Relationship between fat distribution and cardiometabolic risk in Hispanic girls

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Abstract

Objective*:* In adults, certain body fat depots have greater impact on cardiometabolic risk than total adiposity. Whether similar relationships exist in children is uncertain. The aim of this study was to examine the relationships among dual x-ray absorptiometry (DXA) measures of body fat distribution and total body adiposity with cardiometabolic risk factors in Hispanic girls.

Methods: Measures of total body percent fat, percent of total fat within the android, gynoid, leg, and trunk regions, and cardiometabolic biomarkers (insulin, glucose, homeostatic model assessment of insulin resistance (HOMA-IR), triglycerides (TG), low and high lipoprotein cholesterol (LDL-C, HDL-C)) were obtained from 232 Hispanic girls (age 10.7 ± 1.1 years). Regression models for each metabolic parameter were run against adiposity measures. Partial correlations of the adiposity measures were used to compare associations between adiposity measures and the cardiometabolic risk factors, controlling for somatic maturation.

Results*:* Total and regional adiposity were significantly related with cardiometabolic risk factors ($p<0.05$) except fasting glucose. The partial correlations of total and regional adiposity measures with each cardiometabolic biomarker were similar; more variance was explained for insulin and the HOMA-IR (33-43%) than other risk factors. Partial correlations for the percent of total fat in the gynoid and leg regions with insulin, HOMA-IR, TG, and LDL-C were negative, and positive with HDL-C.

Conclusion: Measures of total and regional fat perform similarly in predicting cardiometabolic risk in Hispanic girls. A higher proportion of fat distributed in the gynoid or leg is associated with lower cardiometabolic risk.

Keywords: cardiovascular disease; body composition; children; obesity, Hispanic

Introduction

Being overweight or obese as an adult is associated with 4-12 (females) and 2-7 (males) fold greater risk for the development of insulin resistance and type 2 diabetes and a 2-3 fold (females) and 1-2 fold (males) greater risk for developing cardiovascular disease (Guh et al., 2009). In adults, it is clear not all fat is created equal. Depending on location, fat depots differ in their metabolic properties and hence their contribution to metabolic disease risk (Bastien, Poirier, Lemieux, & Despres, 2014). Fat within the abdominal region, in adults, is more strongly related with metabolic complications than total excess body fat (Despres & Lemieux, 2006). In contrast, adipose tissue located at peripheral sites, such as the thigh and legs, appears to be protective against metabolic syndrome (Park et al., 2014). Moreover, in adults, subcutaneous fat appears to be less metabolically deleterious than fat distributed within visceral depots or within muscle (Bastien et al., 2014). The relationships among various fat depots and cardiometabolic risk in children is less clear.

During childhood, and in particular, during puberty, major changes in fat distribution occur (Katzmarzyk et al., 2012; Staiano & Katzmarzyk, 2012). Previous studies have proposed that an android distribution of body fat is the strongest indicator of disease risk in children (Aucouturier, Meyer, Thivel, Taillardat, & Duche, 2009; Samsell, Regier,

Walton, & Cottrell, 2014), whereas other studies indicate that both total body fat and regional fat measures predict metabolic markers to a similar degree (Aristizabal, Barona, Hoyos, Ruiz, & Marin, 2015; Cruz, Bergman, & Goran, 2002; Tershakovec et al., 2003). Inconsistent findings could be due to multiple factors such as the fat depot studied, the metabolic biomarkers assessed, variation in total body fat, and the ethnicity of the population being studied. It has been suggested that the amount and location of fat depots may have differential relationships with different risk factors (Park et al., 2014; Sanchez-Lopez et al., 2013). For example, Samouda et al. found that visceral adipose tissue had significant positive correlations with triglycerides (TG) and high density lipoprotein cholesterol (HDL-C), whereas leg fat mass did not have a significant correlation with TG, but had a significant positive correlation with HDL-C in overweight and obese children (Samouda et al., 2016). This suggests that different fat depots affect certain metabolic measures differently. In addition, the relationships among various regional adiposity measures and metabolic markers may be affected by the degree of total adiposity (Ball & McCargar, 2003; Caprio et al., 1996). For example, Caprio et al. found that visceral adipose tissue was only related to cardiovascular risk factors in obese adolescent girls but not in non-obese girls (Caprio et al., 1996). Some studies also suggest that the total amount and distribution of fat may contribute to cardiometabolic outcomes differently depending on a child's ethnicity and/or race (Casazza, Dulin-Keita, Gower, & Fernandez, 2009). Available epidemiological data show that Hispanic children have a higher prevalence of obesity and a greater proportion of abdominal fat compared to similarly aged Caucasian and African American children (Cornier et al., 2011; Samara, Ventura, Alfadda, & Goran, 2012). Few studies have addressed the relationships among body fat

