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# Relationship between Adiposity and Admixture in African American and Hispanic American Women

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## Abstract

**Objective—**To investigate whether differences in admixture in African American (AFA) and Hispanic American (HA) adult women are associated with adiposity and adipose distribution.

**Design—**The proportion of European, sub– Saharan African and Amerindian admixture was estimated for AFA and HA women in the Women's Heath Initiative using 92 ancestry informative markers. Analyses assessed the relationship between admixture and adiposity indices.

**Subjects—**11712 AFA and 5088 HA self– identified post– menopausal women.

**Results—**There was a significant positive association between body mass index (BMI) and African admixture when BMI was considered as a continuous variable, and age, education, physical activity, parity, family income and smoking were included covariates ($p < 10^{-4}$). A dichotomous model (upper and lower BMI quartiles) showed that African admixture was associated with a high odds ratio [OR = 3.27 (for 100% admixture compared to 0% admixture),



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95% confidence interval (CI) 2.08 – 5.15]. For HA there was no association between BMI and admixture. In contrast, when waist to hip ratio (WHR) was used as a measure of adipose distribution, there was no significant association between WHR and admixture in AFA but there was a strong association in HA ($p<10^{-4}$; OR Amerindian admixture = 5.93, CI = 3.52 – 9.97).

**Conclusion—**These studies show that 1) African admixture is associated with BMI in AFA women; 2) Amerindian admixture is associated with WHR but not BMI in HA women; and 3) it may be important to consider different measurements of adiposity and adipose distribution in different ethnic population groups.

**Keywords**

European admixture; African admixture; Amerindian admixture; post–menopausal women; waist to hip ratio; body mass index

## Introduction

Obesity is associated with adverse health outcomes[1-4]. Health surveys including the California Women's Health Survey II.1 (http://www.cdph.ca.gov/pubsforms/Pubs/OWH–CAWomensHlth_2007.pdf) and other studies[5-7] have indicated that African American (AFA) and Hispanic American (HA) women have an increased propensity for this health problem. Multiple indices for adiposity and adipose distribution have been utilized in assessing the impact of obesity on cardiovascular disease and diabetes including body mass index (BMI), waist circumference (WC), hip circumference (HC) and waist to hip circumference ratio (WHR)[2, 3, 8-13]. Potential differences in these indices of adiposity for different population groups are also suggested by some of these previous studies[2, 3]. Recent admixture mapping studies in African Americans have suggested that there are several susceptibility loci that are derived from African ancestry[14, 15] and at least one derived from European ancestry[16].

In some previous studies WHR has been found to be a better predictor of mortality in older people than either BMI or WC[17-19] or a better predictor of cardiovascular disease[12, 20-22]. These findings are not without controversy since other studies have found a stronger correlation with adverse health consequences with either WC or BMI[23-26]. Although WC has been proposed as an alternative non– invasive indicator of abdominal adiposity[27], WC is highly correlated with BMI and may give less information about regional adipose distribution than WHR[18]. In a large study of Chinese women, WHR appears to be an independent predictor of mortality risk and this finding was observed even in women with lower BMI measurements ($<25$ kg/m$^2$)[19].

Although there is substantial epidemiologic data suggesting differences between populations in body habitus and obesity, few studies have examined differences within particular admixed population groups[14-16, 28]. In the current study we examine whether differences in adiposity and adipose distribution are influenced by the relative proportion of sub– Saharan African (AFR), Amerindian (AMI) and European (EUR) admixture in a large group of self–identified AFA and Hispanic American (HA) participants in the Woman's Health Initiative (WHI) studies.

# Methods

## Study Subjects

The current study includes self– identified AFA and HA participants in the WHI. Descriptions of the WHI study and additional details describing this study have been published[29-31]. All studies were conducted with appropriated informed consent and in agreement with established Human Institutional Review Board procedures. The initial sample size included a total of 19641 AFA and HA women for whom WHI DNA samples were available. Subjects were excluded from analyses based on inadequate DNA samples and/or technical assay failures (1605), failure to meet genotyping quality filtering (<90% complete typing) (788) or unrecognized cryptic relationship (65 pairs of samples), and 138 who did not have complete phenotypic information. The final sample size that was utilized in the phenotypic analyses included 16800 individuals had complete phenotypic information (11712 self– identified AFA and 5088 self– identified HA).

## Phenotypes and Covariates

BMI, WHR, HC, WC and all covariates were determined from baseline WHI data. All study participants had their weight, height, and waist and hip circumferences measured at baseline using a calibrated balance, stadiometer, and standard tape measures. BMI was computed as measured weight (kg) divided by the square of measured height ($m^2$). WHR was computed as the ratio of WC (cm) to hip circumference (HC) (cm). For covariates the scales were as developed by WHI with the exception of education for which a modified WHI scale was used. For smoking (smoke years) the following scale was used: 1) <5 pack years; 2) 5 – 9 pack years; 3)10 – 19 pack years; 4) 20 – 29 pack years; 5) 30 – 39 pack years, 6) 40 – 49 pack years; and 7) >50 pack years. For physical activity (MET score) an energy– expenditure score reporting total physical activity as a multiple of basal metabolic expenditure was calculated as per WHI protocol[32]. Briefly, this protocol applies a standardized classification of the energy expenditure associated with self– report of hours spent on physical activities and the intensity of these activities compared to basal energy expenditures for a given period of time. For parity the following score was used: – 1) never pregnant; 0) never had term pregnancy; 1 to 5 corresponding to the number of full term pregnancies. Income was assessed using family income and the following categorical scores: 1) < $10,000; 2) $10,000 – $19,999; 3) $20,000 – $34,999; 4) $35,000 – $49,999; 5) $50,000 – $74,999; 6) $75,000 – $99,999; 7) $100,000 – $149,999; and 8) >$149,999. For education, we used a modified scale with the following categorical classification: 1) high school or below; 2) vocational; 3) some college (includes associate degree); 4) college degree BA/BS; and 5) beyond college. Caloric intake in kilocalories (kcal) was calculated using the WHI food frequency questionnaire (FFQ) as previously reported[33, 34]. This method includes detailed questions about 122 food and food groups and uses an established instrument for computing caloric intake. Specific analysis of the effect of specific dietary components was considered beyond the scope of this manuscript. A summary of the included study subject characteristics are provided in Tables 1 and 2.

