Effect of Android to Gynoid Fat Ratio on Insulin Resistance in Obese Youth

Julien Aucouturier, MSc; Martine Meyer, MD; David Thivel, MSc; Michel Taillardat, MD; Pascale Duché, PhD

Background: Upper body fat distribution is associated with the early development of insulin resistance in obese children and adolescents.

Objective: To determine if an android to gynoid fat ratio is associated with the severity of insulin resistance in obese children and adolescents, whereas peripheral subcutaneous fat may have a protective effect against insulin resistance.

Setting: The pediatric department of University Hospital, Clermont-Ferrand, France.


Participants: Data from 66 obese children and adolescents coming to the hospital for medical consultation were used in this study.

Main Outcome Measures: Subjects were stratified into tertiles of android to gynoid fat ratio determined by dual-energy x-ray absorptiometry. Insulin resistance was assessed by the homeostasis model of insulin resistance (HOMA-IR) index.

Results: There were no differences in weight, body mass index, and body fat percentage between tertiles. Values of HOMA-IR were significantly increased in the 2 higher tertiles (mean [SD], tertile 2, 2.73 [1.41]; tertile 3, 2.89 [1.28]) compared with the lower tertile (tertile 1, 1.67 [1.24]) of android to gynoid fat ratio ($P<.001$). The HOMA-IR value was significantly associated with android to gynoid fat ratio ($r=0.35; P<.01$).

Conclusions: Android fat distribution is associated with an increased insulin resistance in obese children and adolescents. An android to gynoid fat ratio based on dual-energy x-ray absorptiometry measurements is a useful and simple technique to assess distribution of body fat associated with an increased risk of insulin resistance.

Arch Pediatr Adolesc Med. 2009;163(9):826-831

The rising prevalence of childhood obesity represents an early risk factor for the development of metabolic and cardiovascular diseases in adults. Among obese children and adolescents, there is also an increased number of cases of type 2 diabetes mellitus, which was once considered as an adult-onset disease.

Since Vague, it has been well established that the development of insulin resistance and the risk of cardiovascular diseases are associated with excess body fat in abdominal rather than in peripheral fat depots. Imaging techniques, such as magnetic resonance imaging and computed tomography, have enabled differentiation between subcutaneous and visceral fat. The visceral fat area has been shown to be correlated with glucose intolerance independently of total fat mass and subcutaneous abdominal adipose tissue. Conversely, several studies have also shown that peripheral subcutaneous fat may represent a "metabolic sink" for the storage of excess energy. When peripheral fat depots fail to expand to store excess energy intake, fat accumulates by default in liver, pancreas, and skeletal muscles, thereby inducing metabolic alterations leading to type 2 diabetes. Indeed, there is some evidence showing that in individuals of similar waist circumference, those with a high thigh fat accumulation have a lipoprotein-lipid profile associated with lower risks of cardiovascular diseases. In addition, a protective effect of peripheral fat depots may even be expected owing to the secretion of adiponectin, which enhances insulin sensitivity and has antiatherogenic properties. In agreement with results in adults, obese ado-
Adolescents with a high visceral to subcutaneous fat ratio exhibit an impaired glucose tolerance in comparison with those with a low ratio. Moreover, there are several reports in obese children and adolescents showing that ectopic fat storage and hypertriglyceridemic waist are associated with declined insulin sensitivity. Weiss et al have shown that the development of severe peripheral insulin resistance in obese children and adolescents with impaired glucose tolerance was closely associated with intramyocellular and intra-abdominal lipid accumulation. A high intramyocellular lipid deposition has been shown to occur early during childhood and adolescence in association with peripheral insulin resistance. Most studies investigating metabolic alterations in relation with regional fat deposition have focused on subcutaneous abdominal, visceral, or thigh fat depots. Dual-energy x-ray absorptiometry (DXA) measurements have been used in several studies to assess regional body fat distribution in children and the association with cardiovascular risk factors. Moreover, there is a good agreement between magnetic resonance imaging measurements of abdominal adipose tissue and DXA fat measurements. Little attention has been paid to the association between gynoid fat storage and insulin resistance in obese children. In this study, we attempted to determine if the ratio between abdominal, or android fat pattern, and lower limb fat deposition and insulin resistance in obese children. In this study, we attempted to determine if the ratio between abdominal, or android fat pattern, and lower limb fat percentage, or gynoid fat pattern, determined by DXA scan was associated with the severity of insulin resistance assessed by the homeostasis model of insulin resistance (HOMA-IR) index. We hypothesized that children with a high android to gynoid fat ratio would exhibit an increased insulin resistance.

