Journal of Athletic Training 2008;43(6):608–616
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Presence of Metabolic Syndrome in Football Linemen

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Context: Metabolic syndrome is a clustering of symptoms associated with abdominal obesity that demonstrates a high risk for cardiovascular disease and type II diabetes mellitus.

Objective: To evaluate football linemen in National Collegiate Athletic Association Divisions I, II, and III schools for the presence of metabolic syndrome according to the American Heart Association/National Heart, Lung, and Blood Institute criteria as well as to document other related biomarkers.

Design: Cross-sectional descriptive study.

Setting: Three university locations on the first full day of football camp in early morning.

Patients or Other Participants: Of 76 football linemen, 70 were able to provide blood samples.

Main Outcome Measure(s): Height, mass, blood pressure, upper-body skinfolds, and waist circumference were measured at various stations. Two small venous samples of blood were collected and analyzed in a hospital laboratory for fasting insulin, glucose, high-density lipoprotein, total cholesterol, triglycerides, C-reactive protein, and glycosylated hemoglobin. The last station was a verbal family history for cardiovascular disease and diabetes; also, athletes filled out a nutrition attitudes questionnaire.

Results: Of the 70 athletes, 34 were identified as having metabolic syndrome according to measures of blood pressure, waist circumference, fasting glucose, high-density lipoprotein, and triglycerides. The mean total cholesterol-to-high-density lipoprotein cholesterol ratio for the group was 4.95, with 32 participants displaying values higher than 5.0. Twelve volunteers had total cholesterol levels greater than 200 mmol/L, 15 had high levels of C-reactive protein, and 9 had slightly elevated levels of glycosylated hemoglobin.

Conclusions: Although athletes might be assumed to be protected from risks of cardiovascular disease, we found a high incidence of metabolic syndrome and other associated adverse biomarkers for heart disease in collegiate football linemen. Early screening, awareness, and intervention may have favorable effects on the overall health outcomes of football linemen.

Key Words: obesity, football players, dyslipidemia, hypertension, insulin, C-reactive protein

Key Points

- Football linemen with abdominal adiposity exhibited the clustering of symptoms associated with higher risks of diabetes and cardiovascular disease (metabolic syndrome).
- Athletes with a waist circumference equal to or greater than 40 in (101.60 cm) should be evaluated for other risk factors (fasting blood glucose, blood cholesterol, and triglyceride levels and prehypertensive blood pressure levels) to determine metabolic syndrome status and risks.
- Athletes with metabolic syndrome should be counseled about the associated risks and educated about lifestyle choices that may reduce these risks.

Recent authors[1–4] have demonstrated that football linemen are obese according to body mass index (BMI) measures. It may be tempting to discount these reports because of the inappropriate application of BMI in athletes, but football linemen may not be as healthy as we presume them to be, and closer evaluation of these large athletes for metabolic syndrome is needed. Metabolic syndrome (MetSyn) is typically defined as a clustering of clinical symptoms associated with increased abdominal adiposity and includes negative health correlates such as high blood pressure, dyslipidemia, insulin resistance, impaired glucose metabolism, and possibly elevated inflammatory and prothrombotic makers.[5] Clustering of MetSyn abnormalities increases the risk of coronary heart disease and diabetes.[6–8] The physique of football linemen can be consistent with increased body and abdominal fat stores,[9] which may be associated with the presence of MetSyn.

Football linemen often seek advice for a weight gain routine (diet and weight training), with the goal of becoming larger than their opponents.[10] Ideally, the increased body weight would be increased muscle mass, but often players increase their body size by accumulating more adipose tissue, specifically in the abdominal region. In our experience as athletic trainers and sports nutritionists, some athletes are indifferent to the composition of the weight gain; they just want to be immovable and more competitive with large opponents.

Numerous guidelines have been published by various professional groups for the identification of MetSyn. The

purpose of our cross-sectional, descriptive study was to identify the incidence of MetSyn according to the American Heart Association and National Heart, Lung, and Blood Institute (AHA/NHLBI) criteria[5] in football linemen at the National Collegiate Athletic Association (NCAA) Division I (DI), II (DII), and III (DIII) levels. The most common criteria for MetSyn include elevated waist circumference, blood pressure, fasting blood glucose (FBG), and triglycerides (TG) and depressed high-density lipoprotein (HDL) cholesterol. Markers of inflammation and insulin resistance may be secondary markers of MetSyn and may reflect increased risk. Therefore, a secondary aim of our study was to document fasting insulin, C-reactive protein (CRP), and glycosylated hemoglobin (HbA1c) levels in this cohort of collegiate football linemen.

