International Journal of Obesity (2007) 31, 622–629

www.nature.com/ijo

PEDIATRIC HIGHLIGHT

General and visceral adiposity in black and white adolescents and their relation with reported physical activity and diet

IS Stallmann-Jorgensen[1], B Gutin[1], JL Hatfield-Laube[1], MC Humphries[1], MH Johnson[2] and P Barbeau[1]

[1]*Department of Pediatrics, Medical College of Georgia, Georgia Prevention Institute, Augusta, GA, USA and* [2]*Department of Biostatistics, Medical College of Georgia, Augusta, GA, USA*

Background: Excess body fat accumulation may begin in youth and is linked with increased risk of cardiovascular disease. Examination of physical activity (PA) and diet behaviours predictive of adiposity may help target efforts to reduce chronic disease risk.
Objective: We hypothesized that energy intake (EI) from fat, vigorous PA (VPA), and their interaction would predict body fat percentage (%BF) and visceral adipose tissue (VAT) in youth and that sedentary behaviours and intake of dairy, fruit, vegetable and whole grain foods would be related to adiposity.
Design: A cross-sectional, observational study of reported PA and diet behaviours and objective adiposity measures.
Subjects: Six-hundred sixty-one healthy black and white adolescents aged 14–18 years.
Measurements: Diet by 24-h recalls using Nutrition Data Systems for Research (Minneapolis, MN, USA), VPA by previous day physical activity recalls (PAR), and %BF with dual-energy X-ray absorptiometry. VAT by magnetic resonance imaging for 434 subjects.
Results: Reported EI and VPA were positively correlated with each other and were negative predictors of %BF. Time spent watching television or movies and %EI from protein were positive predictors of %BF. Adjusted for EI, none of the independent variables predictive of %BF retained their significance. %BF and VAT were highly correlated ($r = 0.73$, $P < 0.0001$). EI was the sole and negative predictor of VAT.
Conclusions: Higher energy 'throughput', not energy restriction, characterize leaner youths. Youths should be advised to engage in VPA so that they can eat sufficient calories to obtain the nutrients required for optimal health while remaining lean.
International Journal of Obesity (2007) **31,** 622–629. doi:10.1038/sj.ijo.0803587

Keywords: adiposity; visceral adipose tissue; diet; energy intake; physical activity

Introduction

Adolescence is a period of rapid growth and development during which youth undergo marked changes in lean and fat mass.[1] Physical activity (PA) and diet are two aspects of lifestyle that interact with genetic and hormonal factors to determine body composition.[2] Findings from the Bogalusa Heart Study showed that the atherosclerotic process starts in youth, and that high body mass index (BMI) is a risk factor.[3] Thus, excess body fat is considered an intermediary in the causal pathway from health to development of cardiovascular disease (CVD).[4] Excess visceral adipose tissue (VAT) may be especially deleterious to cardiovascular health [5] and central fatness may increase risk for the metabolic syndrome.[6] The increased rates of adolescent overweight and at risk for overweight in the US are well documented,[7] but indications that there may be greater gains in abdominal than in general adiposity [8] may not be as widely appreciated. If this is true, implications for the future health of our youth may be more serious than suggested by increased rates of overweight status alone. Use of BMI is a convenient and low cost method for assessment of overweight, but it does not distinguish between the contributions of muscle and fat mass and has been shown to misclassify some individuals in regard to adiposity status.[9] Likewise, waist circumference (WC) lacks precision for assessment of VAT because WC

Correspondence: Dr P Barbeau, Medical College of Georgia, 1499 Walton Way, HS1755, Augusta, GA 30912, USA.
E-mail: pbarbeau@mcg.edu
Received 12 September 2006; revised 11 December 2006; accepted 31 January 2007

comprises both subcutaneous abdominal adipose tissue and VAT.[10] Our study utilized dual-energy X-ray absorptiometry (DXA) and magnetic resonance imaging (MRI) to obtain the currently best possible estimates of percentage of body fat (%BF) and VAT.

We tested the hypotheses that (1) lifestyle factors such as high percentage of kilojoules as dietary fat (%FAT),[11–13] low vigorous PA (VPA),[2,14] and their interaction would be associated with higher %BF and VAT in black and white adolescents, (2) sedentary behaviours such as television and/or movie viewing (TV/MOVIE) and use of computer and/or videogames (COMP/VGAME) [15] would be associated with greater adiposity, and (3) intake of foods considered beneficial for health, preventive of CVD,[16] and linked with lower BMI or maintenance of a normal weight (i.e. dairy foods, [17,18] fruits and vegetables,[19,20] and whole grain foods [21,22]), would be associated with lower adiposity. The negative effect of trans fatty acid (TFA) intake on heart health has been documented.[23] We included percentage of energy intake (EI) from TFA (%TFA) in our analyses to test their effect on %BF and/or VAT. By including black and white boys and girls, we wanted to determine whether PA and diet interacted with race and sex in their influence on adiposity.