**METHODS**

**SUBJECTS**

Participants in this study were 66 obese children and adolescents (31 girls and 35 boys) and their parents coming to the Department of Pediatrics, University Hospital, Clermont-Ferrand, France, for medical consultation. Parents and children who agreed to take part to the study signed an informed consent. The experimental protocol of this study was approved by the local ethics committee (Comité de Protection des Personnes, Sud Est IV). Children included in this study were higher than the 95th percentile of body mass index (BMI) for age and sex defined by the International Obesity Task Force.

Medical examination and anthropometric measurements were performed for each subject by a pediatrician. Body mass was measured to the nearest 0.05 kg with a digital scale (model 873; Seca Omega, Hamburg, Germany). Height was measured with a standing stadiometer and recorded with a precision of 1 mm. Body mass index was calculated as weight in kilograms divided by height in meters squared. Body mass index and waist circumference Z scores were calculated for age and sex reference values. Waist circumference was measured in a standing position with a nonelastic tape that was applied horizontally midway between the costal arch and the iliac crest. All subjects were free of medication known to affect energy metabolism and none of the subjects had evidence of significant disease, non-insulin-dependent diabetes mellitus, or other endocrine disease.

**BODY COMPOSITION**

Body composition was determined by DXA scan (QDR 4500 x-ray bone densimeter; Hologic, Waltham, Massachusetts) and version 9.10 of total body scans software (Hologic Inc, Bedford, Massachusetts). Children were asked to lie down in a supine position on the DXA table and to stay still until the end of the scanning procedure. They were also instructed to keep their arms separated from their trunk and their legs separated from one another.

Percentage of abdominal fat was determined manually by an experienced experimenter by drawing a rectangular box around the region of interest between vertebral bodies L1 and L4. The upper limit was set with the horizontal line going through the T2/L1 vertebral space and the lowest limit was set with a horizontal line going through the L4/L5 vertebral space. Data were analyzed with Hologic QDR Software for Windows (version 12.6), which integrates whole-body measurement and standard body regions, such as the trunk, arms, and legs, delineated by specific anatomical landmarks. Gynoid fat deposition was assessed by lower limb fat percentage. Android to gynoid fat ratio was determined by using fat percentage in lower limbs and in the abdominal region. To test the hypothesis that an android to gynoid fat ratio is associated with an impairment of insulin sensitivity, study subjects were grouped into tertiles. We used tertiles to ensure a number of subjects in each subgroup sufficient to give meaningful results.

**BLOOD SAMPLES**

Blood samples were drawn between 8 AM and 10 AM in a fasted state from an antecubital vein. Samples were centrifuged (at 4000 g for 10 minutes at 4°C) and plasma was transferred into plastic tubes and kept at –80°C until analysis. The plasma glucose concentration was determined by enzymatic methods (Modular P900; Roche Diagnostics, Meylan, France). Plasma insulin concentration was assayed by a chemiluminescent enzyme immunoassay on an Immulite 2000 (Diagnostic Products Corporation, Los Angeles, California).

Two indexes of insulin resistance were calculated from glucose and insulin concentrations. The HOMA-IR index was calculated as (fasting insulin level x fasting glucose level)/22.519 and quantitative insulin-sensitivity check index, as 1/(log fasting insulin level + log fasting glucose level).

**STATISTICAL ANALYSIS**

Results are expressed as mean (SD). Normality of the distribution was checked with the Kolmogorov-Smirnov test for each variable. Dependent variables were compared between the 3 groups by using a 1-way analysis of variance. Android to gynoid fat ratio and abdominal fat percentage were similar between boys and girls in the 3 groups. Hence, boys and girls were grouped together in each tertile.

Spearman correlation coefficients were used to describe associations between continuous variables. We also used a multiple stepwise regression to explain the variance of HOMA-IR values. Age, waist circumference Z score, BMI, body fat percentage, and the android to gynoid fat ratio were included as independent variables.

