Differences in Obesity Measures and Selected Comorbidities in Former National Football League Professional Athletes

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Objective: To assess the accuracy of body mass index (BMI) as a measure of obesity compared with percent body fat (%BF) directly measured by dual energy x-ray absorptiometry among retired football players. **Methods:** The level of agreement between BMI and %BF as measures of obesity was assessed by sensitivity, specificity, and the kappa statistic among 129 retired football players. Logistic regression was used to investigate the association between obesity and selected comorbidities. **Results:** Using BMI 30 kg/m^2 or higher to identify obesity had poor specificity (0.36): 87 of 129 subjects were classified as obese, yet only 13 were truly obese based on %BF. Although BMI did not reliably indicate true %BF-obesity, BMI-obesity was significantly correlated with lineman position ($P < 0.0001$), years played ($P = 0.03$), and obstructive sleep apnea ($P = 0.0005$). **Conclusions:** Percent body fat measured by dual energy x-ray absorptiometry provides a more accurate measure of obesity than does BMI among retired football players.

Obesity is defined as an excess accumulation of body fat and has been linked to multiple health outcomes including cardiovascular disease, diabetes, hypertension, and other metabolic complications.[1–3] The World Health Organization (WHO) defines obesity as having a body mass index (BMI) equal to or greater than 30 kg/m^2. Body mass index is often accompanied by anthropometric measures to strengthen predictions. These measurements include waist circumference and waist-to-stature ratio.[4] Because BMI takes into consideration only height and weight, it is questionable whether BMI is an accurate reflection of an individual's excess body fat. Consequently, its interpretation fails to acknowledge the range of variability of lean body mass at a given height.[5]

Another limitation to BMI is that it fails to account for illnesses that may change body composition.[6] In addition, variability in body composition is expected among age, sex, and racial/ethnic categories and in special populations such as athletes and soldiers.[7–11] Thus BMI may not necessarily reflect the increased risk of certain comorbidities due to changes of body composition. Moreover, the BMI cut points recommended by the WHO are derived from the general population and may not be appropriately applied to specific populations. The tendency of BMI to misclassify obesity in certain populations shows that it may not be a good indicator of metabolic parameters for specific populations.[12–14]

Football players have shown to have a greater prevalence of obesity as well as accompanying health outcomes such as the metabolic syndrome and hypertension.[15,16] Because professional athletes have greater muscle mass, they would commonly be assigned a higher BMI. As such, the BMI cutoffs for obesity in this population might not reflect true obesity. A number of studies[9,13,17] have questioned the validity of using BMI to determine obesity in athletic populations. Nevertheless, despite the potential limitation, BMI is the most widely used measure of obesity because of its simplicity and inexpensiveness. Therefore, it is helpful to assess BMI accuracy when defining obesity in this population. To our knowledge, no such study has been undertaken among retired National Football League (NFL) players.

Direct measurements of percent body fat (%BF) provide an improved alternative to measuring obesity among specific populations.[8,18,19] Dual energy x-ray absorptiometry (DEXA) directly measures distribution of fat content, lean tissue mass, and bone. Past validation studies[20,21] have demonstrated strong %BF correlations between DEXA, computed tomography, and magnetic resonance imaging. In addition, measured values can be reproduced between studies and small changes in body composition can be detected.[22]

The objective of this study was to validate the accuracy of BMI when measuring obesity in a retired NFL population. We used %BF measured by DEXA as a gold standard reference for obesity. In addition, we investigated the correlation between obesity and several comorbidities in this population.

METHODS

The study's population consisted of 129 retired athletes from the NFL who were referred to an internal medicine practice during the study period beginning in May 2010 and ending in June 2011. A medical chart review was conducted for each participant to collect demographic information, comorbid conditions, and NFL career information.

