Published in final edited form as:
Obesity (Silver Spring). 2010 February ; 18(2): 274. doi:10.1038/oby.2009.229.

Fat Distribution, Aerobic Fitness, Blood Lipids, and Insulin Sensitivity in African-American and European-American Women

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Abstract

The purpose of this study was to determine independent relationships of intra-abdominal adipose tissue (IAAT), leg fat, and aerobic fitness with blood lipids and insulin sensitivity (S_i) in European-American (EA) and African-American (AA) premenopausal women. Ninety-three EA and ninety-four AA with BMI between 27 and 30 kg/m^2 had IAAT by computed tomography, total fat and leg fat by dual-energy X-ray absorptiometry, aerobic fitness by a graded exercise test, African admixture (AFADM) by ancestry informative markers, blood lipids by the Ektachem DT system, and S_i by glucose tolerance test. Independent of age, aerobic fitness, AFADM, and leg fat, IAAT was positively related to low-density lipoprotein–cholesterol (LDL-C), cholesterol-high-density lipoprotein (HDL) ratio, triglycerides (TGs), and fasting insulin (standardized β varying 0.16–0.34) and negatively related to HDL-cholesterol (HDL-C) and S_i (standardized β −0.15 and −0.25, respectively). In contrast, independent of age, aerobic fitness, AFADM, and IAAT, leg fat was negatively related to total cholesterol, LDL-C, cholesterol-HDL ratio, TGs, and fasting insulin (standardized β varying −0.15 to −0.21) and positively related to HDL-C and S_i (standardized β 0.16 and 0.23). Age was not independently related to worsening of any blood lipid but was related to increased S_i (standardized β for S_i 0.25, insulin −0.31). With the exception of total cholesterol and LDL-C, aerobic fitness was independently related to worsened blood lipid profile and increased S_i (standardized β varying 0.17 to −0.21). Maintenance of favorable fat distribution and aerobic fitness may be important strategies for healthy aging, at least in premenopausal EA and AA women.

INTRODUCTION

Prevention of cardiovascular disease (CVD) can be attained by improvement of cardiovascular and metabolic risk factors such as blood lipids and insulin sensitivity (S_i) (1). It is evident that obesity is an important contributor to increased risk of CVD and type 2 diabetes (2,3). It is also evident that not all stored fat contributes equally to risk of disease, with intra- abdominal adipose tissue (IAAT) most strongly correlated with cardiovascular risk factors in both men and women (4–8). In contrast, several studies suggest that leg fat is associated with an

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DISCLOSURE

The authors declared no conflict of interest.

improvement in blood lipid profile and blood pressure after adjusting for the potential confounding effects of either overall fat mass or IAAT (9–11).

Both cross-sectional and intervention studies show that high aerobic fitness (maximum oxygen uptake; VO_{2max}) attenuates CVD risk independent of weight status (12,13). Physical activity (especially relatively high-intensity aerobic exercise) is an important determinant of aerobic fitness (14), with genetic factors also accounting for a sizable proportion of the between-subject variability in VO_{2max} (15). The beneficial effects of physical activity and aerobic fitness on blood lipids may be partially related to the lower adiposity, and therefore lower IAAT levels found in more active women and men (15). Because exercise training may affect fat distribution, it has been difficult to establish the independent relative importance of fat distribution and aerobic fitness in influencing blood lipids and S_i (16,17). We know of no studies that have attempted to determine the independent relationship between IAAT, leg fat, and aerobic fitness with blood lipids, fasting insulin, and S_i. This is the primary goal of this article.

Previous studies examining the relationship between fat distribution and aerobic fitness with blood lipids and S_i have been with European-American (EA) subjects (4,18,19). To our knowledge, these factors have not been examined in a mixed population of EA and African-American (AA) subjects. This may potentially be important because there are differences in fat distribution and aerobic fitness, as well as blood lipids and S_i between BMI-matched EA and AA women. For example, AA women have lower IAAT, triglycerides (TGs), and cholesterol-high- density lipoprotein (HDL) ratios as well as higher HDL-cholesterol (HDL-C) than EA women (20–22). Paradoxically, AAs have lower S_i than EAs (23–25).

Racial categorization is a potential confounder when exploring phenotypic differences among individuals, particularly because of the multiple factors (physiological, genetic, environmental, and behavioral) that are associated with racial categories. Genetic admixture can be used to tease apart the genetic component underlying racial categorization that contributes to a phenotype profile, assigning individuals with a quantitative value that represents their ancestral background and reducing the confounding effects of population stratification. This technique has been used previously to explore physiological and metabolic population differences (26).

