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Behavioral risk factors in relation to visceral adipose tissue deposition in adolescent females

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Abstract

Objective—To characterize visceral adipose tissue (VAT) and subcutaneous abdominal adipose tissue (SAAT) deposition in girls over the pubertal period and to assess the influence of behavioral risk factors on their deposition.

Participants—In total, 41 subjects of mean age of 13.5 years (standard deviation, SD = 0.9) were assessed at menarche. At 4 years after menarche, follow-up data were available for 24 of these subjects.

Methods—VAT and SAAT were measured by magnetic resonance imaging (MRI) and total body fat by isotopic dilution of ¹⁸O water at menarche and 4 years after menarche in a subset of subjects enrolled in a larger study of growth and development. Smoking, alcohol use, and physical activity were assessed by self-report at both time points. Smoking, alcohol use, and physical activity at 4 years after menarche were assessed in relation to concurrent VAT and SAAT, and to the 4-year change in VAT and SAAT.

Results—Smoking and alcohol use at 4 years after menarche was associated with the change in VAT over the 4-year period, before ($p < 0.03$ and $p < 0.02$, respectively), and after adjustment for total body fat ($p < 0.01$ and $p < 0.02$, respectively).

Conclusions—In addition to the established health risks, smoking and drinking, even at low levels, appear to be associated with increased VAT deposition in adolescent females.

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Keywords

Adolescence; alcohol use; smoking; visceral adipose tissue

Introduction

The significance of fat distribution in adults has been appreciated for more than 50 years (1); its importance in children is increasingly apparent. Several cross-sectional studies of youth have identified associations of central adiposity with elevated levels of cardiovascular disease risk factors (2,3), as well as markers of inflammation (4,5). Although the exact mechanism by which central adiposity confers these risks has not been established, visceral adipose tissue (VAT) is generally believed to be fundamental to the physiological response.

Studies in children suggest that the vast majority of excess fat deposited before puberty is stored subcutaneously (6-8). To our knowledge, only three longitudinal studies have examined changes in fat deposition over the pubertal period. Brambilla et al. (9) found no significant increase in VAT over the pubertal period in 16 obese children studied with magnetic resonance imaging (MRI) over a 4-year period. In contrast, Fox et al. (6) observed increases in VAT determined by MRI of 48.4% in girls from the ages of 11 to 13 years, while subcutaneous abdominal adipose tissue (SAAT) increased by 78.1% over the same period. Huang et al. (10) measured changes in VAT by a single-slice computed tomography (CT) scan over a 3- to 5-year period in white and African-American children with a mean age of 8 years at baseline, and found that VAT increased over time, although the rate of increase appeared to decline with age. A key limitation of these studies was the inclusion of subjects at different developmental stages.

Whereas several investigators have explored modifiable risk factors associated with central adiposity in adults, studies of these factors in youth are rare. Studies of adults generally rely on waist circumference or waist-to-hip ratio as indirect measures of central fat patterning. Cigarette smoking (11-15), alcohol use (16,17), and low levels of physical activity (13,18) have each been associated with a central pattern of fat distribution independent of body mass index (BMI) or other measures of general adiposity in adults. In one study of pre-pubertal children, Saelens et al. found that objectively measured physical activity was associated with lower levels of VAT, after control for total fatness (19). Other behavioral lifestyle factors associated with VAT and its deposition in the adolescent period have not been explored.

A subset of girls enrolled in the MIT Growth and Development Study had direct measures of VAT and SAAT by MRI at menarche and again 4 years later. We hypothesized that the same modifiable risk factors associated with central fat deposition in adults (smoking, alcohol use, physical activity) would have similar effects in adolescents, independent of total fatness.

Methods

Subjects

Subjects in this study were part of a larger cohort of adolescent females (n = 196) enrolled in the MIT Growth and Development study (20) conducted at the MIT Clinical Research Center. The criteria for enrollment were pre-menarcheal status and a triceps skinfold thickness of less than the 85th percentile for age and sex (21). As detailed elsewhere (20), healthy free-living subjects, aged 8–12 years, were followed annually until 4 years after menarche. At the time of their visit, a physician obtained a medical history and examined each subject to ensure that she was in good health. Menarche was determined prospectively. Subjects were asked to phone

when they got their first period, and also were asked at each annual visit if they had reached menarche.

