorta have been demonstrated in elite athletes.5 Although studies have indicated that elite athletes have significantly larger ascending aortic dimensions than the general population,5-7 these changes are small and still fall within established limits for the general population.3 Very few athletes (1.0%-1.8%) have an ascending aorta measuring >40 mm,5,8,9 an arbitrary cut off used clinically and in practice guidelines to define aortic enlargement. To date, studies have been limited to young, currently active athletes. It is unclear whether these changes in aortic dimensions regress, persist, or progress through adulthood. The purpose of this study was to evaluate ascending aortic dimensions in older, former elite athletes, specifically, former National Football League (NFL) athletes and compare them to a similar age and ethnic control group.

See Editorial by Churchill and Baggish

See Clinical Perspective

Methods

This is a cross-sectional study comparing a self-selected sample of former NFL athletes to a presumed nonelite athletic control group from the DHS-2 (Dallas Heart Study-2). Former NFL athletes were invited to participate in voluntary cardiovascular screening
as part of the NFL Players Care Foundation Healthy Body and Mind Screening Program between January 2014 and January 2015 (Canton, OH; Cincinnati, OH; Dallas, TX; Indianapolis, IN; Las Vegas, NV; New York City, NY; Orlando, FL; Phoenix, AZ; and Pittsburgh, PA). The screening was performed by experienced personnel from the Cleveland Clinic Foundation and the data were deidentified and stored in a secure database with MedStar Sports Medicine. Screening was composed of a cardiovascular history questionnaire, which was reviewed by a cardiologist with the player to ensure accuracy of data, basic biometrics (height and weight), 4 blood pressure readings, lipid profile, and a noncontrast computed tomographic (CT) scan for assessment of coronary calcium burden. Former NFL athletes with a history of coronary disease or those who had undergone a recent CT scan (within 1 year) were not offered a CT scan; all others were offered the test after being provided a summary of the risks and benefits of the scan. Those individuals with a recent CT scan were excluded to minimize excess radiation and its associated long-term effects as well as the potential duplication of data. A participant flowchart is displayed in the Figure 1 in the Data Supplement. The study was approved by the MedStar Health Institutional Review Board and all participants signed written informed consent forms for the study.

The DHS was selected as the control group given the ethnic diversity in that population with a large black population. The design details of the DHS has been described in detail previously. Briefly, it is a probability-based population cohort of 3072 adults from Dallas County approved by the University of Texas Southwestern Medical Center Institutional Review Board. Participants were enrolled between 2000 to 2002 and there was intentional oversampling of blacks. The second phase was performed between 2007 to 2009 and included follow-up visits of 2485 DHS participants along with 916 spouses of the original cohort. For the present analysis, we prespecified selection of male, white, and black DHS-2 participants at least 40 years of age, and with a body mass index of at least 20 kg/m². The final DHS control population with interpretable CT scans consisted of 759 male participants (Figure II in the Data Supplement).

CT Imaging

Imaging was performed on a variety of multidetector CT scanners from different vendors as screening for the former NFL athletes was performed in different locations throughout the country. For DHS participants, multidetector CT scans were performed on a Toshiba Aquilion (64 slice). All scans were noncontrast, prospectively acquired, electrocardiographically triggered during diastole (75% of the R-R interval), and with slice thickness of 3 mm performed according to current guidelines. Measurements were made by a licensed imaging physician experienced in cardiac CT. Ascending aortic diameter measurements were measured on axial images at the level of the pulmonary artery bifurcation and measured perpendicular to a line bisecting the ascending and descending thoracic aorta to approximate a true orthogonal diameter (Figure 1) as described previously. Midascending aortic area was calculated from the linear dimension of the ascending aorta, assuming that the aorta is a perfect circle, using $\pi r^2$. To assess reproducibility of the aortic measurements, 2 physicians (C.M. and D.C.) experienced in reading cardiac CT’s reviewed 30 cases. The 30 cases were then reread by one of the physicians (C.M.) 1 week after the initial read.