### Ancestry Informative Markers (AIMs)

The AIMs were chosen based on our previous studies[35, 36] and performance in the TaqMan® OpenArray® assay. The final marker set included 92 SNPs that demonstrated large differences in allele frequency between populations derived from three different continents: Europe; sub– Saharan Africa, and America. The marker set was chosen to exclude SNPs that show differences in allele frequency within different continental groups[35]. As previously characterized these markers distinguish between European, sub–Saharan African and Amerindian groups and show very similar results for several different populations within each continental group[35, 36]. The current study does not address differences in population substructure within the continental contribution. The AIMs and population allele frequencies are provided in Supplemental Table 1.

### Genotyping Methods

Genotyping was performed using the TaqMan® OpenArrays® system (https://products.appliedbiosystems.com/ab/en/US/adirect/ab?cmd=catNavigate2&catID=605783) (ABI) (Foster City, CA 94404 USA). Genotypes were scored using the OpenArray® SNP Genotyping Analysis Software provided by the manufacturer. All assays were validated by concordant results with standard ABI TaqMan® assays (>98% concordance) for >48 assays. All AIM SNPs had >93% call rate and showed >98% concordance in 5% duplicate assays. All individuals had data for >75% of each of the AIM SNPs and >90% call rate when technical exclusions were considered. The mean call rate for the included subjects was 97.1%. All AIM SNPs were in Hardy Weinberg equilibrium (p>0.005) in parental populations.

### Admixture Assessment

The 16800 individuals were assessed for AFR, AMI, and EUR contribution using STRUCTURE analyses of genotyping results with AIMs as previously described[35, 36]. The analyses were performed using representatives of the three parental populations for analyses under the assumption of three populations (K = 3) and with representatives of the two parental populations (K = 2) under the assumption of two populations. The samples used to represent the parental population groups included: 128 European Americans from the New York Cancer Project and 60 CEPH Europeans (CEU) for EUR; 56 Yoruban African (YRI), 19 Bini West African, and 23 Kanuri West African for AFR; and 50 Mayan Amerindians, 26 Quechuan Amerindians, and 29 Nahua Amerindians for AMI as previously described[35]. We performed three separate analyses of population structure for each group or subgroup using STRUCTURE v2.3.3[37, 38] parameters and AIMs previously described[35]. The results were most consistent and reproducible using prior parental population assignment with < 0.02 difference between each of the separate analyses. An example of the admixture assessment results is shown in Figure 1. The African American subject set showed the following admixture contributions [mean +/− standard deviation (SD)]: EUR, 0.225 +/− 0.147; AFR, 0.757 +/− 0.150; and AMI, 0.019 +/− 0.025. The Hispanic American subject set showed the following admixture contributions: EUR, 0.597 +/− 0.189; AFR, 0.135 +/− 0.121; and AMI 0.267 +/− 0.186.

For some of the analyses we examined subgroups of the self– identified population group affiliations. For AFA, we considered the subgroup with >20% AFR and < 5% AMI admixture containing 10854 participants of the total 11712 in self identified AFA group in an effort to minimize potential database or laboratory errors that cause miss– assignment. This definition excludes only extreme outliers (> 2 SD) in the self– AFA admixture analyses. For this AFA subgroup the admixture was then re– evaluated using K = 2 in which the contribution of only AFR and EUR was considered. For the HA, we also examined the subset of individuals with > 10% AMI and <10%AFR admixture to further assess the possible differences between AMI and EUR admixture (1977 of the 5088 self– identified HA). Sample sizes for other subsets included <1000 participants and were not considered in separate analyses.

### Statistical Analyses

Analyses were carried out for the following population groups: ALL (self– identified AFA and HA participants), AFA (self– identified AFA participants), AFA subgroup (self– identified AFA participants with >20% AFR and < 5% AMI admixture), HA (self– identified HA participants), HA subgroup (self– identified HA participants with > 10% AMI and <10%AFR admixture). The effect size of admixture was estimated as the proportion of the SD of either BMI or WHR using models incorporating appropriate covariates. This allows the standardizing of the effect proportional on the amount of variation thus enabling comparison of the effects on different measurement scales. Natural log transformations of the BMI and WHR were adopted to obtain a normal distribution of these traits. The correlation statistic (r) was determined using the standard Pearson product– moment correlation coefficient and the two tailed p values determined from the t– statistic. Linear regression was performed to study the admixture effect on the traits, in which the admixture effect was assessed as a continuous variable on the standardized continuous dependent variable [ln (BMI) or ln (WHR)], adjusting for age at entry, smoking, education, income, parity and physical activity. Logistic regression was conducted to obtain the odds ratios and 95% confidence intervals. To estimate odds ratios for the effect of admixture we defined the phenotypic parameters (BMI and WHR) as dichotomous traits using the top and bottom quartiles (values shown in Table 1). A unit increase in admixture is defined as the effect of the 100% admixture compared to no admixture of the particular continental population. Comparing the effects of 100% vs. 0% admixture corresponds to comparing one parental population to another parental population.

## Results

### Adiposity Measurements in African American and Hispanic American Women

When BMI, WC or HC were used as a measure of adiposity there was a marked difference between the self– identified AFA and HA women (Table 1). The mean BMI, HC and WC of AFA were significantly higher than that of the HA subjects with or without correction for age, education, smoking, parity, physical activity and income covariates (p <0.0001 for both). In contrast there was no difference between AFA and HA when WHR was considered (Table 1).

Very similar results were observed when subsets of subjects from these groups were considered. For the AFA subgroup, the mean BMI, WC, HC and WHR were almost identical to the entire self– identified AFA group. Also, the HA subgroup enriched for AMI admixture with limited AFR admixture (<0.1) showed a nearly identical BMI, WC, HC and WHR to the entire self– identified HA group (Table 1).