patterning and total body fat with risk factors in Hispanic youth. Thus, the aim of this study was to examine the relationships among DXA measures of fat distribution and total body adiposity with cardiometabolic risk factors in a sample of 9-12 year old Hispanic girls.

Methods

Study population

This study included two hundred and thirty-nine 9-to-12 year-old Hispanic girls who had participated in the "Soft Tissue and Bone Development in Young Girls (STAR)" study, which has previously been described (Hetherington-Rauth et al., 2017). In brief, the STAR study was designed to assess the effect of soft tissue composition and cardiometaboolic risk factors on bone development of 9-to-12 year-old girls who were recruited from local schools, pediatric clinics, and wellness community events in Tucson, Arizona. The study protocol was approved by the University of Arizona Human Subjects Protection Committee and all participants and their parents or legal guardians provided written informed consent.

Anthropometric measures

Anthropometric measures including body mass and standing and sitting height were obtained according to standardized protocols (Lohman TG, 1988) and have previously been published (Hetherington-Rauth et al., 2017). BMI was calculated as weight (kg) divided by height (m) squared. BMI percentiles specific for age and gender, based on

CDC growth charts, were used to categorize girls as either underweight (<5th percentile), normal weight (≥5th and <85th percentiles), overweight (≥85th and <95th percentiles), or obese (≥95th percentile) (Barlow & Expert, 2007).

DXA adiposity measures

Total-body fat mass, percent fat, and regional fat masses were obtained from dual energy x-ray absorptiometry (DXA) using GE/Lunar Radiation Corp (Madison, WI) Prodigy with software version 13.60.033 (n=221) and iDXA software version 16.20.059 (n=26) following standard subject positioning and data acquisition protocols. Regions of interest included the legs, trunk, android, and gynoid regions. The legs region includes all soft tissue below the iliac crest, excluding the pelvic triangle and extending laterally to borders that separate the hands and forearms from the legs. The trunk region ranges vertically from immediately below the chin to its lower borders that are angled and fall perpendicular to the femoral necks. Its lateral borders pass through the glenohumeral joint and include the torso but not the arms. The android region is the area extending vertically from the iliac crests to 20% of the distance between the iliac crests and the neck, and laterally to include all of the torso. The gynoid region's upper and lower borders are located below the iliac crests at 1.5 and 3.5 times the height of the android region, respectively, and its lateral borders are positioned at the outer border of the leg region.

Bone and soft tissue within-subject variation in our laboratory has been previously reported (Bea et al., 2010; Going et al., 2003). Calibration of the DXA machine was done

daily according to manufacturer guidelines. One certified technician performed all DXA scan analyses.

