Adipose Tissue Distribution and Plasma Lipoprotein Levels in Obese Women

Important of Intra-abdominal Fat

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Prospective studies have shown that excess abdominal fat is associated with an increased risk of coronary heart disease and related death. We used computed axial tomography (CAT) to assess the association between deep and subcutaneous abdominal adipose tissue and plasma lipoprotein levels in a sample of 52 premenopausal obese women aged 35.7±5.5 years (mean±SD). Whereas the plasma lipoprotein concentrations were not significantly correlated with fat mass, the data obtained by CAT indicated that the absolute amount of deep abdominal fat was negatively correlated with high density lipoprotein cholesterol (HDL-CHOL) levels (r=-0.35, p<0.01), as well as with HDL-CHOL/low density lipoprotein (LDL)-CHOL, HDL-apoprotein (apo) A-I/LDL-apo B, and HDL₆-CHOL/HDL₅-CHOL ratios (−0.32≤r≤−0.40, 0.05>p<0.01). Adipose tissue deposition at the mid-thigh region determined by CAT did not show any significant relationship with plasma lipoprotein levels. When subgroups of women with comparable ages and adiposity but with high and low intra-abdominal fat accumulation were compared, women with a high accumulation of intra-abdominal fat displayed significantly lower HDL-CHOL (p<0.001), LDL-CHOL (p<0.001), HDL₆-CHOL (p<0.01), and HDL-apo A-I (p<0.05) levels, as well as reduced HDL-CHOL/LDL-CHOL (p<0.01), HDL-apo A-I/LDL-apo B (p<0.05), and HDL₆-CHOL/HDL₅-CHOL ratios (p<0.05) in comparison with obese women with low accumulations of intra-abdominal fat. These data indicate that, in a sample of obese women, body fat distribution, especially intra-abdominal fat accumulation, is a significant correlate of plasma lipoprotein levels independent of total fatness. (Arteriosclerosis 9:203–210, March/April 1989)

Several studies have shown the importance of adipose tissue distribution, in contrast to obesity, as a significant and independent cardiovascular risk factor.†−5 Indeed, recent longitudinal studies have indicated that excessive fat deposition in the trunk was associated with an increased incidence of coronary heart disease and related death. Subsequent findings have related excess trunk fat to numerous metabolic disturbances, such as glucose intolerance, hyperinsulinemia, diabetes, hypertension, and hyperglycemia.6−13 Changes in plasma lipoprotein levels may also contribute to the cardiovascular disease risk that is associated with adipose tissue distribution, since low high density lipoprotein (HDL) cholesterol levels have been reported in subjects with excess abdominal fat.14−18 These studies have, however, generally used subcutaneous skinfold measurements and the waist-to-hip circumferences ratio (WHR) to estimate the proportion of abdominal fat.

It has been proposed that the intra-abdominal fat component could be of particular importance in the manifestation of metabolic perturbations that are associated with excess abdominal fat,15,16,20 since peripheral fat deposition is not associated with these metabolic disturbances.14,15,16 The only method that is presently available to measure noninvasively the amount of intra-abdominal fat is computed axial tomography (CAT). In a recent report, the amount of intra-abdominal fat measured by CAT was significantly correlated with plasma cholesterol and triglyceride levels in a sample consisting of both men and women.21 Although numerous studies have reported that the proportion of abdominal fat, as estimated by the WHR, was associated with changes in plasma triglyceride and lipoprotein-cholesterol concentrations,7,9,11,12,13,16,17 few studies have measured the potential relation of deep and subcutaneous abdominal fat accumulation to plasma lipoprotein levels. Therefore, further research on the potential associations between deep as well as subcutaneous fat and plasma lipoprotein and apoprotein (apo) levels appeared warranted. The present study reports on the relationships between adipose tissue distribution, including intra-abdominal fat and mid-thigh deposition of adi-

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pose tissue measured by CAT, and plasma lipoprotein levels in a sample of 52 premenopausal obese women. Our results emphasize the importance of intra-abdominal fat and the negligible effect of thigh fat in the association between body fat distribution and plasma lipoproteins.

**Methods**

**Subjects**

Fifty-two premenopausal obese women were recruited by solicitation through the media. All subjects signed an informed consent document approved by the Laval University Medical Ethics Committee. A complete physical examination, which included medical history, was performed by a physician. Women with cardiovascular disease or endocrine disorders or those on medication were excluded. A glucose tolerance test was performed, and diabetic subjects were excluded from the study. All measurements were performed while the subjects were in the follicular phase of their menstrual cycle and in an apparent weight-stable period.