Between 1995 and 1997, we recruited a subset of the original cohort for a study of VAT deposition.

Subjects were invited to enroll in the sub-study when they informed us that menarche had occurred, as long as it was within 5 months of the menarcheal event. Forty-four subjects were enrolled in the sub-study. Because the sub-study was initiated during follow-up of the full cohort, sub-study girls were about one-half year older at menarche than the original cohort (mean [standard deviation, SD] age: 13.4 [0.9] vs. 12.9 [1.1] years). The study protocol was approved by the Committee on the Use of Humans as Experimental Subjects at MIT and the Institutional Review Board of the New England Medical Center.

Study protocol

At menarche and at 4 years after menarche, participants were admitted to the Clinical Research Center at MIT for an overnight visit. After an overnight fast, subjects, wearing only a hospital gown and slippers, were weighed on a Seca scale (Seca Corporation, Hamburg, Germany) accurate to 0.1 kg. Height was measured to 0.1 cm with a wall-mounted stadiometer. Total body water was measured using ^{18}O water, as previously described (20).

Magnetic resonance imaging measures of VAT and SAAT

An abdominal scan was obtained by MRI at the New England Medical Center either on the afternoon of the overnight visit or the following morning. At menarche, all scans were obtained on a GE Signa Advantage 1.5 Tesla scanner (software version 5.4.2; General Electric, Fairfield, Connecticut). At 4 years after menarche, 3 subjects had images acquired on the GE machine and 21 had the scans acquired on a Siemens Symphony 1.5 Tesla scanner (software version A12; Iselin, New Jersey) because the hospital replaced their MRI instrument. At both time points, a total of twelve 1.0 cm thick axial images were obtained, with a 0.5 cm space between consecutive images. The first image was obtained 7.5 cm below the L4 vertebrae, and the scanned region extended to 10 cm above the L4 vertebra where the twelfth image was obtained. A T-1 weighted, spin-echo sequence with a 200-ms repetition time and a 16-ms echo time were used to obtain the MRI images. The change in instrumentation would not be expected to introduce error because the protocol was not altered. Once acquired, all MRI images were analyzed using specially designed computer software (Slice-O-Matic, TomoVision Inc, Montreal, Canada) to establish volumes of VAT and SAAT (22,23). Abdominal fat was calculated as the sum of VAT and SAAT.

Total body fat

Isotopic analyses for the assessment of total body fat (TBF) based on total body water were conducted at the USDA Human Nutrition Research Center at Tufts University, Boston, MA, as previously described (20).

Smoking and alcohol use

Smoking and alcohol use were assessed by self-report at annual follow-ups with three questions from the Centers for Disease Control and Prevention's Youth Risk Behavior Surveillance Survey (YRBSS) (24). The items queried the frequency (in categories) and number of cigarettes (by category) the child had smoked over the past 30 days. The number of cigarettes smoked per month was estimated as the product of the median frequency for each category and the median number of cigarettes smoked. A dichotomous smoking variable was then defined as <5 cigarettes per month vs. ≥ 5 cigarettes per month. The questionnaire also included a single

item from the YRBSS to assess the frequency of alcohol use. The item that queried the number of days over the past 30 days that alcohol was drunk (3) was dichotomized as alcohol use on ≤ 2 days vs. ≥ 3 or more days in the past month. The cut-off points for these variables were established after examination of the frequencies of these behaviors in the sample, to provide an adequate number of cases for further analysis.

Physical activity

Physical activity was considered as a predictor of central adiposity and also as a covariate. Participants completed questionnaire items that assessed their usual patterns of physical activity and were asked to recall, on an hour-by-hour basis, for a school day and weekend day their participation in five types of activities: sleeping or lying, sitting, standing, walking, and vigorous activity (exercising, playing, or being involved in sports). The average time spent daily in each activity was computed as a weighted average of the school day (5/7) and weekend day (2/7) reports. Information on the reliability of this assessment of physical activity has been described elsewhere (25).

