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PAPER

Generalized abdominal visceral fat prediction models for black and white adults aged 17–65 y: the HERITAGE Family Study

PR Stanforth[1]*, AS Jackson[2], JS Green[3], J Gagnon[4], T Rankinen[5], J-P Després[6], C Bouchard[5], AS Leon[7], DC Rao[8], JS Skinner[9] and JH Wilmore[3]

[1]*Department of Kinesiology and Health Education, The University of Texas, Austin, TX, USA;* [2]*Department of Health and Human Performance, University of Houston, Houston, TX, USA;* [3]*Department of Health and Kinesiology, Texas A&M University, College Station, TX, USA;* [4]*Laboratory of Molecular Endocrinology, Laval University, Québec City, Québec, Canada;* [5]*Pennington Biomedical Research Center, Baton Rouge, LA, USA;* [6]*Québec Heart Institute, Laval Hospital Research Center, Laval University, Québec City, Québec, Canada;* [7]*School of Kinesiology and Leisure Studies, University of Minnesota, Minneapolis, MN, USA;* [8]*Division of Biostatistics, Washington University School of Medicine, St Louis, MO, USA; and* [9]*Department of Kinesiology, Indiana University, Bloomington, IN, USA*

OBJECTIVE: To determine if the relationship between abdominal visceral fat (AVF) and measures of adiposity are different between Black and White subjects and to develop valid field prediction models that accurately identify those individuals with AVF levels associated with high risk for chronic disease.
DESIGN: Cross-sectional measurements obtained from 91 Black men, 137 Black women, 227 White men, and 237 White women subjects, ages 17–65 y, who were participants in the HERITAGE Family Study, both at baseline and following 20 weeks of endurance training.
MEASURMENTS: AVF, abdominal subcutaneous fat (ASF), abdominal total fat (ATF), and sagittal diameter (SagD) were measured by computed tomography (CT). Body density was determined by hydrostatic weighing and was used to estimate relative body fat. Arm, waist (WC), and hip circumferences and skinfold thickness measures were taken, and BMI was calculated from weight (kg) and height (m^2). Since CT abdominal fat variables were skewed, a natural log transformation (Ln) was used to produce a normal distribution. The General Linear Model (GLM) procedure was used to test the relationship between AVF and two different groups of variables—CT and anthropometric.
RESULTS: The AVF of White men and women was significantly higher than that of Black men and women, independent of BMI, WHR, WC, and age, and was greater for men than for women. The CT model showed that the combination of SagD, Ln (ASF), age, and race accounted for 84 and 75% of the variance in AVF in men and women, respectively. The anthropometric model provided two valid generalized field AVF prediction equations. The Field-I equation, which included BMI, WHR, age and race, had an r^2 of 0.78 and 0.73 for men and women, respectively. The Field-II equation, which included BMI (women only), WC, age, and race, had an r^2 of 0.78 and 0.72 for men and women, respectively. The field model equations became less accurate as the estimated AVF increased.
CONCLUSIONS: (1) At the same age and level of adiposity, Black men and women have less AVF than White men and women. These differences are greater in men than in women. (2) The field regression equations can be generalized to the diverse group of adults studied, both in an untrained and trained state. However, their accuracy decreases with increasing levels of AVF.
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Introduction

Abdominal visceral obesity is associated with an increased risk for cardiovascular disease and metabolic and endocrine disorders.[1] Computed tomography (CT)[2–6] and magnetic resonance imaging[7–10] are used to measure abdominal visceral fat (AVF), but these measures are not routinely

***Correspondence: PR Stanforth, Bellmont Hall Rm 222, The University of Texas at Austin, Austin, TX 78712, USA.**
E-mail: p.stanforth@mail.utexas.edu
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obtained due to the high cost and unavailability of the associated equipment. This has led investigators[7,8,11–24] to examine potential predictors of AVF from more accessible demographic, anthropometric, and body composition variables. Most of these studies have included only White subjects, but there is evidence that when controlled in some manner for body fatness, the relationship of anthropometric and body composition measures to AVF may be different for Black and White subjects. Després *et al*[25] observed that Black men and women had less AVF than did White men and women for a given amount of total body fat mass. This is in agreement with most[11,13,17,21] but not all[22] studies that have compared AVF levels in Black and White subjects after adjusting for some measure of adiposity. These results suggest that regression equations established with White subjects to estimate AVF might be biased when applied to Black subjects.