METHODS

Participants

Offensive and defensive linemen were recruited by the football athletic training staffs at NCAA DI, DII, and DIII schools. The protocol was approved by the human subjects committee at each institution, and written informed consent was obtained from each volunteer before participation. A total of 77 athletes consented to the study; 1 athlete withdrew before any data were collected. Six participants were not willing or able to provide a blood sample, leaving 70 who provided complete data. Data collection visits were completed in early August 2006. Participation in DII was excellent, with all linemen choosing to take part (n = 30). Many linemen in DI and DIII chose not to participate: DI participation was 76% (26/34), and DIII participation was 48% (21/44). We wrote the protocol for 80 participants, so heavy recruitment at the last site (DIII) was limited to those athletes willing to give a blood sample. Roster data on all nonparticipants were available for comparison. Linemen totaled 108 in the 3 schools, and 76 of those (70%) participated in the study.

Protocol

Data were collected by a research team of 8 to 12 members at each institution on the first full day of preseason training camp in the early morning after an overnight fast (at least 6 to 8 hours) and before significant team training or testing took place. Once volunteers consented, they proceeded through stations organized to measure height, mass, blood pressure, upper-body skinfolds, and waist circumference. Trained phlebotomists obtained 2 small samples of venous blood, and the athletes completed a short verbal interview to document family history, estimated time spent running and lifting in the last week, and current injury status. The athletes then completed a self-report nutrition attitudes questionnaire.

Specific Station Methods. Height was measured to the nearest 0.1 cm using a wall-mounted SECA stadiometer (model 210; Hanover, MD). Mass was recorded to the nearest 0.1 kg with a digital system (model BWB-800A; Tanita Corp of America, Arlington Heights, IL). Systolic and diastolic blood pressures (SBP and DBP) were obtained with a single measurement, using an extra-large adult cuff with a standard sphygmomanometer and stethoscope. To enhance reliability, the same research team member measured blood pressure at all 3 institutions. The skinfold measurements were standardized in the same manner, with 1 trained research team member obtaining all measures of triceps, subscapular, and chest skinfolds in triplicate for all participants. These skinfolds were selected to simplify data collection because volunteers only needed to remove their shirts.[11] The recorded skinfolds were later summed and entered into standard equations specific to the age and ethnicity of the participant to estimate body density and fatness.[11] While the volunteer's shirt was off, waist circumference was also measured by the same researcher using the anterior superior iliac spine as the landmark to measure to the nearest 0.1 cm.[5]

Table 1. American Heart Association/National Heart, Lung, and Blood Institute Criteria Defining Metabolic Syndrome[a]

Risk Factor	Criterion
Blood pressure	Systolic ≥130 mm Hg or diastolic ≥85 mm Hg
Waist circumference	≥102 cm (40 in)
Fasting blood glucose	≥5.6 mmol/L (≥100 mg/dL)
High-density lipoproteins	<1.03 mmol/L (<40 mg/dL)
Serum triglycerides	≥1.7 mmol/L (≥150 mg/dL)

[a] The presence of 3 or more risk factors indicates the presence of metabolic syndrome.

Blood was obtained by trained phlebotomists using a Vacutainer system (Becton Dickinson, Franklin Lakes, NJ) to draw approximately 25 mL total in serum separator and heparinized sodium tubes with a single needle stick. The serum separator tube was immediately centrifuged at 1300 revolutions per minute for 5 minutes, and both tubes were stored over ice in a cooler until submitted to the hospital laboratory for processing 2 to 6 hours later. Blood measures included fasting insulin; FBG; cholesterol panel (including total [TChol], HDL, and calculated low-density lipoprotein [LDL]; TG; CRP; and HbA1c. The fasting insulin and CRP samples were run on an Immulite system (model 2000; Diagnostic Products Corp, Los Angeles, CA). The SYNCHRON LX System (Beckman Coulter, Fullerton, CA) was used to measure FBG, total and HDL cholesterol, and TGs and LDL. Finally, the HbA1c samples were run on the VARIANT II TURBO instrumentation (Bio-Rad Laboratories, Hercules, CA).