### Correlation of Adiposity Characteristics with Admixture

To examine the effect of admixture on indices of adiposity we first examined the correlation without considering covariates. Natural log transformations of the BMI and WHR resulted in a normal distribution of these traits. Admixture proportions were then ascertained for each individual and mean admixture proportions for the normally distributed intervals were plotted (Fig. 2). In ALL, the complete dataset including both AFA and HA, when each individual measurement (BMI and AFR admixture) was considered, there was a significant correlation between BMI and AFR admixture ($r = 0.18$, $p<0.0001$). This relationship was also observed for the AFA subgroup with a significant correlation between BMI and AFR admixture ($r = 0.095$. $p < 0.0001$). When comparing normally distributed BMI groups there was a high correlation between these groups and AFR admixture (Fig. 2 **panel c**, $r = 0.96$ for this ecological correlation). As expected based on the mean population group results, both AMI and EUR admixture showed inverse correlations with BMI in ALL (AMI, $r = -0.10$, $p < 0.0001$; EUR, $r = -0.16$, $p <0.0001$). For BMI in HA there were no significant correlations either in the self– identified HA or the HA subgroups.

For WHR, AFR admixture had a much weaker correlation in the AFA subgroup ($r = 0.029$, $p = 0.0024$). In contrast to the results with BMI, AMI admixture was significantly correlated in the HA individuals ($r = 0.14$, $p< 0.0001$). Similarly, correlations with AMI admixture were observed in the HA subgroup ($r = 0.084$, $p = 0.0001$) with WHR.

### Estimation of the Effect of Admixture on Adiposity

To more precisely determine the effect of admixture a linear regression model was examined with covariates for age at entry, education, smoking, parity, physical activity and income. When BMI is used as a measurement for adiposity AFR admixture showed a large positive effect size in the total group and in the AFA subgroup (Table 3). AMI and EUR continental admixture showed significant negative effect size for BMI in the total group. EUR admixture also showed a negative relationship in the AFA subgroup. In the HA there was also a positive effect from AFR contribution.

In contrast, when WHR is used as a measurement for adipose distribution, AMI admixture showed a strong effect in the HA with an increase in this index comparable to the effect size of AFR for BMI in AFA (Table 3). This effect was also seen in the HA subgroup.

We also examined both HC and WC (Table 4). For both HC and WC, the results were similar to BMI in that AFR admixture showed a significant positive association in the ALL, AFA and AFA subgroup. However, the effect size was smaller in AFA and the AFA subgroup. The AMI admixture showed a significant negative association with HC and a marginal positive association with WC. Both HC and WC show strong correlations with

BMI for each of the groups analyzed, where as WHR was poorly correlated with these other measurements (Supplemental Table 2).

### Admixture Risk for Adiposity Indices

As another measure of the relationship between admixture and adiposity indices we examined the odds ratios (OR) using the upper and lower quartile of adiposity measurements as a dichotomous measure of adiposity (see **Methods and** Table 1 **for mean and range of dichotomous groups**). The OR and 95% confidence interval were calculated using age at entry, smoking, education, income, parity and physical activity as covariates (Table 5). When BMI is used as a measurement for adiposity, AFR admixture showed a strong effect on increased BMI in the ALL group, AFA, and in the AFA subgroup with significant p–values (OR = 4.91, p < 0.0001; OR= 2.63, p < 0.0001; OR = 3.27, p < 0.0001, respectively) (Table 5). On the other hand, AMI and EUR admixture showed an opposite strong effect on decreased BMI in the ALL group (OR = 0.08, p < 0.0001; OR = 0.15, p < 0.0001, respectively). Together with the previous results these findings further supported the strong association of AFR admixture with increased BMI in the ALL group, AFA group and the AFA subgroup. However, AFR admixture was not significantly associated with BMI in the HA group (p = 0.22) (Table 5).

Similar to the continuous model, the results were very different when WHR is used as a measurement for adiposity. AMI admixture showed higher OR values in the HA (OR = 5.93) and HA subgroup (OR = 7.15) (Table 5) than that in the ALL group (OR = 1.54). Thus, in contrast to the effect of AMI admixture in BMI (minimal effect or negative effect), AMI admixture shows a strong association with increased WHR in the HA and the HA subgroup.

## Discussion

In the current study similar to previous studies in AFA, BMI was associated with AFR admixture[14, 28]. Our results extend this finding to adult postmenopausal women. The data also demonstrate an association of WHR but not BMI with AMI admixture in HA postmenopausal women. Several potential explanations and limitations of our study are considered below. It should be noted that diabetic individuals may have changed both diet and weight as a consequence of their treatments, and many other unknowable confounders may affect results of studies in elderly population groups. When analyses were performed using only non-diabetic participants the results were nearly identical (Supplemental Table 3), however, it is not possible to exclude all confounders. Nevertheless, differences in relative adiposity in these population groups are associated with admixture profiles and may have important implications for future genetic studies as well as therapeutic intervention and assessment.

For BMI in HA, in contrast to the results in AFA, there was only a minimal effect size from admixture. AFR, EUR or AMI admixture all showed insignificant ORs for BMI (Table 5). In a previous study in Mexican Americans, BMI was modestly lower in individuals with higher AMI admixture[39] further suggesting very different results than what we observed with our analyses WHR; in HA, our WHR results showed a significant and strong association with AMI admixture. Thus, the main finding in the current study is the difference in results between BMI and WHR among AFA and HA participants. Specifically, in AFA, AFR admixture is associated with BMI but not WHR while in HA, AMI admixture is associated with WHR but not BMI. The difference with respect to AFA is consistent with findings from studies segmenting body composition from CT scans that show that AFA have less visceral fat than other self– reported ethnic groups[40]. Therefore although WHR may be not a useful measurement in AFA, our findings in HA suggest that WHR may be an important measure in populations with substantial AMI admixture.

In contrast to many of the previous studies, our results were adjusted for multiple covariates. These covariates included the available measures of socio– economic status including self reported family income and education level. Education may serve as a surrogate for socio– economic status during adolescence and early adulthood and has been used as a general surrogate for socio– economic status[41]. It should be noted that the level of education for participants from the WHI study is in general higher than similarly aged women and that the available information may not fully account for socio– economic effects. When the socio– economic covariates were not included in the analysis we did observe a higher effect from AFR admixture (OR = 4.73 compared with OR =3.27 for BMI in the AFA subgroup) (Supplemental Table 4). This result is consistent with barriers and access to health care explaining a substantial proportion of the admixture effect. Although these measurements may not fully account for socio– economic and other cultural factors, they support the conclusion that a component of association with admixture reflects genetic differences. Previous studies identifying specific regions containing risk alleles of AFR origin in admixture mapping studies also support a genetic explanation[14, 15].

