

# Visceral adipose tissue accumulation differs according to ethnic background: results of the Multicultural Community Health Assessment Trial (M-CHAT)<sup>1–3</sup>

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## ABSTRACT

**Background:** It was suggested that body fat distribution differs across ethnic groups, and this may be important when considering risk of disease. Previous studies have not adequately investigated differences in discrete regions of abdominal adiposity across ethnic groups.

**Objective:** We compared the relation between abdominal adipose tissue and total body fat between persons living in Canada of Aboriginal, Chinese, and South Asian origin with persons of European origin.

**Design:** Healthy Aboriginal, Chinese, European, and South Asian participants ( $n = 822$ ) aged between 30 and 65 y were matched by sex, ethnicity, and body mass index (BMI; in  $\text{kg}/\text{m}^2$ ) range. Total abdominal adipose tissue (TAT), subcutaneous abdominal adipose tissue (SAT), visceral adipose tissue (VAT), total body fat mass, lifestyle, and demographics were assessed. Relations between BMI and total body fat, TAT, SAT, and VAT and between total body fat and TAT, SAT, and VAT were investigated.

**Results:** BMI significantly underestimated VAT in all non-European groups. Throughout a range of total body fat mass, VAT was not significantly different between the Aboriginals and the Europeans. With total body fat  $>9.1$  kg, Chinese participants had increasingly greater amounts of VAT than did the Europeans ( $P$  for interaction = 0.008). South Asians had less VAT with total body fat  $>37.4$  kg but more VAT below that amount than did Europeans ( $P$  for interaction  $< 0.001$ ).

**Conclusion:** Compared with Europeans, the Chinese and South Asian cohorts had a relatively greater amount of abdominal adipose tissue, and this difference was more pronounced with VAT. No significant differences were observed between the Aboriginals and the Europeans. *Am J Clin Nutr* 2007;86:353–9.

**KEY WORDS** Visceral adipose tissue, body fat, Aboriginal, South Asian, Chinese, ethnicity

## INTRODUCTION

The prevalence of overweight and obesity is increasing worldwide even where obesity was once rare, such as in Aboriginal, Chinese, and South Asian populations (1, 2). The rates of obesity in Aboriginal populations in North America are almost double the rates in Europeans (3–5). In China, the prevalence of overweight has increased nearly 50% in a 10-y period, (6), and in India the rate of obesity is estimated to be 7.0–13.3% in men and 15.6–23.7% in women (7, 8). In addition, as those of Chinese and

South Asian origin move from rural to urban to Western environments, the prevalence of obesity increases (9–13). Data suggest that Aboriginals, Chinese, and South Asians have more risk factors for type 2 diabetes and cardiovascular disease (CVD) than do Europeans at the same body mass index [BMI; calculated as weight in kilograms divided by height in meters squared ( $\text{kg}/\text{m}^2$ )] or waist circumference (WC) (14–17). This has led to debate surrounding the benefit of using ethnic-specific anthropometric targets for estimating the risk of CVD (1, 18–22). Comparing the distribution of body fat among ethnicities is essential to this decision because abdominal obesity, specifically visceral adipose tissue (VAT), is more strongly associated with risk factors for CVD than other adipose tissue regions (23, 24).

Ethnic-specific differences in VAT have been reported between African-Americans and Europeans, indicating that African-American men have smaller amounts of VAT, whereas African-American women had similar or smaller amounts than Europeans for a given body fat mass (25–28). In contrast, few studies have compared VAT in Aboriginals, Chinese, and South Asians. The single study of North American Aboriginals reported that VAT was similar in 20 Pima Indians and a similar group of Europeans (29). Chowdhury et al (30) found no difference in VAT between 10 South Asian men and 10 European men, whereas Raji et al (31) reported that VAT was greater in a group of 12 South Asians. Park et al (32) reported that 18 women, but not men, of Asian origin had higher amounts of VAT than a group of European women. In addition, Filipino women were reported to have more VAT than European women (33). Those reports suffer from small sample size, lack of sex representation, and lack of consideration for differences in overall body fat among

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**TABLE 1**  
Ethnic cohort by BMI range

BMI range (kg/m <sup>2</sup> )	Aboriginal		Chinese		European		South Asian	
	Men (n = 94)	Women (n = 101)	Men (n = 101)	Women (n = 118)	Men (n = 100)	Women (n = 101)	Men (n = 104)	Women (n = 103)
	n (%)		n (%)		n (%)		n (%)	
18.5–24.9	16 (17)	28 (28)	40 (40)	49 (42)	33 (33)	34 (34)	32 (31)	35 (34)
25–29.9	43 (46)	37 (37)	50 (50)	53 (45)	38 (38)	37 (37)	40 (38)	35 (34)
≥30	35 (37)	36 (36)	11 (11)	16 (14)	29 (29)	30 (30)	32 (31)	33 (32)

the groups. This latter point is necessary to determine whether ethnic differences in VAT are independent of overall body fat.