**Computed Axial Tomography**

CAT was performed on a Siemens Somatom DRH scanner (Erlangen, FRG) using the procedures described by Sjöström et al. The scanning was performed with 125 kV and a slice thickness of 8 mm. Briefly, the subjects were examined in the supine position with their arms stretched above their heads. Three CAT scans were performed, and a radiograph of the skeleton was used as a reference to establish the position of the scans at the nearest millimeter: Th8 to Th9, L4 to L5, and mid-thigh. The total and deep fat areas were calculated by delineating these areas with a graph pen and then computing the adipose tissue surfaces with an attenuation range of -30 to -190 HU. The intra-abdominal fat area was measured by drawing a line within the muscle wall surrounding the abdominal cavity. The subcutaneous fat was calculated by subtracting the amount of intra-abdominal fat from the total fat area. The distance between adjacent scans was also measured, and the adipose tissue volume between these scans was calculated. The average of mid-thigh and abdominal scan areas was multiplied by the distance between these two adjacent scans, and the partial adipose tissue volume added up to the volume of adipose tissue calculated from the abdominal scan to the thoracic scan. These two partial volumes were, therefore, considered as two different cylinders. The assumption underlying this procedure is that there is a linear change in adipose tissue area between adjacent scans. In this regard, we observed that in this sample of obese subjects, there is a close correlation (r=0.94, p<0.0001) between the adipose tissue volume obtained by computed tomography and the body fat mass derived from hydrostatic weighing.

**Measurement of Body Fatness**

Body density was measured by the hydrostatic weighing technique as previously described. The mean of six valid measurements was used in the calculation of percent body fat from body density using the equation of Siri. Fat mass was obtained by multiplying the percent of body fat by body weight. Pulmonary residual volume was measured using the helium dilution method of Meneely and Kaltreider.

Waist and hip circumferences were measured by the procedures of the Airlie Conference. The circumference measurements were performed while the women were wearing light underwear. The women stood erect with the abdomen relaxed. An inelastic tape was placed around each woman in a horizontal plane at the level of the natural waist, that is, the narrowest part of the torso. When this location was not easily found, the smallest horizontal circumference between the ribs and the iliac crest was measured to the nearest 0.1 cm. For the measurement of hip circumference, the measurement was performed at the side of the subject so that the level of maximum extension of the buttocks could be seen. An inelastic tape was placed around the buttocks in a horizontal plane. The maximum circumference at this level was measured to the nearest 0.1 cm.

**Concomitant Lifestyle and Biologic Variables**

Because of their potential association with plasma lipoprotein-cholesterol and apoprotein values, the effects of several concomitant variables: age; maximal oxygen consumption; daily energy intake; percentage of intake from proteins, lipids, and carbohydrates; and alcohol consumption were studied. There were too few smokers in the sample to study the effect of smoking.

Maximal oxygen consumption (Vo2 max) was assessed on a progressive test to exhaustion on a treadmill. Vo2 was recorded with an open gas circuit system, and Vo2 max was considered to be the highest Vo2 recorded during the test for 1 minute. Mean daily energy intake was determined with a 3-day diet record including one weekend day as previously described. The tables of Dubuc and LaHaie were used to determine energy intake and percentage of energy derived from proteins, lipids, and carbohydrates. Alcohol consumption was reported in the 3-day dietary record and was calculated in grams of alcohol per day.

**Plasma Lipoprotein and Apoprotein Analyses**

Blood samples were collected from an antecubital vein into Vacutainer tubes (Becton Dickinson Labware) containing EDTA. Samples were taken in the morning after a 12-hour fast while the subjects were in a supine position. Blood sampling was done in the early follicular phase. Cholesterol (CHOL) and triglyceride (TG) levels were determined in plasma and lipoprotein fractions after extraction with isopropanol and treatment with zetelute according to the Technicon AA-II procedure. Plasma very low density lipoproteins (VLDL, d<1.006 g/ml) were isolated by ultracentrifugation, and the HDL fraction was obtained after precipitation of low density lipoprotein (LDL) in the infranatant (d>1.006 g/ml) with heparin and MnCl2. The CHOL and TG contents of the infranatant fraction were measured before and after the precipitation step. Apo B concentration was measured in plasma and in the infranatant (LDL-apo B) by the rocket immuno-electrophoretic method of Laurell as previously described. Apo A-I concentration was also measured in the infranatant frac-
Table 1. Physical Characteristics and Plasma Lipid Levels in Obese Women Compared with Nonobese Women

