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The Relative Contributions of the Abdominal Visceral and Subcutaneous Fat Depots to Cardiometabolic Risk in Youth

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Abstract

Objective—Evaluate the association of abdominal visceral and subcutaneous fat, independent of total body fat, with cardiometabolic risk factors and insulin resistance among youth.

Methods—Visceral and subcutaneous fat, percent total body fat, insulin resistance (adjusted for lean body mass: $M_{l_{bm}}$), blood pressure, glucose, insulin, and lipids were obtained in 472 youth ages 6–18 years. Linear regression, adjusted for age, sex, race, Tanner stage, and percent total body fat, was used to evaluate associations of visceral and subcutaneous fat with cardiometabolic risk factors.

Results—Visceral fat was associated inversely with $M_{l_{bm}}$ ($p=0.003$) and positively with fasting insulin ($p=0.002$) and triglycerides ($p=0.002$). Visceral fat levels above the mean were associated inversely with HDL cholesterol ($p=0.002$), and positively systolic blood pressure ($p<0.0001$) and non-HDL cholesterol ($p<0.0001$). Subcutaneous fat was associated inversely with $M_{l_{bm}}$ ($p=0.003$) and HDL cholesterol ($p<0.05$), and positively with fasting glucose ($p<0.05$), fasting insulin ($p=0.0003$), systolic blood pressure ($p=0.005$), and triglycerides ($p=0.003$). Subcutaneous fat levels above the mean were associated with non-HDL cholesterol ($p=0.0002$).

Conclusions—These findings suggest that there may be a threshold level of visceral and subcutaneous fat (regardless of total body fat), that when exceeded in childhood, is more likely to be associated with many cardiometabolic risk factors. Triglycerides and insulin resistance appear to be associated with these fat depots at even lower thresholds of abdominal adiposity.

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Author Contributions:

ASK conceived the study idea, interpreted the results, and drafted the manuscript. ASK takes full responsibility for the work as a whole, including the study design, access to data, and the decision to submit and publish the manuscript.

DRD interpreted the results and edited the manuscript.

JH conducted the statistical analysis and edited the manuscript.

LZ conducted the statistical analysis and edited the manuscript.

AM interpreted the results and edited the manuscript.

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JS interpreted the results and edited the manuscript.

Keywords

visceral; subcutaneous; cardiometabolic risk factors; insulin resistance

Introduction

Compared to what is known in adults, the relationship of abdominal adiposity with cardiometabolic risk factors and insulin resistance among children and adolescents is incompletely understood. Pediatric studies have reported an association between abdominal visceral fat, quantified using imaging-based measurement techniques such as magnetic resonance imaging or computed tomography (CT), and fasting insulin,^{1–3} insulin secretion,⁴ insulin resistance,^{3, 4} impaired glucose tolerance,⁵ triglycerides,^{1–3} low levels of HDL cholesterol,¹ components of the metabolic syndrome,^{1, 3, 6–9} low levels of adiponectin,¹⁰ and oxidative stress.¹¹ Similarly, abdominal subcutaneous fat has been shown to be correlated with insulin resistance in overweight and obese children.¹² However, questions remain as to the relative contribution of specific fat depots, vs. total body adiposity, to cardiometabolic risk. The issue is important because it has implications regarding early screening for, and identification of, high-risk obesity phenotypes,¹³ and to inform potential interventions intended to reduce abdominal adiposity.¹⁴ Therefore, the aim of this cross-sectional study was to evaluate the association of abdominal visceral and subcutaneous fat, independent of percent total body fat, with cardiometabolic risk factors and insulin resistance among a large cohort of children and adolescents.

Materials and Methods

Study Design and Participants

This cross-sectional study included 472 children and adolescents (of the 557 total subjects, 85 were excluded because Tanner stage was not available) ages 6–18 years old throughout a range of body mass index (BMI) values (normal weight through obese). Data from two separate studies, both of which obtained cardiometabolic risk factors in children and adolescents and utilized the same data collection methods and procedures, were combined. One was a community-based longitudinal study and the other was a study of childhood cancer survivors and their healthy siblings (the latter group was included in the current study). The respective study protocols were approved by the University of Minnesota Institutional Review Board and consent/assent was obtained from parents/participants.

