The American Journal of Clinical Nutrition

Is percentage body fat differentially related to body mass index in Hispanic Americans, African Americans, and European Americans?[1–3]

José R Fernández, Moonseong Heo, Steven B Heymsfield, Richard N Pierson Jr, F Xavier Pi-Sunyer, Zimian M Wang, Jack Wang, Matthew Hayes, David B Allison, and Dympna Gallagher

ABSTRACT

Background: Limited research has been done to explore differences between ethnic groups, including Hispanic Americans (HAs), in the association between percentage body fat (PBF) and body mass index (BMI; in kg/m^2); the numbers of HAs are increasing in the US population.

Objective: We investigated whether the relation between PBF and BMI in adult HAs differed from that of African Americans (AAs) and European Americans (EAs).

Design: We used a multiple regression model in which PBF measured with dual energy X-ray absorptiometry was predicted by the reciprocal of BMI (1/BMI; in m^2/kg) in a sample of 487 men (n_{EA} = 192, n_{AA} = 148, and n_{HA} = 147) and 933 women (n_{EA} = 448, n_{AA} = 304, and n_{HA} = 181).

Results: For men, our results showed no significant differences between HAs and EAs, AAs and EAs, or HAs and AAs in the slope of the line relating 1/BMI to PBF. In women, there were significant differences in PBF as predicted by BMI between HAs and EAs ($P < 0.002$) and AAs and HAs ($P = 0.020$), but not between AAs and EAs. When PBF was estimated on the basis of predicting equations, the trend of the predicted PBF value in women differed according to ethnic group and BMI category. At a BMI < 30, HAs tended to have more body fat than did EAs and AAs, and at a BMI > 35, EAs tended to have more body fat than did the other groups.

Conclusions: Our results show that the relation between PBF and BMI in HA women differs from that of EA and AA women. *Am J Clin Nutr* 2003;77:71–5.

KEY WORDS Body composition, ethnicity, percentage body fat, body mass index, Hispanic Americans, Hispanics, dual-energy X-ray absorptiometry, DXA

INTRODUCTION

During the past decade, the number of Hispanic Americans (HAs) increased more rapidly than the number of people from any other ethnic group in the United States. The population of HAs increased by 57.9%, compared with an increase of 13.2% for the total population. In the 2000 Census, 35.3 million persons (12.5%) in the US population identified themselves as Hispanic, a broad term encompassing persons descending from Central America, Cuba, the Dominican Republic, Mexico, Puerto Rico, Spain, and South America (Internet: http://blue.census.gov/prod/2001pubs/c2kbr01–3.pdf).

Higher prevalences of overweight and obesity, as measured in terms of body mass index (BMI; in kg/m^2), have been documented among HAs compared with other ethnic groups (1, 2). In a recent study, Casas et al (3) reported that healthy Hispanic women have higher adiposity and lower amounts of fat-free mass than do white women. This higher adiposity has been associated with multiple metabolic syndromes in Hispanic men and with higher fasting insulin concentrations in Hispanic men and women (4). Higher amounts of body fat in HA adults may constitute a public health concern for this population, because evidence shows that HAs are at increased risk for obesity-related conditions such as cardiovascular disease (5) and type 2 diabetes (6).

Body weight adjusted for stature is often used as an alternative to the estimation of adipose tissue mass when evaluating individuals or populations for obesity (7). Many studies have shown that BMI is a reasonable index of adiposity (8–11), given that body weight and stature are simple, inexpensive, safe, and practical measurements to acquire, particularly for groups with limited access to health care. Ethnic differences in the relation between BMI and percentage body fat (PBF) have been found. More specifically, at the same BMI, PBF differed between Asian, African American (AA), and white persons after sex, age, height, and weight were controlled for (12, 13). This relation has not been investigated in HAs. The purpose of this study was to assess the relation between BMI and PBF in HA adults, and to determine whether this relation differs from that in AA and European American (EA) adults.