Further, most prediction equations developed to estimate AVF have had relatively high standard errors of estimate (s.e.e.). However, it is possible that these equations could identify those individuals who are at highest risk due to excessive AVF. Previous studies[26,27] have identified an AVF level of 130 cm^2 as a critical threshold above which glucose, insulin, and lipid–lipoprotein metabolic abnormalities become more prevalent. Rankinen *et al*,[28] in a study of 789 French Canadians, determined that waist circumference (WC) had the best combined sensitivity (probability of correctly detecting those with an AVF $>130\,cm^2$) and specificity (probability of correctly detecting those with an AVF $<130\,cm^2$). Using WC as a predictor of AVF, their sensitivity values ranged from 81 to 91% and their specificity values ranged from 75 to 90% for men and women of varying ages. If an AVF level of 130 cm^2 is a critical threshold for Black as well as White subjects, then the anthropometric values used to identify individuals with an AVF level of $\geq 130\,cm^2$ could be different for Black and White subjects.

Using the HERITAGE Family Study data, we examined the multivariate effect of race, age, and subcutaneous fat on AVF variation. The goals of this study were (a) to determine if the relationship between AVF and measures of adiposity are different between Black and White subjects and (b) to develop valid field prediction models that accurately estimate AVF from easily obtained measures.

Methods

The HERITAGE Family Study is a large, multicenter clinical trial primarily focused on investigating the probable genetic basis for the variability in individual responses to aerobic exercise training with respect to risk factors for cardiovascular disease and Type II diabetes, as well as for various physiological measures. The study included four Clinical Centers located at Indiana University (formerly at Arizona State University), the Pennington Biomedical Research Center (formerly Laval University), the University of Minnesota, and Texas A&M University (formerly at The University of Texas at Austin). The Data Coordinating Center is located at Washington University School of Medicine, St Louis, MO, USA. The aims, experimental design, detailed inclusion and exclusion criteria, and measurement protocols have been presented in detail in a previous publication.[29] The changes in body composition and CT measured abdominal fat data have been reported;[25,30] however, regression equations to predict AVF were not developed.

Participants

The Institutional Review Board for each Clinical Center had previously approved the study protocol, and informed consent was obtained from each participant. Data from 692 men and women from the HERITAGE Family Study were used in the analyses. This sample represents only those subjects who had complete data for all variables used in the analyses for this study, and included 91 Black men, 137 Black women, 227 White men, and 237 White women. Subjects were 17–65 y of age, with resting blood pressures <160 mmHg systolic and <100 mmHg diastolic, not taking any antihypertensive or lipid lowering medication, and sedentary. Baseline (pretraining) data were used in the initial analyses and response to training (post-training) data were used to crossvalidate the models developed with baseline data. Subject characteristics for the baseline sample, contrasted by race and sex, are provided in Table 1.

Measures

CT scans were used to measure abdominal total fat (ATF), abdominal subcutaneous fat (ASF), and AVF using the procedures of Sjöström *et al*.[10] The scanning was performed at 125 kV and a slice thickness of 8 mm. The CT scans were obtained between the fourth (L4) and fifth (L5) lumbar vertebrae while subjects were supine with arms extended above the head. ATF and AVF areas were calculated by delineating the areas with a graph pen and then computing the surface areas by using an attenuation range of -190 to -30 Hounsfield units.[10,16] The AVF area was measured by drawing a line within the inner portion of the muscle wall surrounding the abdominal cavity. ASF area was calculated by subtracting AVF from ATF. Using the recommendations of Sjöström,[31] sagittal diameter (SagD) was measured from the CT scan by measuring the distance from the umbilicus through the vertebrae to the back.

Skinfold thickness was measured at the subscapular, triceps, biceps, midaxillary, suprailiac, abdominal, thigh, and calf skinfold sites as described by Lohman *et al*[32] using a Harpenden skinfold caliper (Quinton Instruments, Inc., #03496–001). Research has documented that skinfold measures are highly intercorrelated and measure a common body fat factor.[33] For this reason, the skinfolds were summed to create a total skinfold fat measure (ΣSkinfolds). Waist (WC),

Table 1 Baseline subject characteristics (mean ± s.d.) contrasted by sex and race.