Anthropometric, Body Fat, and Blood Pressure Measurements

Participants arrived for testing at the University of Minnesota Clinical and Translational Science Institute after an overnight 10–12 hour fast. Tanner stage was determined by trained pediatricians according to pubic hair development in boys and breast and pubic hair development in girls, with the most mature value used to define pubertal status. Weight and height were measured on a calibrated electronic scale and stadiometer, respectively, with light clothes and without shoes. BMI was calculated as weight in kilograms divided by height in meters squared. Waist circumference was measured to the nearest 0.5cm, taken in duplicate, and the mean value was used in the analysis. Percent total-body fat was measured by dual energy X-ray absorptiometry (DXA) (Lunar Prodigy, General Electric Medical Systems, Madison, WI, USA) and analyzed using its enCore™ software (platform version 10.5.). Abdominal visceral and subcutaneous fat was obtained by CT using a Siemens Sensation 16 (Siemens Medical Solutions, Malvern, PA, USA) with two separate slices obtained at the L4-L5 interspace. The two images were subdivided into five mm slices and the 1st and 3rd five mm slices were combined and analyzed for visceral adipose tissue. The

upper limit of adipose tissue density was -30 Hounsfield units (HU) and the lower limit was -190 HU. The average of two blood pressure measurements from the right arm of rested, seated subjects was used in analyses.

Measurement of Insulin Resistance and Lipids

Insulin resistance was measured in those 10 years of age and older by the euglycemic insulin clamp as previously described.¹⁵ Insulin was infused at a constant rate of 1 mU/kg/min for 3 hours, and glucose was infused at a variable rate to maintain euglycemia. Insulin resistance (M) was expressed as the glucose infusion rate (mg/kg/min of glucose), with adjustment for lean body mass ($M_{l_{bm}}$). Lower $M_{l_{bm}}$ represents lower insulin sensitivity/greater insulin resistance. Fasting blood samples were collected for lipids, glucose, and insulin and assays were conducted with standard procedures at the Fairview Diagnostic Laboratories, Fairview-University Medical Center (Minneapolis, MN), a Centers for Disease Control and Prevention-certified laboratory. Homeostasis model of insulin resistance (HOMA-IR) was calculated as described by Matthews et al.¹⁶

Statistical Analysis

Linear regression analysis, adjusted for age, sex, race, Tanner stage, and percent total body fat, was used to evaluate associations of visceral and subcutaneous fat (included in separate models) with cardiometabolic risk factors and $M_{l_{bm}}$, independent of percent total body fat. Generalized estimating equations (GEE), with robust standard errors, were used to account for sibling relationships. In exploratory analyses, certain risk factors were associated with the fat measures in a slightly complicated manner. Specifically, instead of a straight line (linear) association, the association followed a straight line with one bend in it; in particular, a straight line with a change in the line's slope at the mean of the fat measure. Thus for all of the risk factors except triglycerides, insulin, and $M_{l_{bm}}$, in analyses including the fat variables, each fat variable was entered linearly with a change in slope at the mean. Subgroup analyses were done by sex and tanner stage (I, II–IV, and V) for descriptive purposes only. For each outcome measure, visceral and subcutaneous fat were compared according to the amount of variation in the outcome that each explained independently of percent total body fat and the other adjusters. 1000 bootstrap samples of families were drawn (preserving clustering by family); each bootstrap sample was analyzed as above but ignoring clustering, and a two-sided P-value was computed by inverting the bootstrap confidence interval for (R^2 including visceral fat) minus (R^2 including subcutaneous fat).