Clinical Definitions

Hypertension was defined as self-reported history of hypertension and on treatment or being hypertensive (systolic blood pressure $\geq$140 mm Hg and diastolic blood pressure $\geq$90 mm Hg) based on the average of sequential blood pressure measurements for each subject. Diabetes mellitus was defined as self-reported history of diabetes mellitus, hemoglobin A1c $\geq$6.5%, or use of oral hypoglycemic drugs or insulin. Current smoking was defined as any cigarette smoking at the time of screening. Former NFL athletes who played in the quarterback, running back, wide receiver, tight end, cornerback, safety, kicker, or punter position were classified as linemen; those who played in the center, defensive tackle, defensive end, or linebacker were classified as nonlinemen. Aortic enlargement was defined as a midascending aortic dimension $>$40 mm based on the Task Force 7 (Aortic Disease) of the Eligibility and Disqualification Recommendations for Competitive Athletes with Cardiovascular Abnormalities and represents the 99th percentile in male athletes. Aortic dimension $>$40 mm is also a common threshold in which at least annual imaging surveillance is recommended and avoidance of intense weight lifting may be considered in athletes.

Statistical Analysis

Summary statistics for continuous variables are reported as mean (1 SD) and categorical variables are reported as frequency (%). Participant characteristics were compared between the former NFL and DHS cohorts and between linemen and nonlinemen using a Student unpaired $t$ test for continuous variables and the $\chi^2$ test for categorical variables. Multivariable linear regression models were constructed to delineate variables independently associated with ascending aortic diameter and aortic area indexed for height.

The aortic diameters and aortic area indexed for height were modeled by adjusting for a set of a priori variables that included age, black race, systolic blood pressure, hypertension status, diabetes mellitus, current smoking, HDL-C (high-density lipoprotein cholesterol), non-HDL-C, and body surface area (BSA). In light of the previously defined relationships between BSA and age with aortic size, we examined predefined interactions between former NFL player status and these covariates. All multivariable linear regression models report standardized $\beta$ coefficients as the measure of effect size, in which the parameter estimate reflects a 1 SD change in the aortic diameter and a 1 SD change in each of the independent variables. Former NFL status was coded as a categorical variable with DHS as the reference group and included in the model as the primary exposure of interest. Similar models were constructed using logistic regression, with aortic size classified as $>$40 mm. Individuals with missing values for any of the independent variables were excluded from the analysis. The total number of individuals included in each of the final models are listed in the tables.
To further explore the relationship between aortic size, BSA, and age, scatterplots were created, plotting aortic diameter on the y axis and BSA or age on the x axis for both adjusted and unadjusted data. For these plots, the best line was plotted along with the 95% confidence interval (CI) for the regression line. All statistical analyses were performed with SAS version 9.4, and all statistical tests are 2-sided with \( \alpha = 0.05 \).

### Results

#### Baseline Characteristics

Of the 484 former NFL athletes screened, 206 fulfilled inclusion criteria. There was no statistically significant difference between the former NFL athletes who underwent a CT scan than those that did not (Table I in the Data Supplement). Therefore, the study comprised 206 former NFL athletes and 759 male subjects from the DHS. The clinical characteristics of the study population are described in Table 1, including stratification by player position (linemen versus nonlinemen). The former NFL athletes were slightly older (57.1 versus 53.6 years; \( P<0.0001 \)); had a higher BSA (2.4 versus 2.1 m\(^2\); \( P<0.0001 \)) and body mass index (32.4 versus 30.0 kg/m\(^2\); \( P<0.0001 \)) and a lower prevalence of hypertension (36.9% versus 54.8%; \( P<0.0001 \)) and current smoking (8.7% versus 26.5%; \( P<0.0001 \)); and had a more favorable lipid profile (higher HDL-C [53.9 versus 48.3; \( P<0.0001 \]) and lower non-HDL-C [127.5 versus 143.9; \( P<0.0001 \]).