[1] From the Obesity Research Center, St Luke's–Roosevelt Hospital and the Institute of Human Nutrition, Columbia University College of Physicians and Surgeons, New York (JRF, MH, SBH, RNP, FXP-S, ZMW, JW, MH, and DG), and the Departments of Nutrition Sciences (JRF) and of Biostatistics and Clinical Nutrition Research Center (JRF and DBA), University of Alabama at Birmingham.

[2] Supported in part by NIH grants R01DK51716, P30DK26687, P30DK056336, R01ES09912, and P01DK42618.

[3] Reprints not available. Address correspondence to JR Fernández, Division of Physiology and Metabolism, Department of Nutrition Sciences, University of Alabama at Birmingham, Webb 435, 1530 3rd Avenue S, Birmingham, AL 35294-3360. Email: fernandj@shrp.uab.edu.

Received November 20, 2001.

Accepted for publication March 21, 2002.

Downloaded from ajcn.nutrition.org by guest on December 26, 2016

The American Journal of Clinical Nutrition

TABLE 1
Subject age, BMI, percentage body fat (PBF), smoking status, and exercise level by ethnic group and sex[1]

	Age	BMI	PBF	Smoking[2]	Exercise[3]
	y	*kg/m²*	*%*		
African Americans					
Men (n = 148)	48.5 ± 19.9[a]	26.0 ± 3.7[a]	21.3 ± 8.5[a]	0.33 ± 0.47[b]	0.52 ± 0.40
Women (n = 304)	50.8 ± 18.2[c]	29.8 ± 5.5[c]	39.9 ± 8.4[c]	0.16 ± 0.37	0.36 ± 0.48[c]
European Americans					
Men (n = 192)	42.6 ± 20.07[b]	25.8 ± 3.7[a]	20.8 ± 8.8[a]	0.20 ± 0.40[a]	0.60 ± 0.49
Women (n = 448)	42.9 ± 18.0[d]	25.1 ± 5.8[d]	32.5 ± 10.9[d]	0.19 ± 0.39	0.53 ± 0.50[d]
Hispanic Americans					
Men (n = 147)	43.7 ± 15.5[a,b]	27.2 ± 4.4[b]	24.0 ± 8.7[b]	0.30 ± 0.46[a,b]	0.52 ± 0.50
Women (n = 181)	48.1 ± 16.5[c]	27.8 ± 5.3[e]	39.1 ± 7.8[c]	0.23 ± 0.42	0.25 ± 0.43[e]

[1] $\bar{x}$ ± SD. Values in the same column with different superscript letters (a and b for men and c, d, and e for women) indicate significant within-sex differences, $P < 0.05$ (post hoc Tukey's test after a one-factor ANOVA).
[2] Coded as 1 for smokers and as 0 for nonsmokers.
[3] Coded as 1 for subjects who spent ≥4 h/wk exercising and as 0 for other subjects.

SUBJECTS AND METHODS

Subjects

Data for this study were compiled from 11 cross-sectional studies involving body-composition assessments at the New York Obesity Research Center. The ethical standards of human experimentation were followed. The study protocol was approved by St Luke's–Roosevelt Hospital Center, and all subjects provided written, informed consent.

Descriptive characteristics, including the age, sex, and ethnicity distributions of the subjects, are shown in **Table 1**. In all 11 studies, participants were recruited by asking for healthy persons; thus, all subjects defined themselves as healthy. Moreover, subjects who self-reported undernutrition, HIV-AIDS, alcoholism, or diabetes in the questionnaire were excluded from the study. The percentage of subjects in the sample who reported that they smoked was 18.9%, and 40.8% of subjects reported that they exercised for ≥4 h/wk, an arbitrary threshold selected under the assumption that exercise levels exceeding this threshold may affect body composition. Because the objective of the present study was to explore the relation between PBF and BMI in the general public, we included smoking status and exercise level as covariates in the statistical analysis and did not exclude persons who engaged in these behaviors.