To evaluate whether visceral fat, subcutaneous fat, and percent total body fat were associated with the cardiometabolic risk factors and $M_{l_{bm}}$ independently of BMI percentile, waist circumference percentile, and waist-to-height ratio (which addresses whether the more complex and expensive direct measures of body fat provide additional information regarding cardiometabolic risk beyond these conventional anthropometric measures), we estimated separate linear regression models, each adjusted for these three conventional measures. All analyses were done using the SAS system (v. 9.2; SAS Institute, Cary, NC). All P-values are two-sided, and <0.05 is considered statistically significant.

Results

Demographics

Data from 472 children and adolescents (including 95 family units) ages 6–18 years old (246 boys, 226 girls, mean age 12.3 ± 3.7) were included. Demographic data and mean levels of cardiometabolic risk factors and insulin resistance are shown in Table 1.

Associations of Visceral and Subcutaneous Fat with Cardiometabolic Risk Factors

Results of the linear regression analysis evaluating associations of visceral and subcutaneous fat with cardiometabolic risk factors and M_{Ibm} are shown in Table 2. Visceral fat was associated inversely with M_{Ibm} ($p=0.003$) and positively with fasting insulin ($p=0.002$), HOMA-IR ($p<0.05$), and triglycerides ($p=0.002$). Visceral fat levels above the mean were associated inversely with HDL cholesterol ($p=0.002$), and positively with HOMA-IR ($p=0.0002$), systolic blood pressure ($p<0.0001$), and non-HDL cholesterol ($p<0.0001$). Subcutaneous fat was associated inversely with M_{Ibm} ($p=0.003$) and HDL cholesterol ($p<0.05$), and positively with fasting glucose ($p<0.05$), fasting insulin ($p=0.0003$), HOMA-IR ($p=0.0003$), systolic blood pressure ($p=0.005$), and triglycerides ($p=0.003$). Subcutaneous fat levels above the mean were associated with HOMA-IR ($p<0.0001$) and non-HDL cholesterol ($p=0.0002$). Analyses were also performed using systolic blood pressure percentile and the conclusions were the same; therefore, only results with absolute systolic blood pressure are reported, above.

Results by Sex

Among boys, visceral fat was associated with triglycerides ($p=0.005$). Subcutaneous fat was associated with fasting insulin ($p=0.004$), HOMA-IR ($p<0.05$), systolic blood pressure ($p<0.05$), and triglycerides ($p=0.005$). Among girls, visceral fat was inversely associated with M_{Ibm} ($p=0.0006$) and HDL cholesterol ($p<0.05$), and positively associated with fasting glucose ($p=0.005$), fasting insulin ($p<0.05$), HOMA-IR ($p=0.004$), and triglycerides ($p<0.05$). Subcutaneous fat was inversely associated with M_{Ibm} ($p<0.05$) and HDL cholesterol ($p<0.05$), and positively associated with fasting insulin ($p<0.05$), HOMA-IR ($p<0.05$), and systolic blood pressure ($p<0.05$).

Results by Tanner Stage

Within Tanner stage I (pre-puberty), visceral fat was associated with triglycerides ($p=0.008$). Subcutaneous fat was inversely associated with M_{Ibm} ($p<0.05$) and non-HDL cholesterol ($p<0.05$), and positively associated with HOMA-IR ($p=0.006$). Within Tanner stages II-IV (puberty), visceral fat was associated with fasting insulin ($p<0.05$) and triglycerides ($p<0.05$). Subcutaneous fat was associated with fasting insulin ($p<0.05$). Within Tanner stage V (post-puberty), subcutaneous fat was associated with fasting insulin ($p<0.05$) and triglycerides ($p<0.05$).

Associations among Body Fat Measurements

There was a high degree of co-linearity between the abdominal fat measures and the other measures of body fatness. Abdominal visceral fat was significantly correlated with percent total body fat ($r = 0.68$), BMI percentile ($r = 0.56$), waist circumference percentile ($r = 0.58$), and waist-to-height ratio ($r = 0.59$), all $p<0.0001$. Similarly, abdominal subcutaneous fat was significantly correlated with percent total body fat ($r = 0.85$), BMI percentile ($r = 0.65$), waist circumference percentile ($r = 0.65$), and waist-to-height ratio ($r = 0.73$), all $p<0.0001$.