Other covariates used in our analyses (smoking, physical activity, age and parity) have been suggested by previous analyses as potential predictors of obesity[42-52]. These covariates, in contrast to socio– economic covariates, had only modest effects in the current study with the exception of very high parity (data not shown). In addition, we also examined whether self– reported food frequency questionnaire (FFQ) data, in particular daily energy intake, might explain the admixture– BMI association. Energy intake did not alter the results and energy intake had an OR for BMI very close to 1.0 in all groups examined. Interestingly, calorie counts were significantly higher ($p < 0.0001$) in HA (1.48 Kcal +/− 0.90) than AFA (1.44 Kcal +/− 0.89) which is opposite to what might be expected from the BMI population results (Tables 1 and 2). These results show that self reported energy intake does not account for the observed admixture association. However, previous analysis of this self– reported dietary intake instrument (WHI FFQ) has suggested that it underestimates energy intake especially in AFA[34] suggesting that interpretation of the dietary intake results requires some caution.

Multiple studies have used BMI as a predictor for adverse health outcomes due to obesity[8-11]; however, this measurement does not differentiate between body fat and lean mass. Dual– emission X– ray absorption (DXA) is generally considered to be a more accurate method for distinguishing between body fat and lean mass, although variation in tissue hydration can lead to potential errors in assessment of body fat[53]. DXA measurements of truncal body fat were available for less than 15% of the subjects in the current study thus precluding a full analysis of DXA calculated body fat. However, the DXA results from those subjects with measurements of BMI showed a very strong correlation between truncal fat and BMI for the each of the subject subsets (Supplemental Table 2) suggesting that BMI is probably a good surrogate for body fat in our study similar to another recent study[54].

As noted in the introduction, there are multiple contradictory studies with regards to the importance of BMI, waist circumference and WHR as predictive indices for adverse health consequences[12, 17, 20-26]. Our results suggest that both BMI and WHR should be considered as separate variables and that additional study is warranted to determine the importance of these factors in health consequences in different ethnic groups. WC and HC were more similar to BMI consistent with other studies[18, 55, 56] and in our study also correlated with DXA truncal fat (Supplemental Table 2),

It should be emphasized that this study is specifically relevant to adult post– menopausal women and that the mean weight of WHI participants' is greater than the general age matched population. Differences in hormonal patterns may have a profound effect on the deposition and distribution of body fat and changes at menopause have been linked to increased abdominal and visceral adipose tissue accumulation[57, 58]. Whether hormonal or other metabolic pathways differ in populations of different ethnicity is unclear. The thrifty gene hypothesis states that certain genes may have been selected as advantageous in hunter–gatherer populations, especially in child bearing women[59]. Although attractive, this hypothesis has been challenged[60, 61]. Insulin resistance in response to food deprivation has been advanced more recently to explain possible differences in the propensity to obesity and might explain the AMI admixture association with abdominal adiposity observed in HA[61]. Interestingly, a previous study has suggested associations between increased levels of a variety of adipocytokines and higher EUR admixture in AFA[62]. Clearly additional studies are necessary to determine the underlying mechanisms.

In summary, our study found that differences in both adiposity and adipose distribution are associated with continental admixture in adult post– menopausal women and provide additional support to the hypothesis that differences in ethnic origins may be a critical component for etiologic and therapeutic studies. The results also emphasize that different indices of adiposity and adipose distribution should be carefully assessed in genetic and epidemiologic studies.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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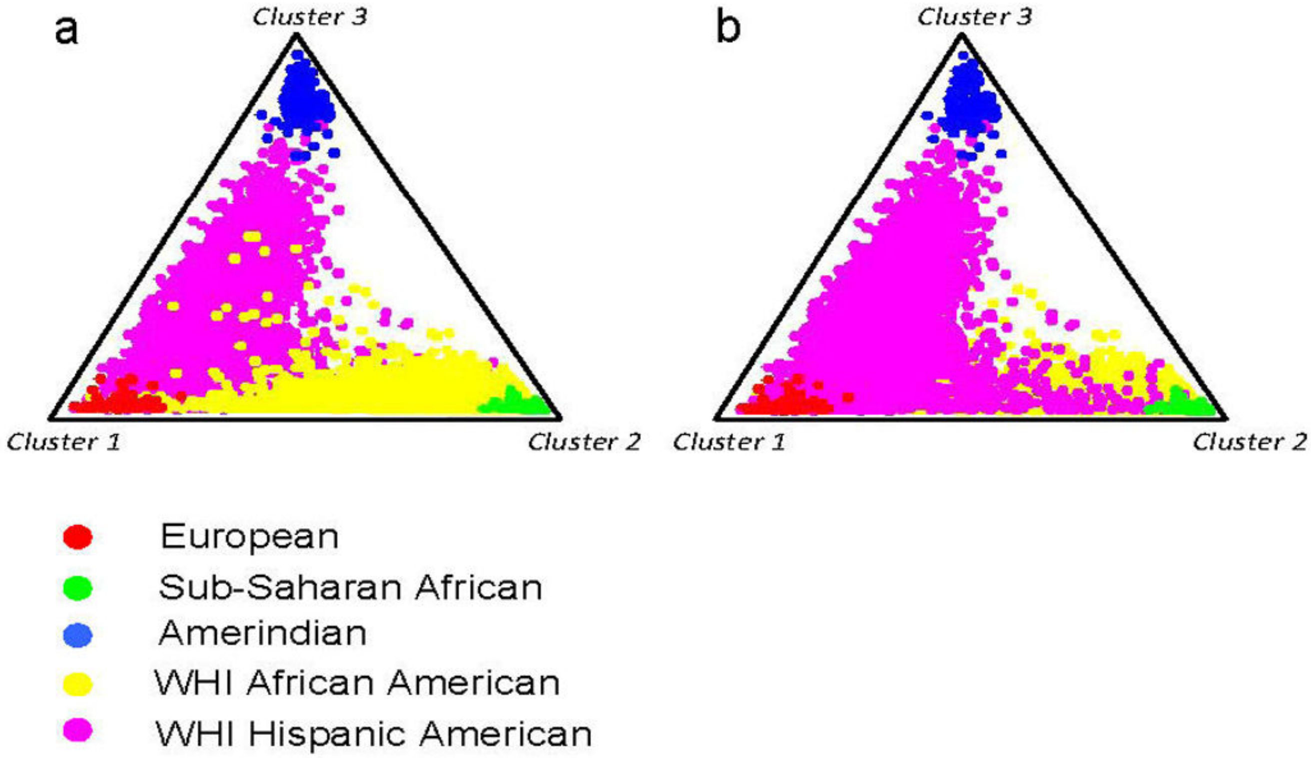