Metabolic measures

Details regarding the collection and analysis of metabolic measures have been described previously (Hetherington-Rauth et al., 2017). Metabolic measures assessed included, serum fasting glucose, total triglycerides (TG), high density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C), and insulin. Intra- and inter-assay variability, respectively, were 0.54% and 3.22% for glucose, 0.48% and 2.85% for TG, 1.25% and 4.12% for HDL-C, 0.46% and 5.61% for LDL-C, and 2.9% and 7.5% for insulin. The homeostatic model assessment of insulin resistance (HOMA- IR) was used as a surrogate measure of insulin resistance and was calculated as follows: HOMA-IR=(insulin [μU/ L]×glucose [mM/L])/22.5.(Matthews et al., 1985) Triglyceride-to-HDL-ratio was calculated as TG (mg/dL)/HDL (mg/dL). Previous research has suggested that TG/HDL ratio to be more strongly related to the hyperinsulinemic-euglycemic clamp, the gold standard for measuring insulin resistance, than HOMA-IR (Giannini et al., 2011).

Covariates

Maturity offset, an estimate of years from peak height velocity (PHV), was estimated from age and anthropometric measures (height, weight, sitting height, and leg length) using the Mirwald equation (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002). After PHV is reached maturity offset is positive while a negative maturity offset represents

years before PHV. Maturation status was also measured using a self-reported questionnaire where girls self-reported menarcheal status and rated their breast and pubic hair development based on pictures illustrating the Tanner stages of pubertal maturation (Marshall & Tanner, 1969). Physical activity was assessed using Actigraph GT3X+ (Pensacola, FL) accelerometers, initialized at a 30hz frequency. All girls were instructed to wear the accelerometer on their hip for seven consecutive days. Data were saved in 60-second epochs with the "low frequency extension" option selected. Daily moderate-to-vigorous physical activity was estimated using algorithms and cut-points developed by Evenson et al. (Evenson, Catellier, Gill, Ondrak, & McMurray, 2008).

Statistical Analysis

Of the 239 Hispanic girls recruited, data from 232 girls were used in the analysis since 5 girls had missing metabolic measures and 2 girls had missing DXA measures.

The sample was described using measures of central tendency (mean) and variability (standard deviation) for normally distributed measures and as median (25th and 75th percentiles) for skewed variables. The relationships among total body fat and regional body fat measures were estimated using Pearson's correlation coefficient. All correlations were adjusted using a Bonferroni-corrected p-value. All DXA regional adiposity measures were expressed as a percent of total body fat ((regional fat mass/total body fat mass) *100).

Multiple linear regression models were used to assess the relationships between cardiometabolic risk factors and each DXA measure of adiposity while adjusting for maturation and other covariates. The adjusted R^2 and partial correlations of the adiposity measure in each model were used to compare the degree of association between the body fat measures and each of the metabolic risk factors. Further adjustment of DXA measures of regional fat distribution by total body percent fat were performed in order to determine if regional fat measures were independently related to risk factors after accounting for total fat. All models were checked for linearity, normality, and homoscedasticity and all metabolic outcome variables were logarithmic transformed in order to meet these linear regression assumptions with the exception of fasting glucose, which had a normal distribution. The variance inflation factor (VIF) was used to assess the presence of multi-collinearity in regression models. All models had a VIF of < 3 indicating low concern for collinearity (Kutner, Nachtsheim, Neter, & Li, 2005). In addition to adjusting all models for maturity offset, a measure of somatic maturation, adjustment for sexual maturation assessed by Tanner staging and other potential confounding factors such as physical activity measured objectively by accelerometery or a physical activity questionnaire did not substantially alter partial correlations between adiposity measures and metabolic risk factors (<0.05 change in r), nor did it alter the variance explained by the models (<0.05 change in adjusted R^2) (data not shown). Thus, they were not included in the final models.

A p-value of <0.05 was considered statistically significant. All analyses were performed using STATA version 13.1.