After the volunteer gave the blood sample and visited the anthropometric stations, he proceeded to an interview station, at which he was asked about demographics and occurrence of obesity, diabetes, heart disease, high blood pressure, and high cholesterol in himself, his father and mother, and both sets of grandparents. The station attendant also asked the athlete to estimate weight training and running history for each day of the past week and if he had a current injury. Once the interview was complete, the athlete was asked to fill out a 24-item Nutrition Attitude Survey to gauge dietary helplessness, food exploration, meat preference, and health concern. This questionnaire was originally designed to measure attitudes germane to coronary risk factors and has been validated in the larger population.[12]

Data Analysis and Statistics. All data were collated into an Excel spreadsheet (version 2003; Microsoft Corp, Redmond, WA), checked, and loaded into SPSS (version 14.0 for Windows; SPSS Inc, Chicago, IL). The AHA/

Table 2. Differences Among National Collegiate Athletic Association Divisions per 1-Way Analysis of Variance (Mean ± SD)

Dependent Variable	Division I	Division II	Division III	Model *P* Value
Age, y	20.6 ± 1.58	20.0 ± 1.46	20.2 ± 1.47	.418
Weight, kg	131.3 ± 12.39[a]	123.4 ± 14.20[a]	108.4 ± 10.59[b]	<.001
Height, cm	191.5 ± 5.94[a]	187.3 ± 4.96[b]	182.0 ± 5.02[c]	<.001
Waist circumference, cm	111.8 ± 8.32[a]	115.3 ± 11.03[a]	104.7 ± 9.46[b]	.001
Percentage of body fat	26.2 ± 2.48[a]	28.3 ± 2.80[b]	25.5 ± 3.92[a]	.003[d]
Fasting blood glucose, mmol/L	5.1 ± 0.40[a]	5.3 ± 0.42 [a,b]	5.0 ± 0.25 [a,c]	.011
Fasting insulin, pmol/L	104.9 ± 58.89[a]	104.9 ± 71.12[a]	61.8 ± 29.79[b]	.022[d]
Running, min in past 7 d	267 ± 120.9[a]	126 ± 92.5[b]	105 ± 125.1[b]	<.001
Lifting, min in past 7 d	353 ± 168.5[a]	374 ± 184.9[a]	146 ± 122.1[b]	<.001

[a,b,c] Groups with the same superscript have statistically similar means; those with different superscripts have different means.
[d] Dunnett C statistic calculated because of unequal variances.

NHLBI MetSyn criteria are a modification of the original Adult Treatment Panel criteria defining MetSyn as the presence of 3 or more criteria listed in Table 1. To determine the presence of MetSyn, we evaluated the criteria variables for each participant and summed the number of positive risk factors. The MetSyn criteria did not include evaluation of fasting insulin, TChol:HDL ratio, CRP, or HbA1c. These additional variables were evaluated and examined within bivariate Pearson correlations to determine the strength and nature of clustering relationships. Other statistical methods applied included 1-way analysis of variance with the Tukey post hoc analysis when variances were equal (Levene statistic, $P > .1$), and the Dunnett C statistic was applied when variances were not assumed equal to identify differences among DI, DII, and DIII groups. When appropriate, *t* tests were performed to identify or confirm differences between groups (participants and nonparticipants, MetSyn and non-MetSyn, and offensive and defensive linemen).

RESULTS

As a result of incomplete study participation at the DI and DIII schools, the study participants at each institution were compared with nonparticipants for height, mass, BMI, and class distribution to lend insight into missed data. The DI nonparticipants were taller than the participants (196.8 versus 191.5 cm, $P = .026$). This resulted in a lower BMI for the DI nonparticipant group (32.7 kg/m^2 versus 35.8 kg/m^2, $P = .009$), despite 3 of the 8 nonparticipants having BMIs greater than 35. The comparison for the DIII nonparticipants to DIII participants yielded similar results in that the nonparticipants were taller (185.4 cm versus 182.0 cm, $P = .016$), with a lower BMI (30.1 kg/m^2 versus 32.9 kg/m^2, $P = .019$). Three of 23 DIII nonparticipants had a BMI slightly higher than 35. The differences in body weight and class distribution were nonsignificant.

Differences among NCAA levels were examined with analysis of variance for all quantitative variables of interest (Table 2). No differences were evident in the ages of the volunteers. The data confirm the assumption that overall body size increases with NCAA level of play, as the DI players were taller and heavier than the DII athletes, who were larger than the DIII athletes. Waist circumferences of the DIII group were smaller than those of the DI and DII groups, and percentage of body fat and sum of skinfolds demonstrated that the DII players were less lean than the DI and DIII players. The FBG was lower in the DIII group than in the DII group, and the DIII group had lower fasting insulin levels than either the DI or DII groups. According to the self-report data for minutes of running and lifting, the DI group had more minutes of running than the DII and DIII groups, and the DIII group had fewer minutes of lifting than the DI and DII groups.