An activity index was calculated from the sum of the average daily hours spent walking and in vigorous activity weighted by their intensity using a metabolic equivalent (MET), as previously detailed (26). The activity index showed predictive validity when compared with activity energy expenditure (by doubly-labeled water) adjusted for body weight ($r = 0.29$, $p < 0.001$) (26).

Sister pairs

There were four non-twin sister pairs in this study, and one pair of identical twins. Based on previous analyses in our cohort, we concluded that non-twin sisters could be retained without assumptions of independence being violated (26). One member of the pair of identical twins was selected at random, and excluded.

Statistical analyses

Descriptive statistics were calculated for body composition and behavioral risk factors at menarche and at 4 years after menarche. We used logarithmic transformations, when necessary, to improve the normality of skewed variables to better meet the assumptions of linear regression.

Difference scores were used to assess the change between menarche and 4 years after menarche for the outcome variables VAT and SAAT; the significance of the changes was determined by paired t-test. Spearman correlations were estimated to evaluate the associations among cigarette smoking, alcohol use, and physical activity. Four-year change in the proportion of subjects who smoked and used alcohol was assessed by chi-square.

We used simple and multiple linear regression analysis to estimate the association of cigarette smoking, alcohol use, and physical activity with VAT and SAAT at 4 years after menarche, and with the change in VAT and SAAT over the 4 years following menarche. These models were fitted with and without adjustment for total body fat. We considered these risk factors as covariates in multivariate regression models and retained them when they contributed to model fit, or changed the coefficient for the exposure variable by $>10\%$. Two-way interactions between smoking and alcohol use were evaluated. Model fit, operationalized as percentage of variance explained, was evaluated with model R^2 .

All statistical analyses were performed using SAS version 9.1 (SAS Institute, Cary, NC). Alpha was set at 0.05; borderline significance was declared when $0.05 < p < 0.10$.

Results

We obtained useable MRI scans at menarche for 41 subjects. Thirty-one (75.6%) subjects were white, 4 (9.8%) were African-American, 4 were Hispanic, 1 (2.4%) was Asian, and 1 was of other race/ethnicity. Of the 38 subjects who returned for a second MRI 4 years after menarche, 2 subjects could not participate because their navel rings could not be removed, 2 subjects had scans that could not be analyzed due to excessive movement, and the MRI scans of ten subjects were lost when the hospital replaced their scanner. Of the 24 subjects studied at 4 years after menarche, 20 (83.3%) were white, 2 (8.3%) were African-American, 1 (4.2%) was Asian and 1 (4.2%) subject was of other race/ethnicity. The 41 subjects originally enrolled and the 24 subjects followed had similar characteristics at baseline (Table I).

Among the 24 subjects with scans at both menarche and 4 years after menarche, both total fat mass and fat-free mass increased significantly at rates of approximately 1 kg/y. We also observed a significant increase in abdominal fat, SAAT and percentage body fat over the 4-year period, but the increase in VAT was of borderline significance (Table I, Figure 1). Although in absolute amounts, more fat was deposited subcutaneously than visceraally, we observed more variability, as reflected by the coefficient of variation (C_v), in VAT than in SAAT 4 years after menarche (86.9% vs. 39.1%, respectively). VAT and SAAT at four 4 years after menarche were highly correlated (Spearman $r = 0.82$, $p < 0.001$).

Cigarette smoking and alcohol use were infrequent at menarche. Of the 33 subjects who responded to the question at menarche, only 1 reported any smoking, and that subject's reported frequency was < 2 cigarettes per month. At 4 years after menarche smoking was more frequent: 16 (66.7%) subjects were categorized as smoking < 5 cigarettes per month and 8 (33.3%) subjects were categorized as smoking > 5 cigarettes per month. Similarly, at menarche only 3 of the 34 subjects who responded to the question reported that they were drinking on more than 3 days per month. At 4 years after menarche, of the 24 subjects studied, fifteen subjects (62.5%) were categorized as drinking on 2 or fewer days per month, and 9 (37.5%) subjects were categorized as drinking on 3 or more days per month. Twenty-three subjects had complete data with which to calculate an activity index. The correlation between total cigarettes smoked and frequency of alcohol use in the past 30 days was moderate (Spearman $r = 0.51$, $p < 0.02$). Seven of the 24 subjects (29.1%) were discordant for smoking and alcohol use. The correlations between the other independent variables were not statistically significant.