Body composition

BMI was calculated from weight and height for each subject. Weight was measured to the nearest 0.1 kg (Weight Tronix, New York) and height was measured to the nearest 0.5 cm (Holtain Stadiometer, Crosswell, Wales, United Kingdom). Total body fat was measured with dual-energy X-ray absorptiometry (DXA; model DPX; Lunar Radiation, Madison WI).

We compared the body weight value measured on the scale with a DXA-derived body weight value. The latter was calculated by adding the values for soft tissue and bone mineral content obtained with DXA. To reduce possible measuring bias, particularly at BMI values > 35, subjects who had a difference of > 2.0 kg between the DXA-measured weight and the scale-measured weight were excluded from the analyses.

Statistical analyses

Single regression models in which PBF was regressed on BMI were used to identify outliers. Subjects with PBF > 2.5 SEE (the estimated SD of the error term in the regression model) were also excluded from subsequent analyses. The effect of such exclusion was evaluated in a sensitivity analysis (*see* Discussion). After exclusion, a total of 487 men (n_{EA} = 192, n_{AA} = 148, and n_{HA} = 147) and 933 women (n_{EA} = 448, n_{AA} = 304, and n_{HA} = 181) were included in the analyses. The average age of subjects in the sample was 45.9 y (range: 18–110 y).

Multiple linear regression models were used to identify significant differences in PBF predicted from BMI for men and women of the 3 ethnic groups. The scatter plot of PBF versus BMI, showing a nonlinear trend in the distribution, is shown in **Figure 1**. To improve the linearity of the relation between the dependent variable and the independent variable, the reciprocal of BMI (ie, 1/BMI; in m^2/kg), defined as INVBMI, was used as a predictor of PBF measured with DXA (Figure 1). A dummy coding system was used to identify ethnicity. The predictor model for each sex defined PBF as a function of ethnicity, smoking status, exercise level, age, INVBMI, and the interaction between INVBMI and ethnicity. This model is defined by the following equation:

$$\begin{aligned} \text{PBF} = b_0 + b_1\,\text{ethnicity} + b_2\,\text{smoking} + b_3\,\text{exercise} \\ + b_4\,\text{age} + b_5\,1/\text{BMI} + b_6\,(1/\text{BMI} \times \text{ethnicity}) \end{aligned} \quad (1)$$

where smoking = 1 for smokers and 0 for nonsmokers and exercise = 1 for subjects who spent ≥4 h/wk exercising and 0 for other subjects.

An interaction term defining age × ethnicity was added to the model to test for differences in the effect of age on the prediction equation across the 3 ethnic groups. Because we found no significant differences in the effect of age across ethnic groups in the prediction of PBF by INVBMI, this component was removed from the model for the final analysis. All analyses were performed by using the linear regression option of SPSS, version 10 (SPSS Inc, Chicago).

RESULTS

The results from the regression model described in Equation *1* are shown in **Table 2**. In this model, the estimates for b_o represent EAs, and the model compares EAs with both AAs and HAs. To test whether differences existed between AAs and HAs, a second model was developed in which b_o represented HAs (results not shown).