All statistical analyses were carried out with Statview software, version 5.0 (Abacus Concepts, Berkeley, California). Statistical significance was set at P < .05.
RESULTS

DESCRIPTIVE STATISTICS OF THE SAMPLE

Descriptive results of the population are presented for boys and girls in Table 1. Body mass, percentage of body fat, and lean body mass were similar in the 3 tertiles. Tertiles were also similar for the number of boys and girls. Because of the study design, the android to gynoid fat ratio was significantly different between the 3 tertiles ($P < .001$ for all comparisons). There were significant differences for percentage of abdominal fat between tertiles 1 and 2 ($P < .001$) and tertiles 1 and 3 ($P < .001$). There was no significant difference for percentage of fat mass in lower limbs between tertiles.

INDEXES OF INSULIN RESISTANCE: FASTING GLUCOSE AND INSULIN CONCENTRATIONS

Mean (SD) HOMA-IR values were significantly higher in tertiles 2 (2.73 [1.41]) and 3 (2.89 [1.28]) than in tertile 1 (1.67 [1.24]) ($P = .009$ and .003, respectively). Mean (SD) quantitative insulin-sensitivity check index values were also significantly higher in tertile 1 (0.37 [0.04]) than in tertiles 2 (0.34 [0.03]) and 3 (0.33 [0.02]) ($P = .005$ and $P = .001$, respectively). Differences were not significant between tertiles 2 and 3. Results are shown in Figure 1 and Figure 2.

Mean (SD) fasting plasma glucose level was not significantly different between tertiles (tertile 1, 85.79 [4.30] mg/dL; tertile 2, 88.79 [6.59] mg/dL; tertile 3, 89.28 [7.50] mg/dL), whereas mean (SD) insulin concentration was significantly higher in tertiles 2 (12.39 [6.12] mU/L) and

---

**Table 1. Descriptive Statistics of the Population**

<table>
<thead>
<tr>
<th>Tertile, Mean (SD)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex, No.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>9</td>
<td>11</td>
<td>11</td>
<td>.07</td>
</tr>
<tr>
<td>F</td>
<td>14</td>
<td>12</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>9.61 (2.70)</td>
<td>11.21 (2.27)</td>
<td>11.11 (2.37)</td>
<td>.07</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>57.00 (29.42)</td>
<td>65.33 (24.43)</td>
<td>61.65 (19.03)</td>
<td>.31</td>
</tr>
<tr>
<td>BMI</td>
<td>24.46 (5.82)</td>
<td>27.94 (5.74)</td>
<td>27.23 (4.94)</td>
<td>.09</td>
</tr>
<tr>
<td>BMI z score</td>
<td>1.91 (0.40)</td>
<td>2.05 (0.38)</td>
<td>1.94 (0.47)</td>
<td>.51</td>
</tr>
<tr>
<td>Body fat, %</td>
<td>36.84 (5.38)</td>
<td>38.75 (6.34)</td>
<td>36.83 (4.48)</td>
<td>.41</td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>78.95 (16.50)</td>
<td>89.23 (17.15)</td>
<td>90.15 (12.73)</td>
<td>.07</td>
</tr>
<tr>
<td>Waist circumference z score</td>
<td>1.94 (0.74)</td>
<td>2.35 (0.57)</td>
<td>2.55 (0.56)</td>
<td>.05</td>
</tr>
<tr>
<td>Abdominal fat, %</td>
<td>30.36 (4.18)</td>
<td>37.24 (6.62)</td>
<td>40.43 (5.11)</td>
<td>.001</td>
</tr>
<tr>
<td>Truncal fat mass, %</td>
<td>32.38 (5.53)</td>
<td>36.22 (5.94)</td>
<td>34.81 (5.27)</td>
<td>.08</td>
</tr>
<tr>
<td>LBM, kg</td>
<td>33.37 (15.24)</td>
<td>37.86 (11.34)</td>
<td>40.81 (14.21)</td>
<td>.21</td>
</tr>
<tr>
<td>Lower limb fat, %</td>
<td>43.82 (6.28)</td>
<td>43.63 (7.79)</td>
<td>40.00 (5.01)</td>
<td>.09</td>
</tr>
<tr>
<td>Android to gynoid fat ratio</td>
<td>0.70 (0.07)</td>
<td>0.86 (0.05)</td>
<td>1.01 (0.04)</td>
<td>.001</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); LBM, lean body mass.

*a* Protected least significant difference Fisher test for comparison between groups: significant difference between tertile 1 and tertile 3, $P < .05$.

*b* Protected least significant difference Fisher test for comparison between groups: significant difference between tertile 1 and tertile 2, $P < .001$; tertile 1 and tertile 3, $P < .001$; and tertile 2 and tertile 3, $P < .05$.

