Neck Circumference Is Not Associated With Subclinical Atherosclerosis in Retired National Football League Players

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ABSTRACT

Background: Neck circumference (NC) is associated with metabolic syndrome (MetS) in the general population. It is not known if NC is associated with MetS and subclinical atherosclerosis in retired National Football League (NFL) players.

Hypothesis: We hypothesized that NC is associated with MetS and subclinical atherosclerosis (assessed as coronary artery calcium [CAC] and carotid artery plaque [CAP]) in retired NFL players.

Methods: NC was measured midway between the midcervical spine and midanterior neck in 845 retired NFL players. CAC presence was defined as total CAC score >0. CAP was defined as carotid plaque of at least 50% greater than that of the surrounding vessel wall, with a minimal thickness of at least 1.2 mm on carotid ultrasound. Logistic regression analysis was used for the association of NC with CAC or CAP.

Results: Of the participants, 21% had MetS. CAC and CAP were present in 62% and 56%, respectively. Those with MetS had a higher median NC than those without MetS (17 vs 16 inches, $P < 0.0001$). NC was not associated with the presence of CAC or CAP in an unadjusted model and after adjusting for age, race, and cardiometabolic risk factors (odds ratio [OR]: 1.11, 95% confidence interval [CI]: 0.94–1.31 for CAC; OR: 0.96, 95% CI: 0.82–1.12 for CAP per 1-standard deviation increase in NC [3.8 inches]). The results were similar when the predictor variable was NC indexed to body mass index.

Conclusions: In retired NFL players with a high prevalence of CAC and CAP, NC was not associated with coronary or carotid subclinical atherosclerosis. NC may not be the most appropriate risk marker for atherosclerosis.

This work was performed primarily at Baylor College of Medicine, Houston, Texas.

The views expressed in this article are those of the authors and do not necessarily represent the views of the Department of Veterans Affairs.

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Additional Supporting Information may be found in the online version of this article.

Introduction

Obesity is present in more than two-thirds of the US population¹ and is associated with metabolic syndrome (MetS), atherosclerosis, and possibly an increased risk of myocardial infarction and stroke.^{1–3} Traditionally, obesity is assessed using body mass index (BMI) and waist circumference (WC).⁴ Neck circumference (NC) has been shown to be associated with cardiometabolic risk in both genders across various ethnicities and age groups in the general population.^{5–16} Some of these studies showed that the association was independent of other measures of adiposity.^{6,12,14,15} Some have proposed using NC as a novel tool to assess adiposity because of its relative ease of measurement compared with BMI or WC.^{5–10}

There are no published studies comparing the association of NC with cardiometabolic risk in retired National Football League (NFL) players. To our knowledge, there is no published study to date assessing the relationship of NC with subclinical atherosclerosis in any population. In prior studies, retired NFL players were shown to have a higher prevalence of MetS^{17,18} compared with the general population. In addition, given the fact that retired NFL players were physically active during their playing years, it is possible that the MetS seen in these players is distinctly different from that seen in the general population. Therefore, it is not known if NC will have similar association with MetS and subclinical atherosclerosis in retired NFL players. Our aim was therefore to first examine the association of NC with other markers of adiposity such as BMI and WC and with various components of MetS. We also examined whether NC was independently associated with subclinical coronary or carotid atherosclerosis as assessed by coronary artery calcium (CAC) or carotid artery plaque (CAP) in retired NFL players.

Methods

Study Population

A total of 1023 retired NFL players voluntarily participated in health screening exams conducted between September 2007 and November 2009, organized and funded by Player Care Foundation and executed by the Living Heart Foundation and Boone Heart Institute. The study details have been previously described.^{17–22} Retired NFL players were invited through mail or local NFL alumni chapter meetings. Participants provided demographics, and medical and professional career information through a questionnaire. Height, weight, WC and NC, and cuff blood pressure (using the CardioVision automated cuff system) were obtained. Three consecutive seated blood pressure readings were obtained; the first reading was discarded and the mean of the second and third readings was used. BMI was defined as weight (in kilograms) divided by height (in square meters). Waist circumference was measured at the top of the umbilicus in inches. Neck circumference was measured (in inches) midway between the midcervical spine and the midanterior neck. In participants with a pronounced laryngeal prominence (Adam's apple), the measurement was made just inferior to the prominence.²³ MetS was defined as per the National Heart Lung and Blood Institute definition.³ Specifically, MetS was defined as the presence of at least 3 of the following 5