The aim of the Multicultural Community Health Assessment Trial (M-CHAT) was to compare body fat distribution of a European cohort with that of Aboriginal, Chinese, and South Asian cohorts (34). We hypothesized that the amount of VAT assessed by computer tomography (CT) and corrected for total body fat would be greater in men and women of Aboriginal, Chinese, and South Asian origin than in Europeans. We also investigated differences in total and subcutaneous abdominal adipose tissue among these groups.

## SUBJECTS AND METHODS

The study methods were described previously (34). Briefly, healthy men and women (aged between 30 and 65 y) with exclusive ancestry of either Aboriginal (reserve and nonreserve residents), Chinese (China, Hong Kong, and Taiwan), European (continental Europe, Ireland, and the United Kingdom), or South Asian (Bangladesh, India, Nepal, Pakistan, and Sri Lanka) origin were potential candidates and screened for eligibility. Ethnicity was determined by participant self-report. We excluded subjects who had undergone recent weight change (>2.2 kg in 3 mo), reported a previous diagnosis of CVD or significant comorbidity (such as HIV, immunocompromised condition, type 1 diabetes mellitus), were taking medications for CVD risk factors (ie, lipid-lowering, antihypertensive, or hypoglycemic medications), or had significant prosthetics or amputations. Chinese, European, and South Asian participants must have resided in Canada for >3 y and be third-generation Canadian or less. These criteria were meant to limit possible differences in acculturation among the immigrant groups. Because of the high prevalence of mixed ethnic origins in Aboriginal populations, those with at least 3 grandparents of exclusive Aboriginal origin were included.

To ensure a range of body fat mass across groups, we aimed to recruit at least 100 men and 100 women from each of the 4 ethnic groups with equal representation (ie, 33% each) from the following BMI ranges: 18.5–24.9 (low range), 25–29.9 (middle range), and ≥30 (upper range). As we could not identify enough Aboriginal men with a BMI < 25, we recruited Aboriginal men of any BMI. Similarly, we had difficulty identifying enough Chinese participants with a BMI ≥ 30; therefore, we changed our target for the upper BMI range of Chinese persons to a BMI ≥ 28. These changes resulted in a study cohort that, although not evenly distributed across the 3 BMI ranges, had sufficient variation in BMI values within each ethnic group (Table 1). Seven CT scans were not available, resulting in a cohort of 195, 219, 201, and 207 participants of Aboriginal, Chinese, European, and South Asian

origin, respectively. All participants gave informed consent. The study was approved by the Simon Fraser University Research Ethics Board.

## Participant assessment

Participants were assessed for sociodemographics, family history of CVD and type 2 diabetes mellitus (occurrence in parents or siblings at any age), anthropometry, lifestyle factors, VAT, and total body fat. WC was recorded as the mean of 2 measurements taken at the maximal narrowing of the waist after a normal expiration. Hip circumference was recorded as the mean of 2 measures taken at the point of maximal gluteal protuberance from the lateral view over undergarments. The breadth of the humerus, used to estimate frame size, was measured at the elbow. Smoking status and alcohol intake were assessed by self-report. A 3-d food record was analyzed for macronutrients by a registered dietitian with the use of the FOOD PROCESSOR SQL software (ESHA, Salem, OR). Ethnic-specific foods were added to the database from local recipes, taking into account preparation methods and local ingredients. Leisure-time physical activity was assessed by self-report as the average minutes per week of activity over the previous year (35).