#### Determinants of Ascending Aortic Dimensions

Mean ascending aortic diameter was significantly larger in former NFL athletes compared with controls from the DHS (38±5 mm versus 34±4 mm; \( P<0.0001 \)). Distribution of the ascending aortic diameters for each group are shown in Figure 2. Multivariable linear regression models were created adjusting for age, race, systolic blood pressure, history of hypertension

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**Figure 2.** Distribution of ascending aortic diameters. Histograms showing the distribution of ascending aortic diameters in former National Football League (NFL) athletes (A) compared with the Dallas Heart Study (B). Mean ascending aortic diameter in the former NFL athletes were 38±5 mm compared with 34±4 mm in the Dallas Heart Study (\( P<0.0001 \)). *Mean ascending aortic diameter.
or diabetes mellitus, current smoking, BSA, non-HDL-C, and HDL-C. Former NFL player status remained associated with significantly larger ascending aortic diameters after multivariable adjustment. Furthermore, age, systolic blood pressure, history of hypertension, BSA, and HDL-C level were found to be independently predictive of ascending aortic diameter (Table 2). Former NFL status also predicted larger aortic area indexed to height (standardized β coefficient of 0.2; \( P<0.001 \)) after adjustment.

In the overall cohort, 126 subjects (13%) had an enlarged ascending aorta >40 mm (former NFL=61 [29.6%]; DHS=65 [8.6%]). On logistic regression modeling, independent predictors of having an ascending aorta >40 mm included being a former NFL player (adjusted odds ratio [OR], 1.99; 95% CI, 1.14–3.44; \( P=0.014 \)), age (adjusted OR, 2.08; 95% CI, 1.65–2.62; \( P<0.0001 \)), BSA (adjusted OR, 1.67; 95% CI, 1.29–2.15; \( P<0.0001 \)), and HDL-C (adjusted OR, 1.36; 95% CI, 1.10–1.68; \( P=0.005 \); Table 3).

**Impact of Player Position**

There was a nonsignificant trend toward having a larger mean ascending aortic diameter in linemen compared with nonlinemen (39±6 versus 37±4 mm; \( P=0.093 \)). Multivariable linear regression modeling was repeated to include player position to evaluate for an association with ascending aortic diameters (Table II in the Data Supplement). Both types of player positions were independently associated with larger aortic diameters in unadjusted and adjusted models compared with the DHS cohort. Repeat logistic regression modeling was also performed with the inclusion of the player position. The previous predictors remained significant, whereas only former linemen remained independently predictive of an ascending aortic diameter >40 mm (adjusted OR, 2.35; \( P=0.014 \)), albeit in a less powered subanalysis (Table III in the Data Supplement).

**Interaction Between BSA and Age**

BSA and age are both well-documented predictors of aortic size and remain 2 major predictors of ascending aortic diameters in this study; the relationship between aortic diameter and age and aortic diameter and BSA between the 2 cohorts is displayed in the Figure 3. Although ascending aortic diameters increase with increasing BSA and increasing age, at any given BSA or age the former NFL cohort has a consistently larger ascending aorta compared with the DHS group. This holds true for unadjusted data and after adjustment for parameters described in Table 2.

**Reproducibility Assessment**

Interclass correlation coefficient between independent readers was excellent (0.998; 95% CI, 0.997–0.999); similarly, the agreement between readers was excellent (0.998; 95% CI, 0.997–0.999).