criteria: WC >40 inches, triglycerides (TGs) >150 mg/dL, high-density lipoprotein cholesterol (HDL-C) <40 mg/dL, fasting glucose $\geq$ 100 mg/dL, or hypertension (HTN). HTN was defined as systolic blood pressure (SBP) of $\geq$ 130 mm Hg or diastolic blood pressure (DBP) of $\geq$ 85 mm Hg or both.

Laboratory Measurements

A fasting venous blood sample was collected in tubes containing ethylenediaminetetraacetic acid for plasma and in serum separator tubes for serum during the screening visit. Centrifugation was performed at the primary sites after blood was collected, and the samples were then sent the same day to Quest Diagnostics (Madison, NJ). Total cholesterol, HDL-C, and TGs were measured, and low-density lipoprotein cholesterol (LDL-C) was calculated using the Friedewald Equation.²⁴ High-sensitivity C-reactive protein (hs-CRP) was measured using commercially available assays.

CAC Measurement

CAC has been shown to be a good marker for the presence of subclinical atherosclerosis^{25–27} and has been shown to be associated with adverse coronary heart disease outcomes^{25–30}; it was therefore used as a marker for the presence of subclinical atherosclerosis in this study. CAC was performed using a modified Agatston protocol³¹ within a week, mostly within the same day of the screening visit. There was 1 designated reader for the CAC scoring at most sites. The total coronary calcium score was calculated by measuring the peak Hounsfield units from each epicardial coronary artery. Coronary calcium was defined as present if the total CAC score was >0.

CAP Measurement

Apart from CAC, we also evaluated CAP as a marker for the presence of subclinical atherosclerosis. CAP is also a well-validated measure of subclinical atherosclerosis,^{32–34} and its presence has shown to be associated with an increase risk of cardiovascular events.^{33–36} Ultrasound examination of the carotid artery was performed using a standardized protocol with a Siemens Sequoia or CV70 system (Siemens Healthcare, Erlangen, Germany), with 6- to 8-MHz linear array transducer imaging in longitudinal and transverse planes, visualizing the common carotid artery, carotid bulb, and proximal internal carotid arteries bilaterally. Sonographers were instructed to obtain 3-beat cine images of any suspected plaque along with Doppler imaging of any suspected stenosis. Carotid artery plaque was defined as the presence of focal thickening 50% greater than that of the surrounding vessel wall, with a minimal thickness of 1.2 mm.²²

Statistical Analysis

Descriptive statistics were evaluated for each variable. We then performed bivariable analysis using a 2-sample Wilcoxon rank sum test for continuous variables and Pearson χ^2 test for categorical variables. We also evaluated the Spearman correlation coefficient to assess the linear correlation of NC with BMI and all the other components of

MetS. Our primary outcomes of interest were the presence of CAC or CAP. Logistic regression was used to calculate the odds ratio (OR) and associated 95% confidence interval (CI) per standard deviation (SD) increase in NC for the presence of CAC or CAP. An initial unadjusted model was first used to determine the association between NC and presence of CAC or CAP. Subsequently, we adjusted for other variables in 2 separate models. In model 1, we adjusted for age, race, SBP, and hs-CRP. In model 2, we adjusted for all the variables from model 1 plus other variables that form part of the MetS (TG, HDL-C, and fasting blood glucose levels).

To further examine the association between NC and subclinical atherosclerosis, we also performed sensitivity analyses by indexing NC to BMI defined by NC/BMI for each participant. This variable was created to provide a standardized measure of NC designed to reflect local neck habitus relative to the overall body habitus. BMI was used in this variable because BMI incorporates height and weight, both of which could be related to NC. We also modeled using the exposure variable as NC >90th percentile for association of subclinical atherosclerosis, based on methods used in a prior published study.¹⁵

Among those retired NFL players with a CAC score >0, we also assessed whether NC was associated with CAC burden using the natural log of CAC as the outcome variable (ie, $\ln[\text{CAC} + 1]$) using linear regression models.

