Journal of
Multicultural, Gender and Minority Studies
Volume 2, Issue 1, 2008

Examining the Validity of the Body Mass Index Cut-Off Score for Obesity of Different Ethnicities

Liette B. Ocker, Assistant Professor, Texas A&M University-Corpus Christi, liette.ocker@tamucc.edu
Don R. Melrose, Associate Professor, Texas A&M University-Corpus Christi, don.melrose@tamucc.edu

Abstract

The purpose of this study was to validate BMI cut-point values associated with obesity in different genders and ethnic groups. The criterion-referenced validity coefficients and decision validity coefficients were high. Obesity sensitivity, the percent of true positives, in Hispanics was higher than the other groups. The specificity, the percent of true negatives, was equally high for all the groups. Asians had a moderately low positive predictive value indicating that low BMI may have high body fat. Finally, the negative predictive values were good in all the ethnic groups.

Introduction

Over the past several decades medical doctors and researchers have indicated that obesity is associated with an increased risk for mortality and morbidity. Obesity as described by the American College of Sports Medicine (ACSM, 2006) is described as an excessive amount of adipose tissue, which is defined in young adults as body fat > 25% in males and > 32% in females. The percentage of body fat can be directly measured by a number of methods including underwater weighing, deuterium dilution, dual energy X-ray absorptiometry (DEXA), and skinfold thickness measurements; however, the applications of these direct methods are limited to laboratory settings or small samples. When conducting epidemiological studies, these direct approaches are time-consuming, expensive, or unavailable (Wellens et al., 1996).

To fill the void in epidemiological studies, the body mass index (BMI) has been a popularly adopted method of evaluating body composition by measuring the individual's body weight/stature^2 (kg/m^2). High BMI values are interpreted as evidence of being overweight or obese (Wellens et al., 1996). The recommended BMI cut-off point for evaluating individuals as overweight and obese is 25 kg/m^2, and 30 kg/m^2, respectively (World Health Organization, 2008). Although BMI is a viable approach, a concern remains that it measures the degree of excessive body weight rather than excessive body fat. Many physically fit individuals can be overweight, yet not over fat. In epidemiological studies, it is the degree of body fatness that determines the level of risk associated with disease. One way to enhance the usability of BMI in epidemiological studies may be to improve its measurement accuracy.

Identifying criterion-referenced cut-point standards for overweight and obesity validly and reliability is essential in evaluating public health issues. Using BMI as a screening measure should accurately detect individuals with the preclinical disease (i.e., obesity) as test-positive and those absent of the disease as test-negative (Hennekens & Buring, 1987). Measuring the overall validity of a criterion-referenced test is decision validity (C coefficient), which is calculated through the number of accurate responses into the entire pool of responses, a+d/a+b+c+d. The information applied to the validity coefficients was found utilizing the following frequency table:

	P	N
P	a	b
N	c	d

To a great extent, validity of criterion-referenced BMI standards may also be evaluated by sensitivity and specificity coefficients. Sensitivity, which is the probability of testing positive for the disease, is calculated by a/(a+c); where 'a' is the true positive and 'c' is the false negative. The number of people incorrectly categorized as not having the disease (false negatives) will decrease as sensitivity increases. Specificity, which is the probability of testing negative for the disease, is calculated by d/(b+d); where 'b' is the false positive, and 'd' is the true negative. As specificity increases, the number of people incorrectly categorized as having the disease (false positive) will decrease. (Hennekens & Buring, 1987). The level of sensitivity and specificity associated with the accuracy of screening obesity using BMI in part determine the validity of the screening test. Wellens et al. (1996) used sensitivity and specificity calculations to examine the accuracy of BMI to screen obesity and found that BMI only correctly identified about 44% of obese men and 52% obese women indicating that BMI was an uncertain diagnostic index of obesity.

When considering the number of people detected by a screening test, the predictive value is commonly considered. The predictive value determines whether or not a test-positive individual truly has the disease. The predictive value probabilities are calculated by using a/(a+b) for predictive value positive (PV+) measuring the probability that the person actually has the disease if screened positive; and d/(c+d) for the predictive value negative (PV-) measuring the probability that the person is actually disease-free after having a negative screening test (Hennekens & Buring, 1987). For instance, if a person is screened and found to be disease-free by a highly sensitive test, the less likely he/she is to have the disease, and the higher the predictive value negative sign. Similarly, if a person is found to have the disease using a highly sensitive test, he/she is less likely to be disease-free and have a high predictive value positive sign. There are several variables that affect the predictive value of a screening test including the validity of the instrument, sensitivity, specificity, and unique traits of the population where the test is applied (Wellens et al., 1996).