**Discussion**

In the present study, we compared ascending aortic size using CT in a sample of former NFL athletes to the male DHS cohort. We found that being a former elite athlete was associated with a larger ascending aorta independent of size, age, race, blood pressure, a history of hypertension or diabetes mellitus, current smoking status, or lipid profile. Indeed, even after adjustment for these parameters, former NFL athletes had a 2-fold higher risk of having aortic dilation, as defined by an aorta dimension >40 mm.\(^3,13,15\) When considering the type of NFL player position, prediction of aortic dilation was driven primarily by linemen as opposed to nonlinemen.
Several studies have addressed the issue of aortic dilation in elite athletes actively participating in their sport.\textsuperscript{5,7,9,14,16} The findings of these studies consistently demonstrate that the aorta in active elite athletes falls within the established limits for the general population. The aorta is rarely (<2%) >40 mm; this arbitrary cut off is used in the updated American Heart Association/American College of Cardiology Eligibility and Disqualification Recommendations as a threshold to indicate aortic dilation with recommendations for comprehensive evaluation for an underlying genetic aortopathy, avoidance of intense weight training and close surveillance if above this threshold.\textsuperscript{13} However, in a meta-analysis by Iskandar et al\textsuperscript{7}, elite athletes did have significantly larger aortas when compared with sedentary controls, in the order of 3.2 mm larger at the level of the sinus of Valsalva. The natural history of this finding as athlete’s age is unknown. Overall, the difference in aortic size between the former NFL cohort and the DHS cohort has a comparable magnitude to that seen in the study by Iskandar suggesting that athletes may develop slight aortic enlargement during their playing days and stay on the normal age related growth curve. This is supported by data presented in the central illustration where the differences in aortic dimensions between former NFL and DHS remain relatively constant independent of age. However, this does not tell the entire story as seen in Figure 2, where there is a larger skew to the right in the former NFL cohort. Although, in general, the difference in size of the aorta between the former NFL and DHS cohorts seems to be constant across all age groups there is a small but substantial number of former NFL athletes with ascending aortas that would be considered significantly dilated according to currently utilized nomograms.\textsuperscript{15,17} This finding could be anticipated according to Laplace law where the larger aorta will be exposed to proportionally greater wall stress over the course of the athlete’s life.

Increased aortic size in elite athletes may be anticipated given the intense hemodynamic stress placed on the aorta during intensive exercise. Highly trained endurance athletes can increase their cardiac output up to 7-fold; this is associated with prolonged exposure to substantial increases in systolic blood pressure not infrequently above 200 mm Hg in men.\textsuperscript{18,19} Resistance training, on the other hand, can result in a massive transient increase in blood pressure particularly if performed to fatigue or with Valsalva.\textsuperscript{20} Amazingly, a central blood pressure of 480/350 mm Hg was recorded on an indwelling arterial catheter in 1 study of professional body builders lifting 1-repetition maximum weight.\textsuperscript{21} The published literature is somewhat at variance about whether 1 type of exercise (endurance versus strength) is associated with greater degrees of aortic

![Figure 3. Ascending aortic diameters in former National Football League (NFL) athletes. Scatterplots showing relationships between ascending aortic diameter and body surface area (BSA; A) and ascending aortic diameter and age (B) in the former NFL and Dallas Heart Study cohorts. This relationship remains constant after adjustment for age, race, systolic blood pressure, history of hypertension, diabetes mellitus, current smoking, body surface area, non-HDL-C (high-density lipoprotein cholesterol), and HDL-C (C and D).](http://circimaging.ahajournals.org/)

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\textsuperscript{5} Gentry et al  Aortic Size in Former Elite Athletes
dilation.\textsuperscript{5,8} The training regimen and playing requirements of linemen is primarily resistance based. We found that linemen were more likely to have aortic dilation, which is consistent with prior work by D’Andrea et al\textsuperscript{10} who demonstrated larger aortic size and increased aortic stiffness in strength versus endurance trained athletes.

