

Distribution of Abdominal Visceral and Subcutaneous Adipose Tissue and Metabolic Syndrome in a Korean Population

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OBJECTIVE—This study aimed to assess the correlation between abdominal subcutaneous adipose tissue (SAT) and metabolic syndrome (MetS) in Korean adults after adjusting for the effects of visceral adipose tissue (VAT).

RESEARCH DESIGN AND METHODS—The SAT/VAT ratio (SVR) was calculated using abdominal computed tomography in 2,655 subjects. We used regression analyses to assess whether the SVR predicted MetS.

RESULTS—For both sexes, the prevalence of elevated triglycerides, reduced HDL, and elevated fasting glucose significantly decreased with increasing quintiles of SVR (P for trend < 0.05). The prevalence and odds ratios of MetS significantly decreased as the SVR increased (men: odds ratio 0.5 [95% CI 0.3–0.7]; women: 0.2 [0.1–0.5] for comparisons of lowest vs. highest quintile; P for trend < 0.05).

CONCLUSIONS—After adjustment for VAT, abdominal SAT was inversely correlated with the occurrence of MetS.

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Metabolic syndrome (MetS) is associated with an increased risk of diabetes and cardiovascular mortality (1). Abdominal obesity, a key component of MetS, is a risk factor for type 2 diabetes (2), cardiovascular disease, and mortality (3).

Abdominal fat is composed of distinct anatomical components: subcutaneous adipose tissue (SAT) and visceral adipose tissue (VAT). VAT is strongly associated with metabolic risk factors (4,5). However, some studies have suggested a

beneficial role of abdominal SAT (6). A recent animal study showed that transplantation of SAT into the visceral fat area may decrease fat mass and induce beneficial changes in serum glucose and insulin sensitivity in mice (7). We postulated that abdominal SAT is inversely associated with cardiometabolic risk factors and MetS.

RESEARCH DESIGN AND METHODS

A cross-sectional observational study of 2,655 men and non-pregnant women was conducted. Eligible

subjects were healthy individuals who voluntarily received routine comprehensive health check-ups, including computed tomography (CT) scan analyses of abdominal adipose tissue, from January to December 2008 at the Seoul National University Hospital Healthcare System Gangnam Center. Data were collected through a questionnaire, anthropometric measurements, blood samples, and CT scans. Subjects with diabetes, cancer, or other chronic wasting diseases were excluded. The Seoul National University Hospital Institutional Review Board approved this study.

Measurements of abdominal adipose tissue and covariates

Detailed descriptions of the method used for the measurement of abdominal adipose tissue have been published previously (8). In brief, a 5-mm thick umbilical level abdominal section from 16-detector row CT imaging of the abdomen was obtained. The cross-sectional area (cm²) of the abdominal fat was calculated using Rapidia 2.8 CT software (INFINITT, Seoul, Korea). The VAT area was defined as intra-abdominal fat bound by parietal peritoneum or transversalis fascia, and the SAT area was calculated by subtracting the VAT area from the total adipose tissue area.

Because of the high colinearity between SAT and VAT, adjustments to the regression model or stratification of VAT are insufficient to control for the effects of VAT on SAT. The ratio between SAT and VAT (SAT/VAT ratio [SVR]) was therefore calculated and used in the current study. MetS was defined according to the modified National Cholesterol Education Program Adult Treatment Panel III (9) and Asia-Pacific abdominal obesity criterion (10).

Statistical analysis

Means with 95% CI and numbers of participants (%) with metabolic risk factors were compared across the SVR quintiles. We used multivariate logistic regressions to evaluate the association between MetS and SVR after adjusting

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for age, smoking, alcohol consumption, BMI, menopausal status, and hormonal replacement therapy (women only). Data are expressed as odds ratio (OR) [95% CI]; and *P* for trend. All analyses were performed using STATA (version 10.0). Significance was defined as *P* < 0.05.

RESULTS—Forty percent of men and 25% of women had elevated blood pressure, 31% of men and 15% of women had elevated fasting glucose, and 25% of men and 14% of women had MetS. The mean SAT and VAT areas were 139.8 cm² and 134.4 cm² in men and 173.1 cm² and 80.0 cm² in women, respectively. Additional characteristics are listed in Supplementary Table 1A.