**Figure 1. Estimation of individual admixture in WHI African American and Hispanic American participants**

The triangle plots show the distribution of individual WHI participants and reference population representative when admixture was assessed using 92 ancestry informative markers (AIMs). The population groups European, sub– Saharan African, Amerindian, WHI African American (AFA), and WHI Hispanic American (HA) are as indicated by color coded symbols in the key. The admixture was assessed under a K=3 model (assuming 3 parental population groups) using the STRUCTURE program that applies a Bayesian clustering algorithm. Panels **a** and **b** show two separate analyses under the same conditions with either the AFA participants in the foreground (panel **a**) or the HA participants in the foreground (panel **b**).

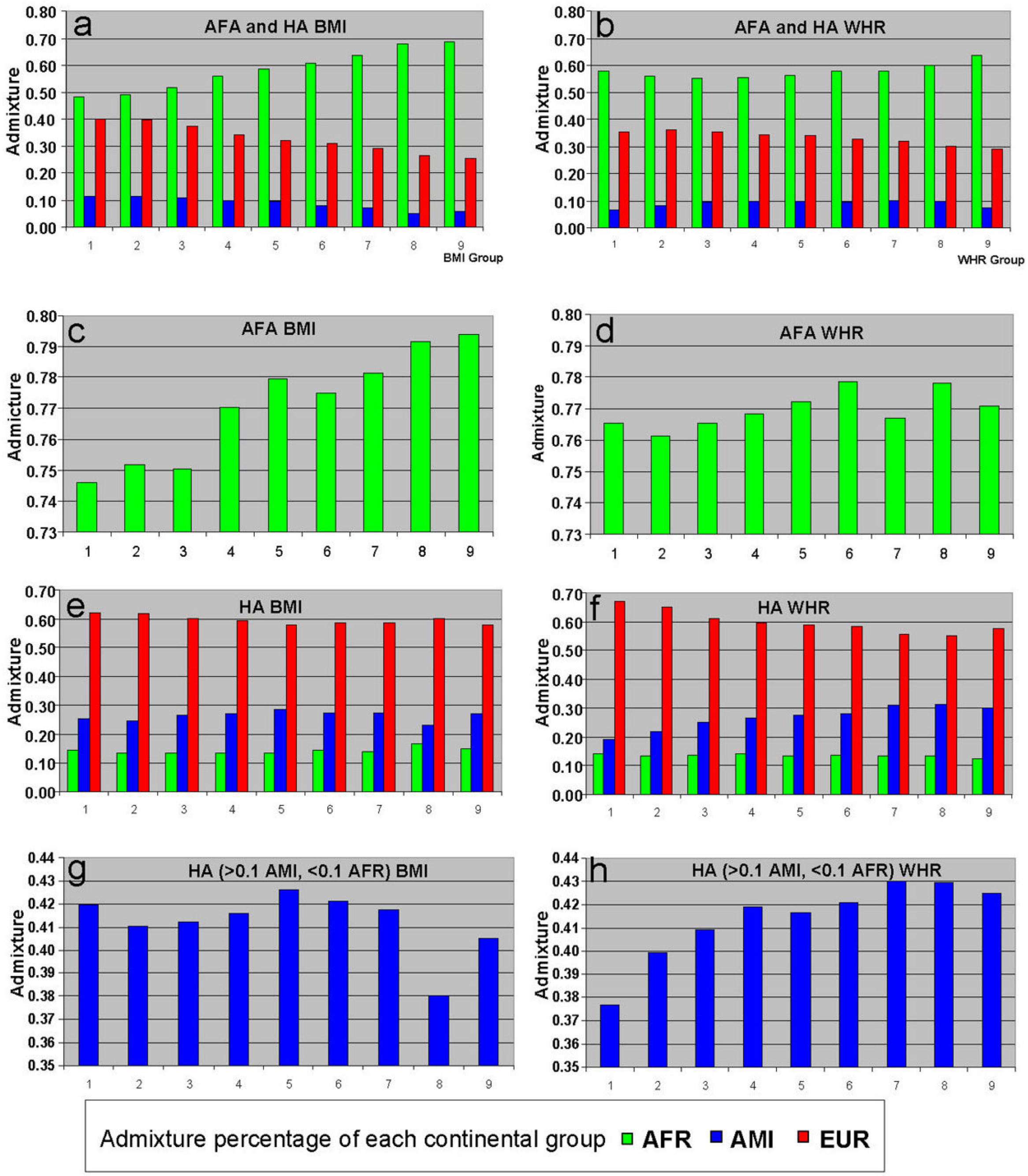


**Figure 2. Histograms showing correlation between continental admixture and adiposity and adipose distribution**

For both the left side [body mass index (BMI)] and the right side panels [(waste hip ratio (WHR)], the admixture corresponding to normally distributed groups (abscissa) is shown by the color coded continental contribution (ordinate). For both BMI and WHR, natural log transformations were used to achieve normal distributions. The BMI and WHR groups corresponded to the following ranges: 1) < 22.20, <0.71; 2) 22.20 – 24.53, 0.71 – 0.74; 3) 24.54 – 27.11, 0.75 – 0.77; 4) 27.12 – 29.96, 0.78 – 0.81; 5) 29.97 – 33.11, 0.82 – 0.84; 6) 33.12 – 33.59, 0.85 – 0.88; 7) 33.60 – 40.44, 0.89 – 0.92; 8) 40.45 – 44.69, 0.93 – 0.97; and

9) >44.69, > 0.98. Panels **a** and **b** show the entire participants [African American (AFA) and Hispanic Americans (HA) included in the analyses. Panels **c** and **d** show the self identified AFA participants (AFR > 0.2, AMI <0.1). Panels **e** and **f** show the self identified HA participants. Panels g and h show the subsets of HA participants with >0.1 AMI and < 0.1 AFR. For panels a, b, e, and f, the admixture was determined using 3 population clusters corresponding to AFR, AMI and EUR. For panels **c** and **d** the admixture was determined using two population clusters corresponding to AFR and EUR (only AFR shown). For panels **g** and **h**, the admixture was determined using two population clusters corresponding to AMI and EUR.