## Body composition assessment

Abdominal adipose tissue was assessed by CT with the use of a CTi Advantage scanner (General Electric, Milwaukee, WI). A cross-sectional 10-mm slice at the L4–L5 intervertebral disc was obtained, and the attenuation range of –190 to –30 Hounsfield units was used to identify adipose tissue. Surface area was calculated with the use of SLICEOMATIC medical imaging software (version 4.2; Tomovision, Montreal, PQ). Total abdominal adipose tissue (TAT) was defined as all pixels within the attenuation range, and VAT was defined as adipose tissue within the inside edge of the abdominal wall. Subcutaneous abdominal adipose tissue (SAT) was defined as the difference between TAT and VAT. Total body fat was measured by dual-energy X-ray absorptiometry with a Norland XR-36 scanner (Norland Medical Systems, White Plains, NY). The percentage of total body fat was calculated from the above data by dividing total body fat by total body mass.

## Statistical methods

Normally distributed continuous variables are reported as means ± SDs, and categorical variables are reported as counts and percentages. VAT, SAT, and weekly physical activity were log-transformed before analyses and are presented as the median and the 25th and 75th percentile. To test for differences among

**TABLE 2**  
Study demographics by ethnicity<sup>1</sup>

	European (n = 201)	Aboriginal (n = 195)	Chinese (n = 219)	South Asian (n = 207)	P for comparison of ethnic cohorts <sup>2</sup>
Age (y)	50.3 ± 9.2 <sup>3</sup>	45.0 ± 8.3	47.9 ± 8.1	45.0 ± 8.3	< 0.001
Born outside of Canada [n (%)]	87 (43)	3 (2)	183 (84)	198 (96)	< 0.001
Mother tongue not English [n (%)]	64 (32)	86 (44)	199 (91)	198 (96)	< 0.001
Maximum education [n (%)]					< 0.037
<High school	9 (5)	38 (20)	22 (10)	28 (14)	
Postsecondary	128 (64)	75 (38)	136 (62)	95 (46)	
Household income [n (%)]					< 0.001
<\$20 000	12 (6)	49 (26)	34 (16)	18 (9)	
>\$60 000	103 (51)	41 (22)	79 (36)	60 (29)	
Family medical history [n (%)]					
CVD	100 (50)	76 (39)	95 (43)	91 (44)	0.193
Type 2 diabetes mellitus	53 (26)	78 (40)	79 (36)	87 (42)	0.005
Smoking status [n (%)]					< 0.001
Never	95 (47)	41 (21)	181 (83)	187 (90)	
Former	90 (45)	92 (47)	31 (14)	14 (7)	
Current	16 (8)	62 (32)	7 (3)	6 (3)	
Alcohol consumption [n (%)]					0.002
Never or ≤1 drink/wk	83 (41)	152 (78)	191 (87)	163 (79)	
1–5/wk	76 (38)	25 (13)	22 (10)	31 (15)	
>5/wk	42 (21)	18 (9)	6 (3)	13 (6)	
Physical activity (min/wk) <sup>4</sup>	321 (148, 541)	295 (104, 568)	184 (79, 364)	166 (71, 294)	< 0.001
Diet					
Total energy (kcal)	2049.5 ± 656.8	1798.3 ± 537.4	2023.5 ± 540.9	1754.4 ± 595.2	< 0.001
Carbohydrate (% of energy)	47.0 ± 8.8	49.9 ± 8.2	47.8 ± 8.2	55.5 ± 8.7	< 0.001
Protein (% of energy)	17.3 ± 4.2	15.6 ± 3.6	19.2 ± 4.3	16.3 ± 3.7	< 0.001
Fat (% of energy)	33.7 ± 7.9	34.0 ± 7.1	32.6 ± 6.7	27.6 ± 7.8	< 0.001
Saturated fat (% of energy)	11.0 ± 3.8	10.4 ± 3.0	9.1 ± 2.6	8.3 ± 2.8	< 0.001

<sup>1</sup> CVD, cardiovascular disease.<sup>2</sup> Between-group differences were analyzed by ANOVA.<sup>3</sup>  $\bar{x}$  ± SD (all such values).<sup>4</sup> Values are median; 25th and 75th percentiles in parentheses.

the groups, we used analysis of variance for continuous variables and the chi-square test for categorical variables.