The literature provides some data to contextualize the numbers reported here, although, the guidelines are somewhat more limited. The 2010 American College of Cardiology thoracic aortic disease guidelines only provide a measurement of 28.6 mm obtained from reports of chest x-rays without providing a range or accounting for sex, age, or BSA.\textsuperscript{15} The 2015 American Society of Echocardiography guidelines only provide data on the aortic root, which is generally slightly larger than the midascending aorta.\textsuperscript{17} Normal ranges are provided for 3 age groups and according to BSA. The upper limit of the 95\% CI in the oldest group with the largest BSA was 44 mm. In our study, 9\% of the former NFL group had an aorta that measured 45 mm. Incidentally, this is also a level at which surgical replacement of the aorta is recommended if the patient is undergoing concomitant cardiac surgery.\textsuperscript{15} In one of the largest studies to date evaluating ascending aortic size in a normal population, Wolak et al\textsuperscript{12} reviewed studies from 4039 patients who underwent screening CT scans for coronary calcium score. They report an average midascending aortic size of 34±4.1 mm in 2510 male subjects, identical to the aortic size reported in the DHS cohort in the current study. In Wolak study, the upper limit of the 95\% CI for the oldest cohort (>65 years) and the largest patients (BSA >2.1 m\textsuperscript{2}) was 42 mm. Of our entire former NFL cohort, 19\% have aortic sizes exceeding this limit. Indeed, of the former NFL cohort who were >65 years old and had a BSA exceeding 2.1 m\textsuperscript{2}, 34\% had an ascending aorta that measured >42 mm.

Indexing aortic size for BSA is proposed as an additional/alternative means of recognizing aortic dilation which accounts for anthropometrics; however, it is widely recognized that at the upper extremes of body size there is a plateauing of aortic size elegantly described by Engel et al\textsuperscript{22} in a study of 526 National Basketball Association athletes among other studies.\textsuperscript{3,16,22} Recent data also suggests the aortic cross-sectional area/height ratio is a robust predictor of outcome.\textsuperscript{26,25} Despite the limitations of using indexed aortic size in larger individuals, when we repeated our analysis indexing aortic area to height our data continued to demonstrate that being a former NFL player remain significantly predictive of a larger aortic cross-sectional area/height ratio compared with the DHS cohort even after adjustment for multiple risk factors known to influence aortic size.

Study Limitations
This is the first study, to our knowledge, to evaluate the natural history of aortic size in elite athletes. Given the relatively small number of former athletes involved, this data should be considered hypothesis generating. The findings are specific to a small select group of former NFL athletes with the potential for selection bias and which may not reflect the entire former NFL population. Further studies should be done in different cohorts of former athletes to corroborate this finding. Potential bias may exist given the assumption that DHS participants were not former elite athletes (although this would bias the findings toward the null hypothesis). We cannot comment on whether this finding results in excessive aortic complications later in life or whether this is a normal adaptation of the aorta and, absent an underlying aortopathy, attributes no additional risk to the individual. On our review of the literature, there is no data to suggest that youthful participation in athletic activity contributes a higher risk of aortic dissection or rupture. This is an important area of research as recommendations on timing of initiation of medical therapy, activity restrictions, and even surgical indications would potentially be influenced.

Conclusions
Ascending aortic dimensions are significantly larger in a select sample of former NFL athletes compared with a presumed nonelite athletic cohort even after accounting for their size and multiple risk factors known to influence aortic size. This may be related to the hemodynamic stress of repetitive strenuous exercise over many years. The clinical significance of this finding is unknown and will require further evaluation.

Sources of Funding
This work was supported in part by the National Football League in association with the NFL Players Care Foundation Healthy Body and Mind Screening Program. The Dallas Heart Study was supported in part by grant UL1TR001105 from the National Center for Advancing Translational Science and the National Institutes of Health.

Disclosures
This work supported in part by the National Football League and grant UL1TR001105 from the National Center for Advancing Translational Science and the National Institutes of Health.