The enrollment, positions, ethnicity, and years of eligibility for each institution are delineated in Table 3. When the MetSyn criteria were applied to the defining variables, 34 of the 70 players who agreed to the blood sample formally qualified for MetSyn (having 3 or more risk factors), and these results for all divisions are also included in Table 3. Waist circumference without an adjustment for body size may be a questionable indicator in large-framed men; therefore, the data were also evaluated using predicted body fat instead of waist circumference when an estimated body fat of more than 25% was substituted as an obesity indicator[11] for the waist circumference risk factor. Nine MetSyn players had a waist equal to or larger than 102 cm with an estimated body fat percentage of less than 25%, but 6 of these 9 still qualified for MetSyn with 3 criteria without including the waist circumference. Using this body fat percentage substitution for waist circumference still yielded 31 players with MetSyn. Of the players who did not provide a blood sample, 5 of the 6 displayed risk factors for waist

Table 3. Descriptive Statistics by National Collegiate Athletic Association Division and Presence of Metabolic Syndrome by Position, Ethnicity, and Year of Eligibility

Division	n[a]	Position: Offensive Line/ Defensive Line	Ethnicity: White/ Non-White	Year of Eligibility			
				Freshman	Sophomore	Junior	Senior
I	26	15/11	20/6	9	3	9	5
II	30	17/13	23/7	14	6	6	4
III	21	14/7	20/1	9	1	5	6
Metabolic syndrome	34	22/12	28/6	17	10	2	5
No metabolic syndrome	36	18/18	28/8	11	10	6	9

[a] Six athletes were unwilling or unable to provide a blood sample; 1 athlete withdrew before any data were collected.

Table 4. Number of Risk Factors for Metabolic Syndrome by National Collegiate Athletic Association Division

No. of Risk Factors	Division			
	I (n = 22)	II (n = 27)	III (n = 21)	Total (n = 70)
0	0	1	0	1
1	3	5	5	13
2	10	6	6	22
3	7	8	10	25
4	2	6	0	8
5	0	1	0	1

circumference and blood pressure (2 of 5 risk factors). The difference in MetSyn by position did not reach statistical significance, but the offensive linemen had a greater waist circumference (115.0 cm versus 105.8 cm, $P < .001$) and a trend for higher percentage of body fat (27.4% versus 26.0%, $P = .058$) than the defensive participants. Table 4 delineates the number of risk factors for players at each NCAA level.

Numerous permutations of values for waist circumference, BP, FBG, HDL, and TG can characterize MetSyn. It is interesting to examine the patterns and heterogeneity of these combinations (Table 5). Increased waist circumference and low levels of HDL occurred in all but 2 of the 34 players and elevated blood pressure in all but 5. The International Diabetes Federation criteria[6] differ from the AHA/NHLBI criteria in that increased waist circumference must be present along with 2 other risk factors. Because each MetSyn athlete in this study also had a waist larger than 102 cm, the International Diabetes Federation and AHA/NHLBI algorithms result in the same outcome in this cohort. If one disputes the reliability of the waist circumference in this cohort, 9 linemen (13%) still qualified for MetSyn using the other 4 criteria.

The 5 criteria to identify MetSyn do not include inflammation markers such as CRP. However, elevated CRP has been suggested to be predictive of diabetes and cardiovascular disease,[13] and the threshold for elevated CRP was 3.0 mg/L.[5] Fifteen participants exceeded that value, and 6 of those were not in the MetSyn group. Three of the MetSyn participants had CRP values between 10 mg/L and 20 mg/L, indicating a very high risk.[13] Notably, none of the 15 participants with CRP levels greater than 3.0 mg/L reported a current injury on the interview portion of data collection, and those who did report a current injury were within the acceptable CRP range of 0 mg/L to 3.0 mg/L. To further explore the possible effect of recent training on CRP, we looked at the self-reported total time spent running or lifting, which did not appear to predict an elevated CRP level in a logistic regression with elevated CRP as the dichotomous dependent variable (running $P = .222$, lifting $P = .998$). Despite the higher variance in the MetSyn group, the mean CRP level was 3.1 mg/L, as compared with 1.6 mg/L in the non-MetSyn group, a significant difference (t test, $P = .035$).

Table 5. Participants' Combinations of Risk Factors for Metabolic Syndrome

No. of Factors	Combination of Factors	No. of Participants
3	Waist, BP, HDL	18
	Waist, TG, HDL	4
	Waist, FBG, HDL	1
	Waist, BP, FBG	1
	Waist, BP, TG	1
4	Waist, BP, TG, HDL	3
	Waist, BP, FBG, HDL	5
5	Waist, BP, FBG, TG, HDL	1

Abbreviations: BP, blood pressure; FBG, fasting blood glucose; HDL, HDL-cholesterol; TG, triglycerides.