Total body fat, TAT, SAT, and VAT were calculated for BMI values of 25 and 30 adjusted for age, sex, and ethnicity with the use of cohort means. To test the association between VAT and total body fat, we analyzed the main effect of ethnicity and then ethnicity × body fat interactions. We also tested for ethnicity × sex and sex × body fat interactions, none of which were significant (data not shown). Regression models incorporated age, sex, BMI, household income, maximum education level, humerus breadth, smoking status, and weekly physical activity. The associations between TAT and SAT and total body fat were modeled in a similar fashion. Dietary information from 44 participants was unavailable. Dietary fat and other macronutrients were removed from the final analyses because they were not significant contributors to any of the regression models (data not shown). The final models are based on 799 participants with complete data. There was no difference in age, sex, ethnicity, VAT, or total body fat between the 799 participants with full data and the 23 participants with incomplete data (data not shown). Residual plots were used to assess model adequacy. All hypothesis tests for the regression analyses were 2-sided with a significance level of 0.05. We used the Bonferroni adjustment for multiple comparisons between each of the Aboriginal, Chinese, and South Asian groups with the European group (*P* set at

0.0167). Statistical analyses were performed with the use of SPSS 14.0 (SPSS Inc, Chicago, IL).

## RESULTS

Demographics are provided in **Table 2**. Most Chinese and South Asian participants were born outside of Canada and had a first language other than English. Smoking status, alcohol intake, physical activity, and dietary intake differed significantly among the groups. There were no diabetic subjects in the cohort, and there were no differences in the menopausal status of the women (26% postmenopausal).

In unadjusted analysis, significant differences were observed among the 4 ethnic groups with respect to anthropometric and adipose tissue measures (**Table 3**). As expected, the Chinese group had a lower BMI than did the other groups. Aboriginals had a greater WC, and the Chinese group had a lower WC than did the Europeans. Aboriginals and South Asians had a significantly greater percentage of body fat than did the Europeans.

**Figure 1** shows the age-adjusted absolute differences in total body fat and TAT (Figure 1A) and the relative differences in SAT and VAT (Figure 1B) at the BMI targets for overweight and obesity compared with the European group. At both BMI targets, body fat mass was not different in the Aboriginal participants, whereas the Chinese had less and South Asians had more body fat

TABLE 3

Body composition by ethnicity

	European (n = 201)	Aboriginal (n = 195)	Chinese (n = 219)	South Asian (n = 207)	<i>P</i> for overall comparison <sup>1</sup>	<i>P</i> for Aboriginal vs European <sup>2</sup>	<i>P</i> for Chinese vs European <sup>2</sup>	<i>P</i> for South Asian vs European <sup>2</sup>
BMI (kg/m <sup>2</sup> )	27.7 ± 5.1 <sup>3</sup>	28.8 ± 5.1	25.7 ± 3.6	27.8 ± 4.9	< 0.001	—	< 0.001	—
Waist circumference (cm)	89.3 ± 12.5	94.7 ± 11.7	83.3 ± 9.6	88.6 ± 12.3	< 0.001	< 0.001	< 0.001	—
Waist-to-hip ratio	0.87 ± 0.09	0.93 ± 0.08	0.87 ± 0.07	0.88 ± 0.09	< 0.001	< 0.001	—	—
Humerus breadth (cm)	7.05 ± 0.52	6.97 ± 0.48	6.53 ± 0.53	6.85 ± 0.52	< 0.001	—	< 0.001	< 0.001
Body fat (%)	32.3 ± 10.2	34.6 ± 9.2	31.0 ± 8.4	36.2 ± 10.0	< 0.001	0.013	—	< 0.001
Total fat mass (kg)	26.71 ± 10.8	28.32 ± 10.08	21.37 ± 7.00	28.10 ± 10.27	< 0.001	—	< 0.001	—
Total abdominal adipose tissue (cm <sup>2</sup> )	403.6 ± 177.6	442.1 ± 158.0	332.2 ± 118.8	446.9 ± 166.0	< 0.001	0.015	< 0.001	0.005
Subcutaneous abdominal adipose tissue (cm <sup>2</sup> ) <sup>4</sup>	265.9 (188.0, 385.2)	304.8 (242.8, 392.6)	221.2 (162.0, 287.7)	309.4 (223.3, 399.0)	< 0.001	0.002	< 0.001	0.005
Visceral adipose tissue (cm <sup>2</sup> ) <sup>4</sup>	100.8 (73.6, 142.9)	111.9 (75.0, 154.0)	100.0 (72.7, 126.6)	115.2 (87.1, 159.0)	< 0.001	—	—	0.009