Cross-sectional associations at menarche

Very low levels of cigarette smoking and alcohol use at menarche precluded further analysis of cross-sectional associations at menarche. Physical activity at menarche was not significantly related to abdominal fat, VAT or SAAT at menarche in any crude or adjusted model (data not shown).

Cross-sectional associations at 4 years after menarche

Cross-sectional analyses of smoking and alcohol use in relation to total abdominal fat, and its sub-compartments, VAT and SAAT, at 4 years after menarche are presented in Table II. Smoking cigarettes was not significantly related to abdominal fat, VAT or SAAT. After adjustment for total fat at 4 years after menarche, however, smoking was related to VAT, but the association was of only borderline statistical significance ($p < 0.066$). With further adjustment for the confounding effects of physical activity level, smoking at 4 years after menarche was significantly associated with VAT ($p = 0.043$) and the regression model explained 69% of the variance in VAT. The association of alcohol use with VAT was of borderline significance in unadjusted analyses ($p = 0.083$), and with adjustment for total fat and physical activity index ($p = 0.091$). In models that included both smoking and alcohol use

variables in relation to VAT, neither was a significant predictor, nor was the interaction between smoking and alcohol use. Neither smoking nor alcohol use was significantly related to SAAT in crude or adjusted models, when considered separately or together in the same model.

Physical activity was not significantly related to abdominal fat, VAT or SAAT in any crude or adjusted model (data not shown).

Change in total abdominal fat, VAT and SAAT over the 4 years after menarche

Smoking and alcohol use at 4 years after menarche in relation to the change in abdominal fat and its sub-compartments are presented in Table III. Smoking was related to a 4-year change in abdominal fat, before (borderline statistical significance) and after adjustment for the change in total fat ($p = 0.089$ and $p = 0.048$, respectively). Alcohol use was also significantly related to change in abdominal fat before and after adjustment for change in total fat ($p = 0.030$ and $p = 0.043$, respectively). In a model that included both smoking and alcohol use in relation to change in abdominal fat, adjusting for change in total fat, neither variable was statistically significant.

Smoking was significantly related to a 4-year change in VAT, before and after adjustment for the change in total fat ($p = 0.034$ and $p = 0.004$, respectively). Alcohol use was also significantly related to change in VAT before and after adjustment for change in total fat ($p = 0.016$ and $p = 0.021$, respectively). Further adjustment for the confounding effects of physical activity level did not improve the model fit. In models that included both smoking and alcohol use variables, smoking remained a significant predictor of change in VAT ($p < 0.03$), with 60% of the variance in the change in VAT explained by the model. No further improvement in fit was observed with the addition of physical activity level.

Change in SAAT was unrelated to smoking or alcohol use in crude models. However, with adjustment for change in total fat, smoking and alcohol use at 4 years after menarche were each significant predictors in separate models of change in SAAT ($p = 0.013$ and $p = 0.053$, respectively). In a model that included both smoking and alcohol use in relation to change in SAAT and adjusted for change in total fat, neither variable was statistically significant.

Four-year change in physical activity was not significantly related to change in abdominal fat, VAT or SAAT in any crude or adjusted model (data not shown).

Discussion

Our goal was to characterize abdominal fat deposition and to evaluate the behavioral correlates of abdominal fat and its sub-compartments, VAT and SAAT, in subjects at menarche, at 4 years after menarche, and over the first 4 years following menarche. We found no evidence to suggest that physical activity was associated with abdominal fat deposition. Our findings do suggest that the risk behaviors of cigarette smoking and alcohol use may contribute to the deposition of abdominal fat over the pubertal period.