Subjects and methods

Subjects

Youths 14–18 years of age were recruited from high schools in the Augusta, Georgia area. Demographic information obtained from the school systems was used to select schools that enrolled both black and white students. After receiving approval from the county superintendents and school principals, flyers were distributed to all students in the selected schools. Subjects were asked to self-identify their ethnicity. Subjects who identified themselves as being white/Caucasian or black/African American were eligible for the study. There are relatively few youths from other racial/ethnic groups in the Augusta area, and they were excluded from the project. Interested youths and parents signed consent forms in accordance with the procedures of the Human Assurance Committee at the Medical College of Georgia. The youths were apparently healthy, had no contraindications to any of the study procedures and were taking no medications that might influence the results. For the primary outcome variable of %BF, we had measurements on 661 youths.

Anthropometrics and body composition

Height and weight were obtained according to standard procedures, using a stadiometer and calibrated electronic scale. These measurements were used to derive BMI (kg/m^2) for determination of subject characteristics.

Dual-energy X-ray absorptiometry

%BF was measured using DXA (Hologic QDR-4500W, software version 6.0, Waltham, MA, USA). We have previously found DXA to provide reliable values for %BF at our institute. In this project, we performed repeat measurements using our new QDR-4500W machine with 219 adolescents and found the intra-class correlation for %BF to be 0.99. For some subjects, DXA values were not available from the Hologic QDR-4500W model, but were available only from the Hologic QDR-1000W model. For these individuals, %BF values were derived from prediction equations based on 284 youths who were assessed on both instruments, using linear regression; race, sex and QDR-1000W measurement. The multiple R^2 value for %BF was 0.99.[24]

Magnetic resonance imaging

VAT measurement was conducted as described previously.[25] In brief, VAT was determined using a 1.5 T MRI system. VAT was measured in the Department of Radiology on equipment dedicated to patient care. We obtained VAT measures on those subjects who underwent testing on days when the MRI equipment was available for our research study. Thus, we have VAT measurements on 434 subjects.

Diet assessment

Diet was measured with individual, non-consecutive, 24-h recalls that covered the period from midnight to midnight for the previous day. The first two recalls were conducted in person at our institute, whereas the remaining interviews were conducted by phone weekly, with all recalls completed within a period of 12 weeks. We sought to obtain seven recalls from each participant, one for each day of the week. Only youths who provided at least four recalls ($n = 661$) were included in the analyses for this paper. A total of 52% of the youths had recalls for all 7 days. The dietary and PA recalls were conducted concurrently by a trained dietitian or dietetic intern. The dietary recalls used the Nutrition Data System for Research (NDS-R),[26,27] which utilizes a multiple-pass, computer-assisted interview approach. To minimize subject fatigue with the recall process, which might negatively impact reliability, interviewers were trained in conducting the recalls until these could be routinely completed in 30 min or less. Subjects were not interviewed if they had been ill on the recall day or when the recall day fell on a major holiday. To minimize the potential for undereating during the time frame for 24-h recalls, youths were blinded to the telephone recall schedule.

Food grouping

Foods in the NDS-R Food and Nutrient Database have been grouped into nine major food categories: fruits, vegetables, grains, sweets, miscellaneous, fats, beverages, meats and dairy/nondairy alternatives. These categories have been further divided into 165 subcategories to analyze for the number of servings consumed of certain types of foods. Serving sizes were based on recommendations from Dietary Guidelines for Americans 2000, or on FDA label serving sizes. For our analyses, we examined EI, macronutrient intake distribution as percentage of energy from carbohydrate (%CHO), protein (%PRO) and fat (%FAT). We also examined intake of the saturated (%SFA), monounsaturated (%MFA), polyunsaturated (%PFA) and %TFA subclasses of fat, and of EI-adjusted dairy (DAIRY), fruit (FRUIT), vegetable (VEG) and whole grain food servings (WGFD).

Physical activity assessment
We compiled a list of activities in which adolescents would typically participate, and assigned metabolic equivalent values to the activities based on the compendium of physical activities.[28] Self-reported PA was quantified using our modified version of the previous day PA recall (PAR), which records activities in 30-min time blocks for a full 24-h period (midnight to midnight).[29] Subjects were asked to recall the activities concurrently with each 24-h diet recall, and state at which level of effort (light, moderate or vigorous) they engaged in each activity. Activities were then re-categorized based on a combination of the activity and the level of effort; for example, light running was assigned a higher metabolic equivalent (MET) level than light walking. In the final categorization, light PA was <3 METs, moderate PA (MPA) was 3–6 METs and VPA was >6 METs. We were mainly interested in the daily mean number of hours spent in MPA and VPA.