The purpose of this study is to determine the independent relationships of IAAT, leg fat, and aerobic fitness with blood lipids, fasting insulin, and S_i in a mixed population of EA and AA premenopausal women. Because increasing age is generally associated with increased risk of disease as well as changes in aerobic fitness and fat distribution, it is a potential confounder in the modeling of blood lipids, fasting insulin, and S_i. We therefore include age in the modeling. Specifically, we hypothesize that independent of fat distribution, aerobic fitness, age, and African admixture (AFADM), IAAT will be associated with a worsened blood lipid profile, fasting insulin, and S_i, whereas leg fat and aerobic fitness will be associated with improved blood lipid profile, fasting insulin, and S_i.

METHODS AND PROCEDURES

Subjects

The study group comprised 187 healthy premenopausal women (93 EA and 94 AA self-identified), with BMI between 27 and 30 kg/m^2. Age ranged from 21 to 46 years. All subjects were nonsmokers, of overall good health, and had normal menstrual cycles. Normal glucose tolerance was documented by fasting and 2-h postprandial blood glucose levels after an oral glucose load. None used oral contraceptives at the time of enrollment into the study or medications known to affect body composition. The Institutional Review Board for Human Subjects–approved informed consent was obtained prior to participation in the study in

compliance with the Department of Health and Human Services Regulations for Protection of Human Research Subjects.

Study design

Subjects participating in the study were maintained in weight-stable state for 4 weeks prior to evaluation in the General Clinical Research Center (GCRC), as part of a larger ongoing study on the role of metabolic factors on obesity. During those 4 weeks, body weight measurements were made at visits to the GCRC 3 days/week for the first 2 weeks, and 5 days/week for the last 2 weeks. During the final 2-week period, all meals were provided through the GCRC Research Kitchen to ensure weight stability of <1% variation from initial weight and to maintain daily macronutrient intake within the range of 20–22% of energy as fat, 17–22% as protein, and 57–62% as carbohydrate. Subjects were then admitted to the GCRC for 4 days, during the follicular phase of the menstrual cycle, and underwent assessment of body composition/fat distribution, aerobic fitness, blood lipids, and S_i. After all assessments were completed, subjects were discharged from the GCRC.

Body composition

Lean and fat tissue for the whole body and legs were determined with the use of dual-energy X-ray absorptiometry (Prodigy; Lunar Radiation, Madison, WI). The scans were analyzed with the use of ADULT software, version 1.33 (Lunar Radiation).

IAAT

Cross-sectional area of IAAT was determined by CT with the use of a HiLight/HTD Advantage scanner (General Electric, Milwaukee, WI) set at 120 kVp (peak kilovoltage) and 40 mA. Subjects were examined in the supine position with their arms stretched above their heads, taking a 5-mm scan for 2 s at approximately the level of the fourth and fifth lumbar vertebrae. With the use of procedures established by Kvist *et al.* (27), the attenuation range for adipose tissue was −30 to −190 Hounsfield units. Cross sections of adipose tissue were determined by using a computerized fat tissue–highlighting technique. IAAT was measured by separating adipose tissue areas by encircling the muscle wall surrounding the abdominal cavity with a cursor. Tissue cross-sections between −30 and −190 Hounsfield units in the respective areas were considered to be IAAT. Both intra- and interobserver test–retest reliability had an *r* value of 0.99 with a CV of <2% for re-evaluation of 20 scans.

Aerobic fitness (Vo_{2max})

VO_{2max} was determined during a maximal modified Bruce graded treadmill protocol (28). O_2 consumption and CO_2 production were measured continuously via open-circuit spirometry and analyzed using a SensorMedics metabolic cart (Model No. 2900; SensorMedics, Yorba Linda, CA). Criteria for achievement of VO_{2max} were heart rate (within 90% of age-predicted maximum), respiratory quotient (>1.1), and plateauing (<1.0 ml/kg/min increase in oxygen uptake when grade was increased 2.5% at a speed of 3 mph) (29). All subjects reached at least two criteria and 82% reached the plateauing criteria.

Collection of sera and frequently sampled, intravenous glucose tolerance test

At ~7 am, after a 12-h fast, flexible intravenous catheters were placed in the antecubital spaces of both arms. Three blood samples were drawn over a 40-min period, and sera subsequently separated and pooled for analysis of lipids. Three additional blood samples were taken over a 20-min period for determination of basal glucose and insulin (the average of the values was used for basal “fasting” concentrations). At time “0”, glucose (50% dextrose: 11.4 g/m^2) was administered intravenously. At 20 min following glucose administration, subjects received an intravenous bolus of insulin (0.02 units/kg). Blood samples were collected at the following

times (min) relative to glucose administration at 0, 2, 3, 4, 5, 6, 8, 10, 12, 14, 16, 19, 22, 23, 24, 25, 27, 30, 35, 40, 50, 60, 70, 80, 90, 100, 120, 140, 160, and 180 min. Sera were analyzed for glucose and insulin, and values were entered into the MINMOD computer program (version 3.0; Richard N. Bergman) for determination of S_i and acute insulin response to glucose (30–32).