References
Aortic Size in Former Elite Athletes


CLINICAL PERSPECTIVE
Former National Football League athletes have significantly larger aortas when compared with controls. This is independent of age, body habitus, or risk factors for aortic dilation and likely reflects adaptation to the hemodynamic stress of repetitive strenuous exercise over many years. When evaluating a patient with an enlarged aorta, a history of longstanding athletic activity should be noted. The clinical significance of this finding is unknown, future studies are needed to evaluate whether these changes translate into negative clinical outcomes or are merely adaptive.
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Data Supplement (unedited) at:
http://circimaging.ahajournals.org/content/suppl/2017/11/08/CIRCIMAGING.117.006852.DC1

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## SUPPLEMENTAL TABLE 1 Baseline Characteristics of former NFL athletes by CT scan

<table>
<thead>
<tr>
<th></th>
<th>CT scan (n = 206)</th>
<th>No CT scan (n = 271)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>57.1 (10.3)</td>
<td>55.0 (13.2)</td>
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<tr>
<td>BSA, m²</td>
<td>2.41 (0.25)</td>
<td>2.39 (0.25)</td>
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<td>BMI, kg/m²</td>
<td>32.5 (5.13)</td>
<td>32.0 (4.83)</td>
<td>0.27</td>
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<td>SBP, mmHg</td>
<td>132 (15.5)</td>
<td>134 (13.9)</td>
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<tr>
<td>Non-HDL-C, mg/dL</td>
<td>127 (37.8)</td>
<td>129 (36.8)</td>
<td>0.63</td>
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<tr>
<td>HDL, mg/dL</td>
<td>54.3 (15.2)</td>
<td>53.9 (16.1)</td>
<td>0.80</td>
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<td>Black</td>
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<tr>
<td>Hypertension</td>
<td>76 (36.9%)</td>
<td>91 (36.4%)</td>
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<td>Diabetes</td>
<td>31 (15.1%)</td>
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<td>Current Smoking</td>
<td>18 (8.7%)</td>
<td>22 (10.3%)</td>
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</table>

Values are mean +/- SD for continuous variables or number (%) for categorical variables. BMI = body mass area; BSA, body surface area; HDL-C, high-density lipoprotein-cholesterol; NFL, National Football League; SBP, systolic blood pressure.
### SUPPLEMENTAL TABLE 2 Predictors of Ascending Aortic Diameter by Type of Player Position

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<th>Risk Factor</th>
<th>Unstandardized Coefficient</th>
<th>Standard Error</th>
<th>p Value</th>
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</thead>
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<td>(Standardized)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Unadjusted</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>N = 965; Adjusted $R^2 = 0.118$</strong></td>
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<tr>
<td>Former non-linemen NFL vs. DHS</td>
<td>0.31 (0.22)</td>
<td>0.04</td>
<td>&lt; 0.0001</td>
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<tr>
<td>Former linemen vs. DHS</td>
<td>0.45 (0.29)</td>
<td>0.05</td>
<td>&lt;0.0001</td>
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<tr>
<td>Constant</td>
<td>3.44</td>
<td>0.02</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td><strong>Adjusted</strong></td>
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<td></td>
<td></td>
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<tr>
<td><strong>N = 932; Adjusted $R^2 = 0.309$</strong></td>
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<tr>
<td>Former non-linemen NFL vs. DHS</td>
<td>0.20 (0.14)</td>
<td>0.04</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Former linemen NFL vs. DHS</td>
<td>0.26 (0.17)</td>
<td>0.05</td>
<td>&lt;0.0001</td>
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<tr>
<td>Age</td>
<td>0.02 (0.37)</td>
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<td>Black</td>
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<tr>
<td>SBP</td>
<td>0.002 (0.07)</td>
<td>0.001</td>
<td>0.030</td>
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<tr>
<td>Hypertension</td>
<td>0.07 (0.08)</td>
<td>0.03</td>
<td>0.022</td>
</tr>
<tr>
<td>Diabetes</td>
<td>-0.05 (-0.04)</td>
<td>0.04</td>
<td>0.188</td>
</tr>
<tr>
<td>Current Smoking</td>
<td>0.003 (0.002)</td>
<td>0.03</td>
<td>0.934</td>
</tr>
<tr>
<td>BSA</td>
<td>0.37 (0.21)</td>
<td>0.06</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Non-HDL-C</td>
<td>0.0003 (0.03)</td>
<td>0.0003</td>
<td>0.371</td>
</tr>
<tr>
<td>HDL-C</td>
<td>0.002 (0.06)</td>
<td>0.001</td>
<td>0.039</td>
</tr>
<tr>
<td>Constant</td>
<td>1.22</td>
<td>0.21</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