Results Adjusting for Clinical Anthropometric Measurements

Results of the separate linear regression model, adjusted for BMI percentile, waist circumference percentile, and waist-to-height ratio, demonstrated that visceral-, subcutaneous-, and percent total body fat were significantly associated with fasting insulin (all $p<0.001$) and triglycerides (all $p<0.05$), but were not associated with blood pressure, cholesterol, or M_{Ibm} . Visceral and subcutaneous fat were associated with HOMA-IR (both $p<0.05$). Only visceral fat was associated with fasting glucose ($p<0.05$).

Relative Strength of Associations – Visceral vs. Subcutaneous Fat

Results of the analysis comparing visceral vs. subcutaneous fat according to the strength of their respective associations with the cardiometabolic risk factors found no statistically significant differences. In other words, neither fat depot appeared to be superior to the other in the strength of its relationship with cardiometabolic risk factors, after accounting for percent total body fat.

Discussion

The primary finding of this study is that the visceral and the subcutaneous depots of the abdominal fat region, independent of percent total body adiposity, appear to have similar associations with many cardiometabolic risk factors and insulin resistance as early as the first two decades of life. The relationships of visceral and subcutaneous fat with many of these risk factors were stronger among children and adolescents who had levels of these respective fat depots at or above the mean, whereas the relationship of these fat depots with triglycerides and insulin resistance tended to be present throughout their entire range of values. These findings suggest that there may be a threshold level of visceral and subcutaneous fat that when exceeded, is more likely to be associated with cardiometabolic risk factors. Triglycerides and insulin resistance appear to be associated with these fat depots at even lower thresholds of abdominal adiposity. Results of this study have implications for both screening for, and treatment of, childhood obesity. In relation to screening, children and adolescents with high levels of abdominal visceral and subcutaneous fat may be at the highest risk for developing later cardiovascular disease and type 2 diabetes. Interventions that target the abdominal fat depot may be effective in terms of reducing risk of these chronic diseases.

The findings of the current study are in agreement with results from a number of other pediatric studies that have reported associations of visceral fat with various cardiometabolic risk factors, insulin resistance, and oxidative stress.^{1–11} Our data confirm the previous findings within the context of a relatively large sample of children and adolescents and provide additional evidence suggesting that the abdominal subcutaneous fat depot is also associated with multiple cardiometabolic risk factors and insulin resistance. This has important screening implications since total abdominal adiposity is relatively easily measured in the clinic setting through simple waist measurement, while visceral adiposity alone requires more sophisticated and expensive techniques.

Our observations show some differences compared to two previous studies reporting that total body fat¹⁷ and subcutaneous fat¹² were more strongly associated with insulin resistance than visceral fat. In the current study, after adjustment for percent total body fat, visceral and subcutaneous fat remained independently associated with insulin resistance. The reasons for the disparate findings may be related to the larger sample size in the current study, the use of a sensitive measure of insulin resistance (euglycemic, hyperinsulinemic clamp), and/or slight differences in locations used for quantification of the fat depots among the studies.

In an attempt to address a more clinically-relevant question, we evaluated whether directly-measured visceral, subcutaneous, and percent total body fat were associated with cardiometabolic risk factors and insulin resistance, independent of various surrogate adiposity measures that can be easily obtained in the clinical setting such as BMI, waist circumference, and waist-to-height ratio. When adjustments were made for these standard anthropometric variables, many of the associations among the measures of body fat and risk factors disappeared. However, this is not surprising because of the relatively high degree of co-linearity among many of these anthropometric measures with adiposity (i.e., BMI, waist circumference, and waist-to-height ratio are surrogate measures of body fat). Therefore,

these results suggest that many of the standard anthropometric techniques used to estimate body fat in the clinic can serve as reasonable surrogates for abdominal adiposity.