Assay of glucose, insulin, and lipids

Analyses were performed in the Core Laboratory of the General Clinical Research Center and the Clinical Nutrition Research Center. Glucose was measured in 10 μl sera using an Ektachem DT system (Johnson and Johnson Clinical Diagnostics, Rochester, NY). In the Core Laboratory, this analysis has a mean intra-assay coefficient of variation of 0.61% and a mean interassay coefficient of variation of 1.45%. Insulin was assayed in duplicate 100 μl aliquots with reagents obtained from Linco (St Charles, MO). In the Core Laboratory, this assay has a sensitivity of 1.0 μIU/ml, a mean intra-assay coefficient of variation of 5%, and a mean interassay coefficient of variation of 5.57%. Commercial quality control sera of low, medium, and high insulin concentration are included in every assay to monitor variation over time. Total cholesterol, HDL-C, and TG were measured with the Ektachem DT II system. With this system, HDL-C is measured after precipitation of low-density lipoprotein (LDL) and VLDL with dextran sulfate and magnesium chloride. Control sera of low and high substrate concentration are analyzed with each group of samples, and values for these controls must fall within accepted ranges before samples are analyzed. The DT II is calibrated every 6 months with reagents and supplied by the manufacturer. LDL-cholesterol (LDL-C) was estimated using the Friedewald formula (33).

Admixture

Genotyping of the ancestry informative markers for the measurement of genetic admixture was performed at PreventionGenetics (http://www.preventiongenetics.com) using the Chemicon Amplifluor SNPs Genotyping System (34) coupled with Array Tape technology (http://www.douglasscientific.com/global-array-array-tape.html). A panel of 85 ancestry informative markers was used to estimate the genetic admixture proportion of each subjects. Molecular techniques for the allelic identification and methodology for genetic admixture application have been described elsewhere (35), and information regarding marker sequences, experimental details, and parental population allele frequencies has been submitted to dbSNP (http://www.ncbi.nlm.nih.gov/SNP) under the handle PSU-ANTH. The information from the ancestry informative markers was translated into estimates of African (AFADM) and European admixture for each subject using ADMIXMAP software (36). Admixture estimate ranged from 1–100, for a total of 100 on each subject.

Statistical analysis

T-tests were used to examine racial differences in descriptive variables. Simple Pearson correlation coefficients were calculated for all the variables of interest: IAAT, leg fat, ratio of leg fat-IAAT, VO_{2max}, age, AFADM with lipid variables, S_i, and insulin. To evaluate independent contributions of IAAT, leg fat, and VO_{2max} on blood lipids and S_i, multiple regression was used to model each of the seven dependent variables (cholesterol, LDL-C, HDL-C, cholesterol-HDL ratio, TGs, fasting insulin, and S_i). Besides inclusion of IAAT, leg fat, and VO_{2max} in the models, AFADM and age were also included to negate any potential confounding effects. In order to further explore the interrelationship between IAAT and leg fat on blood lipids and S_i, subjects were characterized into four groups based on IAAT and leg fat. One quarter of a standard deviation above and below the race-specific mean was used to classify the individuals into groups that were appropriate for race. This supplied separation between groups and allowed adequate sample size in each of the four groups (29, 42, 38, and

24 subjects, respectively): (i) Low IAAT (AA <57.6 cm^2 and EA <87.4 cm^2) and low leg fat (AA <13.2 kg and EA <12.55 kg); (ii) High IAAT (AA >71.0 cm^2 and EA >101.6 cm^2) and low leg fat (AA <13.2 kg and EA <12.55 kg); (iii) Low IAAT (AA <57.6 cm^2 and EA <87.4 cm^2) and high leg fat (AA >14.55 kg and EA >13.83 kg); and (iv) High IAAT (AA >71.0 cm^2 and EA >101.6 cm^2) and high leg fat (AA >14.55 kg and EA >13.83 kg). Subjects were divided into low, medium, and high tertiles for aerobic fitness–based, race-specific frequency distributions. Following the approach recently used by Arsenault *et al.* (4), three (tertile groups for aerobic fitness) by two (race) analysis of covariance was used to determine whether high aerobic fitness resulted in reduced IAAT (after adjusting for % body fat). This approach allowed adequate sample size in each of the six subgroups: high aerobic fitness (AA VO_{2max} >28.7 ml O_2/kg/min with 31 subjects, and EA VO_{2max} >31.0 ml O_2/kg/min with 32 subjects), medium aerobic fitness (AA VO_{2max} <28.7 and >25.8 ml O_2/kg/min with 33 subjects, and EA VO_{2max} <31.0 and >27.0 ml O_2/kg/min with 32 subjects) and low aerobic fitness (AA VO_{2max} <25.8 ml O_2/kg/min with 30 subjects, and EA VO_{2max} <27.0 ml O_2/kg/min with 29 subjects). Where appropriate, post hoc tests were run with Bonferroni corrections. Fasting insulin, S_i, and TGs were log-transformed. All analyses were done using the Statistical Package for the Social Sciences, version 10 (SPSS, Chicago, IL).