Statistical analyses
All variables were checked for normality of distribution, and appropriate transformations applied when necessary. %BF and VAT were the measures of body composition used as the dependent variables in these analyses. The independent variables of interest were measures of PA (MPA, VPA, TV/MOVIE and COMP/VGAME) and measures of eating behaviour (EI, macronutrient distribution and food servings adjusted for EI – servings/4186 kJ). A 2×2 (race $\times$ sex) analysis of covariance, adjusting for age, was used to assess race–sex differences for all variables. Pearson correlations were used to examine bivariate associations among variables.

The base model for each dependent variable included age, race, sex, and the interaction between race and sex. For each dependent variable, each independent variable was entered into this base model as a covariate along with its interaction with race and sex. The amount of variance explained by each independent variable was examined. Those effects that were significant in each of these models were then included as covariates in the full model for each dependent variable. Statistical significance was set at $\alpha=0.01$. SAS version 9.1.3 was used for all analyses.

Results

Participant characteristics
Subject characteristics are presented in Table 1, which shows the significant differences for the different race and sex groups. A detailed discussion of race–sex differences is beyond the scope of this paper; they are presented to show the nature of the adjustments that needed to be made in investigating the relations of the independent variables with measures of adiposity.

Correlations between the variables
In the interest of parsimony, only those independent variables that were shown to be predictors of %BF or VAT are discussed. Of those, only EI and VPA ($r=0.29$, $P<0.0001$) were significantly and positively associated, but no relationship was found among the others. For the subset of subjects ($n=434$) with both %BF and VAT assessments, these measures were highly correlated (r $=0.73$, $P<0.0001$, data not shown).

Determinants of %BF
Table 2 shows the regression analysis for %BF. Only independent variables that explained significant proportions of the variance in %BF are shown in the table. After adjustment for the base model, VPA was negatively related to %BF, but MPA was not. Average number of hours per day spent watching TV/MOVIE was positively related to %BF, but no significant relationship was found between %BF and time spent with COMP/VGAME use.

EI was a negative predictor of %BF, accounting for about 2% of the variance in %BF. Among the macronutrients, %PRO was a positive predictor of %BF, explaining 0.6% of the variance. For the subclasses of fat, there was an interaction between %TFA and race, such that %TFA was a positive predictor of %BF accounting for 0.7% of the variance in whites, but no such relationship was evident in blacks. When the significant predictor variables were considered simultaneously in the model, none of the predictor variables retained their significance after adjustment for EI (data not shown).

The macronutrients %FAT, %CHO, %SFA, %MFA, %PFA and the intakes of DAIRY, FRUIT, VEG and WGFD were also explored, but no significant associations with %BF were identified.

Relations of VPA categories with other independent variables and %BF
Table 3 shows means (s.d.) for MPA, TV/MOVIE, EI and %BF for three categories of VPA, adjusted for age, sex and race. There were no significant differences between hours of MPA for either VPA category. There was no linear relationship between the amount of TV/MOVIE and the categories of

Table 1 Subject characteristics[a]

	Whites		*Blacks*		*Significance*[b]
	Boys (n = *169*)	*Girls* (n = *170*)	*Boys* (n = *163*)	*Girls* (n = *159*)	
Age (years)	16.2 (1.2)	16.0 (1.1)	16.0 (1.2)	16.3 (1.2)	Race*, sex[c]
Height (cm)	174 (7.3)	163 (5.4)	174 (8.0)	163 (6.1)	Increases with age[d] M > F[d]
Weight (kg)	68.6 (14.6)	58.4 (12.0)	70.8 (17.2)	66.4 (17.7)	Increases with age[e] B > W[d], M > F[d]
BMI (kg/m$^{2)}$	22.5 (4.3)	21.9 (4.1)	23.4 (5.2)	25.0 (6.2)	Race*, sex[c]
%BF	19.2 (8.3)	29.2 (7.2)	17.3 (9.1)	30.5 (8.2)	F > M[d]
VAT[f] (cm^3)	103.1 (66.9) *n* = 106	103.6 (55.9) *n* = 106	76.3 (58.2) *n* = 132	116.5 (79.4) *n* = 90	Race*, sex[e]
MPA (h/day)	1.28 (1.04)	1.07 (0.75)	1.12 (0.79)	1.06 (0.83)	Increases with age[d]
VPA (h/day)	0.78 (0.69)	0.43 (0.48)	0.95 (0.72)	0.27 (0.50)	Race*, sex[e]
VPA, n (%)					
None	23 (14)	48 (28)	17 (10)	73 (46)	
> 0 to < 1 h/day	91 (54)	100 (59)	68 (42)	73 (46)	
⩾1 h/day	55 (33)	22 (13)	78 (48)	13 (8)	
COMP/VGAME, h/day	0.97 (1.29)	0.56 (0.57)	0.78 (0.73)	0.37 (0.61)	W > B[c], M > F[d]
TV/MOVIE (h/day)	2.17 (1.26)	1.70 (1.19)	3.25 (1.69)	2.85 (1.50)	B > W[d], M > F[d]
EI (kJ)	9741 (2436)	7259 (2064)	8853 (2424)	6823 (2013)	W > B[e], M > F[d]
EI (kcal)	2327 (582)	1734 (493)	2115 (579)	1630 (481)	
%CHO	53.2 (6.2)	55.3 (6.4)	52.5 (5.5)	53.3 (5.9)	W > B[c], F > M[c]
%FAT	32.9 (4.8)	32.4 (5.1)	34.5 (4.2)	34.2 (4.5)	B > W[d]
%PRO	14.6 (2.8)	13.6 (2.8)	13.8 (2.1)	13.5 (2.8)	M > F[c]
%SFA	11.5 (2.0)	11.3 (2.4)	11.9 (1.8)	11.5 (1.8)	NS
%MFA	12.7 (2.1)	12.4 (2.2)	13.5 (1.9)	13.4 (2.0)	B > W[d]
%TFA	2.7 (0.8)	2.8 (0.8)	2.9 (0.8)	3.0 (0.8)	B > W[c]
%PFA	6.0 (1.7)	6.2 (1.4)	6.2 (1.4)	6.5 (1.6)	NS
FRUIT, servings/ 4186 kJ (1000 kcal)	0.34 (0.34)	0.47 (0.48)	0.37 (0.33)	0.44 (0.38)	F > M[e]
VEG, servings/ 4186 kJ (1000 kcal)	0.71 (0.39)	0.89 (0.65)	0.57 (0.31)	0.66 (0.37)	W > B[d], F > M[e]
WGFD, servings/ 4186 kJ (1000 kcal)	0.50 (0.45)	0.60 (0.46)	0.33 (0.34)	0.34 (0.39)	W > B[d]
DAIRY, servings/ 4186 kJ (1000 kcal)	1.05 (0.49)	1.05 (0.48)	0.77 (0.37)	0.71 (0.39)	W > B[d]