We observed significant increases in percent body fat, SAAT, and abdominal fat in subjects during the pubertal period. Although VAT increased over this period, the absolute changes were of borderline significance. Our findings of only small changes over the pubertal period are consistent with findings from a small study of 16 obese boys and girls in which significant increases were seen in SAAT, but not in VAT, over the 4 years following the start of puberty (mean[SD] age: 12.8 [1.4] years) (9). In a study that included only boys, VAT was found to increase more than SAAT over this period (6). These discrepant findings suggest that sex differences in VAT deposition may begin as early as puberty.

Several studies of adults using anthropometric measures to assess abdominal fat have suggested that abdominal fat deposition may be modified by behavioral factors, such as physical activity (13,18), alcohol use (16,17), and smoking (11-15). Smoking is generally associated with lower BMIs (27), presumably due to the appetite suppressant effects of nicotine (28). However, after adjustment for total fatness by BMI, higher waist circumferences or waist/hip ratios have been observed in smokers (11-15). Furthermore, a dose response association between pack-years of cigarette smoking and waist-to-hip ratio in a population sample of adults (29) suggests a direct effect of smoking on fat distribution. Because all of these studies relied on anthropometric measures to assess abdominal fat, none could distinguish between subcutaneous and visceral fat compartments.

More recently, the impact of behavioral risk factors has been explored using more direct measures of VAT. We (30) reported that adults who were moderately fit had less VAT than those who were less fit for a given BMI or level of total body fat. Saelens et al. studied 8-year-olds deemed at high risk for obesity by virtue of having a BMI >75th percentile (19). In their cross-sectional study, physical activity assessed by accelerometry was related to VAT, but not to SAAT. In a 4-month intervention trial that enrolled obese children, those who received physical training showed significantly smaller increases in VAT than did children in the control group (31). In our study, we did not identify a significant relationship between physical activity and VAT, SAAT, or abdominal fat or the 4-year changes in these fat depots at the time points examined. The absence of a significant relationship may reflect our small sample size, the imprecision of our self-reported physical activity measure, or both.

To our knowledge, the only published study to assess the influence of smoking on directly measured VAT was a cross-sectional study of Japanese-American men who had normal glucose tolerance, impaired glucose tolerance or diabetes. Smoking history was not related to VAT in this study (32). Our results suggest that smoking and alcohol each are related to deposition of VAT and SAAT in young females, but the extent to which these associations are specific is not established by our analyses. Smoking and drinking are moderately correlated ($r = 0.51$) and VAT and SAAT changes even more so ($r = 0.85$). Despite the high correlation of VAT and SAAT (0.82 in our study), distinct regulatory mechanisms are presumed to determine growth of each compartment (10). Although specific mechanisms have yet to be elucidated, the effects of tobacco smoke and alcohol on sex hormones and on adipocytes are suggested (12,33-35). Although it is not clear why effects on VAT (or on SAAT, if they are independent) would be apparent at the low levels of smoking and alcohol observed in our study, the period following menarche may be particularly sensitive to environmental stresses on sex hormones. Whereas the importance of central adiposity in relation to cardiovascular risk factors is increasingly well established (3,36,37), whether VAT *per se* is responsible for these health effects is less clear (38-40). With the exception of VAT effects on lipids outcomes, Gutin et al. failed to establish the independent effect of VAT on other cardiovascular risk factors (2). SAAT may be metabolically important in its own right, or may merely serve as a marker for VAT deposition during the pubertal period in girls.

Our findings should be interpreted cautiously for several reasons. First, although subjects were seen annually, physical activity, smoking and alcohol use were evaluated only at the 2 developmental time points, and smoking and drinking were too rare at menarche to study meaningfully. When we examined annual physical activity changes our conclusions were unchanged: physical activity level was not related to abdominal adiposity or its sub-compartments. When we examined the association between smoking and alcohol use in the prior year (3 years after menarche) in relation to abdominal fat at 4 years after menarche, associations were not statistically significant. We lack measures of abdominal fat in the years between menarche and 4 years after menarche, so this analysis is not complete. Second, the relationships we explored were based on smoking and drinking assessed at 4 years after

menarche, with a reference period of the 30 days prior to the study visit, thus the temporal separation of these risk factors was small. However, intermediate reports indicate that for three-quarters of these subjects these factors were present at visits prior to the visit at 4 years after menarche. For the remaining subjects, it seems unlikely that smoking and drinking occurred during the reporting period only. Third, despite our standard protocol and fixed parameters, the change in MRI instrumentation mid-way through the study may have introduced error. We do not believe the machine to machine differences would exceed the scan to scan variation over time with the same machine. Fourth, because the main study included only girls who were not overweight at enrollment, when their mean age was 10 years old, there were no very overweight girls in the sub-sample studied. Finally and importantly, our limited sample size restricted our ability to fully tease out independent effects of smoking and alcohol use, and precluded our assessment of potential modifying effects by race/ ethnicity.