| Variable          | Obese       | Controls  |
|-------------------|-------------|-----------|
| BMI (kg/m²)       | 34.2±4.9    | 21.0±1.6† |
| Body fat (%)      | 45.9±5.5    | 28.0±5.6‡ |
| Fat mass (kg)     | 41.0±10.4   | 15.5±3.7† |
| Plasma CHOL       | 208.7±37.0  | 177.5±33.9* |
| Plasma TG         | 161.3±110.3 | 70.2±30.8† |
| Plasma HDL-CHOL   | 43.6±9.2    | 52.8±9.4* |

Values are means±SD.
BMI=body mass index, CHOL=cholesterol, TG=triglyceride.
* p<0.001, † p<0.0001.

These lyophilized serum standards for apolipoprotein measurements were prepared in our laboratory and calibrated with reference standards obtained from the Centers for Disease Control, Atlanta, Georgia. The concentrations of LDL-CHOL, LDL-TG, and VLDL-apo B were determined by difference. The cholesterol content of HDL₂ and HDL₃ subfractions prepared by precipitation method was also determined.

**Statistical Analyses**

Relationships between variables were measured by Pearson's product-moment correlation coefficients. The associations between adipose tissue distribution and plasma lipoprotein levels were further studied by comparing two subgroups of ten subjects each with the highest and the lowest WHR values. Differences between these two subgroups were tested for statistical significance using Student's t test. Data on the plasma TG, as well as VLDL components, were log-transformed to normalize their distribution. Multivariate analyses were also performed to test the variance in lipoprotein-cholesterol and apoprotein levels that could be explained by the body fatness, body fat distribution, and concomitant variables. Only variables that displayed significant univariate correlations with the dependent lipoprotein variables were included in the stepwise multiple regression procedure in which all possible permutations of relevant independent variables were tested. The Statistical Analysis System was used to perform these analyses.

**Results**

The physical characteristics and the plasma lipid and HDL-CHOL levels of obese women are presented in Table 1. Their values are compared with those of a sample of 25 nonobese women who were studied for other research purposes but for whom we had adiposity, plasma lipid, and HDL-CHOL measurements taken by the same methods as for the obese women. In addition to having higher adiposity than nonobese women, obese women had significantly higher plasma CHOL and TG, and lower HDL-CHOL levels (p<0.001). The body mass index (BMI) of obese women ranged from 25.6 to 46.5 kg/m², and their body density measurements confirmed that these subjects ranged from modestly (32.1% fat) to massively (58.3% fat) obese.

The correlation coefficients between BMI, fat mass, and WHR and plasma lipoprotein levels in obese women are presented in Table 2. Whereas total adiposity was weakly correlated with the plasma lipoprotein profile, WHR was positively correlated with VLDL-CHOL and VLDL-TG (p<0.001) levels. WHR was also significantly negatively correlated with plasma HDL-CHOL, LDL₂-CHOL, LDL₃-CHOL, and HDL-apo A-I levels. Various lipoprotein ratios were calculated to estimate the coronary heart disease risk associated with total adiposity and fat distribution. Total fat mass was not correlated with any of these ratios, whereas BMI was negatively correlated with the HDL₃-CHOL/LDL₃-CHOL ratio (p<0.05). However, the proportion of abdominal fat, as measured by WHR, was negatively correlated with lipoprotein indices of coronary heart disease (HDL-CHOL/LDL-CHOL, and HDL-apo A-I/LDL-apo B). In addition, WHR was negatively correlated with the HDL-CHOL/HDL-TG ratio (r=-0.45, p<0.001), suggesting an enrichment of the HDL particle with TG in subjects with excess abdominal fat. Such enrichment was not observed in the LDL fraction (results not shown).

There was, however, a positive correlation between WHR and the ratio of LDL-apo B/LDL-CHOL (r=0.35, p<0.05) indicating apoprotein enrichment of LDL particles.

