Original article

Longitudinal changes in visceral and subcutaneous adipose tissue and metabolic syndrome: Results from the Multicultural Community Health Assessment Trial (M-CHAT)

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ABSTRACT

Aim: Few studies have examined whether longitudinal changes in visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT), independent of each other, are associated with the risk of developing metabolic syndrome (MetS). The objective of this study was to examine the longitudinal effects of VAT and SAT on MetS and metabolic risk factors in a multi-ethnic sample of Canadians followed for 5-years.
Materials and methods: In total, 598 adults of the Multicultural Community Health Assessment Trial (M-CHAT) were included in this study. Assessments of body composition using computed tomography (CT) and metabolic risk factors were conducted at baseline, 3-, and 5-years. Mixed-effects logistic regression was used to model the longitudinal effects of VAT and SAT on MetS and metabolic risk factors.
Results: There were significant between-person (cross-sectional) effects such that for every 10 cm^2 higher VAT, the odds of MetS, high-risk fasting glucose levels and high-risk HDL-C levels significantly increased by 16% (95% CI: 9–24%), 11% (3–20%), and 7% (0–14%) respectively. Significant within-person (longitudinal) effects were also found such that for every 10 cm^2 increase in VAT the odds of MetS and high-risk triglyceride levels significantly increased by 23% (9–39%) and 30% (14–48%), respectively. Cross-sectional or longitudinal changes in SAT were not associated with MetS or metabolic risk factors.
Conclusions: This study found a direct relationship between longitudinal change in VAT and MetS risk independent of changes in SAT. Clinical practice should focus on the reduction of VAT to improve cardiovascular health outcomes.

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1. Introduction

With increasing prevalence worldwide, obesity has become a significant public health issue. Obesity has been linked with a number of cardiovascular and metabolic diseases including hypertension, type 2 diabetes, dyslipidemia, and stroke [1,2]. In Canada, it is estimated that over 50% of adults are overweight or obese [3].

There is growing evidence that suggests that different fat compartments contribute differing effects on the cardiometabolic risk associated with obesity [4–8]. Recent studies have found an association between visceral adipose tissue (VAT) and metabolic risk factors including hypertension [9], dyslipidemia [10], dysglycemia [11], and subsequent risk of metabolic syndrome (MetS)

[12]. In contrast, the relationship between subcutaneous abdominal adipose tissue (SAT) and metabolic risk factors has been mixed with some studies showing a negative association [13] and others a positive association [5,8]. Understanding the specific fat depot associated with metabolic risk is important to improve interventions that are currently more generalized to overall weight loss.

The vast majority of studies examining the relationship between abdominal fat depot accumulation and cardiometabolic risk have been cross-sectional; therefore, the relationship between abdominal fat and metabolic risk remains unclear. In a longitudinal sample of Japanese men, Matsushita et al. found that changes in VAT and SAT were independently associated with changes in metabolic risk factors such as blood pressure, glucose, triglyceride and high-density lipoprotein cholesterol (HDL-C). In contrast, Shah et al. found that changes in VAT but not SAT were independently associated with MetS among a multiethnic sample of Americans. More longitudinal studies of multi-ethnic populations are needed

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to assess the relationship between specific abdominal fat depots and metabolic risk factors.

This study followed men and women from four different ethnic groups for five years and assessed the longitudinal association between change in VAT and SAT and MetS and the individual metabolic risk factors of MetS.

1.1. Subjects

Participants for this study were men and women enrolled in the Multicultural Community Health Assessment Trial (M-CHAT) which was designed to compare body fat distributions in four different ethnic populations. Study details including recruitment and protocol can be found elsewhere [14]. Briefly, participants were apparently healthy, between the ages of 30 and 65, of Aboriginal, European, Chinese, or South Asian origin, and residing in Metro Vancouver. Equal proportions of individuals of normal (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), and obese (30 + kg/m^2) BMI weight status for each ethnic category were recruited. Participants were excluded if they reported having cardiovascular disease or a significant comorbidity (e.g., type 1 diabetes mellitus, HIV), having undergone a weight change of more than 2 kg three months prior to their baseline assessment, taking medication known to affect cardiovascular and diabetes risk factors (e.g., antihypertensive, lipid-lowering, or hypoglycemic medications), or having a significant prosthetic or amputation. Baseline assessments were completed for 802 adults between 2004 and 2005. A total of 610 (76%) participants were assessed after three years and 548 (68%) participants were assessed after five years. The current study was limited to the 598 participants who had a baseline and at least one follow-up assessment of both body composition and metabolic risk factors. All participants provided informed consent. The study was approved by the Simon Fraser University Research Ethics Board.