RESULTS

Descriptive characteristics of the 94 AA and 93 EA subjects are contained in Table 1. Subjects were healthy, premenopausal, overweight women. No racial differences were observed for age, height, weight, BMI, % fat, leg fat, cholesterol, LDL-C, or fasting S_i, although the height difference of 1.7 cm had a probability of 0.07. However, AA had lower IAAT, VO_{2max}, TGs, cholesterol-HDL ratio, and SI but higher HDL-C. Pearson product correlations (Table 2) showed that increased IAAT and age were associated with increased significant positive correlations with total cholesterol, LDL-C, cholesterol-HDL ratio, TGs, and fasting insulin. IAAT was also significantly negatively related to HDL-C. Age tended to be related to improved insulin variables having a significant negative relationship with fasting insulin and a borderline positive relationship with S_i ($r = 0.12$, $P = 0.06$). Leg fat was significantly associated with improved blood lipids, fasting insulin, and S_i. AFADM was negatively related to total cholesterol, cholesterol-HDL ratio, TGs, and S_i, and positively related to HDL-C. VO_{2max} was negatively related to cholesterol-HDL ratio and TGs, and positively related to S_i. The ratio of leg fat-IAAT was significantly related to all blood lipids and fasting insulin.

Table 3 contains the multiple regression models for each of the seven dependent variables. Based on potential confounding effects, five variables were entered into each of the seven models: leg fat, AFADM, IAAT, VO_{2max}, and age. Independent of all other variables, leg fat was significantly related to improved blood lipids, fasting insulin, and S_i, whereas IAAT was significantly related to worsening of blood lipids, fasting insulin, and S_i (except total cholesterol for which significance was only approached (standardized $\beta = 0.14$, $P = 0.07$). Independent of the other variables, AFADM was positively related to HDL-C and fasting insulin, and inversely related to cholesterol-HDL ratio, TGs, and S_i. VO_{2max} was independently and positively related to HDL-C and S_i, and inversely related to cholesterol-HDL ratio and TGs. After adjusting for potential confounders, age was not independently related to any dependent variable, whereas it did have a significant positive correlation with S_i and negative correlation with fasting insulin.

Table 4 shows the results for the analysis of blood lipids and S_i for groups characterized into low or high IAAT, and leg fat. The analysis of covariance analysis group effect was significant for all variables at $P < 0.01$ level except for HDL-C that was significant at $P < 0.05$. In general, post hoc results show that the low IAAT/high leg fat group had a significantly better blood lipid profile and higher S_i than either the low IAAT/low leg fat group or the high IAAT/low

leg fat group, whereas the low IAAT/high leg fat group had significantly higher HDL-C and lower cholesterol-HDL ratio than the high IAAT/high leg fat group. The high IAAT/low leg fat group had significantly higher cholesterol-HDL ratio and TGs than the low IAAT/low leg fat group. The high IAAT/high leg fat group had lower cholesterol, LDL-C, TGs, and log insulin but higher log S_i than the high IAAT/low leg fat group.

Figure 1 shows the results of the IAAT analysis of covariance by VO_{2max} tertiles. After adjusting for % body fat, there were significant tertile group and race effects (both <0.01), but no significant tertile group by race interaction ($P = 0.73$). Post hoc analysis revealed that the high tertile group for VO_{2max} had significantly lower IAAT than the low tertile group for VO_{2max}. No other significant differences were observed.