## Table 1

### Adiposity and Adipose Distribution in African American and Hispanic WHI Participants' Studied[a]

| Population[b] | Sample Size | Mean +/− SD All | Mean +/− SD Top 25% | Range Top 25% | Mean +/− SD Bottom 25% | Range Bottom 25% |
|---|---|---|---|---|---|---|
| | | | | **BMI** | | |
| **ALL** | 16800 | 30.45 +/− 6.30 | 39.02 +/− 4.65 | 34.00 – 61.98 | 23.47 +/− 1.91 | 15.18 – 25.97 |
| **AFA** | 11712 | 31.10 +/− 6.50 | 39.95 +/− 4.70 | 34.79 – 61.98 | 23.87 +/− 2.05 | 15.18 – 26.56 |
| **AFA subgroup** | 10854 | 31.13 +/− 6.49 | 39.97 +/− 4.69 | 34.83 – 61.98 | 23.89 +/− 2.06 | 15.18 – 26.58 |
| **HA** | 5088 | 28.93 +/− 5.53 | 36.43 +/− 4.13 | 32.02 – 60.56 | 22.79 +/− 1.65 | 15.54 – 25.00 |
| **HA subgroup** | 1977 | 28.99 +/− 5.43 | 36.36 +/− 3.81 | 32.25 – 53.46 | 22.90 +/− 1.71 | 16.54 – 25.09 |
| | | | | **WHR** | | |
| **ALL** | 16800 | 0.82 +/− 0.08 | 0.92 +/− 0.05 | 0.88 – 1.45 | 0.74 +/− 0.04 | 0.28 – 0.77 |
| **AFA** | 11712 | 0.82 +/− 0.08 | 0.93 +/− 0.05 | 0.88 – 1.42 | 0.73 +/− 0.04 | 0.28 – 0.77 |
| **AFA subgroup** | 10854 | 0.82 +/− 0.08 | 0.93 +/− 0.05 | 0.88 – 1.42 | 0.73 +/− 0.04 | 0.28 – 0.77 |
| **HA** | 5088 | 0.82 +/− 0.07 | 0.91 +/− 0.05 | 0.87 – 1.45 | 0.74 +/− 0.04 | 0.33 – 0.77 |
| **HA subgroup** | 1977 | 0.82 +/− 0.07 | 0.92 +/− 0.06 | 0.88 – 1.45 | 0.74 +/− 0.03 | 0.61 – 0.77 |
| | | | | **WC** | | |
| **ALL** | 16800 | 90.3 +/− 13.6 | 109.1 +/− 8.5 | 99.1 – 191.6 | 74.32 +/− 4.9 | 35.0 – 80.5 |
| **AFA** | 11712 | 91.8 +/− 13.8 | 110.3 +/− 8.6 | 100.3 – 191.6 | 75.77 +/− 5.1 | 35.5 – 82.0 |
| **AFA subgroup** | 10854 | 91.8 +/− 13.8 | 110.4 +/− 8.5 | 100.6 – 191.6 | 75.79 +/− 5.1 | 35.5 – 82.0 |
| **HA** | 5088 | 86.8 +/− 12.5 | 103.6 +/− 8.0 | 94.6 – 158.0 | 72.66 +/− 4.5 | 35.0 – 78.0 |
| **HA subgroup** | 1977 | 87.3 +/− 12.5 | 104.5 +/− 7.9 | 95.5 – 158.0 | 72.75 +/− 4.3 | 56.0 – 78.0 |
| | | | | **HC** | | |
| **ALL** | 16800 | 109.8 +/− 12.9 | 127.8 +/− 9.3 | 117.1 – 178.0 | 95.7 +/− 4.4 | 77.5 – 101.0 |
| **AFA** | 11712 | 111.4 +/− 13.2 | 129.8 +/− 9.3 | 119.2 – 178.0 | 96.7 +/− 4.5 | 77.5 – 102.0 |
| **AFA subgroup** | 10854 | 111.5 +/− 13.2 | 129.7 +/− 9.2 | 119.2 – 178.0 | 96.7 +/− 4.5 | 77.5 – 102.0 |
| **HA** | 5088 | 106.1 +/− 11.5 | 121.8 +/− 8.7 | 112.1 – 170.0 | 93.5 +/− 3.7 | 79.0 – 98.0 |
| **HA subgroup** | 1977 | 105.9 +/− 11.5 | 121.7 +/− 8.6 | 112.1 – 170.0 | 93.5 +/− 3.8 | 79.0 – 98.0 |

[a] The mean values for body mass index (BMI), waist hip ratio (WHR), waist circumference (WC), and hip circumference (HC) is shown for all study participants with admixture information.

[b] ALL consists of all self– identified African American (AFA) and Hispanic Americans (HA) participants; AFA consists of self– identified AFA participants; AFA subgroup consists of the self– identified AFA with >0.2 AFR and <0.05 AMI admixture; HA consists of self– identified HA participants; HA subgroup consists of the self– identified HA with >0.1 AMI and <0.1 AFR admixture.