*c* Protected least significant difference Fisher test for comparison between groups: significant difference between tertile 1 and tertile 2, $P < .001$; tertile 1 and tertile 3, $P < .001$; and tertile 2 and tertile 3, $P < .001$.

---

**Figure 1.** Mean (SD) homeostasis model of insulin resistance (HOMA-IR) index values in tertiles of android to gynoid fat ratio. $* P < .001$.

**Figure 2.** Mean (SD) quantitative insulin-sensitivity check index (QUICKI) values in tertiles of android to gynoid fat ratio. $* P < .001$.
relationships between fat distribution variables and insulin sensitivity variables are shown in Table 2. Percentage of abdominal fat correlated positively with HOMA-IR value (\( r = 0.34; P < .01 \)). The android to gynoid fat ratio was also significantly and positively correlated with fasting insulin concentration (\( r = 0.34; P < .01 \)). Waist circumference and waist circumference z score were significantly correlated with HOMA-IR value (\( r = 0.44; P < .001 \) and \( r = 0.33; P < .01 \)). Body mass index was correlated with HOMA-IR value (\( r = 0.45; P < .001 \)) but not BMI z score. Neither body fat percentage nor lower limbs fat percentage were significantly correlated with insulin sensitivity variables or glucose and insulin concentrations. None of the fat distribution variables had significant correlation with fasting glucose concentration.

### MULTIPLE STEPWISE REGRESSION

The multiple stepwise regression showed that age and the android to gynoid fat ratio were significant predictors of HOMA-IR value (\( \beta \) coefficients were 0.26 and 2.28, respectively). Adjusted \( R^2 \) was 0.30. Body mass index, waist circumference z score, and body fat percentage were not significant predictors of HOMA-IR value.

### COMMENT

Our hypothesis was that a preferential fat storage at the abdominal level rather than in the lower limbs would be associated with increased insulin resistance. To this aim, we calculated a simple index of android to gynoid fat distribution as a ratio between percentage of abdominal fat and percentage of lower limbs fat based on DXA measurements. Insulin resistance was estimated by using simple indexes based on fasting plasma glucose and insulin concentrations. Indexes such as HOMA-IR and the quantitative insulin-sensitivity check index calculated from fasting samples have been shown to be valid to assess insulin resistance during puberty when compared with direct measurement with a glucose clamp.\(^1\)\(^2\) The main finding was that insulin resistance was increased in children with central rather peripheral fat depots in groups matched for body mass and percentage of body fat. Furthermore, insulin resistance was associated with abdominal adiposity without distinction between subcutaneous and visceral fat depots. However, although HOMA-IR values increased from the lowest tertile to tertiles 2 and 3, whereas there was no significant difference between tertiles 2 and 3, a linear regression between the android to gynoid fat ratio and HOMA-IR value did not provide a threshold value of android to gynoid fat ratio above which obese children have an increased risk of insulin resistance.

Indeed, in the present study, there was no significant association between percentage of body fat and insulin resistance. Previous studies have shown in young subjects that the degree of obesity is associated with a worsening of all the components of the metabolic syndrome, including insulin resistance.\(^3\) Several points can explain the lack of correlations between percentage of body fat and indexes of insulin resistance in the present study. Despite a similar degree of obesity, a lower prevalence of impaired glucose tolerance and type 2 diabetes have been reported in European than in American children.\(^4\)\(^5\) Indeed, even though impaired fasting glucose concentration may not be sensitive enough to detect impaired glucose tolerance, only 2 children had a fasting glucose concentration higher than 100 mg/dL. Hence, together with a reduced number of subjects with severe obesity in comparison with other studies, only mild alterations of insulin sensitivity may explain the lack of association between percentage of body fat and insulin resistance. The development of abdominal obesity during puberty may be favored by pubertal insulin resistance and its consequent hyperinsulinemia.\(^3\) A limitation of this study is that data analysis was based on age ranging between 6 and 17 years and not on direct assessment of pubertal stages. Logically, age was a significant predictor of insulin resistance. Moreover, the

### Table 2. Correlation Coefficients for Association Between Fat Distribution Variables and Markers of Insulin Resistance