All analyses were performed using Stata 12 (StataCorp, College Station, TX). All inferences were 2-tailed, and a *P* value <0.05 was considered statistically significant. The study was approved by the institutional review board at the Baylor College of Medicine. The authors are solely responsible for the design, conduct, and analyses of the study, and the drafting, editing, and preparation of the final version of the article.

Results

Baseline Characteristics

After excluding 178 participants with missing information on the presence of CAC or CAP, 845 individuals were included in the final analysis (Table 1). The mean and median NC was 16 inches (SD: 4 inches) and 17 inches (interquartile range [IQR]: 16–18 inches), respectively. Analyses were performed using nonparametric tests because the distribution of TG and LDL-C were slightly skewed (mean and median were 116 and 89 mg/dL, respectively, for TG; and 128 and 125 mg/dL, respectively, for LDL-C). The median age of the retired players at the time of study was 54 years. About 32% of the participants had HTN with median blood pressure of 130/80 mm Hg, and 8% had diabetes mellitus. The median BMI was 31 kg/m² (IQR: 29–35 kg/m²), and the median WC was 40 inches (IQR: 37–44 inches). The median levels of hs-CRP, LDL-C, HDL-C, TG, and fasting blood glucose were 1.2 mg/L, 125 mg/dL, 47 mg/dL, 89 mg/dL, and 91 mg/dL, respectively.

Association of NC With MetS and Its Components

About a quarter of the participants had TG ≥ 150 mg/dL (*n* = 239, 28%), HDL-C <40 mg/dL (*n* = 200, 24%), and fasting blood glucose ≥ 100 mg/dL (*n* = 239, 28%). Overall 21%

Table 1. Characteristics of the Sample of 845 Retired National Football League Players

Characteristic	Value ^a
Age, y	54 (45–63)
White race, n (%)	480 (57%) ^b
Hypertension, n (%)	267 (32%)
Diabetes mellitus, n (%)	62 (8%) ^b
Systolic BP, mm Hg	130 (121–142)
Diastolic BP, mm Hg	80 (74–87)
BMI, kg/m ²	31 (29–35)
Neck circumference, inches	17 (16–18)
Waist circumference, inches	40 (37–44)
Fasting blood glucose, mg/dL	91 (84–98)
hsCRP, mg/L	1.2 (0.6–2.6)
Total cholesterol, mg/dL	196 (171–223)
LDL-C, mg/dL	125 (103–148)
HDL-C, mg/dL	47 (39–56)
Triglycerides, mg/dL	89 (65–141)

Abbreviations: BMI, body mass index; BP, blood pressure; HDL-C, high-density lipoprotein cholesterol; hsCRP, high-sensitivity C-reactive protein; LDL-C, low-density lipoprotein cholesterol.
^aData are presented as median with 25th and 75th percentiles in parenthesis for continuous variables and number of participants with percent in parenthesis for dichotomous variables. ^bPercent calculated from the available data only.

Table 2. Correlation of Various Components of MetS With NC in 845 Retired National Football League Players

Variables	NC, inches	
	<i>r</i>	<i>P</i> Value
WC, inches	0.76	< 0.0001
TG, mg/dL	0.22	< 0.0001
HDL-C, mg/dL	−0.17	< 0.0001
SBP, mm Hg	0.13	< 0.0001
DBP, mm Hg	0.09	0.01
Fasting blood glucose, mg/dL	0.15	< 0.0001

Abbreviations: DBP, diastolic blood pressure; HDL-C, high-density lipoprotein cholesterol; MetS, metabolic syndrome; NC, neck circumference; SBP, systolic blood pressure; TG, triglyceride; WC, waist circumference.
Values are given as Spearman correlation coefficient (*r*) and associated *P* value between NC and covariates.