Results

Participant characteristics are given in Table 1. The girls averaged 11 years of age and were less than 1 year after attainment of peak height velocity. The majority of girls were in Tanner breast stage 2 (n=84) and 3 (n=79) and in Tanner pubic hair stage 1 (n=136). Eighty percent of the girls were pre-menarcheal. Based on age and sex specific percentiles of body mass index (BMI, kg/m^2) 2% of girls were underweight, 56% were normal weight, 18% were overweight, and 25% were obese (Kuczmarski et al., 2000). Using age and gender specific body fat percentiles developed for U.S. children and adolescents (Laurson, Eisenmann, & Welk, 2011), 42% of girls were categorized as normal with the majority (58%) categorized as having excess fat and 36% exceeding the 95^{th} percentile within this category. More fat was distributed within the gynoid region than the android region (19% vs. 7%, respectively). The percent of total body fat distributed within the trunk region was slightly higher than that of the leg (47% vs. 41% respectively). Total body fat mass and percent fat were significantly correlated with regional fat measures ($p<0.00001$). When leg, trunk, android, and gynoid fat were expressed as a percent of total body fat, trunk and android percent fat were positively correlated with total body fat (mass and percent), while leg and gynoid percent fat were negatively correlated to total body fat (mass and percent).

The metabolic parameters are given in Table 1. The mean of glucose and median of HDL-C and LDL-C fell within the normal ranges recommended by the American

Academy of Pediatrics (Expert Panel on Integrated Guidelines for Cardiovascular Health Risk Reduction in Children and Adolescents; National Heart Lung and Blood Institute, 2011). The median TG was near normal (Expert Panel on Integrated Guidelines for Cardiovascular Health Risk Reduction in Children and Adolescents; National Heart Lung and Blood Institute, 2011). There are currently no standard accepted cut-offs for insulin and HOMA-IR in children or adults due to the lack of standardization of insulin assays, which is needed for determining cut-points (Hannon, Bacha, Lee, Janosky, & Arslanian, 2006).

[Table 1 here]

Results of linear regression between each adiposity measure with the cardiometabolic risk factors are presented in Table 2. Overall, after adjusting for maturation, the magnitudes of the partial correlations of total body percent fat and the percent of total fat within the android, gynoid, trunk, and leg regions with a given cardiometabolic risk factor were similar (Table 2). Both total body and regional measures of adiposity were significantly related to each risk factor (Table 2) with the exception of glucose, which was not significantly related to regional adiposity measures. Adjusted R^2s from regression of total body percent fat and regional fat separately with the cardiometabolic indices were also similar and explained 33-43% of the variance in fasting insulin and HOMA-IR, 19-21% in TG/HDL ratio, 14-17% in TG, and 11-17% in HDL-C. All body fat measures were weakly related to LDL-C and fasting glucose, explaining only 1-6% and 5-6% of their variance, respectively (Table 2). After adjustment for total body percent fat, the percent of android, trunk, and leg fat remained significant predictors of fasting insulin, HOMA-IR, TG/HDL, TG, and HDL-C, while percent gynoid remained a

significant predictor of fasting insulin and HOMA-IR (Table 3). However the partial correlation of total body percent fat with fasting insulin and HOMA-IR, was substantially larger than the partial correlations of the regional measures (Table 3). None of the regional measures were significantly related to LDL-C and glucose after controlling for total body percent fat (Table 3). Whether or not there was adjustment for total body percent fat, percent gynoid and percent leg fat had negative partial correlations with HOMA-IR, fasting insulin, TG, TG/HDL, and LDL-C, and a positive partial correlation with HDL-C. All other adiposity measures were positively correlated with each risk factor except for HDL-C, with which they exhibited negative partial correlations.

[Table 2 here]

[Table 3 here]

Discussion

The aim of this study was to examine the relationships among direct (DXA) measurements of total body fat and regional fat patterning with cardiometabolic risk factors in 9-to-12 year-old Hispanic girls. Our results showed that total fat and measures of the regional distribution of total fat by themselves relate significantly and similarly to risk factors, explaining the most variance in insulin resistance. Even when adjusted for total body percent fat, regional fat distribution measures remained significant predictors of insulin resistance. Thus, these results suggest that in young Hispanic girls both total body percent fat and regional fat distribution are important for assessing cardiometabolic risk, especially when it comes to insulin resistance, which has been proposed to be the underlying mechanism driving other cardiometabolic risk factors such as high triglyceride and cholesterol levels (Ginsberg, 2000).