The absolute and relative amounts of intra-abdominal fat measured by CAT were significantly correlated with WHR (r=0.50 and 0.46, respectively, p<0.001). The amount of subcutaneous abdominal fat measured at the L4 to L5 region was not correlated with plasma lipoprotein levels (Table 3). The amount of deep abdominal fat, however, was negatively correlated with plasma HDL-CHOL levels (r=-0.35, p<0.01). Deep abdominal fat
displayed a higher negative correlation with HDL₂-CHOL (r = -0.37, p < 0.01) than with HDL₁-CHOL (r = -0.27, 0.06 > p > 0.05). In concordance with such observations, deep abdominal fat was negatively correlated with the HDL₂-CHOL/HDL₃-CHOL ratio (r = -0.32, p < 0.05). The relative amount of deep abdominal fat (deep/total) was not significantly correlated with plasma lipoprotein levels. The adipose tissue volume measured from the Th8 to Th9 region to the mid-thigh region showed significant negative correlations with plasma HDL₁-CHOL, HDL₂-CHOL, and HDL₃-CHOL levels. Table 3 also indicates that the absolute amount of deep abdominal fat was negatively correlated with HDL₁-CHOL/HDL₃-CHOL (r = -0.40, p < 0.01); HDL₃-CHOL (r = -0.31, p < 0.01); and HDL₂-CHOL/HDL₃-CHOL ratios.

The associations between adipose tissue areas measured at the Th8 to Th9 and mid-thigh regions and plasma lipoproteins were also studied (results not shown). Plasma HDL₁-CHOL levels were negatively correlated with total fat (r = -0.38, p < 0.01); subcutaneous fat (r = -0.36, p < 0.01); and deep fat (r = -0.31, p < 0.05) areas at the Th8 to Th9 level. None of the lipoprotein values were, however, significantly associated with mid-thigh fat deposition (results not shown). Thus, these results indicate that mid-thigh adipose tissue deposition is not correlated with plasma lipoproteins, whereas the amount of deep fat measured at the L4 to L5 scan was the CAT-derived measurement that displayed the highest association with plasma lipoprotein levels.

To further study the associations between fat distribution and plasma lipoprotein levels, subgroups of obese women with the highest and lowest WHR were compared (Table 4). No differences in age and in percent body fat were observed between the two subgroups. Women with higher WHR values did not show higher levels of subcutaneous abdominal adipose tissue than did subjects with low WHR, but they had significantly more deep adipose

| Variable | Low WHR | High WHR |
|----------|---------|----------|
| Age (yrs) | 36.0±4.0 | 36.1±2.8 |
| Body fat (%) | 47.0±6.4 | 49.8±3.2 |
| WHR | 0.74±0.04 | 0.89±0.02 |
| L₄ to L₅ total (cm²) | 658.6±110.0 | 620.0±153.6 |
| L₄ to L₅ subc (cm²) | 551.8±94.7 | 513.5±141.0 |
| L₄ to L₅ deep (cm³) | 107.0±33.4 | 186.7±36.9 |
| L₄ to L₅ total (cm³) | 1.29±0.13 | 1.53±0.19 |
| Mid-thigh total (cm³) | 517.5±93.4 | 527.9±94.9 |

**Table 4. Adiposity and Computed Tomography-derived Measurements of Adipose Tissue Distribution in Obese Subjects with Lowest and Highest Values of Waist-to-Hip Circumference Ratio**

There were 10 women in each group.

WHR = waist-to-hip ratio. L₄ to L₅ = abdominal scan, Subc = subcutaneous.

Values are means ± SD. p<0.05, p<0.01, p<0.001.
Table 5. Plasma Lipid and Lipoprotein Concentrations in Obese Women with High and Low Waist-to-Hip Circumference Ratios

| Plasma variables       | Low WHR | High WHR |
|------------------------|---------|----------|
| VLDL-CHOL              | 14.5±9.2| 34.0±37.2* |
| VLDL-TG                | 82.8±62.4| 176.2±205.5 |
| VLDL-apo B             | 11.2±5.8 | 15.0±17.5 |
| LDL-COL                | 137.7±35.8 | 147.5±42.6 |
| LDL-TG                 | 29.3±9.9 | 33.1±12.5 |
| LDL-apo B              | 77.8±21.8 | 90.9±24.7 |
| HDL-COL                | 48.2±7.9 | 37.3±4.8* |
| HDL-TG                 | 18.0±9.1 | 18.7±5.6 |
| HDL-apo A-I            | 128.5±24.1| 105.6±15.0* |
| HDL-COL                | 19.8±4.0 | 13.8±2.5* |
| HDL-TG                 | 26.5±3.9 | 23.6±3.0† |
| HDL-COL/LDL-COL        | 0.37±0.09 | 0.27±0.07* |
| HDL-apo A-I/LDL-apo B  | 1.71±0.47 | 1.22±0.29* |
| HDL-COL/HDL-TG         | 0.69±0.12 | 0.59±0.09* |

Values are the means±SD in mg/dl. There were 10 women in each group.