In evaluating cardiovascular disease risk factors, it is common to include the ratio of total cholesterol to HDL cholesterol (TChol:HDL), with a desirable ratio being less than 5.[14] The mean ratio for the group was 4.95 (range = 2.8–10.4); 32 participants exceeded the threshold of 5. Comparing the means of this ratio between the groups (with and without MetSyn) demonstrated different ratios (t test, $P < .001$), an expected finding given that low HDL is part of the ratio as well as a criterion of MetSyn. In evaluating for diabetes, the HbA1c is used as an index of recent (past 8–10 weeks) blood glucose control. For males of this age, the HbA1c should be maintained below 5.8%; 9 participants exceeded this value, although no values were grossly out of range (range = 4.4%–6.3%). No differences were noted between the mean values of insulin or HbA1c for the groups as defined by MetSyn ($P = .066$ and $P = .719$, respectively). Of the entire group, 12 participants exceeded the desirable TChol level of 200 mg/dL, with 17 having calculated LDL values between 130 mg/dL and 160 mg/dL and 4 having values of more than 160 mg/dL.

The parental history of heart disease and diabetes variables were collated separately for each participant; 0 indicated *neither parent was reported to have heart disease or diabetes*, 1 indicated *1 parent diagnosed*, and 2 indicated *both parents diagnosed*. The estimated percentage of body fat was positively correlated with parental history of diabetes ($r = .2485$, $P = .0293$). Both TChol ($r = .3325$, $P = .0049$) and calculated LDL ($r = .2826$, $P = .0178$) were associated with parental history of heart disease.

Consistent with its design, the Nutrition Attitude Survey was scored for dietary helplessness, food exploration, meat preference, and health concern.[15] The 4 scores were evaluated as continuous variables; thus, higher scores indicated a greater propensity for the characteristic. No differences were evident among NCAA divisions or between MetSyn and non-MetSyn groups. These variables were evaluated along with all other variables in bivariate correlations for insight into the interrelationships of MetSyn measures in these athletes. Dietary helplessness was negatively correlated with minutes spent lifting ($r = -.2714$, $P = .0177$). Food exploration was positively correlated with minutes spent lifting ($r = .2268$, $P = .0488$). Other negative correlations were meat preference factor and the sum of skinfolds ($r = -.3196$, $P = .0049$), FBG ($r = -.2698$, $P = .0239$), and HbA1c ($r = -.2893$, $P = .0159$).

Several other correlations are worth mentioning:

- Mass was correlated with percentage of body fat ($r = .4840$, $P < .001$), minutes running ($r = .2989$, $P = .0083$), minutes lifting ($r = .2447$, $P = .0320$), insulin ($r = .3786$, $P = .0013$), and CRP ($r = .3805$, $P = .0012$).
- Waist circumference was correlated with mass ($r = .8014$, $P < .001$), percentage of body fat ($r = .7069$, $P < .001$), insulin ($r = .3712$, $P = .0017$), FBG ($r = .3101$, $P = .0090$), HDL ($r = -.222$, $P = .065$ [trend only]), and CRP ($r = .5090$, $P < .001$).

Table 6. Bivariate Correlations

		Nutrition Attitude Survey								
		Meat preference	Health concern	Height	Mass	Waist Circumference	C-Reactive Protein	Diastolic Blood Pressure	Sum of Skinfolds	Percentage of Body Fat
Height	*r*				.4516					
	P				.0000					
	n				77					
Mass	*r*					.8014	.3805		.5268	.4840
	P					.0000	.0012		.0000	.0000
	n					77	70		77	77
Waist circumference	*r*						.5090		.7902	.7069
	P						.0000		.0000	.0000
	n						70		77	77
C-reactive protein	*r*							.2419	.3967	.3488
	P							.0452	.0007	.0031
	n							69	70	70
Systolic blood pressure	*r*							.6105		.2059
	P							.0000		.0743
	n							76		76
Diastolic blood pressure	*r*									
	P									
	n									
Sum of skinfolds	*r*									.7841
	P									.0000
	n									77
Percentage of body fat	*r*									
	P									
	n									
Running	*r*									
	P									
	n									
Lifting	*r*									
	P									
	n									
Fasting blood glucose	*r*									
	P									
	n									
Total cholesterol	*r*									
	P									
	n									
Triglycerides	*r*									
	P									
	n									
High-density lipoproteins	*r*									
	P									
	n									
Cholesterol: high-density lipoproteins	*r*									
	P									
	n									
Low-density lipoproteins	*r*									
	P									
	n									
Nutrition Attitude Survey Dietary helplessness	*r*									
	P									
	n									
Food exploration	*r*	.4571	.3196							
	P	.0000	.0049							
	n	76	76							
Meat preference	*r*								−.3196	−.2716
	P								.0049	.0176
	n								76	76
Health concern	*r*									
	P									
	n									
NCAA division	*r*			−.5756	−.5727	−.2419		−.1967		
	P			.0000	.0000	.0340		.0886		
	n			77	77	77		76		

Abbreviation: NCAA, National Collegiate Athletic Association.

