

Effects of familial predisposition to obesity on energy expenditure in multiethnic prepubertal girls¹⁻⁴

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ABSTRACT

Background: The prevalence of childhood obesity is increasing and the causes of this are unknown.

Objective: The objective of this study was to determine whether energy expenditure (EE), measured by 24-h calorimetry and doubly labeled water, differed in normal-weight-for-height, multiethnic prepubertal girls with or without a familial predisposition to obesity.

Design: Normal-weight, prepubertal white ($n = 52$), African American ($n = 30$), and Hispanic ($n = 19$) girls with a mean (\pm SD) age of 8.5 ± 0.4 y were studied according to parental leanness and overweight or obesity. The girls were grouped according to whether they had 2 lean parents ($n = 30$), 2 obese parents ($n = 27$), or 1 lean and 1 obese parent ($n = 44$). Basal metabolic rate (BMR), sleeping metabolic rate (SMR), 24-h EE, respiratory quotient, heart rate, and activity were measured by 24-h room calorimetry; free-living total EE (TEE), activity-related EE (AEE), and physical activity level were measured by doubly labeled water. EE was standardized by fat-free mass (FFM).

Results: There were no significant differences among familial groups in weight, height, fat mass, FFM, or percentage body fat. African American girls had a higher FFM than did white or Hispanic girls ($P < 0.05$). BMR, SMR, 24-h EE, respiratory quotient, heart rate, and activity levels were not significantly different among familial groups. Additionally, there were no significant familial group differences in TEE, AEE, or physical activity level. However, BMR, SMR, and TEE were lower in African American girls than in white girls ($P < 0.05$).

Conclusion: There was no significant difference in EE between normal-weight, multiethnic prepubertal girls predisposed to obesity and those not predisposed to obesity. *Am J Clin Nutr* 2000;71:893-900.

KEY WORDS Obesity, prepubertal girls, energy metabolism, body composition, calorimetry, doubly labeled water, energy expenditure, physical activity level, parental leanness, parental obesity

INTRODUCTION

Obesity is an increasingly prevalent health problem in children and adolescents (1). Previous studies of biological (2) and adoptive (3) children and twins (4) showed the heritability of obesity. Parental obesity more than doubles the risk of adult obesity in

children aged <10 y (5). Although epidemiologic studies have provided indicators as to which children are at risk of becoming obese, the etiology of childhood obesity is still unknown. Obesity is caused by an imbalance of energy intake relative to energy expenditure (EE). The relative contributions of energy intake and EE to the increased prevalence of childhood obesity are unclear. Furthermore, to differentiate the causes of obesity from the consequences, children need to be studied before obesity develops.

Several well-designed studies of children at risk of becoming obese by virtue of parental obesity, however, yielded conflicting results. Roberts et al (6) reported that total EE (TEE) was lower in 18 infants with overweight mothers than in infants with underweight mothers; however, these results were not substantiated by 2 recent studies of infants of obese mothers (7, 8). Griffiths and Payne (9) found that TEE as measured by heart rate monitoring and resting EE (REE) were lower in 20 overweight children aged 4-5 y with 1 obese parent or 2 normal-weight parents. Both studies indicated that the differences in TEE were partially accounted for by a lower activity-related EE (AEE). Wurmser et al (10) reported that preadolescent girls with 2 obese parents had the lowest REE. In contrast, Goran et al (11) reported no significant differences in TEE and AEE as measured by doubly labeled water in 73 normal-weight and overweight boys and girls predisposed to obesity. Conflicting evidence on the contribution of basal-energy-requiring processes, physical activity, and TEE to the cause of childhood obesity has yet to be resolved.

The present study was designed to comprehensively evaluate EE in prepubertal girls with a familial predisposition to obesity

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who were of normal weight at the time of entry into the study. Highly accurate room respiration calorimeters were used to assess 24-h EE, REE, sleeping EE (SEE), and AEE to help resolve conflicting REE data. The doubly labeled water method was used to assess free-living TEE to address the role of physical activity in childhood obesity. Specifically, the aims of the study were to determine whether the following factors differed in girls with or without a familial predisposition to obesity: 1) 24-h EE and substrate oxidation, 2) basal metabolic rate (BMR) and sleeping metabolic rate (SMR), 3) EE during exercise at 2 intensities, 4) EE of specific physical activities, 5) spontaneous activity, and 6) free-living TEE and AEE. Our overall hypothesis was that EE, measured by 24-h calorimetry and doubly labeled water, would be lower in normal-weight-for-height, multiethnic prepubertal girls with a familial predisposition to obesity than in those without such a predisposition.

SUBJECTS AND METHODS

Design

The overall design was a 2-y longitudinal study examining predictors of weight and fat gain in prepubertal girls with or without a familial predisposition to obesity. Baseline measures of EE are reported in this article. These girls will be observed yearly for measurements of body composition and physical activity. Because the longitudinal study was designed to study the antecedents of obesity, only nonobese girls were enrolled at 8 y of age.