Discussion

Although recent prospective studies have shown that body fat distribution is significantly associated with cardiovascular disease,1-5, the mechanisms for this association remain to be discovered. Since the early works of Vague,6 numerous reports have shown that adipose tissue topography is associated with cardiovascular risk factors such as glucose intolerance, insulin resistance, hypertension, and changes in plasma lipid concentrations.6-13 The link between body fat distribution and these risk factors is considered as one of the metabolic mechanisms by which body fat topography is associated with cardiovascular disease.7,9,11 High levels of abdominal fat have been associated with elevated plasma TG concentrations7,8,10,11,13-18 and low HDL-CHOL levels,13-18 and these associations, which have been shown to be independent of the effect of obesity,15-18 could also help explain the association between regional body fat distribution and cardiovascular disease.

In the present sample of obese women, we found little association between total fatness and plasma lipoprotein levels. Such a lack of relationship could be due to the nature of the sample, since all our subjects were obese. Indeed, when the plasma lipid levels of our obese patients were compared with those measured in lean women of similar ages, significant differences were observed between the two groups, indicating (in concordance with the results of numerous studies7,14-16,49) that obesity is associated with increased levels of plasma lipids. The present study suggests, however, that in a sample of obese women in which little association between total fatness and plasma lipoprotein levels is found, adipose tissue distribution is a significant correlate of plasma lipoprotein concentrations.

The concentration and composition of HDL showed significant associations with fat distribution. In concordance with other studies,16,17,14,44 WHR displayed a significant association with plasma HDL-CHOL levels (r = −0.47, p<0.001). Various lipoprotein ratios were also calculated to estimate the cardiovascular disease risk45-49 associated with body fat distribution. The HDL-COL/LDL-COL and HDL₃-COL/HDL₄-COL ratios were nega-
Table 6. Stepwise Regression Analyses for Relative Contributions of Body Fat, Fat Distribution, and Lifestyle Variables to Variance of High Density Lipoproteins and Lipoprotein Ratios in Obese Women

| Dependent variable | Independent variable(s) (partial $r^2$) | Total $r^2$ |
|--------------------|------------------------------------------|-------------|
| HDL-CHOL           | WHR (22.4%) + alcohol (8.3%)            | 28.7%       |
| HDL$_2$-CHOL       | WHR (18.3%)                             | 18.3%       |
| HDL- apo A-I       | Alcohol (11.6%) + WHR (9.9%)            | 21.5%       |
| HDL-CHOL/LDL-CHOL  | L4 to L5 deep fat (16.9%)              | 16.9%       |
| HDL- apo A-I/LDL- apo B | L4 to L5 deep fat (14.6%) | 14.6%       |
| HDL-CHOL/HDL$_2$-CHOL | L4 to L5 deep fat (10.0%) | 10.0%       |

The waist-to-hip ratio (WHR) was the only independent variable that was significantly associated with plasma VLDL-CHOL and VLDL-TG levels (see Table 2). LDL-CHOL, LDL-TG, and LDL- apo B levels were not significantly correlated with body fat or with body fat distribution in this sample. Only the independent variables that displayed significant univariate correlations with the dependent lipoprotein variables were entered in the stepwise analyses, and all possible permutations of variables were tested.

L4 to L5 = Abdominal scan, HDL = high density lipoprotein, CHOL = cholesterol, apo = apolipoprotein.

See the legend to Table 2 for abbreviations.

The data shows a significant correlation between WHR and HDL-CHOL, HDL$_2$-CHOL, and HDL- apo A-I, with lipoprotein ratios used in the prediction of the cardiovascular disease risk.

A high deposition of fat in the thigh region was not, however, associated with any change in the concentration of plasma lipoproteins. These results on peripheral fat measured by CAT are concordant with previous observations that indicated that peripheral accumulation of body fat, as observed in gynoid obesity, is not associated with metabolic complications and, therefore, does not represent a major health hazard.