Downloaded from ajcn.nutrition.org by guest on December 26, 2016

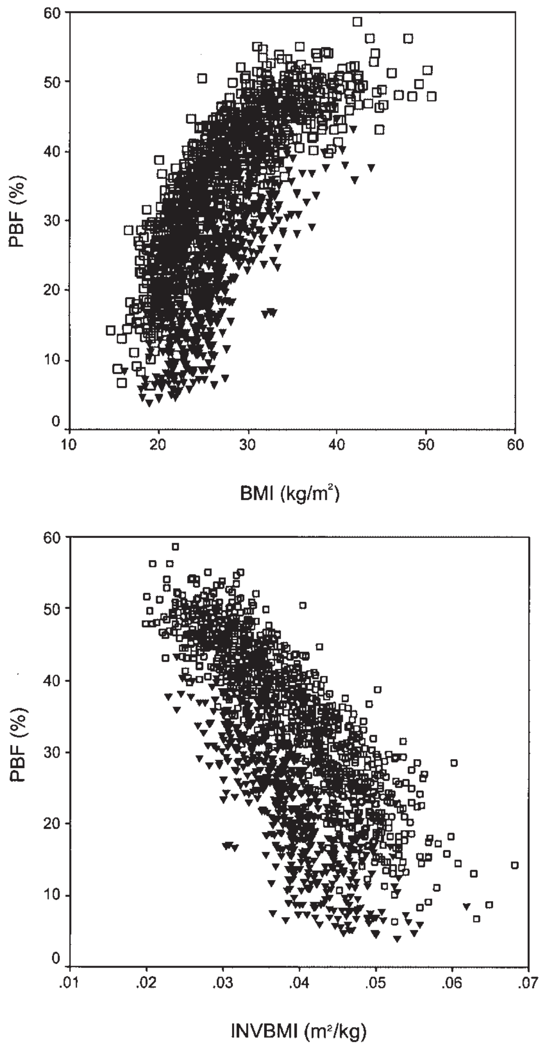


FIGURE 1. Scatter plots of percentage body fat (PBF) versus BMI and PBF versus INVBMI (1/BMI) in men (▼) and women (□).

When PBF was predicted by using BMI, the results showed no significant differences in the slopes between HA and EA men ($P = 0.246$), between AA and EA men ($P = 0.578$), or between HA and AA men ($P = 0.565$). In women, significant differences in PBF as predicted by BMI were observed between HA and EA women ($P = 0.002$) and between AA and HA women ($P = 0.020$), but not between AA and EA women ($P < 0.490$).

The results of the predictor model were used to estimate the trends of predicted PBF in a BMI range of 15–50 for women and 18–50 for men, within each ethnic group. This estimation was performed at consistent values for exercise level, smoking status, and age according to sex, ie, we used the averages for exercise (0.55 ± 0.50 for men and 0.42 ± 0.49 for women), smoking (0.27 ± 0.45 for men and 0.19 ± 0.39 for women), and age (44.7 ± 18.9 y for men and 46.5 ± 18.2 y for women).

The predicted PBF values according to BMI values between 15 and 50 for women and 18 and 50 for men are shown in **Figure 2**. Interestingly, in women, the trend of predicted PBF values among the ethnic groups differs according to BMI: at BMI < 30, HA tended to have higher PBF than did EA and AA, and at BMI > 35, EA tended to have higher PBF than did the other groups.

TABLE 2
Results from the regression equations by sex[1]

	Unstandardized coefficients		
	β	SE	P
Men			
Constant	60.774	3.179	0.001
HA	4.809	4.252	0.259
AA	1.020	4.410	0.817
INVBMI	−1084.429	75.089	0.001
INVBMI × HA	−126.508	108.890	0.246
INVBMI × AA	−61.678	110.89	0.578
Age	0.112	0.014	0.001
Exercise	−1.933	0.506	0.001
Smoking	0.343	0.567	0.546
Women			
Constant	76.956	1.233	0.001
HA	−5.970	2.305	0.010
AA	−2.190	1.790	0.221
INVBMI	−1105.590	26.153	0.001
INVBMI × HA	189.946	59.626	0.002
INVBMI × AA	33.017	47.820	0.490
Age	0.05836	0.009	0.001
Exercise	−1.285	0.321	0.001
Smoking	0.09387	0.385	0.807

[1] HA, Hispanic Americans; AA, African Americans; INVBMI, 1/BMI; INVBMI × HA, interaction between INVBMI and HA; INVBMI × AA, interaction between INVBMI and AA.