## Table 2

**Covariates for Subject Groups**

| | Scale[b] | Population Group[a] | | | | |
|---|---|---|---|---|---|---|
| | | **ALL** | **AFA** | **AFA subgroup** | **HA** | **HA subgroup** |
| **Age (Mean +/− SD)** | | 61.2 +/− 7.1 | 61.7 +/− 7.1 | 61.7 +/− 7.1 | 60.2 +/− 6.8 | 59.9 +/− 6.9 |
| **Physical Activity (Mean +/− SD)** | | 9.87 +/− 13.02 | 9.62 +/− 12.71 | 9.58 +/− 12.65 | 10.48 +/− 13.71 | 10.19 +/− 13.23 |
| **Energy intake (Mean +/− SD)** | | 1.45 +/− 0.89 | 1.44 +/− 0. 89 | 1.44+/− 0.89 | 1.48 +/− 0.90 | 1.498 +/− 0.89 |
| **Education (number, %)** | 1 | 5156 (31.1) | 2980 (25.8) | 2757 (25.7) | 2176 (43.5) | 894 (45.9) |
| | 2 | 2069 (12.5) | 1458 (12.6) | 1360 (12.7) | 611 (12.2) | 243 (12.4) |
| | 3 | 4181 (25.3) | 3042 (26.3) | 2813 (26.3) | 1139 (22.8) | 454 (23.3) |
| | 4 | 1381 (8.3) | 1004 (8.7) | 927 (8.7) | 377 (7.5) | 121 (6.2) |
| | 5 | 3778 (22.8) | 3077 (26.6) | 2855 (26.6) | 701 (14.0) | 238 (12.2) |
| **Parity (number, %)** | − 1 | 1294 (7.8) | 869 (7.5) | 800 (7.5) | 425 (8.5) | 169 (8.7) |
| | 0 | 827 (4.9) | 685 (5.9) | 632 (5.9) | 142 (2.8) | 52 (2.7) |
| | 1 | 2188 (13.2) | 1751 (15.1) | 1614 (15.0) | 437 (8.7) | 145 (7.4) |
| | 2 | 3643 (22.0) | 2632 (22.7) | 2448 (22.8) | 1011 (20.2) | 361 (18.5) |
| | 3 | 3134 (18.9) | 2110 (18.2) | 1940 (18.1) | 1024 (20.4) | 389 (19.9) |
| | 4 | 2261 (13.6) | 1449 (12.5) | 1343 (12.5) | 812 (16.2) | 311 (15.9) |
| | 5 | 3247 (19.6) | 2088 (18.1) | 1958 (18.2) | 1159 (23.2) | 525 (26.9) |
| **Smoke years (number, %)** | 0 | 9394 (55.9) | 6033 (51.5) | 5602 (51.6) | 3361 (66.1) | 1299 (65.7) |
| | 1 | 1091 (6.5) | 685 (5.8) | 633 (5.8) | 406 (8.0) | 172 (8.7) |
| | 2 | 672 (4.0) | 477 (4.1) | 446 (4.1) | 195 (3.8) | 99 (5.0) |
| | 3 | 1604 (9.6) | 1238 (10.6) | 1135 (10.5) | 366 (7.2) | 130 (6.6) |
| | 4 | 1754 (10.4) | 1378 (11.8) | 1266 (11.7) | 376 (7.4) | 134 (6.8) |
| | 5 | 1382 (8.2) | 1144 (9.8) | 1072 (9.9) | 238 (4.7) | 86 (4.3) |
| | 6 | 690 (4.1) | 580 (4.9) | 535 (4.9) | 110 (2.1) | 42 (2.1) |
| | 7 | 213 (1.3) | 177 (1.5) | 165 (1.5) | 36 (0.7) | 15 (0.8) |

| | Scale[b] | Population Group[a] | | | | |
|---|---|---|---|---|---|---|
| | | ALL | AFA | AFA subgroup | HA | HA subgroup |
| Income (number, %) | 1 | 2159 (14.1) | 1356 (12.5) | 1251 (12.5) | 803 (17.8) | 319 (18.2) |
| | 2 | 2818 (18.4) | 1898 (17.5) | 1771 (17.7) | 920 (20.4) | 358 (20.4) |
| | 3 | 3709 (24.2) | 2644 (24.4) | 2441 (24.3) | 1065 (23.6) | 408 (23.3) |
| | 4 | 2722 (17.7) | 1982 (18.3) | 1839 (18.3) | 740 (16.4) | 275 (15.7) |
| | 5 | 2400 (15.6) | 1809 (16.7) | 1665 (16.6) | 591 (13.1) | 244 (13.9) |
| | 6 | 879 (5.7) | 656 (6.1) | 607 (6.1) | 223 (4.9) | 88 (5.0) |
| | 7 | 504 (3.3) | 386 (3.6) | 358 (3.6) | 118 (2.6) | 43 (2.4) |
| | 8 | 146 (1.0) | 95 (0.9) | 92 (0.9) | 51 (1.2) | 19 (1.1) |

[a] ALL consists of all self– identified African American (AFA) and Hispanic Americans (HA) participants; AFA consists of self– identified AFA participants; AFA subgroup consists of the self– identified AFA with >0.2 AFR and <0.05 AMI admixture; HA consists of self– identified HA participants; HA subgroup consists of the self– identified HA with >0.1 AMI and <0.1 AFR admixture.

[b] The scales were as follows. Age is provided in years. For physical activity (metabolic equivalents): exercise per week was calculated from self– report of hours spent at various activities as per WHI protocol. Energy intake was measured in kilocalories as calculated using the WHI food frequency questionnaire (FFQ). For education, we used a modified scale with the following categorical classification: 1) high school or below; 2) vocational; 3) some college (includes associate degree); 4) college degree BA/BS; and 5) beyond college. For parity the following scale was applied: – 1) never pregnant; 0) never had term pregnancy; 1 to 5 corresponding to the number of full term pregnancies. Income (family income/year): 1) < $10,000; 2) $10,000 – $19,999; 3) $20,000 – $34,999; 4) $35,000 – $49,999; 5) $50,000 – $74,999; 6) $75,000 – $99,999; 7) $100,000 – $149,999; and 8) >$149,999. For Smoking (smoke years): 1) <5 pack years; 2) 5 – 9 pack years; 3)10 – 19 pack years; 4) 20 – 29 pack years; 5) 30 to 39 pack years, 6) 40 – 49 pack years; and 7) >50 pack years.

## Table 3

**Effect of Admixture on Adiposity and Adipose Distribution in African American and Hispanic American Women**

| | | BMI | | | WHR | | |
|---|---|---|---|---|---|---|---|
| **Group[a]** | **Admixture[b]** | **Estimate[c]** | **SEM** | **p– value** | **Estimate** | **SEM** | **p– value** |
| | **AFR** | 0.58 | 0.03 | <.00001 | 0.09 | 0.03 | 0.001 |
| **ALL** | **EUR** | − 0.68 | 0.03 | <0.0001 | − 0.22 | 0.04 | <0.0001 |
| | **AMI** | − 0.88 | 0.06 | <0.0001 | 0.14 | 0.06 | 0.010 |
| | **AFR** | 0.34 | 0.06 | <0.0001 | 0.02 | 0.07 | 0.762 |
| **AFA** | **EUR** | − 0.35 | 0.07 | <0.0001 | − 0.03 | 0.07 | 0.707 |
| | **AMI** | − 0.21 | 0.37 | 0.566 | 0.14 | 0.38 | 0.700 |
| **AFA subgroup** | **AFR** | 0.42 | 0.08 | <0.0001 | 0.01 | 0.08 | 0.860 |
| | **AFR** | 0.30 | 0.12 | 0.017 | 0.05 | 0.12 | 0.696 |
| **HA** | **EUR** | − 0.15 | 0.08 | 0.060 | − 0.67 | 0.08 | <0.0001 |
| | **AMI** | 0.03 | 0.08 | 0.741 | 0.68 | 0.08 | <0.0001 |
| **HA subgroup** | **AMI** | 0.05 | 0.23 | 0.816 | 0.74 | 0.23 | 0.001 |