Despite these limitations, our data gathered on a small cohort of girls over a precisely defined developmental period suggest that in addition to their established health risks, smoking and drinking, even at low levels, may be associated with increased VAT deposition in girls over the pubertal period. Our hypotheses were formulated *a priori* based on the adult literature. The relationships we identified appear to be specific; these factors were unrelated to percentage body fat. These associations, if confirmed, would have substantial public health significance, given the high rates of smoking and alcohol use in teens, especially smoking in adolescent girls.

Several areas of future research on this topic are warranted. Larger studies would provide a sample with more statistical power, to assess if smoking and alcohol use are independent, to allow for assessment of hormonal mediation of significant effects, as well as to permit stratification by any effect modifiers identified. More frequent measures of the smoking and drinking behaviors and fat deposition (e.g., from annual assessments) would permit better characterization of these behaviors over time, perhaps including the role of cessation on visceral adipose tissue. Studying this relationship in a cohort with higher prevalence of these behaviors might further elucidate the dose-response relationship between the behaviors and the outcome. Finally, it would be important to investigate these relationships in a cohort of girls and boys to explore differences by sex.

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Girl, age 12.5

Weight (kg)	41.1
Body fat (kg)	11.0
%Body Fat	26.7
VAT (L)	0.112

Girl, age 16.5

Weight (kg)	54.3
Body fat (kg)	16.6
%Body Fat	30.5
VAT (L)	0.216

Figure 1.
The magnetic resonance image of a representative subject at menarche and 4 years post menarche.

Table 1

Characteristics of the participants.

	At Baseline		At Baseline (follow-up sample)		Menarche+4 Years	
	Mean±SD	Median	Mean±SD	Median	Mean±SD	Median
<i>n</i>	41		24		24	
Age (years)	13.5±0.9	13.6	13.6±1.0	13.7	17.5±1.0 [†]	17.7
Age at menarche (years)	13.4±0.9	13.4	13.4±1.0	13.5	-	-
Fat-free mass (kg)	37.9±4.6	38.1	37.7±4.9	38.4	42.0±4.8 [†]	42.1
Fat (kg)	11.6±3.2	11.0	10.8±2.4	10.40	15.4±3.4 [†]	15.5
% body fat	23.3±4.2	22.3	22.3±3.3	21.9	26.6±4.2 [†]	26.5
Abdominal fat (L)	1.56±0.81	1.29	1.43±0.65	1.23	1.85±0.75 [*]	1.80
VAT (L)	0.104±0.05	0.09	0.11±0.06	0.08	0.16±0.139 [‡]	0.117
SAAT (L)	1.45±0.77	1.22	1.33±0.60	1.14	1.69±0.66 [*]	1.69
Cigarettes smoked past 30 days	0.045±0.26	0	0.07±0.32	0	1.81±2.50	0
Frequency alcohol use (days)	0.382±0.92	0	0.55±1.10	0	1.46±0.1.25	1
Physical activity index	13.8±6.6	12.8	13.0±5.95	12.3	9.34±5.56	8.24

VAT: visceral adipose tissue, SAAT: subcutaneous adipose tissue.

Values are means.

* p <0.01

[†] p <0.001,

[‡] p =0.066 for paired comparison from menarche to 4 years after menarche (n = 24).

Table II

Relationship between smoking and alcohol use and abdominal fat, VAT, and SAAT at 4 years after menarche.