Strengths of the current study included the relatively large sample size, the wide age range of the participants, and the use of well-validated and accurate techniques to measure insulin resistance (euglycemic, hyperinsulinemic clamp) and visceral/subcutaneous fat (CT). It should be noted that when CT is used to measure visceral and subcutaneous fat depots, the values obtained may not be representative of the total volume of adiposity in these areas because only a limited number of slices can be obtained (in our study between the L4-L5 interspace). The cross-sectional nature of the study did not allow for any inferences regarding whether visceral or subcutaneous fat play a causal role in the development of cardiometabolic risk factors or insulin resistance. Longitudinal studies will be needed in order to shed light on this question.

In conclusion, results of the current study, which utilized a relatively-large sample size and included direct measures of abdominal visceral and subcutaneous fat and insulin resistance, provide evidence that the visceral and subcutaneous depots of the abdominal fat region, independent of percent total body adiposity, appear to have similar associations with many cardiometabolic risk factors and insulin resistance early in life. Relationships of visceral and subcutaneous fat with many of the risk factors were stronger among individuals with levels of these respective fat depots at or above the mean. However, the relationships of these fat depots with triglycerides and insulin resistance existed throughout their entire range of values. These findings suggest that there may be a threshold level of visceral and/or subcutaneous fat that when exceeded, regardless of total body adiposity level, place these youth at increased risk of developing cardiovascular disease and type 2 diabetes later in life compared to those with lower levels of abdominal fat. Perhaps interventions targeting reductions in centrally-located adiposity will have the largest impact on improving cardiometabolic risk factors among obese children and adolescents.

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Reference List

1. Caprio S, Hyman LD, McCarthy S, Lange R, Bronson M, Tamborlane WV. Fat distribution and cardiovascular risk factors in obese adolescent girls: importance of the intraabdominal fat depot. *Am J Clin Nutr.* 1996; 64(1):12–7. [PubMed: 8669407]
2. Gower BA, Nagy TR, Goran MI. Visceral fat, insulin sensitivity, and lipids in prepubertal children. *Diabetes.* 1999; 48(8):1515–21. [PubMed: 10426367]
3. Taksali SE, Caprio S, Dziura J, et al. High visceral and low abdominal subcutaneous fat stores in the obese adolescent: a determinant of an adverse metabolic phenotype. *Diabetes.* 2008; 57(2):367–71. [PubMed: 17977954]
4. Caprio S, Hyman LD, Limb C, et al. Central adiposity and its metabolic correlates in obese adolescent girls. *Am J Physiol.* 1995; 269(1 Pt 1):E118–E126. [PubMed: 7631766]
5. Weiss R, Dufour S, Taksali SE, et al. Prediabetes in obese youth: a syndrome of impaired glucose tolerance, severe insulin resistance, and altered myocellular and abdominal fat partitioning. *Lancet.* 2003; 362(9388):951–7. [PubMed: 14511928]