[a] *r* Values are Pearson correlations; *P* values are for 2-tailed testing; n is based on 76 participants with data: 70 with blood data, 69 with insulin values, and 69 with lipid profiles.

Table 6. Extended

Running	Lifting	Fasting Blood Glucose	Total Cholesterol	High-Density Lipoproteins	Cholesterol: High-Density Lipoproteins	Low-Density Lipoproteins	Insulin	Glycosylated Hemoglobin	Parental History of Heart Disease	Parental History of Diabetes
	.2588 .0231 77		−.2393 .0460 70		−.2727 .0224 70	−.2994 .0118 70				
.2989 .0083 77	.2447 .0320 77	.2211 .0659 70					.3786 .0013 69			
		.3101 .0090 70					.3712 .0017 69			
				−.2097 .0815 70						
		.3671 .0019 69								
		.2527 .0362 69								
		.2701 .0238 70								
		.2668 .0256 70	.2059 .0872 70			.2714 .0230 70				.2485 .0293 77
	.3665 .0010 77									
							.2310 .0562 69			
							.3806 .0013 69	.4572 .0001 69	−.2463 .0399 70	
					.3961 .0007 70	.9151 .0000 70			.3325 .0049 70	
				−.3209 .0068 70	.3989 .0006 70			−.3788 .0013 69		
					−.7644 .0000 70					
						.5163 .0000 70				
									.2826 .0178 70	
	−.2714 .0177 76									
	.2268 .0488 76									
		−.2698 .0239 70						−.2893 .0159 69		
					−.2308 .0545 70		−.2552 .0343 69			
−.4973 .0000 77	−.4052 .0003 77						−.2795 .0200 69			

- Systolic and diastolic blood pressures were correlated ($r = .6105$, $P < .001$), and both correlated with FBG ($r = .3671$, $P = .0019$ and $r = .2527$, $P = .0362$, respectively). Diastolic blood pressure was also correlated with CRP ($r = .2419$, $P = .0452$).
- Percentage of body fat was correlated with FBG ($r = .2668$, $P = .0256$), calculated LDL ($r = .2714$, $P = .0230$), and CRP ($r = .3488$, $P = .0031$).
- Triglycerides were negatively correlated with HDL ($r = -.3209$, $P = .0068$) and HbA1c ($r = -.3788$, $P = .0013$).

Our findings continue to reinforce the multifaceted nature of the MetSyn and clustering of risk factors. Significant bivariate correlations are shown in Table 6.

DISCUSSION

Authors[1–3] have calculated BMIs from the heights and weights provided on football rosters at the professional and high school levels to examine the prevalence of obesity according to a BMI greater than 30 kg/m^2, drawing attention to the size of these young men. However, BMI is not a valid gauge for athletes, and health care professionals might be inclined to discount these findings. An item on *HealthDay News* (as posted on Medline Plus) demonstrated more firm evidence that football linemen may be more prone to MetSyn than leaner football players and the general population, with more than 50% of retired football linemen exhibiting the cluster of symptoms.[4]

Our purpose was to better define the magnitude of the problem in active collegiate linemen. Physicians, health educators, athletic trainers, sports nutritionists, and other health care providers are obligated to help these athletes better understand the latent influence their day-to-day choices may have on their genetics and their current and future health. Some heavy linemen already exhibited MetSyn, and the laboratory values confirm a reason for concern about the risk of future diabetes and heart disease as a result of the weight and central adiposity of this group.

Epidemiologic studies in the United States have shown a gradual increase in the incidence of obesity, MetSyn, and diabetes over the past 10 years.[16] It is possible that this same trend is occurring in linemen, as evidenced by comparing the findings of Collins et al[9] in 1999 with ours. Collins et al noted percentages of body fat of 23.5% and 19.6% in offensive and defensive linemen, respectively, whereas we showed values of 26% and 26.3%, respectively.