(*n* = 155) fulfilled the criteria for MetS. NC was positively correlated with BMI, WC, TG, fasting blood glucose, SBP, and DBP with respective Spearman correlation coefficients (*r*) of 0.66, 0.76, 0.22, 0.15, 0.13, and 0.09 (*P* < 0.0001 for all except DBP for which *P* = 0.01) (Table 2). NC was negatively correlated with HDL-C (*r* = −0.17, *P* < 0.0001).

Table 3. Association Between Neck Circumference and Presence of Subclinical Atherosclerosis (CAC or CAP) in Retired National Football League Players

Outcome	Unadjusted OR (95% CI) ^a	Model 1, OR (95% CI) ^a	Model 2, OR (95% CI) ^a
CAC	1.01 (0.88–1.16)	1.11 (0.95–1.3)	1.11 (0.94–1.31)
CAP	1.03 (0.90–1.18)	0.97 (0.83–1.13)	0.96 (0.82–1.12)

Abbreviations: CAC, coronary artery calcium; CAP, carotid artery plaque; CI, confidence interval; OR, odds ratio.

Model 1: Adjusted for age, race, systolic blood pressure, high-sensitivity C reactive protein. Model 2: Adjusted for model 1 plus triglycerides, high-density lipoprotein cholesterol, fasting blood glucose.

^aOR per standard deviation increase in neck circumference (3.8 inches).

Table 4. Associations of NC/BMI With Presence of CAC and CAP in Retired National Football League Players

Outcome	Unadjusted Model, OR (95% CI) ^a	Model 1, OR (95% CI) ^a	Model 2, OR (95% CI) ^a
CAC	1.00 (0.87–1.15)	0.98 (0.83–1.15)	1.01 (0.85–1.20)
CAP	0.97 (0.85–1.11)	0.97 (0.83–1.13)	0.95 (0.81–1.12)

Abbreviations: BMI, body mass index; CAC, coronary artery calcium; CAP, carotid artery plaque; CI, confidence interval; NC, neck circumference; OR, odds ratio.

Model 1: Adjusted for age, race, systolic blood pressure, high-sensitivity C reactive protein. Model 2: Adjusted for model 1 plus triglycerides, high-density lipoprotein cholesterol, fasting blood glucose.

^aOR per standard deviation increase in NC/BMI (0.12398 inches × m²/kg).

Retired NFL players with MetS had a higher median NC than those without (17 vs 16 inches, $P < 0.0001$).

Associations Between NC and Subclinical Atherosclerosis

Overall, 522 participants (62%) had CAC, and 470 participants (56%) had CAP. In unadjusted analyses, NC was not associated with the presence of CAC (OR: 1.01, 95% CI: 0.88–1.16) or CAP (OR: 1.03, 0.90–1.18) (Table 3). When adjusted for age, race, SBP, and hs-CRP, each SD increase in NC (3.8 inches) was not associated with the presence of CAC (OR: 1.11, 95% CI: 0.95–1.3) or CAP (OR: 0.97, 95% CI: 0.83–1.13). The association for either CAC or CAP remained nonsignificant when the model was further adjusted for other metabolic syndrome criteria such as TG, HDL-C, and fasting blood glucose levels (OR: 1.11, 95% CI: 0.94–1.31 per SD increase in NC for the presence of CAC; and OR: 0.96, 95% CI: 0.82–1.12 per SD increase in NC for the presence of CAP).

Sensitivity Analysis

As seen in Table 4, NC indexed to BMI (NC/BMI) was not associated with the presence of CAC or CAP in the unadjusted model or the model adjusted for age, race, SBP, and hs-CRP (model 1) or model 1 plus TG, HDL-C, and fasting blood glucose (OR: 1.01, 95% CI: 0.85–1.20 per SD increase in NC/BMI for the presence of CAC; and OR: 0.95, 95% CI: 0.81–1.12 per SD increase in NC/BMI for the presence of CAP). We also modeled our exposure variable

as NC >90th percentile (= 18 inches). Using NC >90th percentile as the exposure variable, there was no significant association for the presence of CAC or CAP in partially or fully adjusted models, except for the presence of CAC when adjusted for age, race, SBP, and hs-CRP (OR: 1.87, 95% CI: 1.02–3.42). Stratified analysis by the presence or absence of MetS did not change our result in either group (see Supporting Tables 1 and 2 in the online version of this article).