Measures

Key measures included obesity defined by BMI standards of the WHO and obesity defined by %BF. Players considered obese had a BMI greater than 30 kg/m^2 based on height and weight measurements. Nevertheless, true obesity for this study was defined as players with a %BF greater than 25% for those who were 20 to 40 years old or a %BF greater than 27% for those who were older than 40 years.[23] The %BF was measured with DEXA (Hologic Discovery model QDR, Hologic Inc, Bedford, MA). The function and validation of DEXA has been described elsewhere.[24–26] The accuracy of using DEXA has been previously studied and shown to have a high precision rate and minimal influences on variations in measuring bone mineral density, lean tissue mass, and %BF.[27]

Other measures included age, ethnicity, and selected comorbid conditions. Information about positions played, years played, and years retired was also collected. Ethnicity was categorized as white versus African American. As a result of the larger discrepancy in size and body mass, positions played was categorized as lineman versus nonlineman.

Data Analysis

Descriptive statistics, including means, standard deviation, and percentages, were calculated to describe participant characteristics. Obesity defined by BMI was compared with obesity defined by %BF to evaluate agreement between these two definitions of obesity. Considering obesity as mesured by %BF as the gold standard

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for diagnosis, the consistency of BMI with %BF upon evaluation of obesity was investigated by sensitivity, specificity, and κ statistic.

Sensitivity is defined as the proportion of actual obese subjects who are correctly identified by BMI according to the %BF definition. Specificity is defined as the proportion of actual nonobese subjects who are correctly identified by BMI according to the %BF definition. Kappa coefficient was also used to adjust for agreement that may occur by chance.[28] Values of κ can range from -1 to $+1$. Negative values indicate agreement worse than chance, zero is agreement by chance alone, and positive values signify agreement better than chance. For this study, a value less than 0.21 is considered to be slight agreement; 0.21 to 0.40 is fair agreement; 0.41 to 0.60 is moderate agreement; 0.61 to 0.80 is substantial agreement; and values more than 0.80 indicate perfect agreement.

Receiver operating characteristic (ROC) curves were conducted to define the optimal BMI cut point corresponding to %BF-obesity. ROC curves are combinations of plots of sensitivity (true-positive rate) and 1-specificity (false-positive rate). The ideal coordinate (0, 1) indicates that the diagnostic test has a sensitivity of 100% and specificity of 100%. The closer the points on the ROC curve to the ideal coordinate, the more accurate the test is. The optimal point on the ROC was determined as the point closest to the ideal coordinate.

We also conducted multivariable logistic regression analyses to examine the association between obesity and selected comorbidities as well as other potential explanatory factors, including age, ethnicity, position played, years played, and years retired. All statistical analyses were conducted using SAS, version 9.1 (SAS Inc, Cary, NC); two-sided alpha levels of $P < 0.05$ were considered to be statistically significant.

RESULTS

A total of 129 NFL players were included in this study. Table 1 shows the participants' characteristics. Their average age was about 42 years and they were mainly African American (80%). Approximately half played in a linemen position. The average years played for the NFL among this group was 8 years. Participants were all retired from the NFL, with a range from 1 to 32 years in retirement. Hypertension and obstructive sleep apnea (OSA) were the two most common comorbidities among this population, with about 42% of the sample having both conditions. Other comorbidities noted were left ventricular hypertrophy (21%), gastroesophageal reflux disease (19%), and diabetes mellitus (8%).

On the basis of the BMI-obesity definition, 87 subjects were classified as obese in this study. Nevertheless, only 13 had true obesity when using a %BF definition. When using %BF greater than 25% for those who were 20 to 40 years old or a %BF greater than 27% for those who were older than 40 years as reference criterion of obese, a cut point of a BMI of 30 kg/m^2 or more showed 100% sensitivity (95% confidence interval [CI]: 0.75 to 1.00) but only 0.36 specificity (95% CI: 0.27 to 0.46). In addition, for BMI 30 kg/m^2 or more, the κ statistic showed poor agreement between %BF-obese and BMI-obese ($\kappa = 0.10$).

The optimal BMI cut point to detect %BF-obese was calculated via the ROC curves (Fig. 1). The ROC curves showed that the optimal BMI cut point was 40 kg/m^2 when using %BF as the reference criterion for obesity, which resulted in a sensitivity of 77% and a specificity of 91%.