Three major individual background variables including: age, gender, and ethnicity, affect body composition. Both body fat and BMI increase as males and females age. However, because BMI is a function of body weight and males have more body density than females, there tends to be a slight difference in BMI between the genders (Deurenberg, Weststrate, & Seidell, 1991). Gallagher et al. (1996) found no differences in body fat and BMI among ethnic groups, yet additional studies indicated that in some populations there might be differences (Deurenberg et al., 1991; Deurenberg-Yap, Schmidt, van Staveren, & Deurenberg, 2000; Ko et al., 2001; Wang et al., 1994; WHO Expert Consultation, 2004; World Health Organization, 2008). For example, a study on Asian American anthropometric measurements found that Asian Americans had a lower BMI than Caucasians; however their percent fat was higher (Wang et al., 1994). Rose (1991) found that reducing the cut-point for obesity from 30 kg/m2 to 27 kg/m2 could increase the prevalence of obesity in a population by as much as 14 percentage points. These differences may require different cut-points for evaluating obesity using BMI among different ethnic groups. It appears that when using BMI to classify individuals into no risk, low risk, and high-risk categories, the gender and ethnic backgrounds should be taken into consideration.

The purpose of this study was to use criterion-referenced measurements to validate the BMI cut-point values reported by the World Health Organization (2008), through examining the sensitivity, specificity, predictive value positive, and predictive value negative coefficients for gender and ethnicity.

Method

Subjects

The subjects (*N* = 596) were obtained from archival data, derived from students enrolled in a required fitness and health physical education class at a major urban university. The student's participation was voluntary and all information was confidential. Background information are presented in Table 1. There were more females than males in all of the ethnicities, with African American females (67.39%) outnumbering the males (32.61%) by the greatest margin. The African American group was the smallest accounting for only 15.44% of the total subjects, which were reflective of the university student population.

Table 1. Descriptive Statistics of the Subject's Gender and Ethnic Group

Criterion Variable	Male		Female		Total	
	N	%	N	%	N	%
Subjects	251	42.11%	345	57.89%	596	100%
Ethnicity						
Asian	88	47.31%	98	52.69%	186	31.21%
African American	30	32.61%	62	67.39%	92	15.44%
Caucasian	92	43.19%	121	56.81%	213	35.74%
Hispanic	41	39.05%	64	60.95%	105	17.62%

Procedures

The variables that were examined for this study included: age, gender, ethnicity, height, weight, and sum of skinfolds. Except for the sum of skinfolds that was measured by the class instructor, all the variables used were self-report information collected from questionnaires and recorded onto a data form, which is a normal practice for epidemiology studies. The sum of skinfolds was obtained by measuring the double thickness subcutaneous fat of the triceps, hip, and thigh of the females, and the chest, abdomen, and thigh of the males, then summing the three measures. These procedures of predicting percent fat from the sum of skinfolds have been proven to be a valid method of evaluation (Jackson & Pollock, 1985). The prediction equations for calculating percent fat from the sum of skinfolds was determined utilizing the following formulas (Jackson & Ross, 1997):

Percent Fat (men) = (0.275 x Σ Chest, Abdomen, Thigh) + (0.122 x Age) - 2.322
Percent Fat (women) = (0.309 x Σ Arm, Hip, Thigh) + (0.053 x Age) + 3.670

The instructors were trained to measure each student using the standardized protocol. Height and weight information were converted to metric units of measure (i.e., pounds to kilograms and inches to meters) and BMI was calculated using the following formula:

BMI = weight/stature^2; kg/m^2.

Statistical Analysis

SPSS software was utilized for the data analysis. The BMI as a diagnostic index for obesity was investigated using decision validity a+d/(a+b+c+d), sensitivity a/(a+c), and specificity d/(b+d) calculations against body fat as a criterion variable (Hennekens & Buring, 1987). The cut-off value of 30 kg/m^2 defined obesity (World Health Organization, 2008). The selection of a BMI cut off value was based on the stability between high sensitivity and low specificity. Finally, the predictive values for both the positive a/(a+b) and negative d/(c+d) probabilities were examined to determine the rate at which an individual truly does or does not have obesity (Hennekens & Buring, 1987).

Results

The descriptive statistics for age, height, weight, BMI, and body fat are shown in Table 2.

Table 2. Descriptive Statistics of Age, Height, Weight, Body Mass Index (BMI), and Body Fat.