Among retired NFL players with CAC >0, NC was not associated with CAC burden (β coefficient = −1.05 and $P = 0.24$ per SD increase in NC) when adjusted for age, race, SBP, hs-CRP, TGs, HDL-C, and fasting blood glucose.

Discussion

In this study of 845 retired NFL players, NC was highly correlated with WC and BMI. NC was positively correlated with all the components of MetS, except for HDL-C, where the correlation was negative. Retired NFL players with MetS had a thicker NC than those without MetS. NC or NC/BMI had no association with CAC or CAP in unadjusted or adjusted models.

NC has been shown to be associated with MetS and its components in studies from various populations such as predominantly young African American females,⁵ middle-aged Caucasians,¹⁴ middle-aged to elderly Chinese,^{6,16} Israelis,⁸ Brazilian men and women,^{9,11} Turkish children, and Greeks.¹² Some of these studies have shown that the association is independent of other measures of obesity such as BMI or WC.^{6,12,14,15} It is likely that NC tracks with obesity because of its consistent correlation with BMI or WC in all of these studies, including ours. This hypothesis is further supported by the consistent correlation of NC with MetS and its components in studies from different populations.

We did not have data to assess the prevalence of cardiovascular risk factors and MetS in these NFL players while they were actively playing in the NFL. In addition, there is paucity of data in the literature comparing risk factors in the general population with elite NFL players during their playing years. In cross-sectional analyses, it has been shown that retired NFL players have a higher prevalence of MetS compared to the general population.^{18,19} Retired NFL players have been physically active for a good part of their lives. Therefore, it can be speculated that the progression of cardiovascular risk factors and the MetS seen in retired NFL players could be distinctly different compared to the general population who have relatively sedentary lifestyle throughout their lives.

To our knowledge, ours is the first study examining the association of NC with subclinical atherosclerosis in any population. We measured subclinical atherosclerosis at 2 separate vascular sites. NC did not have significant association with subclinical coronary or carotid atherosclerosis, despite the higher prevalence of CAC and CAP in the study population. It is possible that increased NC in retired NFL players may be relatively less reflective of adiposity compared to the general population. Increased NC in this population could reflect a higher than usual contribution from neck muscle given their background of weight lifting and training during their professional years.

There are only a few studies that evaluated the association of NC with adverse cardiovascular outcomes. In a

case-control study of 376 Brazilians referred for elective coronary angiogram, NC above the 90th percentile was significantly associated with at least 50% coronary stenosis after controlling for traditional risk factors of coronary artery disease.¹⁵ In 3086 participants from the Framingham Heart Study, despite having a significant correlation with all the risk factors for MetS, NC was not significantly associated with an increase in incident cardiovascular disease or coronary heart disease after a mean 6.7 years of follow-up in an adjusted model.¹⁴ There was also no significant interaction of NC with gender for these outcomes.

The paradox on the consistent association of NC with MetS, but not with cardiac outcomes from the limited available studies, should be answered by longitudinal well-designed studies to examine if there is any biological reason for this observation or if this is a result of methodological limitations of the currently available studies. It is also not known if the lack of association of NC with subclinical atherosclerosis is unique to our study population, which has overall higher prevalence of MetS and higher BMI and unique body habitus, or applicable to the general population. Further research should inform us if similar lack of association exists in athletes involved in different kinds of sports (eg, athletes involved in rugby football) or persons with similar body habitus from various populations. It must be emphasized that although NC was not associated with subclinical atherosclerosis in our study, NC could still play a role in the pathogenesis of other cardiovascular disorders such as obstructive sleep apnea in this population.