BSA = body surface area; DHS = Dallas Heart study; HDL-C = high-density lipoprotein cholesterol; N = number; NFL = National Football League; SBP = systolic blood pressure.
### SUPPLEMENTAL TABLE 3 Predictors of an Enlarged Ascending Aorta > 40 mm by Type of Player Position

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Odds Ratio (95% CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unadjusted</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>N = 965; N = 126 with aorta &gt; 40 mm</strong></td>
<td></td>
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<tr>
<td>Former non-linemen NFL vs. DHS</td>
<td>3.52 (2.14, 5.78)</td>
<td>&lt;0.0001</td>
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<tr>
<td>Former linemen NFL vs. DHS</td>
<td>5.87 (3.58, 9.63)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Adjusted</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>N = 932; n = 124 with aorta &gt; 40 mm</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Former non-linemen NFL vs. DHS</td>
<td>1.77 (0.95, 3.31)</td>
<td>0.075</td>
</tr>
<tr>
<td>Former linemen NFL vs. DHS</td>
<td>2.35 (1.19, 4.65)</td>
<td>0.014</td>
</tr>
<tr>
<td>Age (per 1 SD)</td>
<td>2.09 (1.65, 2.64)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Black</td>
<td>0.81 (0.51, 1.27)</td>
<td>0.359</td>
</tr>
<tr>
<td>Systolic blood pressure</td>
<td>1.00 (0.987, 1.01)</td>
<td>0.966</td>
</tr>
<tr>
<td>Hypertension</td>
<td>1.40 (0.86, 2.29)</td>
<td>0.182</td>
</tr>
<tr>
<td>Diabetes</td>
<td>0.73 (0.41, 1.32)</td>
<td>0.303</td>
</tr>
<tr>
<td>Current Smoking</td>
<td>0.65 (0.34, 1.24)</td>
<td>0.193</td>
</tr>
<tr>
<td>BSA (per 1 SD)</td>
<td>1.63 (1.25, 2.12)</td>
<td>&lt;0.0003</td>
</tr>
<tr>
<td>Non-HDL-C (per 1 SD)</td>
<td>1.05 (0.84, 1.33)</td>
<td>0.650</td>
</tr>
<tr>
<td>HDL-C (per 1 SD)</td>
<td>1.36 (1.10, 1.68)</td>
<td>0.005</td>
</tr>
</tbody>
</table>

BSA = body surface area; CI = Confidence interval; DHS = Dallas Heart Study; HDL-C = high-density lipoprotein cholesterol; NFL = National Football League; SD, standard deviation.
Supplemental Figures:

Supplemental Figure 1

Attendees to the NFL Players Screening Program (484)

Exclusions:
- No CT scan
- Known coronary artery disease (26)
- Refused or recent CT scan (245)
- Incomplete data (7)

Final study population of former NFL athletes (206)

Supplemental Figure 2

DHS-2 participants (3,401)

Exclusions:
- Females (2,015)
- Non black or white race (255)
- Age < 40 and/or BMI < 20 (217)
- No CT available (143)
- Unusable or uninterpretable CT (12)

Final study population of DHS-2 participants (759)
Supplemental Figure Legends:

Supplemental Figure 1: Former NFL Participant Flowchart
A participant flowchart is displayed showing the reasons for participant exclusion for the former NFL athletes. Those individuals with a recent CT scan were excluded to minimize excess radiation and its associated long-term effects as well as the potential duplication of data.

Supplemental Figure 2: DHS Participant Flowchart
A participant flowchart is displayed showing the reasons for participant exclusion from the DHS cohort.