Gender	Asian American		African American		Caucasians	
	MEAN	SD	MEAN	SD	MEAN	SD
Males						
Age (y)	22.31	2.86	21.47	3.77	23.07	4.54
Height (cm)	171.70	8.88	182.37	8.50	179.92	8.77
Weight (kg)	68.33	13.18	81.38	15.23	82.78	15.16
BMI	23.16	4.02	24.32	3.28	25.63	4.68
Body fat (%)	19.54	6.68	16.66	6.15	21.82	7.77
Females						
Age (y)	22.32	2.95	20.35	3.61	23.11	4.59
Height (cm)	158.63	7.42	163.93	8.50	164.95	6.06
Weight (kg)	52.37	7.62	68.80	15.98	64.46	12.77
BMI	20.81	2.68	25.62	5.67	23.66	4.34
Body fat (%)	21.97	4.44	24.82	7.38	25.12	7.52
Overall						
Age (y)	21.78	2.94	20.72	3.68	23.09	4.55
Height (cm)	164.81	10.43	169.95	12.12	171.42	10.44
Weight (kg)	59.92	13.27	72.90	16.74	72.37	16.55
BMI	21.92	3.57	25.20	5.03	24.51	4.58
Body fat (%)	20.82	5.73	22.16	7.96	23.69	7.79

Continue Table 2.

Gender	Hispanic		Total	
	MEAN	SD	MEAN	SD
Males				
Age (y)	22.66	3.03	22.54	3.70
Height (cm)	173.90	7.92	176.35	9.56
Weight (kg)	80.87	17.42	77.23	16.22
BMI	26.75	5.30	24.79	4.60
Body fat (%)	21.78	8.88	20.40	7.59
Females				
Age (y)	21.48	3.17	21.80	3.88
Height (cm)	160.44	7.49	162.14	7.67
Weight (kg)	61.46	12.76	61.25	13.59
BMI	23.85	4.49	23.24	4.57
Body fat (%)	23.77	6.28	23.92	6.63
Overall				
Age (y)	21.94	3.15		
Height (cm)	165.70	10.08		
Weight (kg)	69.04	17.48		
BMI	24.98	5.00		
Body fat (%)	22.99	7.43		

Table 3 presents the diagnostic value of BMI versus percent fat resulting from decision validity, sensitivity, and specificity measures for the four ethnic groups and gender. The decision validity coefficients were all within acceptable levels (i.e., above .80) ranging from .85 for Hispanic males to .99 for Asian females. When examining the culmination of ethnicities, the sensitivity was 57.98% for men and 59.26% for women, and the specificity was 89.22% for men and 94.65% for women. The sensitivity ranged from 47.83% in Caucasians to 80% in Hispanics, while the specificity ranged from 85.26% in Hispanics to 97.25% in Asians. The positive predictive values were moderately low indicating that in Asians 28.57% of those who are diagnosed as obese using BMI actually have a high percent fat using skinfold measures. The negative predictive values were high in all the ethnic groups, which show that a high percentage of those who test negative for obesity using BMI actually were not obese.

Table 3. Diagnostic and Predictive Values (%) of BMI Versus Percent Fat by Ethnicity

	Asian	African American	Caucasian	Hispanic
Males				
Validity (C)	.93	.90	.87	.85
Sensitivity (%)	50.00	0.00[a]	62.50	80.00
Specificity (%)	95.24	93.00	89.29	85.26
PV^+	33.33	0.00[a]	35.71	36.36
PV^-	97.56	96.43	96.15	97.59
Females				
Validity (C)	.99	.87	.88	.94
Sensitivity (%)	0.00[ab]	75.00	40.00	100.00[b]
Specificity (%)	98.98	88.89	94.34	93.33
PV^+	0.00[a]	50.00	50.00	50.00
PV^-	100.00[b]	96.00	91.74	100.00[b]
Overall				
Validity (C)	.96	.88	.87	.85
Sensitivity (%)	50.00	66.67	47.83	80.00
Specificity (%)	97.25	90.36	92.11	85.26
PV^+	28.57	42.86	42.31	36.36
PV^-	98.88	96.15	93.58	97.59

[a] no subjects were identified in category 'a'
[b] no subjects were identified in category 'c'

Discussion

The decision validity coefficients for this criterion-referenced test were desirable for each ethnic group and both genders. The range was from .85 in Hispanic males to .99 in Asian females. Sensitivity reflects the proportion of people who are truly obese in a homogeneous population, while specificity reflects those who are truly not obese. Consequently, values are not influenced by the ratio of obese to non-obese subjects in this study. This study found that Hispanics had the highest sensitivity value (.80), followed by African Americans (.66), and then Asians (.50) and Caucasians had the lowest value (.48) when the males and females were combined. The sensitivity values for males and females for each ethnic group were similar to those found in the overall groupings. However, African American males and Asian females were not evaluated because no one was identified as obese either with BMI or skinfolds. The sensitivity represents the percentage of individuals who were truly obese if they had a BMI of 30 or greater. This indicates that only about 50% of truly obese Asians and 48% of truly obese Caucasians were identified by skinfold percent fat when using a BMI criterion. These relatively low values indicate that individuals who are at risk for obesity related diseases may not be identified accurately through BMI alone.