DISCUSSION

Consistent with our hypotheses, IAAT was independently and positively related to worsening of blood lipids and S_i, whereas both leg fat and aerobic fitness were independently and positively related to improved blood lipids and S_i. Previous studies have shown similar relationships for IAAT and leg fat (9–11,37–39). However, to our knowledge, this is the first study to show these results to be independent of age and aerobic fitness in a mixed group of AA and EA women. Although not the focus of the study, it is interesting to note that age was not related to worsening of the blood lipid profile after adjusting for fat distribution and aerobic fitness. In fact, the significant negative adjusted β for age and fasting insulin, and significant positive adjusted β for age and S_i suggested less risk for type 2 diabetes with increasing age if IAAT is kept low and aerobic fitness is kept high. The women in this study were relatively homogeneous for body composition, being neither obese nor lean. In addition, none of the women were diabetic and few had an abnormal blood lipid profile. Therefore, caution must be made in applying these results to a more heterogeneous population. However, within confines of these limitations, the results suggest that both maintenance of a favorable fat distribution and aerobic fitness may be important strategies for healthy aging, at least in premenopausal AA and EA women.

In previous studies, the negative relationship of leg fat with cardiometabolic risk only occurred after adjusting for trunk fat, IAAT, or total fat (9–11). In fact, leg fat has usually been positively related to increased risk for CVD and type 2 diabetes when no adjustments were made (9,10). This was not the case in this study. Leg fat was negatively related to fasting insulin and all blood lipids, except HDL-C for which it was positively related. In addition, it was positively related to S_i (Table 2). It continued to be significantly and inversely related when expressed as a ratio (leg fat-IAAT) or after adjustments in a linear regression (Table 3). Our analysis in which subjects were divided into low and high IAAT, and low and high leg fat groups further supports the potential importance of leg fat in improving blood lipid profile and S_i (Table 4). The group that had relatively low IAAT and relatively high leg fat consistently had the best blood lipid profile, fasting insulin, and S_i. Of particular note is that the high IAAT/high leg fat group actually had a better fasting blood lipids, S_i, and blood lipid profile (with the exception of HDL-C and cholesterol-HDL ratio) than the high IAAT/low leg fat group (Table 4). Regardless of IAAT increases, increased leg fat seems to be related to improved blood lipid profile and S_i in these women.

IAAT may be associated with increased risk of CVD and type 2 diabetes through its detrimental effect on metabolism in the liver. Hepatic insulin extraction is decreased when exposed to increases in IAAT-derived free fatty acids, which in turn leads to increased fasting insulin. Both risk for CVD and type 2 diabetes is thus increased. On the other hand, leg fat has been proposed to have a protective effect because it has a low rate of lipolysis (40) when compared to IAAT, and may act as a sink for storing fat, thus improving lipid profile and S_i (11). A

relatively new alternative hypothesis for explaining the positive relationship between IAAT, and blood lipids and S_i may involve a larger production of cytokines in IAAT (41). IAAT is associated with the pro-inflammatory cytokine tumor necrosis factor-α and its receptors tumor necrosis factor-RI and tumor necrosis factor-RII, whereas subcutaneous body fat is not associated with this cytokine in premenopausal overweight women (42). In addition, tumor necrosis factor-α has been implicated with a reduction in insulin signaling (43,44), suggesting that inflammation is associated adversely with S_i.

The data from the present study do not necessarily show cause and effect between leg fat, and blood lipids and S_i, but do lend support for the intriguing possibility that leg fat may convey a protective effect on individuals with genetic propensity to store fat in the gluteofemoral region. Another equally plausible explanation for an apparent protective effect of leg fat involves the endocrine environment. It is possible that women who tend to deposit fat in the legs when they gain weight may have a particular hormone profile that is protective. For example, a more estrogenic environment may direct fat storage toward the legs, whereas a more androgenic environment may direct fat storage toward IAAT (45). Estrogens also have a beneficial effect on lipid profile and S_i through action on lipid metabolism and glucose uptake (46–48).

The inverse association between aerobic fitness and blood lipids is highly consistent across studies (49). Low aerobic fitness is considered a predictor of CVD as well as low S_i (50,51) and all-cause mortality in both men and women (52–54). We found that aerobic fitness was an independent predictor of HDL-C, cholesterol-HDL ratio, TGs, and S_i (Table 3). It is important to point out that this is the first time that these relationships with aerobic fitness have been shown to be independent of fat distribution and African admixture in a mixed population of AA and EA women. Aerobic fitness has a genetic component as well as a training component, but it is impossible to separate their respective contributions to blood lipids and S_i in this study.

Consistent with the results of Arsenault *et al.* (4), it is important to point out that women in the highest tertile for aerobic fitness had lower IAAT than women in the lowest tertile for aerobic fitness even after adjusting for percent body fat, suggesting exercise training may have a positive effect on maintaining a favorable fat distribution (Figure 1). If this is the case, aerobic fitness would possibly have both an independent effect on blood lipids and S_i (as shown by the relationships discussed in the previous paragraph), and an indirect one through improvement of fat distribution.