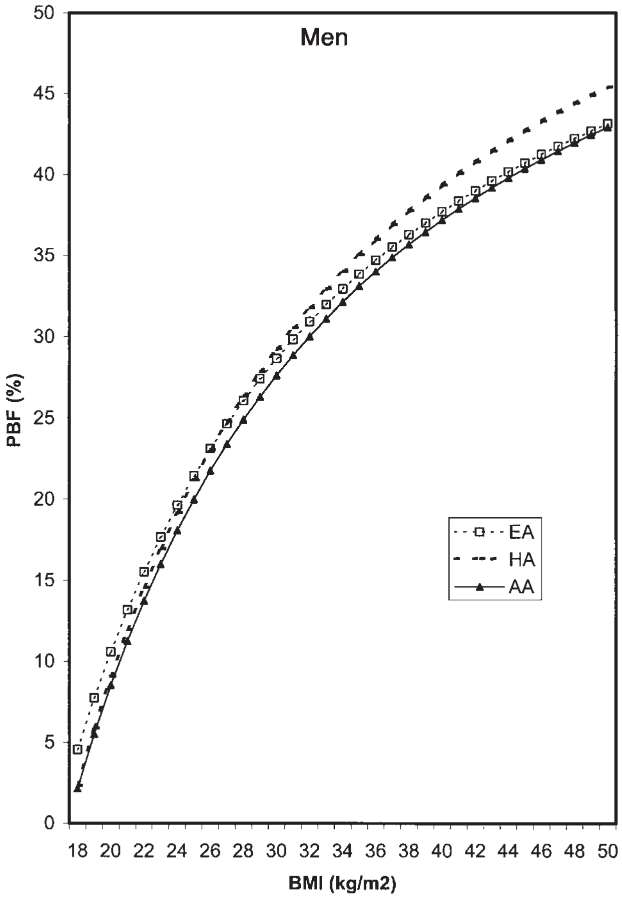
DISCUSSION

The present study is the first to our knowledge that has investigated whether the relation between PBF and BMI in HAs differs from that in AAs and EAs. The results show significant differences in the slope of the line predicting PBF from BMI when HA women were compared with AA and EA women, but no significant differences between EA and AA women or between any combination of these ethnic groups in men. These findings show that at the same BMI, women of HA ethnicity have different PBF values when compared with women of EA and AA descent. Although there are some potential explanations for these differences, including sedentary lifestyles and possible differences in genetic makeup among the ethnic groups, the mechanisms underlying these differences require further investigation. Similar observations regarding the mediation of BMI on PBF by sex and ethnicity have been reported in groups other than HAs (12, 14–16).

The estimation of PBF from BMI by sex in each ethnic group (Figure 2) shows almost identical PBF values in AA and HA men at BMIs of 18 to 24, in HA and EA men at BMIs of 24 to 31, and in AA and EA men at BMIs of 39 to 50. In women, we found almost identical PBF values at BMIs of 15 to 25 for AAs and EAs, 29 to 35 for EAs and HAs, and 39 to 46 for AAs and HAs. It is important to emphasize that the PBF values obtained from BMI in this study are estimates determined on the basis of our sample and that significant differences were only found in women. To assess how sensitive the results were, we tested the multiple regression models without excluding the outliers and without excluding those persons who met the exclusion criteria described previously. The results obtained were consistent across all the conditions; there were significant differences in the slopes between EA and HA women and between AA and HA women, but not