In examining the results from an athlete's blood test and body measurements for each of the risk factors for MetSyn separately, the practitioner might not prioritize a blood pressure of 132/88 mm Hg, an FBG of 106 mg/dL, or a 43-in (109.22-cm) waist. Seeking evidence of clustered symptoms that define MetSyn should become a standard health care practice performed by those clinicians supporting the athlete. Blood pressure, waist circumference, and body fatness (skinfolds) are easy and inexpensive to assess. The blood tests for this study cost about $57 per participant and would be a useful screening panel for incoming freshmen, allowing physicians and athletic trainers to screen for MetSyn to identify athletes likely to benefit from early education and intervention.

The multiple correlations in this study (Table 6) reinforce the clustering of symptoms in metabolic syndrome.[5] Intervention studies indicate that reducing abdominal adiposity is the best way to prevent disease or to interrupt the progression of disease, and reducing this adiposity helps reduce insulin and FBG and promote a more favorable lipid profile. The positive correlations in this study among body fatness, waist circumference, insulin, FBG, and CRP support the advice that losing body mass likely attenuates the influence of those variables used to define MetSyn.[16,17] Given the premium on body size for football linemen, "weight loss" during the competitive years is not typically an acceptable solution, but helping these athletes with body weight issues after the competitive years may be more realistic. Carroll and Dudfield[16] suggested that for each kilogram decrease in body weight, visceral fat is reduced by 2% to 5%. The family history correlations with body fat and elevated cholesterol represent the genetic predisposition handed down to these men. Therefore, part of the treatment program should be devoted to helping these athletes learn how to adapt lifestyle and nutrition habits to better modify genetic predispositions.

Treatment of MetSyn depends on the symptoms present[5] and is well outlined in the "Therapeutic Lifestyle Changes" described in the National Cholesterol Education Program.[18,19] Helping the athlete understand the potential role central adiposity plays in overall health may provide motivation to prevent progression of MetSyn into diabetes or heart disease in later life by changing body fat and lean muscle distribution. It may be helpful to share the data from McGill et al[20] and Zieske et al,[21] who demonstrated clear and progressive coronary artery disease occurring linearly with BMI, abdominal adiposity, and elevated CRP in postmortem studies of young people (15–34 years of age) who died of noncardiovascular causes. Weight loss in individuals with MetSyn has resulted in improved glucose regulation and blood pressure, confirming the importance of such efforts.[16,17] If lifestyle modifications are unsuccessful in patients with MetSyn, team physicians may consider prescribing medications to control borderline hypertension and elevated fasting insulin.[5,17]

General dietary guidelines to reduce the risk of cardiovascular disease typically include weight reduction by portion control, selection of nutrient-dense food, limiting fats (especially saturated and hydrogenated [trans] fats), reducing sodium intake if sodium sensitive, increasing intake of fruits and vegetables, and emphasizing whole grains as carbohydrate sources.[22] Specific dietary interventions may include ingesting more omega-3 fatty acids, which may help to decrease inflammation (by decreasing cytokine levels) and increase insulin sensitivity.[23] The Therapeutic Lifestyle Changes proposed by the National Cholesterol Education Program suggest that saturated fats constitute no more than 7% of total fat calories, with up to 10% of calories from polyunsaturated fats and up to 20% of calories from monounsaturated fats; fats should constitute 25% to 35% of daily calories; and cholesterol consumption should not total more than 200 mg/d.[18,19] Additionally, diets high in simple sugars have been implicated in elevated levels of TGs and depressed levels of HDLs,[24] whereas others[25] have suggested that a diet of high glycemic index foods may contribute to higher levels of fasting insulin. The Therapeutic Lifestyle Changes guidelines recommend 50% to 60% of total calories as

carbohydrates and 20 g to 30 g of fiber per day, although the current Dietary Recommended Intake for men in this age group is 38 g of fiber daily.[26] Based on our knowledge of other studies and the natural progression of the disease, it seems prudent to recommend that athletes with MetSyn follow the Therapeutic Lifestyle Changes Guidelines, but more research on the influence of diet on MetSyn characteristics and performance is needed in this age group and in athletes.

Football linemen are considered strength athletes: "stronger is better." They spend a significant amount of time in intensive weight training. It is no secret that many of these larger athletes detest aerobic conditioning activities. Although we did not measure the aerobic capacity of our participants, it is plausible that a relative lack of aerobic conditioning prevented the exercise-associated increase in HDLs assumed as a benefit of regular exercise. We also do not know if early-season aerobic conditioning improves this metabolic profile to cycle athletes in and out of MetSyn as the season progresses. The prehypertension and low levels of HDL identified in this group should encourage coaching and strength staffs to favor more aerobic training. Improper resistance training techniques and prolonged static contractions are generally known to increase blood pressure; therefore, correcting lifting techniques in MetSyn athletes may help to limit peak blood pressures. The last few repetitions of any maximal effort set should be accompanied by experienced spotting to limit the voluntary concentric failure (isometric in nature) and to promote a less static contraction while breathing properly (ie, no Valsalva maneuver).[27] It is not possible to ascertain if the years of maximal-intensity strength training or the static nature of the lineman position (or both) is partially responsible for the prehypertension values we found in this study. The low levels of HDL in this group of football linemen as compared with those of Jonnalagadda et al[10] also deserve prompt attention by researchers to identify the probable stimulus and relationship to training routine and diet.