	Men (n = *318*)		*Women* (n = *374*)	
Variable	*Black* (n = *91*)	*White* (n = *227*)	*Black* (n = *137*)	*White* (n = *237*)
Age (y)	31.8 ± 11.2	36.3 ± 14.9[a]	32.0 ± 11.4	34.6 ± 13.9
Height (cm)	176.4 ± 7.0	177.5 ± 6.3	162.9 ± 6.6	163.8 ± 6.5
Weight (kg)	85.3 ± 19.8	83.0 ± 15.2	74.9 ± 18.1[b]	66.2 ± 13.1
BMI (kg/m^2)	27.3 ± 5.6	26.3 ± 4.6	28.2 ± 6.4[b]	24.7 ± 4.7
Percent fat (%)	22.8 ± 8.4	22.7 ± 9.0	36.1 ± 9.0[b]	29.9 ± 9.7
Fat weight (kg)	20.8 ± 12.0	19.8 ± 10.7	28.3 ± 13.1[b]	20.8 ± 10.5
Fat-free weight (kg)	64.5 ± 9.6	63.2 ± 7.6	46.6 ± 6.4	45.4 ± 5.1
WC (cm)	92.1 ± 16.4	93.6 ± 13.1	90.6 ± 15.8[b]	85.3 ± 14.0
HC (cm)	102.9 ± 11.7	102.4 ± 8.5	106.8 ± 12.8[b]	101.8 ± 10.2
WHR (ratio)	0.89 ± 0.08	0.91 ± 0.07[a]	0.84 ± 0.07	0.83 ± 0.08
Skinfold fat (mm)	121 ± 61	128 ± 52	181 ± 67[b]	162 ± 56

[a]White men were significantly older and had higher WHR than black men ($P < 0.05$). [b]Black women had a significantly higher weight, BMI, %fat, fat weight, WC, HC, and skinfold fat than White women ($P < 0.01$). WC = waist circumference; HC = hip circumference; BMI = body mass index.

hip (HC), and arm circumference (AC) measurements were taken as described by Lohman *et al*.[32] The waist and hip circumferences were used to compute the waist-hip ratio (WHR). Body density was determined by hydrostatic weighing and was used to estimate relative body fat (% body fat). Refer to other HERITAGE publications for details on the anthropometric, skinfold, and hydrostatic weighing techniques.[30,34]

Quality assurance and quality control

Extensive quality assurance and quality control procedures, as described by Gagnon *et al*,[35] were followed at each Clinical Center. A random sample of 10% of the X-ray films collected at each Clinical Center was sent for review by the consortium CT scan reading center at the Quebec Clinical Center. A calibration unit, composed of lard and sealed in a special plastic cylinder, was sent to each Clinical Center on two different occasions to assess potential intercenter differences. As previously reported, the reproducibility of anthropometric and body composition measures at all Clinical Centers was very high.[34]

Statistical procedures

Analysis of variance (ANOVA) and covariance (ANCOVA) were used to determine gender and race differences in the independent variables.[36] Product–moment correlations defined the relationship between the CT scan abdominal fat variables and the independent variables of the study. The General Linear Model (GLM)[37] procedure was used to test the relationship between the dependent variable, AVF, and the independent variables that consisted of two different types, CT and 'field' measures. The first GLM (ie, the CT models) used the CT variables of ASF and SagD in combination with age and race. While not completely necessary, this CT model, which included a direct measure of abdominal subcutaneous fat, was developed as an additional method for evaluating the quality of the field model. The independent variables for the second GLM (ie, the field models) included the anthropometric variables in combination with age and race. The correlation results were used to select the independent variables for the second GLM. In both GLM procedures, race was dummy coded: Black = 0, and White = 1. A step-down analysis was used to determine if race and age, and their interaction, accounted for AVF variance while statistically controlling for the CT or anthropometric variables. Multiple regression[36] was used as a *post hoc* test to determine if the regression weight of each independent variable differed significantly from zero.[37] Multiple regression defined the generalized AVF prediction models.

The prediction models were crossvalidated by two ways. First, the PRESS procedure[38,39] was used to crossvalidate the regression models. Second, the field models developed with the baseline (pretraining) data were applied to the HERITAGE final (post-training) data. This second crossvalidation method used simple linear regression to determine if the slopes between estimated and measured AVF were within sampling variation of 1.0 and the intercepts did not differ from 0. Product–moment correlation was used to determine the relationship between estimated and measured AVF. The difference between estimated and measured AVF values was then used to calculate the crossvalidation s.e.e. of the field models.