[a]Means (s.d.) are given for each race–sex group unless otherwise noted. [b]Groups were compared by ANOVA for age and by ANCOVA (with age as the covariate) for the other variables. [c]$P \leqslant 0.01$. [d]$P \leqslant 0.0001$. [e]$P \leqslant 0.001$. [f]Log transformed before analysis. Abbreviations: BMI, body mass index; MPA, moderate physical activity; VPA, vigorous physical activity; COMP/VGAME, computer and/or video game use; TV/MOVIE, television and/or movie viewing; EI, energy intake; %CHO, percentage of energy from carbohydrate; %FAT, percentage of energy from fat; %PRO, percentage of energy from protein; %SFA, percentage of energy from saturated fatty acids; %MFA, percentage of energy from monounsaturated fatty acids; %TFA, percentage of energy from trans fatty acids; %PFA, percentage of energy from polyunsaturated fatty acids; FRUIT, servings of fruit; VEG, servings of vegetables; WGFD, servings of whole grain foods; DAIRY, servings of dairy foods; %BF, percentage body fat; VAT, visceral adipose tissue; s.d., standard deviation; M, males; F, females; W, whites; B, blacks; NS, not significant.

VPA. For EI, there was a significant difference between subjects in the no VPA and those in the highest amount of VPA category, with EI positively related to VPA. For %BF, there was a statistically significant difference between those who reported no VPA and those with the most reported VPA, with VPA inversely related to %BF.

Table 4 shows that after adjustment for EI, there was no statistically significant difference in %BF between the three categories of VPA, but there was a trend towards lower %BF with higher amounts of VPA.

Determinants of VAT

Table 5 shows that for log VAT, the only significant behavioural predictor was EI, which was negatively related to VAT.

Discussion

Our study examined reported PA and diet behaviours of black and white adolescents. We identified behavioural determinants of %BF and VAT, and determined how demographic characteristics influenced these relationships. Discussion of racial and sex differences in behavioural factors are beyond the scope for this paper, but we identified a number of differences (Table 1).

Physical activity factors

VPA was negatively related to %BF, but did not maintain significance when controlling for EI. Thus, in these black and

Table 2 Behavioural predictors of percentage body fat[a]

	Base model	*VPA*	*TV/MOVIE*	*EI*	*%PRO*	*%TFA*
Age	−0.2 (0.3)	—	—	—	—	—
Race[b]	−1.2 (0.9)	—	—	—	—	—
Sex[c]	−13.1 (0.9)[d]	F > M[d]	F > M[d]	F > M[d]	F > M[d]	F > M[d]
Race*, sex	2.8 (1.3)	—	—	—	—	—
Predictor[e]	—	Negative[f]	Positive[f]	Negative[d]	Positive[f]	—
Predictor*, race[b,e]	—	—	—	—	—	Positive for W[f]
Model R^2	0.333	0.340	0.340	0.354	0.339	0.340

[a]Model parameter estimates (s.e.) and model R^2 values ($n = 661$). [b]Black race is reference group. [c]Female sex is reference group. [d]$P \leqslant 0.0001$. [e]Negative and positive indicate the direction of association between the predictor variable and percentage body fat. [f]$P \leqslant 0.01$. Abbreviations: VPA, vigorous physical activity; TV/MOVIE, television and/or movie viewing; EI, energy intake; %PRO, percentage of energy from protein; %TFA, percentage of energy from trans fatty acid; M, male; F, female, W, white; B, black; s.e., standard error.