Similar to our findings Samsell et al. found that both total body percent fat and regional fat distribution, expressed as the ratio of android fat to gynoid fat, were significantly related to HOMA-IR, TG, and HDL-C in a sample of 7-13 year old U.S. children (Samsell et al., 2014). Both total body percent fat and the android-to-gynoid ratio explained more variance in HOMA-IR than the other risk factors (Samsell et al., 2014). He et al. also reported that when combined together in the same regression model, DXA measured total fat mass (kg) and trunk fat mass (kg) were significantly associated with insulin in young Chinese children (He et al., 2007). We did not assess the relationships of total body fat mass (kg) and measures of regional fat mass (kg) with metabolic risk factors. Rather, we expressed all regional fat measures as a percent of total fat because we were interested in how various depots, represented as a proportion of total body fat mass, were related to risk. As total body fat mass increases, the increase in fatness at different regions occurs at different rates such that a higher percentage of fat gets deposited centrally and less peripherally (Goulding, Taylor, Gold, & Lewis-Barned, 1996; Wells et al., 2006). Assessing relative regional fat distribution in relation to total body fat can help tease out the independent effect of regional fat on metabolic risk from its linear relationship with total fat mass. For example, Wiklund et al. found that both DXA measured abdominal and gynoid fat mass (g) had a positive relationship with the cardiovascular variables studied in adult men and women (Wiklund et al., 2008). However, when expressed as a percent of total body fat, gynoid percent fat had a negative relationship with the risk factors. Staiano et al. also reported a decreased likelihood of metabolic risk factors in White and African American children and adolescents with

higher leg fat and lower trunk fat relative to total body fat (Staiano, Gupta, & Katzmarzyk, 2014). In agreement with these findings, both gynoid and leg percent fat had negative relationships with the adverse risk factors of insulin, glucose, HOMA-IR, TG, and LDL-C and a positive relationship with the protective factor HDL-C in our sample of Hispanic girls, whereas the percent of android and trunk fat had the opposite relationships with the aforementioned metabolic factors. Hence, having a greater percentage of total body fat distributed in the lower body compared to upper is associated with less cardiometabolic risk.

Physiological and molecular studies have shown that visceral fat is more insulin resistant, is more susceptible to catecholamine stimulated lipolysis due to its higher expression of beta-adrenoceptors, has greater lypolytic activity resulting in higher circulation of free fatty acids, and has a higher secretion of pro-inflammatory cytokines than lower body gynoid fat (Despres, 2012; Manolopoulos, Karpe, & Frayn, 2010). Gynoid fat and fat distributed in the leg region are thought to have more effective storage of free fatty acids and to secrete more beneficial adipocytokines that are anti-inflammatory in nature contributing to its protective effect (Manolopoulos et al., 2010). In our sample, girls with higher levels of total body fat had a higher percent of android and trunk fat and lower percent of gynoid and leg fat than girls with lower levels of total body fat. Although our data are cross-sectional, this suggests that as girls gain fat, it is gained preferentially on the trunk. This could indicate that the increased cardiovascular risk in overweight and obese girls is due to the proportionally higher levels of abdominal fat relative to gynoid fat. Similar findings have been reported by Park et al. in adults with and without

metabolic syndrome (Park et al., 2014). Those with metabolic syndrome had a higher percent of android fat and lower percent of leg fat (Park et al., 2014). On the contrary, Aucouturier et al. found that percent leg fat had a positive correlation with risk factors (Aucouturier et al., 2009). However, they did not indicate whether the percent leg fat was calculated using total fat mass or total leg mass as the denominator, which could affect the interpretation of results, since leg fat divided by the total mass of the leg represents the proportion of the leg region that is fat (leg % fat) instead of the proportion of total body fat that is distributed in the leg (% leg fat).