Results

Table 1 gives the descriptive statistics for the men and women contrasted by race. As previously reported,[25,30] the men were taller, heavier, and leaner than the women. ANOVA was used to evaluate race differences for each gender. The only male race differences were that White men were nearly 5 y older and had a larger WHR. The mean fat weight for Black women was 7.5 kg higher than that of White women, which was associated with a higher total body weight, BMI, percent body fat, WC, HC, and Σskinfolds

in the Black women. The Black and White women did not differ in fat-free weight and WHR.

Table 2 presents the values for the CT variables contrasted by sex and race. The s.d. of the CT abdominal fat variables were large in relation to the mean, suggesting that the CT fat variables were skewed in a positive direction. A natural log (Ln) transformation was therefore applied to each abdominal fat variable, which normalized the distributions. All subsequent analyses were then conducted on the log-transformed CT fat values.

ANOVA showed there was a significant sex by race interaction for ATF ($F(1, 588) = 11.37$; $P < 0.01$). The data in Table 2 show that the mean ATF for White men was higher than that for Black men, but the mean ATF for White women was lower than that for Black women. The sex by race interaction supported the strategy of analyzing the men's and women's data separately. The Black and White men did not differ in ASF, while the mean for the Black women was significantly higher than that for the White women. Both Black men and women had lower AVF values than White men and women. However, product–moment correlation coefficients showed that the log-transformed ASF and AVF variables were significantly correlated ($r = 0.72$ and 0.80 for women and men, respectively). The correlations between ASF and AVF in their original metric were much lower ($r = 0.60$ for both women and men). Owing to the significant correlation between ASF and AVF, ANCOVA was used to compare the racial AVF difference, using ASF as the covariate. ANCOVA showed that the mean AVF of White men ($F(1, 315) = 55.2$; $P < 0.01$) and White women ($F(1, 371) = 20.1$; $P < 0.01$) was significantly higher than that of their Black counterparts. The SagD means for Black and White men did not differ, but the mean SagD for Black women was significantly higher than that for White women.

Zero-order correlations were used to examine the relationship between Ln (AVF) and the independent variables contrasted by sex. All correlations were significantly different from zero, but the patterns differed by sex. The range in correlations between the anthropometric variables and Ln (AVF) for men ranged from a low of $r = 0.66$ for BMI and skinfold fat to a high of $r = 0.79$ for WC and $r = 0.80$ for WHR. The female anthropometric correlations ranged from a low of $r = 0.64$ for WHR to a high of $r = 0.76$ for WC. The correlations between Ln (AVF) and age were $r = 0.63$ for females and $r = 0.66$ for males. The correlation between SagD and Ln (AVF) was $r = 0.76$ for both males and females.

Table 3 gives the GLM, multiple regression and PRESS crossvalidation results for the CT variables. The GLM showed that ASF and SagD (Model CT-I) accounted for significant, independent sources of AVF variance. Adding age and race

Table 2 Baseline values for CT variables (mean ± s.d.) contrasted by sex and race.[a]

	Males (n = *318*)		*Females* (n = *374*)	
Variable	*Black* (n = *91*)	*White* (n = *227*)	*Black* (n = *137*)	*White* (n = *237*)
ATF (cm^2)	307 ± 217	329 ± 175	417 ± 209	354 ± 176
ASF (cm^2)	233 ± 176	222 ± 128	348 ± 181	281 ± 140
AVF (cm^2)	74 ± 54	107 ± 64	68 ± 41	73 ± 50
Ln (ATF)	5.43 ± 0.85	5.63 ± 0.62[b]	5.88 ± 0.59[c]	5.74 ± 0.53
Ln (ASF)	5.11 ± 0.93	5.22 ± 0.65	5.70 ± 0.60[c]	5.51 ± 0.53
Ln (AVF)	4.05 ± 0.75	4.49 ± 0.64[b]	4.04 ± 0.64[c]	4.09 ± 0.62
SagD (cm^2)	22.3 ± 4.7	21.7 ± 3.9	22.1 ± 4.5[c]	19.7 ± 4.0

[a]Analyses were conducted only on Ln (ATF, ASF, and AVF) values, not raw values. [b]White men had significantly higher Ln (ATF) ($P < 0.05$) and Ln (AVF) ($P < 0.01$) than Black men. [c]Black women had significantly higher in Ln (ATF) ($P < 0.05$), Ln (ASF) ($P < 0.01$), SagD ($P < 0.01$), and significantly lower in Ln (AVF) ($P < 0.01$) than White women. ATF = abdominal total fat; ASF = abdominal subcutaneous fat; AVF = abdominal visceral fat; SagD = sagittal diameter.