Inclusion of AFADM as a covariate strengthened this study because we accounted for the ancestral genetic variation that underlies racial classification, and we did not limit our design to a dichotomous (AA or EA) race variable. The worsened metabolic profile found with increased IAAT and improved metabolic profile found with increased leg fat were unaffected by adjustments for AFADM. After adjustments for fat distribution, aerobic fitness, and age, AFADM was related to an improved lipid profile (positive relationship with HDL and negative relationship with cholesterol-HDL ratio and TGs) but lower S_i and higher fasting insulin. Thus, aside from any genetic contribution to fat distribution and aerobic fitness, genetic differences still account for variability in cardiometabolic profile.

In conclusion, our findings suggest that IAAT is a consistent independent predictor of increased worsened blood lipid profile, fasting insulin, and S_i, whereas leg fat and aerobic fitness are consistent independent predictors of improved blood lipid profile, fasting insulin, and S_i in a mixed group of EA and AA premenopausal women. Age was not related to any blood lipid after adjustments were made for fat distribution and aerobic fitness. However, age was related to decreased fasting insulin and increased S_i after adjusting for aerobic fitness and fat distribution in these premenopausal EA and AA women.

Acknowledgments

We thank Robert Petri, David Bryan, Amy Thomas, Paul Zuckerman, and Betty Darnell who provided invaluable technical assistance in the conduct of the study. Supported by NIH grants R01 DK 49779 and R01 DK51684, General Clinical Research Center grant M01-RR00032, Clinical Nutrition Research Unit grant P30-DK56336, and UAB University-wide Clinical Nutrition Research Center grant. Stouffer's Lean Cuisine entrées were provided by the Nestlé Food (Solon, OH), and Smart Ones entrées were provided by H.J. Heinz Frozen Foods.

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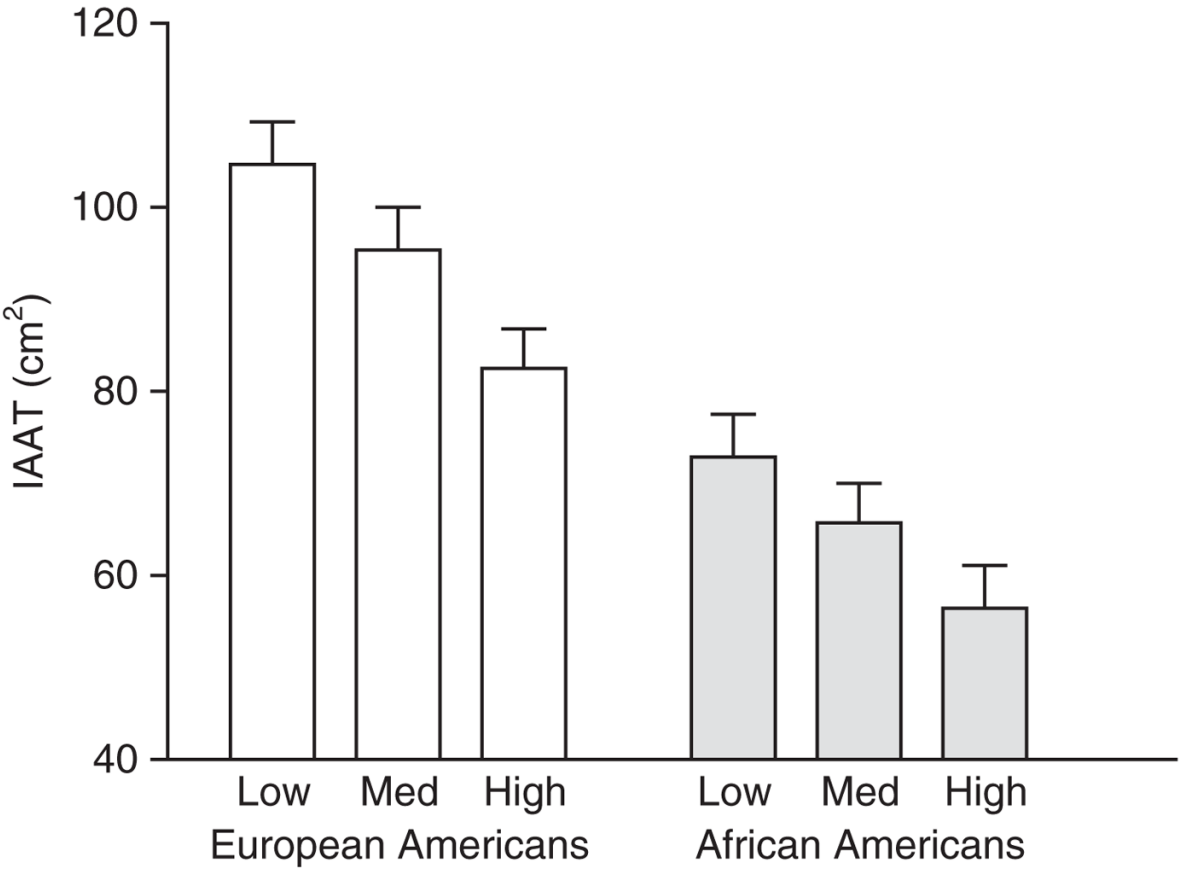

Figure 1.
IAAT by tertiles of aerobic fitness. IAAT, intra-abdominal adipose tissue; Med, medium.