<sup>1</sup> Between-group differences were analyzed by ANOVA.<sup>2</sup> Pairwise comparisons were analyzed by ANOVA; only data with *P* < 0.017 are reported, based on the Bonferroni correction for multiple comparisons.<sup>3</sup>  $\bar{x} \pm SD$  (all such values).<sup>4</sup> Medians; 25th and 75th percentiles in parentheses.

than did the Europeans. TAT was higher at both BMI values for the South Asian cohort. SAT was higher in the Aboriginal and South Asian participants at both BMI values. VAT was higher in the Aboriginal, Chinese, and South Asians than in the Europeans at both BMI values.

Because BMI is a surrogate marker for general adiposity, we investigated the relation between VAT and total body fat. Adjusted for age, BMI, and total body fat, Aboriginal, Chinese, and South Asian men and women had greater amounts of VAT than did the European men and women (Figure 2). With further

adjustment for sex, maximal education, humerus breadth, smoking status, and physical activity, ethnic background was a significant modifier of the relation between VAT and total body fat (overall ethnicity × body fat interaction: *P* < 0.001) such that the slopes were significantly different between the Chinese and South Asian participants and the European participants (ethnicity × body fat interaction: *P* = 0.008 and *P* < 0.001, respectively) (Figure 3). The slopes of the Chinese and European groups crossed at ≈9.1 kg total body fat such that above this value Chinese participants had an increasingly greater amount of

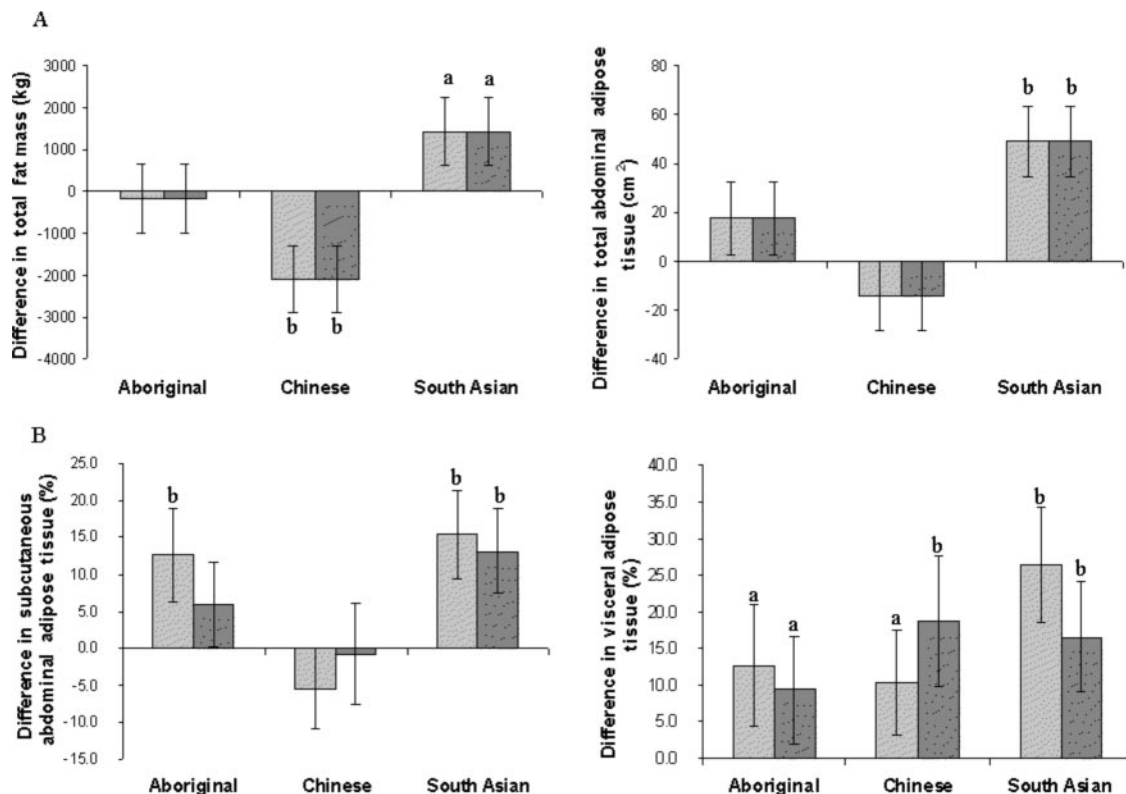
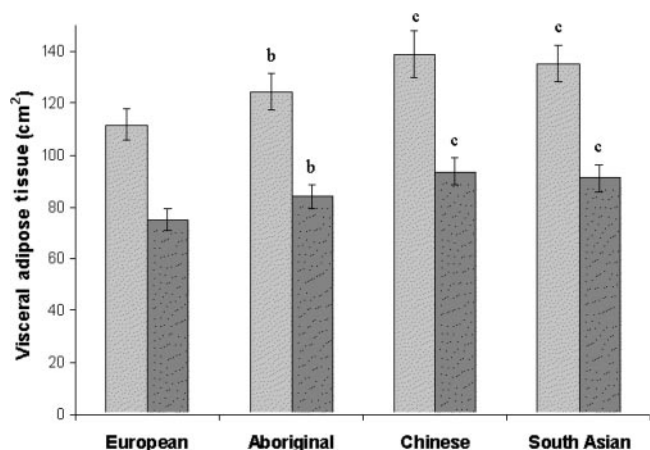