Our study has limitations. Because the retired NFL players' participation in the study was on a voluntary basis, the possibility of selection bias cannot be excluded. Our study was limited to subclinical atherosclerosis and not to hard cardiovascular outcomes. Our study participants were all male and consisted mainly of Americans of European descent and African Americans. We did not have information on other possible confounders such as smoking status and treatment of other risk factors. Moreover, our study was cross-sectional in design, and therefore the findings are only hypothesis generating.

Conclusion

Although NC was correlated with MetS and its components, it was not associated with coronary or carotid subclinical atherosclerosis in retired NFL players with a high prevalence of CAC and CAP.

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References

- Go AS, Mozaffarian D, Roger VL, et al. Heart disease and stroke statistics—2013 update: a report from the American Heart Association. *Circulation*. 2013;127:e6–e245.
- Thomsen M, Nordestgaard BG. Myocardial infarction and ischemic heart disease in overweight and obesity with and without metabolic syndrome. *JAMA Intern Med*. 2014;174:15–22.
- Grundy SM, Brewer HB Jr, Cleeman JI, et al. Definition of metabolic syndrome: report of the National Heart, Lung, and Blood Institute/American Heart Association conference on scientific issues related to definition. *Circulation*. 2004;109:433–438.
- Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: executive summary. Expert Panel on the Identification, Evaluation, and Treatment of Overweight in Adults. *Am J Clin Nutr*. 1998;68:899–917.
- Arnold TJ, Schweitzer A, Hoffman HJ, et al. Neck and waist circumference biomarkers of cardiovascular risk in a cohort of predominantly African-American College Students: a preliminary study. *J Acad Nutr Diet*. 2014;114:107–116.
- Zhou JY, Ge H, Zhu MF, et al. Neck circumference as an independent predictive contributor to cardio-metabolic syndrome. *Cardiovasc Diabetol*. 2013;12:76.
- Ben-Noun L, Sohar E, Laor A. Neck circumference as a simple screening measure for identifying overweight and obese patients. *Obes Res*. 2001;9:470–477.
- Ben-Noun L, Laor A. Relationship of neck circumference to cardiovascular risk factors. *Obes Res*. 2003;11:226–231.
- Stabe C, Vasques AC, Lima MM, et al. Neck circumference as a simple tool for identifying the metabolic syndrome and insulin resistance: results from the Brazilian Metabolic Syndrome Study. *Clin Endocrinol*. 2013;78:874–881.
- Kurtoglu S, Hatipoglu N, Mazioglu MM, et al. Neck circumference as a novel parameter to determine metabolic risk factors in obese children. *Eur J Clin Invest*. 2012;42:623–630.
- Tibana RA, Teixeira TG, Farias DL, et al. Relation of neck circumference and relative muscle strength and cardiovascular risk factors in sedentary women. *Einstein (Sao Paulo)*. 2012;10:329–334.
- Vallianou NG, Evangelopoulos AA, Bountziouka V, et al. Neck circumference is correlated with triglycerides and inversely related with HDL cholesterol beyond BMI and waist circumference. *Diabetes Metab Res Rev*. 2013;29:90–97.
- Preis SR, Pencina MJ, D'Agostino RB Sr, et al. Neck circumference and the development of cardiovascular disease risk factors in the Framingham Heart Study. *Diabetes Care*. 2013;36(1):e3.
- Preis SR, Massaro JM, Hoffmann U, et al. Neck circumference as a novel measure of cardiometabolic risk: the Framingham Heart study. *J Clin Endocrinol Metab*. 2010;95:3701–3710.
- Zen V, Fuchs FD, Wainstein MV, et al. Neck circumference and central obesity are independent predictors of coronary artery disease in patients undergoing coronary angiography. *Am J Cardiovasc Dis*. 2012;2:323–330.
- Yan Q, Sun D, Li X, et al. Neck circumference is a valuable tool for identifying metabolic syndrome and obesity in Chinese elder subjects: a community based study. *Diabetes Metab Res Rev*. 2014;30:69–76.
- Virani SS, Pompeii L, Lincoln AE, et al. Association between traditional cholesterol parameters, lipoprotein particle concentration, novel biomarkers and carotid plaques in retired National Football League players. *Atherosclerosis*. 2012;222:551–556.
- Miller MA, Croft LB, Belanger AR, et al. Prevalence of metabolic syndrome in retired National Football League players. *Am J Cardiol*. 2008;101:1281–1284.
- Albuquerque FN, Kuniyoshi FH, Calvin AD, et al. Sleep-disordered breathing, hypertension, and obesity in retired National Football League players. *J Am Coll Cardiol*. 2010;56:1432–1433.
- Chang AY, FitzGerald SJ, Cannaday J, et al. Cardiovascular risk factors and coronary atherosclerosis in retired National Football League players. *Am J Cardiol*. 2009;104:805–811.
- Croft LB, Belanger A, Miller MA, et al. Comparison of National Football League linemen versus nonlinemen of left ventricular mass and left atrial size. *Am J Cardiol*. 2008;102:343–347.
- Hurst RT, Burke RF, Wissner E, et al. Incidence of subclinical atherosclerosis as a marker of cardiovascular risk in retired professional football players. *Am J Cardiol*. 2010;105:1107–1111.
- Tucker AM, Vogel R, Lincoln AE, et al. Prevalence of cardiovascular disease risk factors among National Football League players. *JAMA*. 2009;301:2111–2119.
- Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin Chem*. 1972;18:499–502.