Table 1

Descriptive variables

	African American	European American	*P*
Age (years)	34.0 ± 6.1	34.7 ± 6.3	0.39
African admixture (%)	65.8 ± 11.0	17.9 ± 5.1	<0.01
Height (cm)	164.1 ± 6.4	165.8 ± 6.4	0.07
Weight (kg)	76.6 ± 6.4	78.1 ± 7.4	0.12
BMI (kg/m^2)	28.3 ± 1.3	28.3 ± 1.4	0.92
% Fat	43.2 ± 3.7	44.0 ± 3.4	0.11
Leg fat (kg)	13.8 ± 2.4	13.2 ± 2.6	0.11
IAAT (cm^2)	64.4 ± 26.2	94.5 ± 28.5	<0.01
VO_{2max} (ml/kg/min)	27.5 ± 3.3	29.0 ± 3.7	<0.01
Cholesterol (mg/dl)	153.6 ± 33.2	159.5 ± 31.9	0.21
LDL-cholesterol (mg/dl)	96.9 ± 31.4	100.4 ± 28.3	0.45
HDL-cholesterol (mg/dl)	42.9 ± 11.1	35.9 ± 9.2	<0.01
Cholesterol-HDL ratio	3.8 ± 1.2	4.7 ± 1.4	<0.01
Triglycerides (mg/dl)	68.7 ± 25.8	116.0 ± 52.7	<0.01
Fasting insulin	12.2 ± 4.4	11.5 ± 3.4	0.20
Insulin sensitivity	2.4 ± 1.3	3.6 ± 1.9	<0.01

Values are expressed in mean ± s.d. $N = 187$ except for fasting insulin and S_I for which $N = 172$.

HDL, high-density lipoprotein; IAAT, intra-abdominal adipose tissue; LDL, low-density lipoprotein; S_I, insulin sensitivity; VO_{2max}, maximal oxygen uptake.

Table 2

Pearson product moment correlations between % fat and fat distribution with blood lipids, fasting insulin, and insulin sensitivity

	Age	% Fat	Leg fat	IAAT	Ratio of leg fat-IAAT	AFADM	VO_{2max}
Total cholesterol	0.20**	−0.09	−0.20**	0.24**	−0.20**	−0.12*	−0.06
LDL-cholesterol	0.18**	−0.12	−0.21**	0.24**	−0.24**	−0.09	−0.06
HDL-cholesterol	0.01	−0.03	0.16*	−0.31**	0.35**	0.32**	0.10
Cholesterol/HDL-cholesterol	0.16*	−0.02	−0.24**	0.43**	−0.38**	−0.37**	−0.15*
Log triglycerides	0.12*	0.01	−0.22**	0.44**	−0.34**	−0.50**	−0.13*
Log fasting insulin	−0.18**	0.10	−0.16*	0.17*	−0.19**	0.05	−0.02
Log insulin sensitivity	0.12	−0.01	0.17*	−0.03	0.09	−0.35**	0.20**

AFADM, African admixture; HDL, high-density lipoprotein; IAAT, intra-abdominal adipose tissue; LDL, low-density lipoprotein.

*$P < 0.05$.

**$P < 0.01$.

Table 3

Multiple regression models for estimation of blood lipids, fasting insulin, and insulin sensitivity