FIGURE 1. (A) Absolute difference in total fat mass and total abdominal adipose tissue and (B) relative difference in subcutaneous abdominal adipose tissue (overall ethnicity × BMI interaction: *P* = 0.009) and visceral adipose tissue (overall ethnicity × BMI interaction: *P* < 0.001) relative to the European group at a BMI of 25 (light gray bars) and a BMI of 30 (dark gray bars) adjusted for age and sex with the use of linear regression analysis. Error bars indicate 95% CIs. The Bonferroni correction was used to account for multiple comparisons. <sup>a</sup>*P* < 0.017 compared with the European group at the same BMI. <sup>b</sup>*P* < 0.001 compared with the European group at the same BMI.



**FIGURE 2.** Visceral adipose tissue adjusted for age, BMI, and total fat mass stratified by sex [men (light gray bars) and women (dark gray bars)] with the use of linear regression analysis. Error bars indicate 95% CIs. <sup>a</sup>*P* < 0.01 compared with Europeans of the same sex. <sup>c</sup>*P* < 0.001 compared with Europeans of the same sex.

VAT at a higher total body fat; at 20 kg and 40 kg of total body fat, Chinese participants had an average of 11.6% and 36.4%, respectively, more VAT than did the European participants. Nearly all Chinese participants (98%) had a total body fat > 9.1 kg, indicating that the majority of Chinese participants had a greater proportion of VAT for a given total body fat. The slopes of the South Asian and European groups crossed at ≈37.4 kg total body fat such that below this value South Asian participants had a greater amount of VAT; at 20 kg and 40 kg total body fat, South Asian participants had an average of 22.6% more and 3.0% less (NS) VAT, respectively, than did the European participants. The majority of South Asian participants (82%) had a total body fat < 37.4 kg, indicating that most South Asians in our study had a greater proportion of VAT for a given total body fat. No differences were observed for the relation of VAT to total body fat

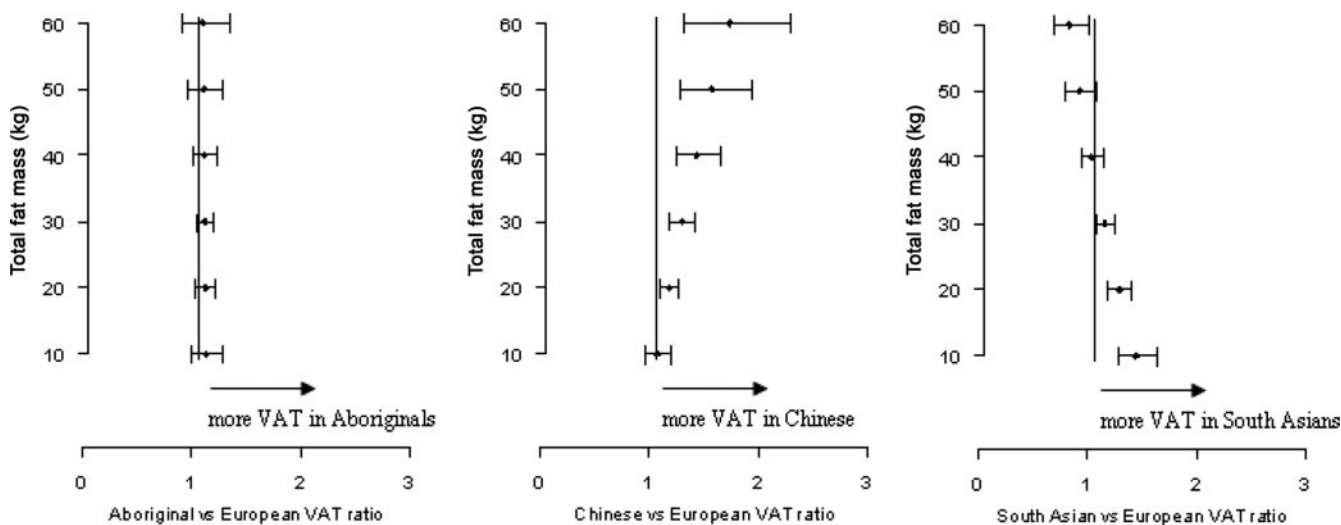
between the Aboriginal and European participants. These findings did not change when we excluded those Aboriginal participants who had one grandparent of non-Aboriginal origin (*n* = 45) (data not shown).