6. Druet C, Baltakse V, Chevenne D, et al. Independent effect of visceral adipose tissue on metabolic syndrome in obese adolescents. *Horm Res.* 2008; 70(1):22–8. [PubMed: 18493146]
7. Kim JA, Park HS. Association of abdominal fat distribution and cardiometabolic risk factors among obese Korean adolescents. *Diabetes Metab.* 2008; 34(2):126–30. [PubMed: 18289908]
8. Lee S, Kuk JL, Kim Y, Arslanian SA. Measurement site of visceral adipose tissue and prediction of metabolic syndrome in youth. *Pediatr Diabetes.* 2011; 12(3 Pt 2):250–7. [PubMed: 21129140]
9. Syme C, Abrahamowicz M, Leonard GT, et al. Intra-abdominal adiposity and individual components of the metabolic syndrome in adolescence: sex differences and underlying mechanisms. *Arch Pediatr Adolesc Med.* 2008; 162(5):453–61. [PubMed: 18458192]
10. Bacha F, Saad R, Gungor N, Arslanian SA. Adiponectin in youth: relationship to visceral adiposity, insulin sensitivity, and beta-cell function. *Diabetes Care.* 2004; 27(2):547–52. [PubMed: 14747242]
11. Kelly AS, Jacobs DR Jr, Sinaiko AR, Moran A, Steffen LM, Steinberger J. Relation of circulating oxidized LDL to obesity and insulin resistance in children. *Pediatr Diabetes.* 2010; 11(8):552–5. [PubMed: 20102528]
12. Maffei C, Manfredi R, Trombetta M, et al. Insulin sensitivity is correlated with subcutaneous but not visceral body fat in overweight and obese prepubertal children. *J Clin Endocrinol Metab.* 2008; 93(6):2122–8. [PubMed: 18397988]
13. Arsenault BJ, Beaumont EP, Despres JP, Larose E. Mapping body fat distribution: A key step towards the identification of the vulnerable patient? *Ann Med.* 2012; 44(8):758–72. [PubMed: 22149719]
14. Borel AL, Nazare JA, Smith J, et al. Visceral and not subcutaneous abdominal adiposity reduction drives the benefits of a 1-year lifestyle modification program. *Obesity (Silver Spring).* 2012; 20(6):1223–33. [PubMed: 22262155]
15. Sinaiko AR, Jacobs DR Jr, Steinberger J, et al. Insulin resistance syndrome in childhood: associations of the euglycemic insulin clamp and fasting insulin with fatness and other risk factors. *J Pediatr.* 2001; 139(5):700–7. [PubMed: 11713450]
16. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia.* 1985; 28(7):412–9. [PubMed: 3899825]
17. Goran MI, Bergman RN, Gower BA. Influence of total vs. visceral fat on insulin action and secretion in African American and white children. *Obes Res.* 2001; 9(8):423–31. [PubMed: 11500522]

What is already known about this subject

- The relationships of visceral and subcutaneous fat with cardiometabolic risk factors and insulin resistance have been well-described in adults.
- However, the role of visceral and subcutaneous fat in mediating cardiometabolic risk among children and adolescents is incompletely understood, particularly in relation to percent total body adiposity.

What this study adds

- The visceral and the subcutaneous depots of the abdominal fat region, independent of percent total body adiposity, appear to have similar associations with many cardiometabolic risk factors and insulin resistance among youth.
- The relationships of visceral and subcutaneous fat with many of the risk factors was stronger among youth who had levels of these respective fat depots at or above the mean, whereas the relationship of these fat depots with triglycerides and insulin resistance tended to be present throughout their entire range of values.

Table 1

Demographic and Clinical Characteristics of the Study Sample

Variable	All (N=472)	Boys (N=246)	Girls (N=226)
Age (years)	12.3±3.7	12.2±3.7	12.4±3.7
Race/Ethnicity			
Non-Hispanic White	344 (72.9)	182 (74.0)	162 (71.7)
Non-Hispanic Black	81 (17.2)	39 (15.9)	42 (18.6)
Other	47 (10.0)	25 (10.2)	22 (9.7)
Tanner Stage			
I	184 (39.0)	105 (42.7)	79 (35.0)
II	44 (9.3)	31 (12.6)	13 (5.8)
III	42 (8.9)	23 (9.4)	19 (8.4)
IV	73 (15.5)	28 (11.3)	45 (19.9)
V	129 (27.3)	59 (24.0)	70 (31.0)
BMI percentile (%)	62.5±28.5	63.1±29.9	61.8±27.0
Waist percentile (%)	41.8±27.4	43.5±27.6	39.9±27.2
Waist to Height Ratio	0.46±0.06	0.46±0.06	0.46±0.06
Total Body Fat (%)	24.5±10.6	21.0±10.1	28.2±9.7
Visceral Fat (cm ³)	17.4±10.7	17.5±11.9	17.3±9.2
Subcutaneous Fat (cm ³)	66.7±62.3	56.2±58.1	78.5±64.8
Systolic Blood Pressure (mmHg)	104.3±10.7	105.6±10.8	102.8±10.6
Diastolic Blood Pressure (mmHg)	59.5±8.7	59.6±8.8	59.3±8.6
Total Cholesterol (mg/dL)	150.5±26.8	150.1±26.3	151.1±27.4
Non-HDL Cholesterol (mg/dL)	100.8±25.2	100.6±25.2	101.0±25.3
LDL (mg/dL)	86.1±23.3	85.8±22.7	86.4±23.9
HDL (mg/dL)	49.7±11.3	49.5±11.7	50.0±10.8
Triglycerides (mg/dL)	74.7±38.3	73.8±37.0	75.8±39.7
Glucose (mg/dL)	81.2±18.7	83.2±22.6	78.9±12.9
Insulin (mU/L)	8.5±7.5	8.2±7.3	8.9±7.7
HOMA-IR	1.8±1.7	1.7±1.7	1.9±1.8
*M _{Ibm} (mg/kg/min)	13.2±4.6	13.7±4.9	12.7±4.2