The American Journal of Clinical Nutrition

Downloaded from ajcn.nutrition.org by guest on December 26, 2016



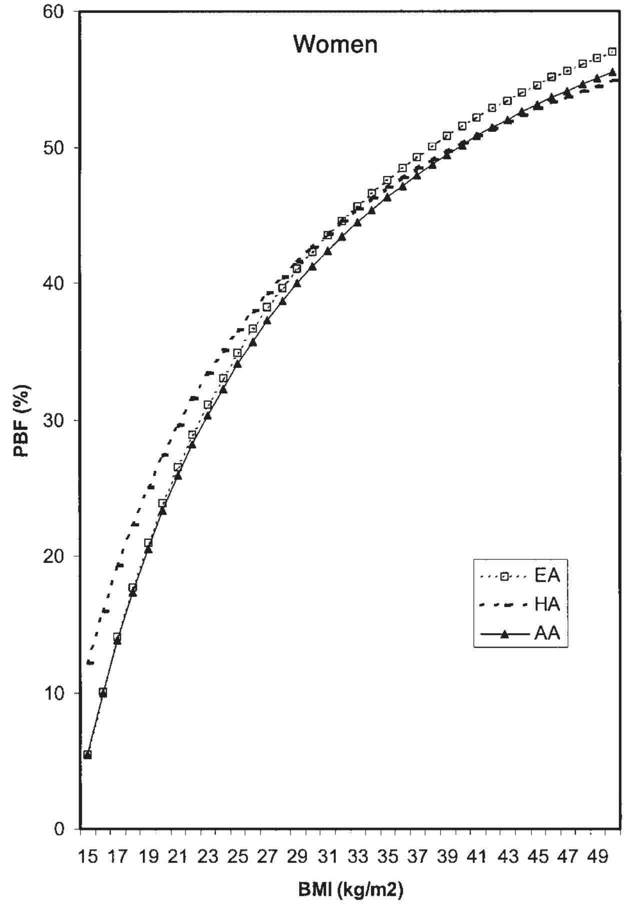


FIGURE 2. Percentage body fat (PBF) in African American (AA), European American (EA), and Hispanic American (HA) men and women estimated from Equation *1* after adjustment for age, exercise level, and smoking status. The adjusted equations for PBF are as follows: HA_{women}, PBF = 73.175 − 915.644 × INVBMI; EA_{women}, PBF = 79.145 − 1105.59 × INVBMI; AA_{women}, PBF = 76.955 − 1072.573 × INVBMI; HA_{men}, PBF = 69.622 − 1210.938 × INVBMI; EA_{men}, PBF = 64.813 − 1084.43 × INVBMI; and AA_{men}, PBF = 65.832 − 1146.108 × INVBMI. INVBMI = 1/BMI.

between AA and EA women or between any combination of the ethnic groups in men.

Three aspects of our model deserve further discussion. These aspects are the use of INVBMI as a predictor, the inclusion of smokers in the sample, and the inclusion of exercisers in the sample. The prediction model used in this study was developed on the basis of linear multiple regression, and thus it appeared advisable to maximize the linearity of the predictor variable before modeling. The use of the inverse of BMI in the model was supported by the observation that it increased the linearity of the predictor (17).

This study investigated the prediction of PBF from BMI in the general public, and it is known that a substantial portion of the US population uses tobacco. This fact supported the inclusion of smokers in our sample, with a statistical adjustment for the effect of smoking as a covariate. According to the Centers for Disease Control and Prevention, the prevalence of cigarette smoking by adults in the United States ranges from 13.9% to 31.5%, depending on the state of residence. In our sample, 18.9% of subjects smoked, which is somewhat lower than the smoking rate of 21.9% in the state of New York (Internet: http://www2.cdc.gov/nccdphp/osh/state/rpt_epi_display.asp?rpt_id = E1). Similarly, exercise level was used as a covariate in the prediction equation, because 22.2% of the subjects in the sample reported exercising for >4 h/wk.

We measured PBF with the DXA method, which is a well-validated tool for the measurement of body fat. The use of DXA to quantify the outcome variable reduced biases that might have resulted from measurement errors. However, the statistical analyses were limited by the lack of inclusion of other possible confounders that might have influenced the relation between BMI and PBF, such as menopausal status, hormone use, or dietary habits, and by the arbitrary selection of 4 h/wk as a cutoff for exercise level.

An important issue to consider when interpreting the results of this study is the use of the term Hispanic. Members of this ethnic group carry the cultural and genetic background of admixed populations with different combinations of Amerindian, European, and African ancestry. These populations are highly admixed, not only in terms of genetic background, but also in terms of cultural and dietary factors. Therefore, dividing the category Hispanic into subgroups with genetic, cultural, and dietary similarities would provide a more accurate research tool and deserves further exploration. Nonetheless, this investigation supports the importance of using prediction equations for PBF as a tool for studying obesity in epidemiologic and public health applications. BMI can be used by the general public to assess a person's risk for chronic disease and illnesses, because BMI is easily calculated and is therefore accessible to the layperson. Reducing the risk of obesity-related

The American Journal of Clinical Nutrition
Downloaded from ajcn.nutrition.org by guest on December 26, 2016

comorbidities by empowering members of at-risk minority groups to self-assess their risk should be a priority of public health and educational leaders.