Among women, the prevalence of elevated fasting glucose, elevated triglycerides (TGs), and reduced HDL cholesterol (HDL-C) significantly decreased as the SVR quintile increased (26, 16, and 37% in quintile 1 vs. 5, 4, and 11% in quintile 5, respectively; all *P* for linear trend < 0.05). Robust linear decreases in these risk factors were also seen among men (Supplementary Table 1B).

Multivariable-adjusted logistic regressions with SVR and MetS

ORs of MetS significantly decreased across all 5 quintiles of the SVR after adjusting for covariates in both men (OR 1.0 for quintile 1 vs. 0.5 in quintile 5; 95% CI 0.3–0.7 for quintile 5; *P* for linear trend < 0.01) and women (OR 1.0 for quintile 1 vs. 0.2 in quintile 5; 95% CI 0.1–0.5 for quintile 5; *P* for linear trend < 0.01) (Table 1).

CONCLUSIONS—The purpose of this study was to assess the cross-sectional correlation of abdominal SAT with MetS in a Korean study population. We found

that as the SVR increased, MetS components such as reduced HDL-C, elevated TGs, and elevated fasting glucose decreased in both sexes. Furthermore, this relationship was maintained even after the adjustment for a variety of variables.

Small adipocytes in SAT play the role of powerful buffers, uptaking circulating free fatty acids and TGs in the postprandial period. But if they lose their function in adipogenesis or fat storage capacity in SAT, fat begins to accumulate in tissues not suited for lipid storage such as VAT. Dysfunction of SAT and ectopic fat contribute to insulin resistance (11). Peroxisome proliferator-activated receptor- γ (PPAR- γ) agonists stimulate the differentiation of adipocytes, resulting in increased accumulation capacity in SAT (12). The PPAR- γ coactivator 1 α mRNA expression is significantly higher in subcutaneous fat than in omental fat (13). This mechanism explained the finding that treatment with thiazolidinedione improves insulin sensitivity (6).

VAT and SAT differ in cytokine secretion profile such as leptin, adiponectin, interleukin-6, interleukin-8, plasminogen activator inhibitor 1, and angiotensin, which may play some role in the development of MetS (14,15).

Longitudinal associations of VAT/SAT change with MetS, and with leptin and/or adiponectin level should be the focus of future studies.

There are some potential limitations to the current study. Gluteofemoral SAT, which may act as a confounding factor, was not considered in the study. However, the current study included the analysis of a large dataset of CT-measured SAT and VAT. Moreover, the study population was generally healthy, which implies that the results can be applied to the general Korean population.

In summary, increased SAT is negatively correlated with the prevalence of MetS. Cumulatively, these results indicate that SAT may be considered a protective fat deposit.

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Table 1—Unadjusted and adjusted ORs and 95% CI from logistic regressions predicting the likelihood of MetS for each of the SVR quintiles

| SVR quintiles | Men | | Women | |
|---------------------------|------------------------|-----------------------|------------------------|-----------------------|
| | Unadjusted OR (95% CI) | Adjusted OR (95% CI)* | Unadjusted OR (95% CI) | Adjusted OR (95% CI)* |
| Q1 | 1.00 | 1.00 | 1.00 | 1.00 |
| Q2 | 0.8 (0.6–1.2) | 0.9 (0.6–1.3) | 0.6 (0.4–1.0) | 0.7 (0.4–1.2) |
| Q3 | 0.7 (0.5–1.0) | 0.7 (0.5–1.0) | 0.5 (0.3–0.8) | 0.73 (0.4–1.3) |
| Q4 | 0.53 (0.4–0.7) | 0.51 (0.3–0.7) | 0.3 (0.2–0.6) | 0.72 (0.4–1.3) |
| Q5 | 0.47 (0.3–0.7) | 0.49 (0.3–0.7) | 0.1 (0.02–0.2) | 0.2 (0.1–0.5) |
| <i>P</i> for linear trend | <0.001 | <0.001 | <0.001 | 0.005 |

*Adjusted ORs take into consideration age, smoking, alcohol consumption, BMI, and menopausal status, hormone replacement therapy (women only).

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