Table 3 Moderate physical activity, television and/or movie watching, energy intake and percentage body fat for three categories of VPA[a]

	N	*MPA, h*	*TV/MOVIE, h*[b]	*EI, kJ ((kcal))*[b]	*%BF*[b]
VPA					
None	161	1.09 (0.82)	2.48 (1.47)[a,b]	7296 (2206)[a]	28.6 (9.5)[a]
>0 to <1 h/d	332	1.17 (0.91)	2.53 (1.62)[a]	8091 (2440)[a,b]	24.1 (9.6)[a,b]
⩾1 h/d	168	1.10 (0.80)	2.39 (1.43)[b]	9217 (2645)[b]	19.4 (9.7)[b]
P-value[c]		NS	$P \leqslant 0.01$	$P \leqslant 0.01$	$P \leqslant 0.01$

Abbreviations: MPA, moderate physical activity; TV/MOVIE, television and/or movie viewing; EI, energy intake; %BF, percentage body fat; VPA, vigorous physical activity; s.d., standard deviation. [a]All values are means (s.d.). [b]Means followed by the same letter are not statistically different from each other. [c]The effect after adjustment for age, race and sex.

Table 4 Body fat percentage by category of VPA[a]

	%BF
VPA	
None	25.6 (0.7)
>0 to <1 h/day	23.8 (0.4)
⩾1 h/day	23.0 (0.7)
P-value[b]	0.024

Abbreviations: %BF, percentage body fat; VPA, vigorous physical activity. [a]Least-squares means (s.e.) after adjusting for energy intake. [b]The effect after adjustment for age, race, sex and energy intake.

Table 5 Relation of energy intake with visceral adipose tissue (VAT), adjusting for the influence of age, race and sex[a]

	Base model	*EI*
Age	0.008 (0.011)	—
Race[b]	−0.018 (0.038)[c]	B > W[c]
Sex[d]	−0.19 (0.04)[e]	F > M[c]
Race*, sex	0.17 (0.05)[c]	BM < WM, WF, BF[f]
Predictor	—	Negative[f,g]
Predictor*, sex[d]	—	—
Model R[b]	0.089	0.111

Abbreviations: VAT, log-transformed visceral adipose tissue; EI, energy intake; B, black; W, white; M, male; F, female; s.e. standard error. [a]Model parameter estimates (s.e.) and model R^2 values ($n = 434$). [b]Black race is reference group. [c]$P \leqslant 0.01$. [d]Female sex is reference group. [e]$P \leqslant 0.0001$. [f]$P \leqslant 0.001$. [g]Negative relationship between EI and VAT.

white youths, VPA and EI contributed somewhat independent information about %BF. A reason for the negative relation of EI with %BF could be that higher EI intake is a 'marker' for an active lifestyle with both higher EI and energy expenditure (EE). VPA increases EE, and may also be contributing independently to the lower %BF through a temporary increase in nutrient oxidation. Resting EE has been shown to be elevated post-exercise in young men;[30] this mechanism would favour a less positive energy balance (EB). Enhanced fat oxidation from activity diminishes fat available for storage into body depots,[30,31] and especially VPA increases oxidation of certain fats.[32] Our data showed no relation of MPA with %BF; perhaps the amount of MPA was insufficient to affect %BF. Of the sedentary behaviours examined, only TV/MOVIE positively predicted part of the variance in %BF. TV viewing and video use have been shown to be related to BMI.[33] Sedentary youths may be at risk for higher %BF because their low EE could place them in a more positive EB than that required for normal growth. Although TV/MOVIE and COMP/VGAME demand similarly low EE, TV viewing may encourage greater EI through the influence of TV food advertising,[34] but COMP/VGAME would not provide the same exposure. Once adjusted for EI and VPA, TV/MOVIE failed to predict an independent proportion of %BF. Combining these two slightly different activities (TV and MOVIE watching) into one factor may have weakened any relationship with %BF. TV viewing has been shown to be a risk for increased %BF in children followed over time, even adjusting for EI and PA. Perhaps the longitudinal study design was able to capture the cumulative affect of even small excesses in EB on %BF.[15] Youths with no reported VPA did not watch significantly more TV/MOVIE than those in the intermediate or highest category of VPA. Youths in all VPA categories exceeded the guideline of a maximum of 1–2 h of TV per day,[35] suggesting that even considerable TV/MOVIE watching did not necessarily preclude VPA participation.