We also conducted analyses of sensitivity, specificity, and κ statistic to compare agreement between various BMI cut points with the %BF-obese. Results are summarized in Table 2. A BMI cutoff at 40 kg/m^2 yielded the best agreement with a peak κ value of 0.53, indicating moderate agreement between BMI-obese and %BF-obese. This cut point was consistent with the optimal BMI cut point from the ROC curves.

TABLE 1. Sample Descriptive Statistics ($N = 129$)

	Value
Age (yr)	
Mean (SD)	42.2 (7.7)
Range	28.0–63.0
Ethnicity, *n* (%)	
White	24 (18.6)
African American	103 (79.8)
Other	2 (1.6)
Weight (lb)	
Mean (SD)	251 (49.3)
Range	167.0–415.0
Years played	
Mean (SD)	8 (3.6)
Range	1.0–20.0
Years retired	
Mean (SD)	11.9 (7.3)
Range	1.0–32.0
Lineman position (*n*,%)	
Yes	62 (48.8)
Comorbidity (*n*,%)	
HTN (Yes)	55 (42.6)
OSA (Yes)	156 (41.1)
LVH (Yes)	27 (20.9)
GERD (Yes)	25 (19.4)
DM (Yes)	10 (7.8)

DM, diabetes mellitus; GERD, gastroesophageal reflux disease; HTN, hypertension; LVH, left ventricular hypertrophy; OSA, obstructive sleep apnea.

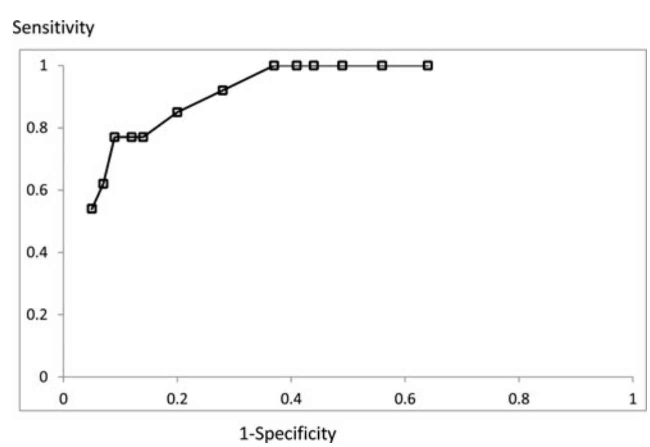

FIGURE 1. Receiver operating characteristics

To evaluate the assessment of obesity indices on metabolic risk, we performed bivariate analysis to investigate the associations between selected comorbid conditions (hypertension, left ventricular hypertrophy, diabetes mellitus, OSA, and gastroesophageal reflux disease with both BMI-obese and %BF-obese. Bivariate analyses showed BMI-obese was highly significant with OSA ($P < 0.0001$); none of the comorbidity was associated with %BF-obese.

Table 3 shows the multivariable analyses for both BMI-obese and %BF-obese. Lineman position was a significant factor associated

TABLE 2. Sensitivity, Specificity, and κ Statistic

BMI Cutoff	Sensitivity	Specificity	κ
≥30	1.00	0.36	0.10
≥31	1.00	0.44	0.14
≥32	1.00	0.51	0.17
≥33	1.00	0.56	0.20
≥34	1.00	0.60	0.23
≥35	1.00	0.63	0.25
≥36	0.92	0.72	0.31
≥37	0.85	0.80	0.38
≥38	0.77	0.86	0.44
≥39	0.77	0.88	0.47
≥40	0.77	0.91	0.53
≥41	0.62	0.93	0.50

BMI, body mass index.

TABLE 3. Adjusted Logistic Regression Models for BMI-Obese and %BF-Obese

	BMI-Obese		%BF-Obese	
	AOR	P	AOR	P
Age	0.80	0.104	0.91	0.418
African American	1.32	0.703	2.35	0.315
Years retired	1.33	0.055	1.17	0.206
Years played	1.35	0.030	1.01	0.915
Lineman (Yes)	18.87	<0.0001	9.53	0.0064
OSA (Yes)	7.40	0.0005	NA	NA

AOR, adjusted odds ratio; BF, body fat; BMI, body mass index; OSA, obstructive sleep apnea; NA, not applicable/available.

with both BMI-obese (adjusted odds ratio [AOR]: 18.87; $P < 0.0001$) and %BF-obese (AOR: 9.53; $P < 0.0064$). In addition, the risk of being BMI-obese significantly increased along with the years played (AOR: 1.35; $P = 0.03$). Moreover, BMI-obese players were more likely to have OSA than those who were not (AOR: 7.40; $P = 0.0005$). Age, ethnicity, and years in retirement were not significant factors associated with obesity.