2. Materials and methods

2.1. Body composition assessment

Measurement of abdominal adipose tissue was conducted at each assessment time by computed tomography (CT) from a single cross-sectional scan centred at the L4-L5 intervertebral disc. Scans were performed with a CTi Advantage Scanner (General Electric, Milwaukee, Wis., USA). Scan parameters were set at 120kV(p), 300 mA for 1s, 10 mm thickness, 512 × 512 matrix, using a 48 cm field of view. Computation of surface area was conducted with SliceOmatic v4.2 (Tomovision, Montreal, Quebec, Canada), using the attenuation range of −190 to −30 Hounsfield units for adipose tissue. Total abdominal adipose tissue was calculated as total pixels and area in square centimeters in the attenuation range in the abdominal slice image. VAT was calculated as total pixels and area within the attenuation range that fell within the visceral peritoneum (abdominal wall) and SAT was calculated as the difference between the total abdominal adipose tissue and VAT. Body mass index (BMI) was calculated by dividing weight (kg) with height (m) squared.

2.2. Metabolic risk factors and metabolic syndrome

Fasting blood samples were collected at each assessment time and processed for total cholesterol, HDL-C, tryglycerides, and glucose. All measurements were conducted at the same clinical laboratory using standard procedures. Blood pressure (BP) was recorded as the average of five successive measurements following ten minutes of seated rest using an automated oscillometric office BP monitor (VSM MedTech Ltd. Coquitlam, British Columbia). Participants were diagnosed with MetS using the International Diabetes Federation (IDF) definition [15]. As this was a multi-ethnic population, the appropriate IDF ethnic cut-offs for waist circumference were used. The IDF cut-points for each metabolic risk factor were used to define high risk.

2.3. Statistical methods

Descriptive statistics were used to summarize baseline, 3-year, and 5-year assessments of body composition and metabolic risk factors. Mixed-effects logistic regression with random intercepts was used to assess the associations between changes in VAT and SAT on each metabolic risk factor (triglyceride, HDL, blood pressure, and fasting glucose) and MetS individually. All outcomes were treated as binary (presence or absence of MetS; metabolic risk factors above or below high risk cut-off). Covariates include baseline age, person-mean-centered (PMC) VAT and SAT to assess between-person differences, change in VAT and SAT from PMC value to assess within-person differences, sex, ethnicity, and baseline values of BMI, household income, smoking status, and all metabolic risk factors (triglyceride, HDL-C, mean BP ((systolic + diastolic BP)/2), and fasting glucose) and indicators for time 2 and 3 (3 year and 5 year assessment). Interactions with sex and VAT, sex and SAT, ethnicity and VAT, and ethnicity and SAT were examined to investigate whether the association between abdominal fat depots and metabolic risk differed by sex and ethnicity. All

Table 1
Baseline characteristics of study participants by metabolic syndrome (MetS) status (N = 598).

	No MetS at baseline (n = 451) (%)	MetS at baseline (n = 147) (%)	p-value[*]
Female	239 (53.0)	67 (45.6)	0.12
Mean age, yrs (SD)	47.4 (8.8)	47.1 (9.5)	0.74
Ethnicity			0.03
European	135 (29.9)	41 (27.9)	
Aboriginal	67 (14.9)	21 (14.3)	
Chinese	137 (30.4)	31 (21.1)	
South Asian	112 (24.8)	54 (36.7)	
Income			0.74
<$30,000	103 (23.3)	35 (24.0)	
$30,000–$60,000	163 (36.9)	58 (39.7)	
>$60,000	176 (39.8)	53 (36.3)	
Current smoker	27 (6.0)	17 (11.6)	0.02
Body mass index			<0.001
<25 kg/m^2	198 (43.9)	3 (2.0)	
25–29.9 kg/m^2	177 (39.3)	69 (46.9)	
≥30 kg/m^2	76 (16.9)	75 (51.0)	

[*] p-value determined from Chi-square test or t-test, where applicable.