Abdominal fat is comprised of more than just visceral fat. In children, the amount of visceral fat can be variable but is less than that found in adults as adipose tissue in prepubertal children is preferentially deposited subcutaneously (Casazza et al., 2009; McCarthy, 2006). Due to this distribution, it has been proposed that for children, unlike in adults, visceral fat is not as physiologically important and does not contribute significantly to metabolic risk (Ali et al., 2014; Semiz, Ozgoren, Sabir, & Semiz, 2008; Teixeira, Sardinha, Going, & Lohman, 2001). Unfortunately, one of the limitations of DXA in children is its inability to differentiate between subcutaneous and visceral fat in its measurement of android or trunk fat (both Prodigy and iDXA have options for visceral adipose tissue estimates only in adults). Hence we were unable to determine if the positive relationship of the percent of total fat distributed in the android and truncal region with metabolic risk was being driven by visceral or subcutaneous fat. A previous study in children has indicated that DXA android percent fat is more strongly correlated with magnetic resonance imaging (MRI) measured subcutaneous adipose tissue

percentage than visceral adipose tissue percentage (Tinggaard et al., 2017). On the other hand, percent trunk fat was more highly correlated and accounted for more variability in visceral fat than subcutaneous fat in female adolescents (Savgan-Gurol et al., 2010).

Overall, this study had several strengths. First, our study had a large sample of Hispanic girls, which has been an understudied and at risk population. The mean total amount and percent of body fat as well as the BMI distribution of girls in our sample were similar to those from national samples of Hispanic girls, supporting generalization of our findings to this population (Borrud et al., 2010; Ogden, Carroll, Kit, & Flegal, 2012). Second, use of DXA for measures of soft tissue composition allowed for a direct quantification of total body regional fat distribution. Our sample fell within a narrow age range and had a wide range of body fat levels, which allowed for assessment of the relationship of adiposity measures with metabolic risk factors to be determined for a range of body fat levels without added confounding effects of gender or a wide age range. We also controlled for maturation and physical activity, which could potentially influence the relationship between total and regional adiposity measures and metabolic risk. Maturation status was determined using maturity offset, which relies on objective anthropometric measurements of linear growth instead of the self-reporting of secondary sex characteristics as used in Tanner staging, which can be misinterpreted by children and adolescents (Faria, Franceschini Sdo, Peluzio Mdo, Sant'Ana, & Priore, 2013). Although somatic maturation is not synonymous with sexual maturation it has been shown that there is a strong association of somatic maturation to pubertal timing (Granados, Gebremariam, & Lee, 2015), and in our sample maturity offset was more strongly related

to metabolic biomarkers than Tanner stage. In spite of these strengths, this study was limited by its cross-sectional nature and therefore we were unable to determine how changes in body fat distributions relate to changes in metabolic risk factors over time as girls progress through puberty and into adulthood. Future research should be focused on assessing how body fat patterning changes from childhood to young adulthood in both healthy and obese individuals as well as how changes in fat patterning over this time affect metabolic factors.

In young pre-teen Hispanic girls, both total body and regional adiposity measures are significantly related to metabolic risk factors, suggesting that overall total percent body fat and its regional distribution are both important influencers of risk. Similar to that of adults, our findings of attenuated cardiometabolic risk when there was a higher proportion of total body fat distributed in the leg and gynoid region as opposed to in the trunk and android region suggests that adipose depots are not homogenous and do not relate to risk in the same way in preadolescent Hispanic girls. These findings can be applied to cardiometabolic risk assessment and aid in the development of future clinical intervention studies aimed at reducing metabolic and cardiovascular disease risk in Hispanic children.

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Author Contributions

MHR, VRL, RMB, and JWB were involved in data collection. Data analysis was performed by MHR and TGL. Data interpretation was done by MHR, TGL, SBG. MHR was primarily responsible for drafting the manuscript, and all authors gave critical feedback and approval prior to submission of the final manuscript.