Variable	Crude n = 24			Adjusted for total body fat only n = 24			Adjusted for total body fat and physical activity index n = 23		
	Estimate (SE)	p-value	Model R ²	Estimate (SE)	p-value	Model R ²	Estimate (SE)	p-value	Model R ²
Abdominal fat									
Smoking	0.128 (0.331)	0.701	0.01	0.036 (0.155)	0.819	0.79	$\frac{.7}{.7}$	-	-
Alcohol use	0.344 (0.316)	0.287	0.05	0.032 (0.153)	0.618	0.80	$\frac{.7}{.7}$	-	-
Smoking	-0.001 (0.356)	0.999	0.05	0.009 (0.170)	0.958	0.80	$\frac{.7}{.7}$	-	-
Alcohol use	0.344 (0.347)	0.332		0.074 (0.168)	0.663		-	-	
InVAT									
Smoking	0.392 (0.269)	0.159	0.09	0.325 (0.167)	0.066	0.66	0.382 (0.177)	0.043	0.69
Alcohol use	0.464 (0.255)	0.083	0.13	0.276 (0.170)	0.119	0.65	0.317 (0.178)	0.091	0.67
Smoking	0.251 (0.283)	0.385	0.16	0.258 (0.179)	0.312	0.68	0.314 (0.182)	0.102	0.72
Alcohol use	0.374 (0.276)	0.189		0.184 (0.177)	0.164		0.226 (0.178)	0.220	
SAAT									
Smoking	0.024 (0.291)	0.935	0.00	-0.055 (0.146)	0.710	0.76	0.021 (0.153)	0.892	0.79
Alcohol use	0.236 (0.279)	0.406	0.03	0.006 (0.146)	0.967	0.76	0.076 (0.148)	0.616	0.79
Smoking	-0.074 (0.314)	0.815	0.03	-0.066 (0.161)	0.165	0.76	0.257 (0.178)	0.164	0.79
Alcohol use	0.262 (0.305)	0.400		0.030 (0.159)	0.312		0.184 (0.177)	0.312	

InVAT: natural logarithm of visceral adipose tissue; SAAT: subcutaneous adipose tissue.

Subjects were categorized as those who smoked <5 cigarettes/mo vs. ≥ 5 cigarettes/mo.Subjects were categorized as those who consumed alcohol ≤ 2 days/mo vs. ≥ 3 days/mo.

Addition of the physical activity index did not improve model fit.

Table III

Relationship between smoking and drinking alcohol and change in abdominal fat, VAT and SAAT over the 4 years after menarche (n = 24).

Variable	Crude			Adjusted for the change in total body fat		
	Estimate (SE)	p-value	Model R ²	Estimate (SE)	p-value	Model R ²
Abdominal fat change						
Smoking	0.458 (0.257)	0.089	0.13	0.402 (0.192)	0.048	0.54
Alcohol use	0.557 (0.239)	0.030	0.20	0.407 (0.189)	0.043	0.54
Smoking	0.286 (0.263)	0.289	0.24	0.292 (0.199)	0.159	0.59
Alcohol use	0.455 (0.256)	0.090		0.303 (0.197)	0.140	
InVAT change						
Smoking	0.054 (0.024)	0.034	0.19	0.059 (0.018)	0.004	0.55
Alcohol use	0.059 (0.022)	0.016	0.24	0.048 (0.019)	0.021	0.47
Smoking	0.037 (0.024)	0.142	0.31	0.047 (0.019)	0.022	0.60
Alcohol use	0.046 (0.023)	0.066		0.030 (0.019)	0.121	
SAAT change						
Smoking	0.339 (0.218)	0.135	0.01	0.395 (0.145)	0.013	0.62
Alcohol use	0.236 (0.279)	0.406	0.03	0.312 (0.152)	0.053	0.57
Smoking	0.205 (0.227)	0.376	0.20	0.321 (0.153)	0.228	0.65
Alcohol use	0.356 (0.221)	0.121		0.191 (0.153)	0.252	

InVAT: natural logarithm of visceral adipose tissue; SAAT: subcutaneous adipose tissue.

Subjects were categorized as those who smoked <5 cigarettes/mo or ≥5 cigarettes/mo at exit.

Subjects were categorized as those who consumed alcohol ≤2 days/mo or ≥3 days/mo at exit.