These results further support the concept that the rather moderate association that is consistently found between obesity and cardiovascular disease could be due, at least partly, to the fact that obese subjects are metabolically heterogeneous and that an alteration in body fat distribution is the critical variable in detecting the obesity-related metabolic complications. Our findings in obese women with extreme WHR values further emphasize this point. Although the subgroup of obese women with the lowest WHR had almost 50% of their body weight as fat, they did not show substantial elevations in their plasma CHOL and TG concentrations. In contrast, women with high WHR of similar age and relative adiposity, but showing greater absolute and relative amount of deep fat at the abdominal region, displayed a lipoprotein profile that is associated with an increased risk of cardiovascular disease. In comparison with the obese women with low WHR, obese women with high WHR had reduced plasma HDL-CHOL, HDL$_2$-CHOL, and HDL- apo A-I levels, and reduced ratios of HDL$_2$-CHOL/HDL-CHOL, HDL-CHOL/ LDL-CHOL, as well as a reduced HDL- apo A-I/LDL- apo B ratio, indicative of an increased cardiovascular disease risk. The data on these subgroups of obese women with similar body composition, but differing only in their amount of intra-abdominal fat, further emphasize the importance of deep abdominal fat as a significant covariate of plasma lipoprotein levels in obese subjects.

Results from our multivariate analyses, which included concomitant variables such as age, energy intake, proportion of intake as proteins, lipids and carbohydrates, alcohol intake, and $V_Q$ max indicated that intra-abdominal fat accumulation displayed significant associations with lipoprotein ratios (HDL-CHOL/LDL-CHOL, HDL- apo A-I/LDL- apo B, HDL$_2$-CHOL/HDL$_2$-CHOL) that were independent from all other variables studied. Indeed, no other variable could account for a significant portion of the variance of these ratios after intra-abdominal fat had been entered into the regression models. WHR was, however, better than deep abdominal fat as an independent covariate of HDL-CHOL, HDL$_2$-CHOL, and HDL- apo A-I. Therefore, from a practical standpoint, it could be argued that an inexpensive WHR can be used to assess the proportion of
abdominal fat instead of measuring deep abdominal fat by an expensive CAT technique. From a physiological point of view, however, the results of the present study suggest that deep abdominal fat is probably the important body fat distribution variable because it is an independent covariate of the lipoprotein ratios considered important in estimating cardiovascular disease risk. The results from multivariate analyses indicate that WHR does not always "capture" the relation of deep abdominal fat to plasma lipoproteins. Therefore, in epidemiological studies, WHR is probably the best anthropometric estimator of deep abdominal fat accumulation available. In metabolic studies, however, it appears important to directly measure intra-abdominal fat accumulation to further understand the mechanisms involved in the association between body fat distribution and metabolic complications.

It has been suggested that the high plasma VLDL levels associated with excess abdominal fat may be secondary to an increased free fatty acid (FFA) flux from the omental adipocytes to the liver. Such a condition has also been associated with a reduced hepatic extraction of Insulin. The resulting peripheral hyperinsulinemia combined with high plasma FFA levels would induce an increased hepatic VLDL secretion. The positive correlation observed between WHR and the ratio of apo A-I/CHOL in the HDL fraction suggests a cholesterol depletion of HDL particles associated with excess abdominal fat and an enrichment of HDL with triglycerides, a phenomenon that has been reported in subjects with high plasma triglyceride levels. Because glucose intolerance and hyperinsulinemia are conditions associated with abdominal obesity, we performed preliminary analyses that indicated that alterations in carbohydrate metabolism could not account for much of the variance in plasma lipoprotein levels associated with deep abdominal fat accumulation (results not shown). Although further research is needed to address this issue, these preliminary data suggest that additional mechanisms may be operative in the body fat distribution/plasma lipoproteins association.

It has been shown that human fat cells can interact specifically and partially with HDL. The fat cell-HDL metabolism displays regional variation, and a positive correlation has been reported between abdominal fat cell size and the level of adipocyte HDL binding. Because of the selective uptake of HDL cholesterol ester by human fat cells, the increased fat cell/HDL interaction observed in abdominal obesity could be another factor explaining the negative association between the amount of abdominal fat and plasma HDL cholesterol concentration.

In summary, the present study suggests that the altered lipoprotein profile associated with an excessive deposition of intra-abdominal fat should be considered as an important variable in the assessment of the cardiovascular disease risk of obese women. Further research is clearly warranted to identify the mechanisms responsible for this association and to verify whether this covariation represents a cause-effect relationship.

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Index Terms: obesity • body fat distribution • high density lipoprotein cholesterol • omental fat