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Table 1: Participant Characteristics

Characteristic	Median (25th quartile -75th quartile)
Age (years)	10.7 ± 1.1‡
Maturity Offset (years)	0.25 ± 1.2‡
Tanner breast stage	2.5 ± 1.0‡
Tanner pubic hair stage	1.6 ± 0.9‡
Menarche [n(%)]	47 (20.3%)
MVPA (min/d)†	19.1 (11.6-28.1)
Weight (kg)	41.8 (33.6-53.45)
Height (cm)	145.3 ± 9.4‡
BMI Percentile Status [n(%)]	
Underweight (<5th)	4 (1.7%)
Normal (≥5th and <85th)	130 (56.0%)
Overweight (≥85th<95th)	41 (17.7%)
Obese (≥95th)	57 (24.6%)
DXA-derived body composition	
Total fat mass (kg)	14.0 (8.7-21.5)
Total body fat (%)	33.5 ± 9.7‡
Percentiles of Total body fat [n(%)]§	
<85th	98 (42.2%)
≥85th and <95th	51 (22.0%)
≥95th	83 (35.8%)
Android fat (kg)	1.0 (0.5-1.8)
% Android fat	7.3 (6.0-8.3)
Gynoid fat (kg)	2.6 (1.8-3.8)
% Gynoid fat	19.1 (17.3-21.7)
Trunk fat (kg)	6.7 (3.5-10.6)
% Trunk fat	46.5 (42.3-49.6)
Leg fat (kg)	5.4 (3.7-8.0)

% Leg fat	40.6 (37.2-43.9)
Metabolic Measures	
Fasting Glucose (mg/dL)	93.4± 6.9‡
Fasting Glucose ≥ 100 mg/dL [n(%)]¶	37 (16.0%)
TG (mg/dL)	91.0 (70.0-127.5)
TG ≥ 130 mg/dL [n(%)]¶	56 (24.1%)
HDL-C (mg/dL)	50.0 (45.0-57.0)
HDL-C < 40 mg/dL [n(%)]¶	24 (10.3%)
LDL-C (mg/dL)	96.5 (82.0-117.0)
LDL-C ≥ 130 mg/dL [n(%)]¶	27 (11.6%)
Fasting Insulin (μU/mL)	17.8 (13.2-24.5)
HOMA-IR	4.0 (3.0-5.7)
TG-HDL-ratio	1.8 (1.2-2.7)

n=232
†n=217
‡mean ± SD
§Fat percentiles based on body fat percentile curves for US children and adolescents(Laurson et al., 2011)
¶Cutpoints based on recommendations by the American Academy of Pediatrics (Expert Panel on Integrated Guidelines for Cardiovascular Health Risk Reduction in Children and Adolescents; National Heart Lung and Blood Institute, 2011).
Note: % Android fat = (android fat mass (kg)/total fat mass (kg))*100; % Gynoid fat mass = (gynoid fat mass (kg)/total fat mass (kg))*100; % Trunk fat = (trunk fat mass (kg)/total fat mass (kg))*100; % Leg fat = (leg fat mass (kg)/total fat mass (kg))*100; MVPA, moderate-to-vigorous physical activity; HOMA-IR, homeostatic model assessment of insulin resistance; TG, triglycerides; HDL-C, high density lipoprotein cholesterol (mg/dL); LDL-C, low density cholesterol (mg/dL)

Table 2: Linear Regression of DXA Total body and Regional Fat Measures with Metabolic risk factors adjusted for maturation