With respect to the relation between TAT and total body fat, the Aboriginal and South Asian groups had on average 13.8 cm<sup>2</sup> (*P* = 0.025, NS after correction for multiple comparisons) and 23.5 cm<sup>2</sup> (*P* < 0.001) more TAT, respectively, than did the European group. No difference was observed between the Chinese and European groups. For the relation between SAT and total body fat (overall ethnicity × body fat interaction: *P* < 0.001), the slopes of the Chinese and South Asian groups were significantly different from that of the European group (ethnicity × body fat<sup>2</sup> interaction: *P* < 0.001 and *P* = 0.020, respectively). With a body fat mass > 22.2 kg, Chinese participants had increasingly greater amounts of SAT than did the European participants. With a total body fat < 39.7 kg, South Asians had more SAT than did the Europeans. No differences were observed in the relations of TAT and SAT with total body fat between the Aboriginal and European groups.

**DISCUSSION**

The M-CHAT is the first comprehensive investigation of body fat distribution among Aboriginal, Chinese, and South Asian persons. Results of the M-CHAT study support the argument that body fat distribution, as measured by total body fat, TAT, SAT, and VAT, differs according to ethnicity. More importantly, for a given amount of total body fat, Chinese participants and most South Asians had more SAT and VAT than did the Europeans. In contrast, no differences were observed between the Aboriginal and European participants.

Previous studies have reported that those of Chinese and South Asian origin have more body fat at a given BMI than do Europeans (36–38). Although our results in the South Asian cohort are consistent with those earlier studies, we report a lower total



**FIGURE 3.** Ratio of visceral adipose tissue at various total body fat mass values compared with the European group. Error bars indicate 95% CIs. Adjusted for age, sex, household income, maximum education level, humerus breadth, smoking status, and physical activity with the use of linear regression analysis (overall ethnicity × body fat interaction: *P* < 0.001). Interactions of ethnicity × body fat were significant between the Chinese and European groups (*P* = 0.008) and between the South Asian and European groups (*P* < 0.001).

body fat mass in persons of Chinese origin. This latter inconsistency may be the result of the use of percentage of body fat in earlier studies, which can vary at the same fat mass with a change in lean body mass. In the present study, we restricted our primary analysis to total body fat mass because of the inherent limitations of using percentage of body fat. In addition, our results extend the notion that BMI is an inadequate measure of body fat distribution to specific regions of abdominal adiposity and, in particular, that BMI significantly underestimates VAT in our non-European cohorts. This is consistent with other findings that measures of abdominal obesity (WC and sagittal diameter) are superior markers of risk (39, 40).

At a given total body fat, abdominal adiposity, TAT, SAT, and VAT were not different between the Aborigines and Europeans. This finding is unexpected given the distant Asiatic roots and elevated rates of obesity and type 2 diabetes mellitus in Aboriginal populations (3, 41). Our results may be indicative of the fact that VAT alone may not explain the high rates of diabetes. The only similar study in Aborigines also found no difference in VAT between 20 Pima Indians and 20 Europeans matched for BMI (29). In contrast to that and other studies in Aboriginal populations (3, 29, 41, 42), we included persons with diverse Aboriginal origins, who are commonly excluded from research (ie, nonreserve, urban living Aborigines). In addition, Aboriginal participants were required to have at least 3 of 4 grandparents of Aboriginal origin. This requirement excluded persons of mixed origin who were included in previous studies. We believe this strategy gives our findings broader relevance to other Aboriginal populations.