The specificity, those who are truly not obese, found in this study was all relatively high, ranging from .85 in Hispanics to .97 in Asians when evaluating the total sample. The specificity was also similarly high in the groups when gender was separated from ethnicity. The specificity values indicated that nearly all those individuals identified as truly not obese with BMI values less than 30, concurred with skinfold percent fat measures. Past research has given more importance to sensitivity than specificity because a false positive was not considered as serious a health consequence than a false negative (Wellens, et al., 1996). For that reason, the low sensitivity values signify a lower BMI cut point could identify more obese adults when using skinfold measures.

The feasibility of predicting obesity found with skinfolds with the BMI criterion showed low positive predictive values and high negative predictive values. In other words, this study found that approximately 1 out of every 2 to 3 people who were determined to have obesity using BMI actually did have the disease using skinfolds. The negative predictive values for this study resulted in virtually all the different ethnic groups testing negative for obesity with BMI when skinfold percent fat indicated they actually were not negative. The observations in this study indicate that there was a difference among the ethnic groups when using the BMI cut value as 30 or greater to identify obesity. The choice of the optimum cut value, where there is a good trade-off between sensitivity and specificity is subjective. Presently the World Health Organization (2008) decided against adjusting the BMI values for different ethnic groups, but will continue to monitor research findings such as this study in the future. Finally, future researchers may consider applying this information into a Receiver Operator Curve to graphically provide objectivity when identifying the BMI obesity values related to ethnicity.

References

American College of Sports Medicine (ACSM). 2006. *ACSM's Guidelines for Exercise Testing & Prescription* (7^{th} ed.). Philadelphia: Lippincott Williams & Wilkins.

Deurenberg, P., Weststrate, J. A., & Seidell, J. C. (1991). Body mass index as a measure of body fatness: age- and sex-specific prediction formulas. *British Journal of Nutrition, 65*(2), 105-114.

Deurenberg-Yap, M., Schmidt, G., van Staveren, W. A., & Deurenberg, P. (2000). The paradox of low body mass index and high body fat percentage among Chinese, Malays and Indians in Singapore. *International Journal of Obesity and Related Metabolic Disorders, 24*(8), 1011-1017.

Gallagher, D., Visser, M., Spulveda, D., Peirson, R. N., Harris, T., & Heymsfield, S. B. (1996). How useful is BMI for comparison of body fatness across age, sex and ethnic groups. *American Journal of Epidemiology, 143,* 228-239.

Hennekens, C. H., & Buring, J. E. (1987). Screening. In S. L. Mayrent (Ed.), *Epidemiology in Medicine* (1st ed., pp. 327-347). Boston: Little, Brown and Company.

Jackson, A. S., & Ross, R. M. (1997). Body composition, nutrition, and weight control, *Understanding Exercise for Health and Fitness* (3rd ed., pp. 76-90). Dubuque, IA: Kendall/Hunt.

Ko, G.T.C., Tang, J., Chan, J.C.N., Sung, R., Wu, M.M.F., Wai, H.P.S., & Chen, R. (2001). Lower BMI cut-off value to define obesity in Hong Kong Chinese: An analysis based on body fat assessment on bioelectrical impedance. *British Journal of Nutrition, 85*, 239-242.

WHO Expert Consultation (2004). Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet,* 157-163.

World Health Organization. (2008, June 2). BMI classification. Retrieved from http://www.who.ino/bmi/index.jsp?intropage=intro_3.html

Rose, G. (1991). Population differences of risk and disease. *Nutrition, Metabolism and Cardiovascular Disease, 1,* 37-40.

Wang, J., Thornton, J. C., Russell, M., Burastero, S., Heymsfield, S., & Pierson, R. N., Jr. (1994). Asians have lower body mass index (BMI) but higher percent body fat than do whites: Comparisons of anthropometric measurements. *American Journal of Clinical Nutrition, 60*(1), 23-28.

Wellens, R. I., Roche, A. F., Khamis, H. J., Jackson, A. S., Pollock, M. L., & Siervogel, R. M. (1996). Relationships between the Body Mass Index and body composition. *Obese Research, 4*(1), 35-44.