Dietary factors

Reported EI was the strongest negative predictor of %BF, accounting for about 2% of the variance. While perhaps counterintuitive, weak or no relations of EI and general adiposity have been reported,[20] suggesting that a positive EB is mainly the result of a low EE.[36] Inverse relations between EI and adiposity have been shown by others,[37] lending support to the results of this study.

Underreporting of EI in youth is a phenomenon which could in part explain conflicting results between studies of diet and adiposity, and could obscure existing relationships. Subjects' age and adiposity status[38] have been noted to influence reporting accuracy, but not all studies that include subjects likely to underreport have confirmed this behaviour.[39] Without proven methods for accurately identifying underreporters in paediatric studies,[40] the exclusion of suspected underreporters may introduce unknown biases and eliminate subjects of greatest interest to the study questions.[41] We included all subjects with 4- or more 24-h recalls and PARs for these analyses, recognizing that we measured reported diet and PA behaviours.

TFA research has focused mainly on their effect on CVD risk;[23] the effect of TFAs on adiposity is not established with certainty. Our results indicate that black adolescents consume a greater %TFA than whites, yet %TFA was related to %BF only in whites. The reason for this is unclear. Possible explanations include racial differences in intake of specific TFA isomers, which may affect body composition differently, and genetic differences between blacks and whites in TFA metabolism. The %TFA and %BF relation likely involves factors not studied in this investigation. %PRO was a positive predictor of %BF. Protein intake at 2 years has been found to be related to body fatness at 8 years,[42] but little is known about relations between %PRO and %BF in adolescents. More research is needed to confirm this result. We were not able to show that %FAT and %BF were related in these youths. Studies of fat intake and adiposity in children have shown both nonexistent[13] and positive relations.[11] The difficulty of estimating fat intake, use of different body composition assessment methods and study designs might explain the varied results. Likely, %FAT is not a main influence on %BF and other factors are more important.[43] Dairy foods have been shown to be negatively related to body fat[17] with racial differences in the strength of the effect. We were not able to show that intake of DAIRY, FRUIT, VEG and WGFD were associated with adiposity in these black and white adolescents, although this has been reported in other studies.[20,21,44,45] Intake of these foods averaged about half the servings of fruit and vegetables, half to three-fourth the servings of dairy foods, and a third or less the whole grain food servings currently recommended.[46] Intakes at these levels may not have been sufficient to show relations with %BF in these black and white adolescents.

VAT was highly correlated with %BF, so similar results could be expected. Only EI was associated with VAT. To our knowledge no large studies of VAT in adolescents have been reported with which to compare our results. The benefit of high energy throughput appears to apply to VAT as is the case with %BF.

Our findings that both EI and VPA were inversely related to %BF makes sense in the context of overall EB. VPA increases EE, and increased post-exercise fat oxidation reduces energy available for storage as fat. The inverse %BF and VPA relation is supported by other results from our institute in which adolescents' VPA was measured with accelerometers.[2]

In summary, our hypothesis that VPA would predict %BF was confirmed, but %FAT, DAIRY, FRUIT, VEG and WGFD showed no relation with %BF. We found that white adolescents with a greater %TFA, or black and white youth with higher %PRO intake, could be at some risk for higher %BF. An examination of the %TFA by race interaction for differences in intakes of specific TFA isomers might explain the interaction. Our results do not suggest that restricting EI is desirable to help youths develop a healthy body composition. Youth should be encouraged to limit TV/MOVIE watching and include VPA daily, so that they can ingest high levels of energy from a variety of nutrient-dense foods to derive the benefit of the nutrients, while remaining lean.

Acknowledgements

No author has a financial or personal conflict of interest related to this research or its source of funding from the National Institute of Health (HL64157). Drs Gutin and Barbeau participated in the design of the study and preparation of the paper. Dr Gutin and Ms Stallmannn-Jorgensen had primary roles in preparing the paper. Ms Johnson performed the statistical analyses and participated in the preparation of the paper. Ms Hatfield-Laube, Ms Stallmann-Jorgensen and Mr Humphries played major roles in the implementation of the study and data collection. We appreciate the efforts of Ms Elizabeth Stewart in data management, research assistants for data collection, schools that cooperated in subject recruitment, and the youths who served as subjects for this study.