Table 3 CT models demonstrating the effect of Ln (ASF), SagD, age, and race on Ln (AVF) contrasted by sex.

	Women CT models		*Men CT models*	
Independent variable	*CT-I b*	*CT-II b*	*CT-I b*	*CT-II b*
Intercept	1.12[a]	0.95[a]	0.62[a]	0.53[a]
Ln (ASF)	0.22[a]	0.13[a]	0.49[a]	0.33[a]
SagD	0.08[a]	0.08[a]	0.05[a]	0.06[a]
Age		0.02[a]		0.02[a]
Race[b]		0.23[a]		0.36[a]
r^2	0.59[a]	0.75[a]	0.66[a]	0.84[a]
$r^2\Delta$		0.16[a]		0.18[a]
r (PRESS)	0.77[a]	0.87 (0.86)	0.82[a]	0.91 (0.91)
s.e.e. (PRESS)	0.40	0.31 (0.32)	0.41	0.29 (0.29)

[a]$P < 0.001$. [b]Race: Black = 0 and White = 1.

(Model CT-II) accounted for a significant 18 and 16% increase in AVF variance for men and women, respectively, beyond the CT variables of Ln (ASF) and SagD. The age by race interaction terms for women ($F(1, 373) = 0.58$; $P > 0.05$) and men ($F(1, 317) = 0.41$; $P > 0.05$) were not statistically significant. The *post hoc* analysis showed that all regression coefficients of CT-II models were statistically significant. The polarity of regression coefficients revealed that AVF increased independently with age and that the age effect was 0.02 Ln (AVF) units per year for both men and women. The regression coefficients in Table 3 show that with ASF, SagD, and age statistically controlled, the AVF of White men and women was higher than that of the Black men and women. The 95% confidence interval for the race coefficients showed that the male race effect was greater than the female race effect.

Table 4 gives the GLM results for the field models (Field I and II). The independent variables used for Field-I were BMI and WHR. WC replaced WHR for Field-II. The accuracies of Field-I and -II for women were similar to CT-II, with an r^2 of only 2–3% less than that obtained with CT-II. In contrast, the r^2 of the two men's field models was 6% less than obtained with the male CT-II model. Replacing WHR with WC did not influence the accuracy of the field models, as the s.e.e. estimates were identical. There was a sex difference in Field-II, which replaced WHR with WC. The regression weights for both BMI and WC were statistically significant for the women's Field-II, while the BMI regression weight for the men's Field-II was not statistically significant. This gender difference can be traced to the high correlation ($r = 0.93$) between BMI and WC for the sample of men with similar correlations between Ln (AVF) and WHR ($r = 0.80$) and WC ($r = 0.79$).

The race regression weights in Table 4 show that the AVF values of White men and women were significantly higher than for Black men and women. In addition, the race regression weights for men were higher than for women. The 95% confidence intervals for the race effect of the CT-II models were 0.16 to 0.30 for women and 0.28 to 0.43 for men. The women's and men's race regression weights for the field measures were within these 95% confidence intervals suggesting that the race effect between the CT and Field models were within chance variation. The crossvalidation PRESS statistics for the field models were identical to the model values supporting the validity of the generalized field regression equations.

Table 5 gives the crossvalidation analysis of the field models for men and women. The equations developed from the HERITAGE baseline (pretraining) data were applied to all HERITAGE subjects who had post-training data. The cross-validation correlations were nearly identical to the validation multiple correlations in Table 4. The 95% confidence interval showed that the crossvalidation correlations were within chance variation of the validation values. Simple

Table 4 Field models for estimating Ln (AVF) from anthropometric variables in combination with age and race.