	Insulin†	HOMA-IR†	TG/HDL†	TG†	HDL-C†	LDL-C†	Glucose
Total % Fat							
Partial correlation	0.54***	0.53***	0.39***	0.32***	-0.37***	0.25**	0.14*
Adjusted R^2	0.43	0.43	0.21	0.16	0.15	0.05	0.06
% Android fat							
Partial correlation	0.48***	0.47***	0.39***	0.33***	-0.36***	0.20*	0.12
Adjusted R^2	0.38	0.38	0.21	0.17	0.15	0.03	0.06
% Gynoid fat							
Partial correlation	-0.52***	-0.51***	-0.37***	-0.32***	0.31***	-0.26***	-0.13
Adjusted R^2	0.41	0.41	0.19	0.16	0.11	0.06	0.06
% Trunk Fat							
Partial correlation	0.42***	0.41***	0.37***	0.29***	-0.38***	0.16*	0.11
Adjusted R^2	0.33	0.33	0.19	0.14	0.17	0.02	0.06
% Leg Fat							
Partial correlation	-0.41***	-0.41***	-0.36***	-0.29***	0.37***	-0.15*	-0.10
Adjusted R^2	0.33	0.33	0.19	0.14	0.16	0.01	0.05

n=232

†log transformed

HOMA-IR, homeostatic model assessment of insulin resistance; TG, triglycerides; HDL-C, high density lipoprotein cholesterol (mg/dL); LDL-C, low density cholesterol (mg/dL); % Android fat = (android fat mass (kg)/total body fat mass (kg))*100; % Gynoid fat mass = (gynoid fat mass (kg)/total body fat mass (kg))*100; % Trunk fat = (trunk fat mass (kg)/total body fat mass (kg))*100; % Leg fat = (leg fat mass (kg)/total body fat mass (kg))*100

***p <0.0001

**p <0.001

*p <0.05

Table 3: Linear Regression of combined DXA Total body fat (%) and Regional Fat Measures with Metabolic risk factors adjusted for maturation

	Insulin†	HOMA-IR†	TG/HDL†	TG†	HDL-C†	LDL-C†	Glucose
% Android fat + Total body fat (%)							
% Android fat							
Partial correlation	0.16*	0.15*	0.17*	0.14*	-0.15*	0.03	0.04
Total body fat (%)							
Partial correlation	0.32***	0.31***	0.17*	0.13*	-0.16*	0.16*	0.07
Adjusted R^2	0.44	0.44	0.23	0.18	0.17	0.05	0.06
% Gynoid fat + Total body fat (%)							
% Gynoid fat							
Partial correlation	-0.15*	-0.14*	-0.09	-0.11	0.003	-0.10	-0.02
Total body fat (%)							
Partial correlation	0.23**	0.23**	0.16*	0.10	-0.21*	0.06	0.06
Adjusted R^2	0.44	0.44	0.21	0.17	0.15	0.06	0.06
% Trunk Fat + Total body fat (%)							
% Trunk fat							
Partial correlation	0.16*	0.16*	0.20*	0.14*	-0.23**	0.02	0.05
Total body fat (%)							
Partial correlation	0.41***	0.40***	0.24**	0.20*	-0.20*	0.20*	0.09
Adjusted R^2	0.44	0.44	0.24	0.18	0.20	0.05	0.06
% Leg Fat + Total body fat (%)							
% Leg fat							
Partial correlation	-0.18*	-0.17*	-0.20*	-0.15*	0.23**	-0.02	-0.03
Total body fat (%)							
Partial correlation	0.42***	0.41***	0.25**	0.21*	-0.21*	0.20*	0.10
Adjusted R^2	0.44	0.44	0.24	0.18	0.19	0.05	0.06

n=232

†log transformed
HOMA-IR, homeostatic model assessment of insulin resistance; TG, triglycerides; HDL-C, high density lipoprotein cholesterol (mg/dL); LDL-C, low density cholesterol (mg/dL); % Android fat = (android fat mass (kg)/total body fat mass (kg))*100; % Gynoid fat mass = (gynoid fat mass (kg)/total body fat mass (kg))*100; % Trunk fat = (trunk fat mass (kg)/total body fat mass (kg))*100; % Leg fat = (leg fat mass (kg)/total body fat mass (kg))*100
***p <0.0001
**p <0.001
*p <0.05