REFERENCES

1. Flegal KM, Carroll MD, Kuezmarski RJ, Johnson CL. Overweight and obesity in the United States: prevalence and trends, 1960–1994. Int J Obes Relat Metab Disord 1998;22:39–47.
2. Wang J, Thornton JC, Burastero S, et al. Comparisons for body mass index and body fat percent among Puerto Ricans, blacks, whites and Asians living in the New York City area. Obes Res 1996;4:377–84.
3. Casas YG, Schiller BC, Desouza CA, Seals DR. Total and regional body composition across age in healthy Hispanic and white women of similar socioeconomic status. Am J Clin Nutr 2001;73:13–8.
4. Okosun IS, Liao Y, Rotimi CN, Prewitt TE, Cooper RS. Abdominal adiposity and clustering of multiple metabolic syndrome in White, Black and Hispanic Americans. Ann Epidemiol 2000;10:263–70.
5. Sundquist J, Winkleby MA, Pudaric S. Cardiovascular disease risk factors among older black, Mexican-American, and white women and men: an analysis of NHANES III, 1988–1994. Third National Health and Nutrition Examination Survey. J Am Geriatr Soc 2001;49:109–16.
6. Okosun IS. Ethnic differences in the risk of type 2 diabetes attributable to differences in abdominal adiposity in American women. J Cardiovasc Risk 2000;7:425–30.
7. Keys A, Fidanza F, Karvonen MJ, Kimura N, Taylor HL. Indices of relative weight and obesity. J Chronic Dis 1972;25:329–43.
8. Frisancho AR. Anthropometric standards for the assessment of growth and nutritional status. Ann Arbor, MI: University of Michigan Press, 1990.
9. Fuller NJ, Jebb SA, Laskey MA, Coward WA, Elia M. Four-component model for the assessment of body composition in humans: comparison with alternative methods, and evaluation of the density and hydration of fat-free mass. Clin Sci (Colch) 1992;82:687–93.
10. Pierson RN Jr, Wang J, Colt EW, Neumann P. Body composition measurements in normal man: the potassium, sodium, sulfate and tritium spaces in 58 adults. J Chronic Dis 1982;35:419–28.
11. Russell-Aulet M, Wang J, Thornton J, Pierson RN Jr. Comparison of dual-photon absorptiometry systems for total-body bone and soft tissue measurements: dual-energy X-rays versus gadolinium 153. J Bone Miner Res 1991;6:411–5.
12. Deurenberg P, Yap M, van Staveren WA. Body mass index and percent body fat: a meta analysis among different ethnic groups. Int J Obes Relat Metab Disord 1998;22:1164–71.
13. Gallagher D, Heymsfield SB, Heo M, Jebb SA, Murgatroyd PR, Sakamoto Y. Healthy percentage body fat ranges: an approach for developing guidelines based on body mass index. Am J Clin Nutr 2000;72:694–701.
14. Gallagher D, Visser M, Sepulveda D, Pierson RN, Harris T, Heymsfield SB. How useful is body mass index for comparison of body fatness across age, sex, and ethnic groups? Am J Epidemiol 1996;143:228–39.
15. Wang J, Thornton JC, Russell M, Burastero S, Heymsfield S, Pierson RN Jr. Asians have lower body mass index (BMI) but higher percent body fat than do whites: comparisons of anthropometric measurements. Am J Clin Nutr 1994;60:23–8.
16. Ortiz O, Russell M, Daley TL, et al. Differences in skeletal muscle and bone mineral mass between black and white females and their relevance to estimates of body composition. Am J Clin Nutr 1992;55:8–13.
17. Flegal KM. Is an inverted weight-height index a better index of body fatness? Obes Res 1997;5:93S (abstr).

The American Journal of Clinical Nutrition

Downloaded from ajcn.nutrition.org by guest on December 26, 2016