References

1 Rogol AD, Roemmich JN, Clark PA. Growth at puberty. *J Adolesc Health* 2002; **31**: 192–200.
2 Gutin B, Yin Z, Humphries MC, Barbeau P. Relations of moderate and vigorous physical activity to fitness and fatness in adolescents. *Am J Clin Nutr* 2005; **81**: 746–750.
3 Berenson GS, Srinivasan SR, Bao W, Newman III WP, Tracy RE, Wattigney WA. Association between multiple cardiovascular risk factors and atherosclerosis in children and young adults. The Bogalusa Heart Study. *N Engl J Med* 1998; **338**: 1650–1656.
4 Goodman E, Dolan LM, Morrison JA, Daniels SR. Factor analysis of clustered cardiovascular risks in adolescence: obesity is the predominant correlate of risk among youth. *Circulation* 2005; **111**: 1970–1977.
5 Matsuzawa Y, Shimomura I, Nakamura T, Keno Y, Kotani K, Tokunaga K. Pathophysiology and pathogenesis of visceral fat obesity. *Obes Res* 1995; **3** (Suppl 2): 187S–194S.
6 Ferreira I, Twisk JW, van Mechelen W, Kemper HC, Stehouwer CD. Development of fatness, fitness, and lifestyle from adolescence to the age of 36 years: determinants of the metabolic syndrome in young adults: the Amsterdam growth and health longitudinal study. *Arch Intern Med* 2005; **165**: 42–48.
7 Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States, 1999–2004. *JAMA* 2006; **295**: 1549–1555.
8 McCarthy HD, Ellis SM, Cole TJ. Central overweight and obesity in British youth aged 11–16 years: cross sectional surveys of waist circumference. *Br Med J* 2003; **326**: 624.
9 Neovius MG, Linne YM, Barkeling BS, Rossner SO. Sensitivity and specificity of classification systems for fatness in adolescents. *Am J Clin Nutr* 2004; **80**: 597–603.
10 Kuk JL, Lee S, Heymsfield SB, Ross R. Waist circumference and abdominal adipose tissue distribution: influence of age and sex. *Am J Clin Nutr* 2005; **81**: 1330–1334.
11 McGloin AF, Livingstone MB, Greene LC, Webb SE, Gibson JM, Jebb SA *et al*. Energy and fat intake in obese and lean children at varying risk of obesity. *Int J Obes Relat Metab Disord* 2002; **26**: 200–207.
12 Garaulet M, Martinez A, Victoria F, Perez-Llamas F, Ortega RM, Zamora S. Difference in dietary intake and activity level between normal-weight and overweight or obese adolescents. *J Pediatr Gastroenterol Nutr* 2000; **30**: 253–258.
13 Atkin LM, Davies PS. Diet composition and body composition in preschool children. *Am J Clin Nutr* 2000; **72**: 15–21.
14 Patrick K, Norman GJ, Calfas KJ, Sallis JF, Zabinski MF, Rupp J. Diet, physical activity, and sedentary behaviors as risk factors for overweight in adolescence. *Arch Pediatr Adolesc Med* 2004; **158**: 385–390.
15 Proctor MH, Moore LL, Gao D, Cupples LA, Bradlee ML, Hood MY. Television viewing and change in body fat from preschool to early adolescence: The Framingham Children's Study. *Int J Obes Relat Metab Disord* 2003; **27**: 827–833.
16 Gidding SS, Dennison BA, Birch LL, Daniels SR, Gilman MW, Lichtenstein AH *et al*. Dietary recommendations for children and adolescents: a guide for practitioners: consensus statement from the American Heart Association. *Circulation* 2005; **112**: 2061–2075.
17 Novotny R, Daida YG, Acharya S, Grove JS, Vogt TM. Dairy intake is associated with lower body fat and soda intake with greater weight in adolescent girls. *J Nutr* 2004; **134**: 1905–1909.
18 Skinner JD, Bounds W, Carruth BR, Ziegler P. Longitudinal calcium intake is negatively related to children's body fat indexes. *J Am Diet Assoc* 2003; **103**: 1626–1631.
19 Nystrom AA, Schmitz KH, Perry CL, Lytle LA, Neumark-Sztainer D. The relationship of weight-related perceptions, goals, and behaviors with fruit and vegetable consumption in young adolescents. *Prev Med* 2005; **40**: 203–208.
20 Cullen KW, Baranowski T, Klesges LM, Watson K, Sherwood NE, Story M *et al*. Anthropometric, parental, and psychosocial correlates of dietary intake of African-American girls. *Obes Res* 2004; **12** (Suppl): 20S–31S.
21 Steffen LM, Jacobs Jr DR, Murtaugh MA, Moran A, Steinberger J, Hong CP *et al*. Whole grain intake is associated with lower body mass and greater insulin sensitivity among adolescents. *Am J Epidemiol* 2003; **158**: 243–250.
22 Ludwig DS, Pereira MA, Kroenke CH, Hilner JE, Van Horn L, Slattery ML *et al*. Dietary fiber, weight gain, and cardiovascular disease risk factors in young adults. *JAMA* 1999; **282**: 1539–1546.
23 Mozaffarian D, Katan MB, Ascherio A, Stampfer MJ, Willett WC. Trans fatty acids and cardiovascular disease. *N Engl J Med* 2006; **354**: 1601–1613.
24 Litaker MS, Barbeau P, Humphries MC, Gutin B. Comparison of Hologic QDR-1000/W and 4500W DXA scanners in 13- to 18-year olds. *Obes Res* 2003; **11**: 1545–1552.
25 Owens S, Gutin B, Barbeau P, Litaker M, Allison J, Humphries M *et al*. Visceral adipose tissue and markers of the insulin resistance syndrome in obese black and white teenagers. *Obes Res* 2000; **8**: 287–293.
26 Schakel SF, Sievert YA, Buzzard IM. Sources of data for developing and maintaining a nutrient database. *J Am Diet Assoc* 1988; **88**: 1268–1271.
27 Schakel S. Maintaining a nutrient database in a changing marketplace: Keeping pace with changes in food products – a research perspective. *Food Comp Anal* 2001; **14**: 315–322.
28 Ainsworth BE, Haskell WL, Leon AS, Jacobs Jr DR, Montoye HJ, Sallis JF *et al*. Compendium of physical activities: classification of energy costs of human physical activities. *Med Sci Sports Exerc* 1993; **25**: 71–80.
29 Weston AT, Petosa R, Pate RR. Validation of an instrument for measurement of physical activity in youth. *Med Sci Sports Exerc* 1997; **29**: 138–143.
30 Jamurtas AZ, Koutedakis Y, Paschalis V, Tofas T, Yfanti C, Tsiokanos A *et al*. The effects of a single bout of exercise on resting energy expenditure and respiratory exchange ratio. *Eur J Appl Physiol* 2004; **92**: 393–398.
31 Hansen K, Shriver T, Schoeller D. The effects of exercise on the storage and oxidation of dietary fat. *Sports Med* 2005; **35**: 363–373.
32 Votruba SB, Atkinson RL, Schoeller DA. Prior exercise increases dietary oleate, but not palmitate oxidation. *Obes Res* 2003; **11**: 1509–1518.
33 Utter J, Neumark-Sztainer D, Jeffery R, Story M. Couch potatoes or french fries: are sedentary behaviors associated with body mass index, physical activity, and dietary behaviors among adolescents? *J Am Diet Assoc* 2003; **103**: 1298–1305.
34 Wiecha JL, Peterson KE, Ludwig DS, Kim J, Sobol A, Gortmaker SL. When children eat what they watch: impact of television viewing on dietary intake in youth. *Arch Pediatr Adolesc Med* 2006; **160**: 436–442.
35 American Academy of Pediatrics. Children, adolescents, and television. *Pediatrics* 2001; **107**: 423–426.
36 Guillaume M, Lapidus L, Lambert A. Obesity and nutrition in children. The Belgian Luxembourg Child Study IV. *Eur J Clin Nutr* 1998; **52**: 323–328.
37 Kimm SY, Barton BA, Obarzanek E, McMahon RP, Sabry ZI, Waclawiw MA *et al*. Racial divergence in adiposity during adolescence: The NHLBI Growth and Health Study. *Pediatrics* 2001; **107**: E34.
38 Livingstone MB, Robson PJ, Wallace JM. Issues in dietary intake assessment of children and adolescents. *Br J Nutr* 2004; **92** (Suppl 2): S213–S222.
39 Gillis LJ, Kennedy LC, Gillis AM, Bar-Or O. Relationship between juvenile obesity, dietary energy and fat intake and physical activity. *Int J Obes Relat Metab Disord* 2002; **26**: 458–463.
40 Livingstone MB, Robson PJ, Black AE, Coward WA, Wallace JM, McKinley MC *et al*. An evaluation of the sensitivity and