[a] ALL consists of all self– identified African American (AFA) and Hispanic Americans (HA) participants; AFA consists of self– identified AFA participants; AFA subgroup consists of the self– identified AFA with >0.2 AFR and <0.05 AMI admixture; HA consists of self– identified HA participants; HA subgroup consists of the self– identified HA with >0.1 AMI and <0.1 AFR admixture.

[b] Analysis was performed using the following covariates: age at entry, smoking, education, income, parity and physical activity.

[c] The estimate is the proportion of the SD attributed to admixture from each continent based on complete (100%) admixture.

## Table 4

**Effect of Continental Admixture on Hip and Waist Circumference in African American and Hispanic American**

| | | Hip Circumference | | | Waist Circumfirence | | |
|---|---|---|---|---|---|---|---|
| **Group[a]** | **Admixture[b]** | **Estimate[c]** | **SEM** | **p value** | **Estimate** | **SEM** | **p value** |
| **ALL** | **AFR** | 0.63 | 0.03 | <0.0001 | 0.54 | 0.03 | <0.0001 |
| | **EUR** | − 0.66 | 0.03 | <0.0001 | − 0.65 | 0.03 | <0.0001 |
| | **AMI** | − 1.15 | 0.06 | <0.0001 | − 0.80 | 0.05 | <0.0001 |
| **AFA** | **AFR** | 0.21 | 0.07 | 0.002 | 0.18 | 0.06 | 0.006 |
| | **EUR** | − 0.22 | 0.07 | 0.001 | − 0.19 | 0.07 | 0.005 |
| | **AMI** | 0.04 | 0.38 | 0.991 | 0.10 | 0.37 | 0.794 |
| **AFA subgroup** | **AFR** | 0.28 | 0.08 | 0.0003 | 0.23 | 0.08 | 0.002 |
| **HA** | **AFR** | 0.32 | 0.12 | 0.011 | 0.27 | 0.12 | 0.032 |
| | **EUR** | 0.18 | 0.08 | 0.031 | − 0.28 | 0.08 | 0.001 |
| | **AMI** | − 0.33 | 0.08 | <0.0001 | 0.17 | 0.08 | 0.036 |
| **HA subgroup** | **AMI** | − 0.40 | 0.23 | 0.079 | 0.15 | 0.23 | 0.508 |

[a] ALL consists of all self– identified African American (AFA) and Hispanic Americans (HA) participants; AFA consists of self– identified AFA participants; AFA subgroup consists of the self– identified AFA with >0.2 AFR and <0.05 AMI admixture; HA consists of self– identified HA participants; HA subgroup consists of the self– identified HA with >0.1 AMI and <0.1 AFR admixture.

[b] Analysis was performed using the following covariates: age at entry, smoking, education, parity, exercise and income.

[c] The estimate is the proportion of the SD attributed to admixture from each continent based on complete (100%) admixture.

**Table 5**

**Admixture Odds Ratios for Adiposity and Adipose Distribution in African American and Hispanic American Women**

| | | BMI | | | WHR | | |
|---|---|---|---|---|---|---|---|
| **Group[a]** | **Admixture** | **OR[b]** | **95% CI** | **P value** | **OR** | **95% CI** | **p value** |
| | **AFR** | 4.91 | 4.16 – 5.79 | <0.0001 | 1.27 | 1.08 – 1.48 | 0.004 |
| | **EUR** | 0.15 | 0.12 – 0.19 | <0.0001 | 0.57 | 0.46 – 0.70 | <0.0001 |
| **ALL** | **AMI** | 0.08 | 0.06 – 0.12 | <0.0001 | 1.54 | 1.09 – 2.18 | 0.014 |
| | **AFR** | 2.63 | 1.82 – 3.80 | <0.0001 | 0.92 | 0.63 – 1.36 | 0.681 |
| | **EUR** | 0.38 | 0.26 – 0.56 | <0.0001 | 1.06 | 0.72 – 1.58 | 0.761 |
| **AFA** | **AMI** | 0.23 | 0.03 – 1.84 | 0.166 | 1.99 | 0.23 – 17.34 | 0.534 |
| **AFA subgroup** | **AFR** | 3.27 | 2.08 – 5.15 | <0.0001 | 0.93 | 0.57 – 1.46 | 0.740 |
| | **AFR** | 1.57 | 0.77 – 3.22 | 0.217 | 1.29 | 0.62 – 2.68 | 0.500 |
| | **EUR** | 0.56 | 0.34 – 0.92 | 0.022 | 0.17 | 0.10 – 0.28 | <0.0001 |
| **HA** | **AMI** | 1.46 | 0.89 – 2.42 | 0.137 | 5.93 | 3.52 – 9.97 | <0.0001 |
| **HA subgroup** | **AMI** | 1.39 | 0.35 – 5.53 | 0.640 | 7.15 | 1.83 – 27.90 | 0.005 |

[a] ALL consists of all self– identified African American (AFA) and Hispanic Americans (HA) participants; AFA consists of self– identified AFA participants; AFA subgroup consists of the self– identified AFA with >0.2 AFR and <0.05 AMI admixture; HA consists of self– identified HA participants; HA subgroup consists of the self– identified HA with >0.1 AMI and <0.1 AFR admixture.

[b] The odds ratio (OR) attributed to a unit (0 to 100%) increase in admixture. For these analyses the top and bottom quartiles were compared and the OR reflects the increased or decreased risk for higher adiposity measurement attributed to admixture of the indicated continental contribution. Analysis was performed using the following covariates: age at entry, smoking, education, income, parity and physical activity.