Comparison of the Chinese group to the European group showed that TAT was not different, yet SAT and VAT were relatively higher at a higher body fat. The point at which the difference in VAT occurred in the Chinese participants was 9.1 kg and applies to 98% of our cohort who had a body fat mass above this value. An earlier study reported that age and fat-adjusted amounts of VAT were higher in Asian women than in European women; however, there was no difference in the men (32). Our analysis showed that a 2-fold greater total body fat was associated with a 3-fold greater VAT when men or women of Chinese ethnicity were compared with Europeans. The difference in our findings may be due to previous study cohorts having a low mean BMI of  $20.7 \pm 2.0$  for the Asian women, a small sample size (18 women, 19 men), and participants of unknown Asian origin. In addition, their cohort was younger by  $\approx 15$  y, and the investigators reported that with age the difference in VAT among women increased.

At a given total body fat, the majority of the South Asians (80–95%) had a greater TAT, SAT, and VAT than did the Europeans. Only at extremely high values of body fat mass were these measures not different between the 2 groups. Because we oversampled for obese participants, the general South Asian population is likely to fall into the range of those with relatively more TAT, SAT, and VAT than are the Europeans. Although no previous study has investigated differences in TAT and SAT, 2 small studies have reported contrasting results when comparing VAT in South Asian men with European men (30, 31). Those studies were underpowered ( $< 12$  participants) and did not adjust for possible differences in BMI or total body fat. In addition, the mean BMI for the South Asians in those studies was much lower than ours ( $\approx 23$  compared with  $27.8 \pm 4.9$  in ours). Why South Asians ( $\approx 18\%$  of our cohort) had less VAT than the Europeans

at higher amounts of body fat is at present unclear. This finding may be due to differences in initial values of VAT or its rate of accumulation.

Because participants self-described their ethnic origin, we cannot rule out possible inaccuracies that can only be confirmed through the use of genetic biomarkers. However, if inaccuracies in ethnic stratification occurred, our results would likely underestimate the actual differences among the ethnic groups. In addition, the term ethnicity is a discrete marker that reflects a number of differences in various social or environmental and genetic factors. We therefore adjusted for demographic and lifestyle variables (income, education, smoking status, diet, and physical activity) known to be associated with ethnicity and body fat. Participants were also recruited from the same metropolitan area and therefore lived within a common environment. This ensured that our findings support at least some physiologic basis for the observed differences. Although we are not able to identify the mechanism for our findings, work has uncovered a number of hormones produced by adipose tissue and the gastrointestinal tract that are involved in body fat regulation (43). It is possible that ethnic differences in these hormones may account for the differences in body fat distribution reported here.

Our study cohort was purposely recruited from a wide range of BMI values and not a random population sample because our study was designed to investigate differences in body fat distribution. However, there is no reason to believe that these results are not applicable to the general populations of our target ethnic groups. Given that our primary focus was VAT, a self-selection bias is unlikely.

The M-CHAT shows that Chinese and South Asian backgrounds are determinants of discrete regions of abdominal adiposity. We found that Chinese participants had a greater SAT and VAT than did European participants and that most South Asians had more TAT, SAT, and VAT than did the Europeans. These differences were more marked for VAT, which is more strongly associated with diabetes and CVD risk factors than are other regions of adipose tissue. Therefore, the Chinese and South Asian participants possibly deposit more VAT per kilogram of total body fat than do the Europeans. These results are particularly important because of the increasing prevalence of obesity in Asian populations. In contrast, no difference was observed in the distribution of body fat between Aborigines and Europeans. Therefore, current anthropometric targets may be appropriate for Aborigines. Our conclusions are strengthened by the precise methods for the measurement of body fat distribution, the large sample size, and the wide range of body fat mass of our participants. In conclusion, those of Chinese and South Asian background have relatively more abdominal adipose tissue than do Europeans and this difference was more pronounced for VAT, whereas no difference was observed between the Aborigines and Europeans.

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