<table>
<thead>
<tr>
<th>Variable</th>
<th>HOMA-IR</th>
<th>QUICKI</th>
<th>Plasma Glucose Level</th>
<th>Plasma Insulin Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdominal fat, %</td>
<td>0.34(^a)</td>
<td>-0.36(^a)</td>
<td>0.12</td>
<td>0.34(^a)</td>
</tr>
<tr>
<td>Lower limb fat, %</td>
<td>0.04</td>
<td>0.01</td>
<td>0.08</td>
<td>0.05</td>
</tr>
<tr>
<td>Android to gynoid fat ratio</td>
<td>0.35(^a)</td>
<td>-0.41(^a)</td>
<td>0.20</td>
<td>0.34(^a)</td>
</tr>
<tr>
<td>BMI</td>
<td>0.45(^b)</td>
<td>0.46(^a)</td>
<td>0.13</td>
<td>0.47(^a)</td>
</tr>
<tr>
<td>BMI z score</td>
<td>0.22</td>
<td>0.22</td>
<td>0.24</td>
<td>0.22</td>
</tr>
<tr>
<td>Waist circumference</td>
<td>0.44(^a)</td>
<td>0.52(^a)</td>
<td>0.06</td>
<td>0.48(^a)</td>
</tr>
<tr>
<td>Waist circumference z score</td>
<td>0.33(^a)</td>
<td>0.45(^a)</td>
<td>0.11</td>
<td>0.35(^a)</td>
</tr>
<tr>
<td>Body fat, %</td>
<td>0.20</td>
<td>-0.19</td>
<td>0.00</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); HOMA-IR, homeostasis model of insulin resistance index; QUICKI, quantitative insulin-sensitivity check index.

\(^a\) \( P < .01 \).

\(^b\) \( P < .05 \).

\(^c\) \( P < .001 \).
effect of puberty was partly controlled by the use of age- and sex-specific BMI and waist circumference growth charts.

Several studies have already used DXA to provide measurements of abdominal fat mass. Measurement by DXA of central adiposity from L1 to L4 has previously been shown to be associated with insulin resistance in adults and to be a valid alternative to other techniques. However, a limitation of the present study is that abdominal fat determined by DXA does not allow the distinction between visceral and subcutaneous abdominal tissues. Bacha et al observed that in 2 groups of obese adolescents with a similar percentage of body fat (42.5 and 44.2) those who had the lowest visceral fat area and the lowest subcutaneous fat area at L4-L5 exhibited only a moderate insulin resistance. On the other hand, Maffeis et al recently showed that visceral adipose tissue area was not associated with insulin sensitivity, but may rather alter insulin sensitivity through its effect on liver fat content, which explained 16% of the variation in insulin sensitivity in obese children. Hence, questions remain about the importance of visceral fat for the development of insulin resistance. Finally, significant correlations between waist circumference or waist circumference z score and HOMA-IR confirm that simple anthropometric measurements are also reliable to assess an association between upper body adiposity and insulin resistance.

We did not observe any association between lower body fat percentage and insulin resistance. This result is similar to previous findings in adults. Although subcutaneous adipose tissue stores approximately 90% of thigh fat, it is other compartments quantitatively minor for fat storage, such as intramuscular triglycerides, that are significantly associated with insulin resistance. In obese children, both intramyocellular and extramyocellular triglycerides stores are associated with central adiposity, suggesting that deposition of fat in these tissues is interdependent. Meanwhile, an important leg fat storage, almost at the subcutaneous level, reflects the ability of this depot to be a metabolic sink for excess energy intake, thereby preventing ectopic accumulation. Together, android to gynoid ratio and age explained 30% of the variance of insulin resistance. Fitness level, which was not assessed in the present study, has important effects on indexes of insulin sensitivity even in obese children and may be a factor that could also explain an important part of variability of insulin resistance in our population.

To conclude, the present study showed that an android rather than gynoid fat distribution was associated with an increased insulin resistance in obese children and adolescents. Hence, an android to gynoid fat ratio based on DXA measurement may be a useful and simple technique to assess a pattern of body fat distribution associated with an increased insulin resistance. This study also confirmed that the severity of insulin resistance is associated with abdominal obesity, which can be assessed by waist circumference measurement, whether fat is located essentially in visceral or subcutaneous adipose tissue in children and adolescents.


Call for Papers

Archives of Pediatrics and Adolescent Medicine will devote their May 2010 issue to papers on the effects of life experiences occurring during the critical window of birth age 5 years on the emotional and psychological health and development—or ill health—of children both during that age and at later ages during childhood and adolescence. Papers submitted by September 30, 2009, have the best chance of acceptance.