Given the likely metabolic differences in MetSyn athletes, it would be desirable to have a blood lipid profile before nutritional counseling intended to improve performance. In the absence of MetSyn, the traditional recommendation would be to place these athletes on a fairly high-carbohydrate training diet and to provide enough protein for the increase in muscle mass stimulated by the training routine.[28] As was the case in the study of Cole et al,[29] many of our athletes seemed to value meat in the diet, as indicated by the high preference for meat on the Nutrition Attitude Survey. The negative correlations of meat preference with waist circumference, decreased body fatness, and apparent better glucose handling (eg, FBG and HgbA1c levels) deserve more attention from the research community amid the feuds over high-protein diets in athletes. Our findings indicate that a preference for meat is associated with a slightly better MetSyn profile. It is unclear from these data if the preference for meat is equivalent to a high-protein diet or if these athletes simply consider meat important. Athletes with MetSyn may need different nutritional guidance than the usual high-carbohydrate, adequate-protein advice for athletes. Additionally, it would be interesting to evaluate these larger athletes for nonalcoholic fatty liver disease, as the literature indicates this condition is often concurrent with insulin resistance,[19] implicating high-fat and possibly high-carbohydrate diets.[30] Nonalcoholic fatty liver disease may help to explain the increased CRP levels associated with MetSyn.[28] This does not necessarily mean that a high-protein, low-carbohydrate diet will be advised, but clinical studies are justified to identify desirable macronutrient intakes for health and performance in this group of heavy athletes.

Examining the use of dietary supplements in these athletes is another perspective to consider in future research. Ma huang, caffeine, and other stimulants may increase blood pressure. Many football athletes use dietary supplements that contain multiple ingredients (including stimulants) designed to promote muscle growth and increase performance. Athletes with hypertension should be carefully questioned about the use of supplements because some of these agents can increase blood pressure.

Limitations

The main limitation of this study is the volunteer nature of human subject research. Many of the athletes at the DI and DIII schools chose not to participate. A few volunteers chose not to allow blood sampling. The physical activity and diet data in this analysis are insufficient to draw firm conclusions about their influence on the MetSyn, as the participants self-reported their estimated physical activity for the past week, which is not validated or necessarily reliable. The Nutrition Attitude Survey tool gives insight into dietary attitudes but does not allow for specific comparisons regarding the influence of the macronutrient composition of the diet. We cannot compare the incidence of MetSyn in this athlete cohort with that of the general population because the former is biased toward larger body size than that studied in most investigations of the latter. Many variables in this study, such as blood and blood pressure measures, may have improved accuracy with multiple measures. We designed our research as a field study to require limited participant effort and minimal time commitment. Body fatness may have been better measured in a BOD POD (Life Measurement Inc, Concord, CA) or underwater tank, but this method was time prohibitive and cost prohibitive for this field study, as not all institutions had access and some athletes would have had to travel.

CONCLUSIONS

Our findings should generate significant doubt about the presumed health of collegiate football linemen. Through various blood and anthropometric measures, we demonstrated that larger athletes, such as football linemen, should be screened for MetSyn. The current health of the athlete is of obvious ongoing concern in the field of sports medicine, but the future health of the larger athlete warrants more preventive consideration than it may be receiving. With a high prevalence of MetSyn in these collegiate athletes, we should look at the prevalence in younger football linemen as well as older linemen to examine the initiation and progression of symptoms. The physical activity of football linemen does not seem to confer enough protective benefit to avoid MetSyn, creating concern for these athletes when they retire from the sport if they choose to become less active.

ACKNOWLEDGMENTS

We thank the National Football League Charities for funding this project. Thank you to graduate student Amy Virden for setting up and coordinating the study, to each of the sports nutrition students who helped us collect and check the data, and to Tim Dunlavey, ATC (The Ohio State University) for his recruitment support. And finally, thank you to Barbara Lorson, Diane Habash, and Martha Belury (and her laboratory group) for insightful comments in review of the manuscript.

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