	Model variables	Intercept	Slope	Model *R*	Standardized *β*	*P*
Total cholesterol		168.7 ±35.5		0.31		<**0.01**
	Leg fat		−2.07 ±0.98		0.16	**0.04**
	AFADM		−5.30 ±10.6		−0.05	0.60
	IAAT		0.141 ±0.09		0.14	0.07
	VO_{2max}		−0.541 ±0.71		−0.06	0.44
	Age		0.641 ±0.39		0.12	0.11
LDL-cholesterol		111.0 ±32.5		0.30		<**0.01**
	Leg fat		−2.00 ±0.90		−0.17	**0.03**
	AFADM		−0.25 ±9.7		−0.01	0.98
	IAAT		0.15 ±0.09		0.16	**0.04**
	VO_{2max}		−0.45 ±0.65		−0.06	0.48
	Age		0.44 ±0.36		0.09	0.22
HDL-cholesterol		8.31 ±11.2		0.43		<**0.01**
	Leg fat		0.67 ±0.31		0.16	**0.03**
	AFADM		10.0 ±3.36		0.28	<**0.01**
	IAAT		−0.051 ±0.03		−0.15	<**0.05**
	VO_{2max}		0.519 ±0.23		0.18	**0.02**
	Age		0.212 ±0.12		0.12	0.09
Cholesterol/HDL-cholesterol		7.76 ±1.37		0.53		<**0.01**
	Leg fat		−0.11 ±0.04		−0.21	<**0.01**
	AFADM		−1.44 ±0.41		−0.30	<**0.01**
	IAAT		0.008 ±0.004		0.19	**0.01**
	VO_{2max}		−0.078 ±0.03		−0.21	<**0.01**
	Age		0.005 ±0.02		0.02	0.75
Log triglycerides		2.43 ±0.19		0.68		<**0.01**
	Leg fat		−0.017 ±0.005		−0.20	<**0.01**
	AFADM		−0.321 ±0.055		−0.44	<**0.01**
	IAAT		0.001 ±0.001		0.22	<**0.01**
	VO_{2max}		−0.001 ±0.004		−0.17	<**0.01**

	Model variables	Intercept	Slope	Model *R*	Standardized *β*	*P*
	Age		−0.0001 ±0.002		0.01	0.94
Log fasting insulin		1.25 ±0.16		0.38		<**0.01**
	Leg fat		−0.008 ±0.004		−0.15	<**0.05**
	AFADM		0.108 ±0.047		0.21	**0.02**
	IAAT		0.0015 ±0.001		0.34	<**0.01**
	VO_{2max}		−0.0003 ±0.003		−0.01	0.91
	Age		−0.0071 ±0.002		−0.31	<**0.01**
Log insulin sensitivity		−0.218 ±0.25		0.52		<**0.01**
	Leg fat		0.022 ±0.007		0.23	<**0.01**
	AFADM		−0.376 ±0.073		−0.44	<**0.01**
	IAAT		−0.0019 ±0.001		−0.25	<**0.01**
	VO_{2max}		0.0117 ±0.005		0.17	**0.02**
	Age		0.0097 ±0.003		0.25	<**0.01**

AFADM, African admixture; HDL, high-density lipoprotein; IAAT, intra-abdominal adipose tissue; LDL, low-density lipoprotein.

Boldface values indicate $P < 0.05$.

Obesity (Silver Spring). Author manuscript; available in PMC 2010 February 1.

Table 4

Blood lipids, fasting insulin, and insulin sensitivity according to classification of low and high IAAT and leg fat

	Low IAAT Low leg fat (*n* = 29)	High IAAT Low leg fat (*n* = 42)	Low IAAT High leg fat (*n* = 38)	High IAAT High leg fat (*n* = 24)
Total cholesterol	162.0 ± 5.9	170.5 ± 5.1	146.1 ± 5.2[a,b]	150.1 ±6.4[b]
LDL-cholesterol	104.7 ± 5.4	111.1 ± 4.6	88.0 ± 4.7[a,b]	95.6 ± 5.8[b]
HDL-cholesterol	39.2 ± 1.8	36.8 ± 1.5	42.2 ± 1.5[b,c]	36.2 ± 1.9
Cholesterol/HDL-cholesterol	4.3 ± 0.2	4.9 ± 0.2[a]	3.6 ± 0.2[a,b,c]	4.5 ± 0.3
Triglycerides	90.0 ± 6.9	113.1 ± 5.9[a]	79.9 ± 6.0[b]	91.3 ± 7.4[b]
Log fasting insulin	11.9 ± 3.8	13.3 ± 5.0	10.4 ± 2.7[a,b]	11.0 ± 3.3[b]
Log insulin sensitivity	2.5 ± 1.3	2.8 ± 1.6	3.9 ± 2.3[a,b,d]	3.3 ± 1.6[b]

ANCOVA analysis adjusted for African admixture and age. ANCOVA analysis group effect significant for all variables significant at <0.01 level except for HDL-cholesterol that was significant at <0.05. ANCOVA analysis was done on log triglyceride, log insulin, and log insulin sensitivity. Back-transformed values are displayed in table. ANCOVA, analysis of covariance; HDL, high-density lipoprotein; IAAT, intra-abdominal adipose tissue; LDL, low-density lipoprotein.

[a] Significantly different from low IAAT and low leg fat group at <0.05.

[b] Significantly different from high IAAT and low leg fat group at <0.05.

[c] Significantly different from high IAAT and high leg fat group at <0.05.

[d] Significantly different from high IAAT and high leg fat group at <0.10.