	Women field models		*Men field models*	
Independent variable	*Field-Ib*	*Field-IIb*	*Field-Ib*	*Field-IIb*
Intercept	0.33[a]	1.13[a]	−0.70[a]	0.66[a]
BMI	0.05[a]	0.03[a]	0.05[a]	
WHR	1.85[a]		3.20[a]	
WC		0.02[a]		0.03[a]
Age	0.02[a]	0.02[a]	0.02[a]	0.02[a]
Race[b]	0.22[a]	0.20[a]	0.36[a]	0.32[a]
r^2	0.73[a]	0.72[a]	0.78[a]	0.78[a]
r (PRESS)	0.85 (0.85)	0.85 (0.85)	0.88 (0.88)	0.88 (0.88)
s.e.e. (PRESS)	0.33 (0.33)	0.33 (0.33)	0.33 (0.34)	0.33 (0.34)

[a]$P < 0.001$. [b]Race: Black = 0 and White = 1. WHR = waist-hip ratio; WC = waist circumference; s.e.e. = standard errors of estimate.

Table 5 Crossvalidation analysis of the field equations applied to trained HERITAGE subjects.

	Women (n = *409*)		*Men* (n = *312*)	
Statistic	*Field model-I*	*Field model-II*	*Field model-I*	*Field model-II*
Correlation	0.87	0.87	0.88	0.88
(95% CI)	(0.85, 0.90)	(0.85, 0.90)	(0.85, 0.90)	(0.85, 0.89)
Slope	1.03	1.03	1.00	1.00
(95% CI)	(0.97, 1.08)	(0.97, 1.09)	(0.94, 1.06)	(0.94, 1.06)
Intercept	−0.13	−0.12	−0.04	−0.04
(95% CI)	(−0.36, 0.10)	(−0.36, 0.11)	(−0.31, 0.22)	(−0.32, 0.23)
s.e.	0.31	0.31	0.34	0.34

linear regression analysis was used to examine the fit of the field equations applied to measured Ln (AVF). Table 5 gives the slopes and intercepts for these models and the 95% confidence intervals for both. This analysis showed that all slopes were within chance variation of 1.0 and the intercepts were within chance variation of 0. The crossvalidation s.e. of the field models were within 0.02 U of the validation s.e. (Table 4). These analyses showed that the equations developed with baseline data from untrained subjects could be generalized to trained subjects.

Discussion

The results of this study demonstrated that when age and subcutaneous fat, or other measures of adiposity, were controlled, Black men and women had significantly less AVF than White men and women. This difference was greater in men than in women. These results agree with the only other study comparing Black and White men. In a study of 196 young adult men, Hill *et al*[17] reported that AVF, when adjusted for percent body fat, total body fat, BMI, WC WHR, or SagD, was significantly less in Blacks than in Whites. The present study results are also in agreement with those from most studies comparing Black and White women, although studies with larger sample sizes are equivocal. In studies with small sample sizes (8–25 subjects per race/sex cell), Albu *et al*[11] determined that obese Black women had significantly less AVF than obese White women after controlling for total body mass and WHR. Conway *et al*[13] found obese Black women to have less AVF than obese White women at L2-L3, but not at L4-L5. In a group of primarily obese women, Lovejoy *et al*[21] found Black women to have less AVF than White women when the means were adjusted for BMI. In studies with larger sample sizes (55–105 subjects per race/sex cell), young Black women had significantly lower AVF than White women when adjusted for WC or SagD, but not when adjusted for percent body fat, total body fat, BMI, or WHR.[17] In another study by Lovejoy *et al*[22] there was a slight, nonsignificant trend for middle-aged Black women to have less AVF than middle-aged White women after adjusting for total body fat and age.

In the development of prediction models for AVF, this study demonstrated that variation in AVF was an independent function of race, age, and subcutaneous fat. The most accurate prediction models were obtained with age and race in combination with the CT scan variables of Ln (ASF) and SagD. While the field prediction models were less accurate than the CT-II models, the differences were small. Also, these differences were less between the women's models than between the men's models. The women's CT-II model accounted for 2% more Ln (AVF) variance and its s.e.e. was lower (0.31 *vs* 0.33) than the field models, while the men's CT-II model accounted for 6% more Ln (AVF) variance and its s.e.e. was lower (0.29 *vs* 0.33) than the field models.

The PRESS statistics demonstrated that the models were valid for inactive Black and White men and women who varied substantially in age. A limitation of the equations and PRESS crossvalidation results is that they were developed on the baseline data representative of untrained subjects. The crossvalidation results presented in Table 5 showed that the field equations were accurate when applied to the trained HERITAGE subjects, thus demonstrating that the derived field equations were also valid for physically active Black and White men and women.