specificity of energy expenditure measured by heart rate and the Goldberg cut-off for energy intake: basal metabolic rate for identifying mis-reporting of energy intake by adults and children: a retrospective analysis. *Eur J Clin Nutr* 2003; **57**: 455–463.

41 Livingstone MB, Black AE. Markers of the validity of reported energy intake. *J Nutr* 2003; **133** (Suppl 3): 895S–920S.

42 Rolland-Cachera MF, Deheeger M, Akrout M, Bellisle F. Influence of macronutrients on adiposity development: a follow up study of nutrition and growth from 10 months to 8 years of age. *Int J Obes Relat Metab Disord* 1995; **19**: 573–578.

43 Willett WC, Leibel RL. Dietary fat is not a major determinant of body fat. *Am J Med* 2002; **113** (Suppl 9B): 47S–59S.

44 Baric IC, Cvjetic S, Satalic Z. Dietary intakes among Croatian schoolchildren and adolescents. *Nutr Health* 2001; **15**: 127–138.

45 Slavin JL. Dietary fiber and body weight. *Nutrition* 2005; **21**: 411–418.

46 US Department of Health and Human Services, US Department of Agriculture. *Dietary Guidelines for Americans, 2005*. US Department of Health and Human Services, US Department of Agriculture: Washington DC, 2005.