Results are presented as mean±standard deviation except for Race/Ethnicity and Tanner Stage, which are presented as number (%)

* 149 subjects (78 boys and 71 girls) did not have M_{Ibm} data

Table 2

Associations of Abdominal Visceral and Subcutaneous Fat with Cardiometabolic Risk Factors and Insulin Resistance

	Visceral fat (cm ³)		Subcutaneous fat (cm ³)	
Variable	Estimate (SE)	P-value	Estimate (SE)	P-value
Systolic Blood Pressure (mmHg)				
<= Mean	0.30 (0.16)	0.0635	0.12 (0.04)	0.0049
> Mean	0.29 (0.06)	<0.0001	0.04 (0.02)	0.0373
Diastolic Blood Pressure (mmHg)				
<= Mean	-0.28 (0.17)	0.1148	-0.09 (0.04)	0.0491
> Mean	0.12 (0.07)	0.0768	0.01 (0.01)	0.5485
Total Cholesterol (mg/dL)				
<= Mean	0.24 (0.48)	0.6132	-0.11 (0.15)	0.5003
> Mean	0.67 (0.17)	0.0001	0.14 (0.05)	0.0027
Non-HDL Cholesterol (mg/dL)				
<= Mean	0.41 (0.43)	0.3450	0.02 (0.17)	0.9227
> Mean	0.89 (0.17)	<0.0001	0.18 (0.05)	0.0002
LDL (mg/dL)				
<= Mean	0.20 (0.41)	0.6315	-0.05 (0.16)	0.7883
> Mean	0.59 (0.16)	0.0003	0.13 (0.04)	0.0024
HDL (mg/dL)				
<= Mean	-0.22 (0.20)	0.2690	-0.11 (0.06)	0.0328
> Mean	-0.23 (0.07)	0.0015	-0.04 (0.03)	0.1558
Triglycerides (mg/dL)				
Slope	1.64 (0.42)	0.0015	0.25 (0.08)	0.0032
Glucose (mg/dL)				
<= Mean	1.21 (0.77)	0.1260	0.17 (0.06)	0.0285
> Mean	0.04 (0.08)	0.5920	0.02 (0.02)	0.2633
Insulin (mU/L)				
Slope	0.30 (0.08)	0.0017	0.07 (0.01)	0.0003
HOMA-IR				
<= Mean	0.05 (0.02)	0.0181	0.02 (0.01)	0.0003
> Mean	0.07 (0.02)	0.0002	0.02 (0.00)	<0.0001
M_{ibm} (mg/kg/min)				
Slope	-0.11 (0.03)	0.0034	-0.03 (0.01)	0.0027

mean and > mean indicate relation to mean of visceral and subcutaneous fat

Only the slope is shown for triglycerides, insulin, and M_{ibm} since the relationships were linear

Results are presented as estimate (SE); p-value