An examination of the AVF distribution showed that both the men and women's distributions were skewed in a positive direction. A natural log transformation produced a normal distribution. This is an important finding. The skewed distribution found in these data is consistent with the descriptive statistics published by Janssen *et al*.[18] They reported that the mean ($\pm$s.d.) for L4-L5 visceral fat area (cm^2) was 77 ($\pm$59) and 137 ($\pm$83) for men and women, respectively. The reported ranges were 3–290 cm^2 for men and 3–482 cm^2 for women. An examination of the plot of the residuals and estimated Ln (AVF) from the results of the present study (graph not shown) suggested that the skewed distribution affected prediction errors when the residuals were expressed in the original metric (cm^2).

An important advantage of the derived field equations is the variables that comprise the model are easy to obtain. A limitation of the regression model is that the predicted value is log transformed which makes it more difficult to interpret. An examination of the relationship between estimated Ln (AVF) and the residuals (ie, measured−estimated Ln (AVF)] in the original unit of measurement (cm^2) showed that predictions were less accurate with individuals at the higher levels of Ln (AVF). An important clinical objective of estimating AVF is to identify individuals at risk of a metabolic abnormality (AVF value $\geq$130 cm^2). Logistic regression and receiver operating characteristic (ROC) analyses[37,40] were used to identify an estimated Ln (AVF) value to identify risk. These analyses showed that the sensitivity of the Ln (AVF) value of 4.5 was 88 and 92% for males and females. These sensitivity estimates were associated with false positive rates (ie, 1—specificity) of 13% for females and 15% for males. These findings suggest that an estimated Ln (AVF) value of 4.5 would be suitable to define the risk of a metabolic abnormality in both men and women for both Black and White subjects.

Using the Field-II equation, with a BMI of 27 kg/m^2, WC values of 115, 101, and 88 cm for 20, 40, and 60-y-old White men, and 125, 112 and 99 cm for 20, 40, and 60-y-old Black men result in a Ln (AVF) of 4.5. WC values of 108, 88, and 68 cm for 20, 40, and 60-y-old White women and 118, 98, and 78 cm for 20, 40, and 60-y-old Black women, result in a Ln (AVF) of 4.5. This illustrates that if the same relationship exists between AVF and metabolic risk variables regardless of age and race, the WC value used to identify risk varies with age and race. These WC values are higher than the values of 90 and 81 cm determined by Rankinen *et al*[28] and 90 and

91 cm determined by Lemieux *et al*[41] for identifying French Canadian men <40 and ≥ 40 y of age, respectively, with an AVF $\geq 130\,cm^2$. No similar data has been published on women. These are indications that further crossvalidation research is needed in this area.

The estimated Ln (AVF) values for men and women were correlated with hydrostatically determined fat weight in an effort to gain a better understanding of the validity issue. The correlations between estimated Ln (AVF) and measured fat weight were 0.75 and 0.77 for men and women, respectively. These correlations were lower than the correlations between the sum of skinfold fat and fat weight of 0.89 for men and 0.84 for women. Multiple regression showed that both the sum of skinfold fat and Ln (AVF) were independently related to total fat weight. The standardized regression coefficients were: males, skinfold fat $= 0.67$, Ln (AVF) $= 0.31$; and females, skinfold fat $= 0.57$, Ln (AVF) $= 0.36$. This demonstrated that the field regression models provide estimates of total body fat that differed from subcutaneous fat and supports the value of measuring both AVF and subcutaneous fat.

We found no difference in the accuracies of our Field-I equations, which in addition to age and race, included BMI and WHR, and our Field-II equations, which for men included WC instead of BMI and WHR, and for women included WC instead of WHR. Many other investigations[11,12,14,17,19,20,28,42–44] have found WC to be more strongly correlated with and a better predictor of AVF than WHR. The difference between our study and these other investigations is that the correlation between WHR and AVF was higher in our study. We cannot explain this difference. Our data also support using WC instead of WHR in estimating AVF since we found WC to be as good a predictor as WHR and it involves taking only one measurement instead of two.

In summary, these results show that at a similar age and level of adiposity, Black men and women have less AVF than White men and women. This race difference is greater in men than women. The validity of the field regression equations can be generalized to the diverse group of adults studied who were either untrained or trained. A limitation of the field prediction models is the accuracy decreases with increasing levels of estimated AVF. These data suggest that an estimated Ln (AVF) of 4.5 provides a reasonable estimate of an increased risk for a metabolic abnormality (AVF value $\geq 130\,cm^2$), but needs additional crossvalidation research.

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