25. Pletcher MJ, Tice JA, Pignone M, et al. Using the coronary artery calcium score to predict coronary heart disease events: a systematic review and meta-analysis. *Arch Intern Med.* 2004;164:1285–1292.
26. Detrano R, Guerci AD, Carr JJ, et al. Coronary calcium as a predictor of coronary events in four racial or ethnic groups. *N Engl J Med.* 2008;358:1336–1345.
27. Greenland P, Bonow RO, Brundage BH, et al. ACCF/AHA 2007 clinical expert consensus document on coronary artery calcium scoring by computed tomography in global cardiovascular risk assessment and in evaluation of patients with chest pain: a report of the American College of Cardiology Foundation Clinical Expert Consensus Task Force (ACCF/AHA Writing Committee to Update the 2000 Expert Consensus Document on Electron Beam Computed Tomography). *Circulation.* 2007;115:402–426.
28. Tota-Maharaj R, Blaha MJ, McEvoy JW, et al. Coronary artery calcium for the prediction of mortality in young adults <45 years old and elderly adults >75 years old. *Eur Heart J.* 2012;33:2955–2962.
29. Sarwar A, Shaw LJ, Shapiro MD, et al. Diagnostic and prognostic value of absence of coronary artery calcification. *JACC Cardiovasc Imaging.* 2009;2:675–688.
30. Blaha M, Budoff MJ, Shaw LJ, et al. Absence of coronary artery calcification and all-cause mortality. *JACC Cardiovasc Imaging.* 2009;2:692–700.
31. Agatston AS, Janowitz WR, Hildner FJ, et al. Quantification of coronary artery calcium using ultrafast computed tomography. *J Am Coll Cardiol.* 1990;15:827–832.
32. Wyman RA, Fraizer MC, Keevil JG, et al. Ultrasound-detected carotid plaque as a screening tool for advanced subclinical atherosclerosis. *Am Heart J.* 2005;150:1081–1085.
33. Nambi V, Chambless L, Folsom AR, et al. Carotid intima-media thickness and presence or absence of plaque improves prediction of coronary heart disease risk: the ARIC (Atherosclerosis Risk In Communities) study. *J Am Coll Cardiol.* 2010;55:1600–1607.
34. Hunt KJ, Sharrett AR, Chambless LE, et al. Acoustic shadowing on B-mode ultrasound of the carotid artery predicts CHD. *Ultrasound Med Biol.* 2001;27:357–365.
35. Norris JW, Zhu CZ, Bornstein NM, et al. Vascular risks of asymptomatic carotid stenosis. *Stroke.* 1991;22:1485–1490.
36. Hougaku H, Matsumoto M, Handa N, et al. Asymptomatic carotid lesions and silent cerebral infarction. *Stroke.* 1994;25:566–570.