DISCUSSION

This study assessed agreement between BMI and %BF as measures of obesity in a population of former NFL players. Overall, findings from this study showed that using BMI to identify obesity has poor specificity in this population. This indicates a low level of agreement between BMI-obese and %BF-obese. The low specificity means that BMI overestimates obesity by misclassifying a large percentage of normal fat individuals into the obese category in a NFL player population.

Some studies have assessed the diagnostic performance of BMI to identify obesity in relation to %BF. The results from these studies have been mixed, with sensitivity from 8.9% to 100% and specificity from 42% to 100%.[14,29–33] Nevertheless, comparison of our results with previous research may be difficult due to difference in study design, population, and methods for measuring %BF. For example, BMI showed a sensitivity of 13.3% and a specificity of 100% in the diagnosis of obesity compared with %BF determined by DEXA in a Swiss population, whereas another study reported both relatively high sensitivity (90.5%) and specificity (86.6%) for BMI as a measure of obesity when compared with bioelectrical impedance analysis.

Consistent with previous studies of a similar population,[14,17] our results suggest that BMI is not a good indicator of obesity for this athletic population. Variability of body composition exists between athletes and nonathletes. Athletes have lower skinfold measurements than nonathletes with the same BMI.[9] As expected, the BMI cutoff corresponding to the %BF-obese in this study population was much higher than the WHO cutoff derived from the general population. The ROC curves showed that a BMI cutoff of 40 kg/m^2 is better for obesity classification than the 30 kg/m^2 cutoff. Consistently, the κ statistics further supported the 40 kg/m^2 BMI cutoff as an optimal cut point with its peak κ value yielded. Nevertheless, variability in body composition is expected on the basis of age, sex, and ethnicity. Further study will be needed to better understand the age-, sex-, and ethnicity-specific cutoffs of BMI corresponding to the %BF cutoffs among specific populations.

No significant association was found between %BF-obese and the selected comorbidities in this study. It might be possible that the small number of %BF-obese subjects had limited power to detect statistical differences. Nevertheless, these findings showed that BMI-obese was a significant predictor of OSA. Thus, despite the inability of BMI to effectively represent %BF-obese in this population of retired NFL players, BMI-obese might be considered a good screening factor for certain comorbidities.

Playing a lineman position was found to be significantly associated with both BMI-obese and %BF-obese. This finding is in line with previous studies[15,34] that show elevated % BF found in football linemen. We presume that possible reasons for a higher prevalence of obesity in linemen would be due to specific aspects of the position. There is a large difference in size and body mass among football linemen compared with other positions. Moreover, the training for the lineman position reflects more isometric activities, whereas other skill-based positions require greater aerobic activities in their training and duty requirements. Generally, our data show that linemen had a higher likelihood of being obese relative to nonlinemen, which agrees with previous studies.[16]

This study had limitations. Within the study period of 14 months, only a small number of true obesity cases were identified, which might limit its power to detect statistical difference in some analyses. In addition, the cross-sectional study design prevents an assumption of causality between predictor and dependent variables.

CONCLUSION

We found BMI overestimates the number of obesity cases in a population of retired professional football athletes. Consequently, BMI is not a good indicator of obesity for this unique population. Medical personnel may want to employ %BF measures using DEXA to determine obesity in this population. Further study may need to be conducted to investigate the relationship between BMI and %BF for this unique population. In spite of misclassification of obesity, a BMI of 30 kg/m^2 or more might be used as a screening measure for retired NFL players. Prevention of obesity among this population should particularly focus on subgroups such as linemen and older players if there is a concern about OSA. Future studies should explore the training and requirements of such positions to acquire a better understanding of the elevated risks of obesity.

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