Subjects

Healthy prepubertal girls ($n = 101$) were recruited from the local Houston area. All of the girls were aged 8–9 y and were at Tanner stage 1 as confirmed by their mothers, who were shown drawings of the different Tanner stages. The girls were screened and had to have a percentage body fat within the range of 12–30% to be included in the study. Girls who did not meet the criterion for body fatness were excluded from the study. The girls were grouped according to parental characteristics of leanness and overweight or obesity as follows: 2 lean parents (LN group; $n = 30$), 1 lean and 1 overweight or obese parent (LNOB group; $n = 44$), or 2 overweight or obese parents (OB group; $n = 27$). Body mass index (BMI; in kg/m^2) was used to define lean (BMI < 25) and overweight or obese (BMI > 28) (12). The age of onset of obesity in the parents was self-identified; 46% identified childhood onset (0–19 y of age) and 55% identified adult onset (> 19 y). Recruitment and screening procedures were used to balance the sizes of the 3 familial groups. The ethnicity of each child was established by self-report by the parents. Girls with cardiovascular disease, anemia, diabetes, significant renal or hepatic disease, hypothyroidism, or musculoskeletal problems were excluded. All girls and their parents provided written, informed consent to participate in the study, which was approved by the Institutional Review Board for Human Subject Research for Baylor College of Medicine and Affiliated Hospitals.

Study protocol

All procedures were completed at the US Department of Agriculture Agricultural Research Service Children's Nutrition Research Center. Body composition was measured by dual-energy X-ray absorptiometry on the first visit. The heights and weights of both parents were measured to enable each girl to be placed in the appropriate familial group. On a later date, the girls

were admitted to the Metabolic Research Unit at 0800 after a 12-h overnight fast and received a peak oxygen uptake ($\dot{V}\text{O}_{2\text{peak}}$) test (data not reported here), breakfast, instructions on how to operate all necessary equipment in the calorimeter, and lunch; they completed a 24-h stay in the calorimeter, received doubly labeled water after exiting the calorimeter, and collected urine samples over the next 13 d.

Body composition

Body weights of the girls and their parents were measured to the nearest 0.1 kg with a digital balance (Scale-Tronix, Dallas) and heights were measured to the nearest 1 cm with a stadiometer (Holtain Ltd, Crymych, United Kingdom). BMI was calculated and body composition was then assessed by dual-energy X-ray absorptiometry (QDR 2000; Hologic, Madison, WI). Dual-energy X-ray absorptiometry allows total and regional lean tissue mass, fat tissue mass (FM), and bone mineral content to be measured. Fat-free mass (FFM) was defined as the sum of lean tissue mass and bone mineral content.

Energy intake in the calorimeter

During the calorimetric tests, the girls were fed a balanced diet designed to account for $\approx 55\%$ carbohydrate intake, $\approx 30\%$ fat intake, and $\approx 15\%$ protein intake. The girls' energy intakes were calculated as predicted BMR based on the age-appropriate Schofield (13) equation ($13.34 \times \text{weight}$) + 692.6, multiplied by a factor of 1.6 to account for activity while in the calorimeter. All food not consumed was reweighed. The total energy intake and percentages of energy from carbohydrate, protein, and fat were analyzed by using the Minnesota Database System (version 2.8 NDS, Minneapolis).

Calorimetric measurements

Measurements of 24-h EE were taken in a room respiration calorimeter. The design characteristics and calibration of the calorimeter were described in detail previously (14). The rooms were equipped with a bed, a desk, a chair, a lamp, a toilet, a sink, a television and videocassette recorder, video games, a motion sensor, and a telephone. Oxygen consumption ($\dot{V}\text{O}_2$) and carbon dioxide production ($\dot{V}\text{CO}_2$) were measured continuously by a paramagnetic dioxide gas analyzer (Oxymat 5E; Siemens, Karlsruhe, Germany) and a nondispersive infrared carbon dioxide analyzer (Ultramat 5E; Siemens). The calorimeter was calibrated before each test. Three electrodes were applied to each girl's skin and heart rate was recorded by telemetry at 1-min intervals (DS-3000; Fukuda Denshi, Tokyo). Activity was measured by a radar detector (Doppler microwave sensor D9/50; Microwave Sensors, Ann Arbor, MI). Two 20-min exercise sessions were conducted on stationary bicycles (CombiCycle Ex80; COMBI Co Ltd, Tokyo) at workloads approximating 40% and 60% of each girl's $\dot{V}\text{O}_{2\text{peak}}$.

The staff monitored 30-min sessions of the following activities: doing schoolwork while seated at a desk, doing arts and crafts, playing video games, and lying down watching television or a movie. Each girl was awakened the next morning at 0630 after a 12-h overnight fast, asked to void, and returned to sleep. Twenty minutes later, the girl was awakened, the BMR measurement began, and the girl was assessed for 40 min. The girl was monitored visually and with the activity sensor and was required to lie still for the entire measurement period. For a BMR measurement to be considered valid, average activity counts during the period had to be < 50 counts/min. The girls collected their urine



TABLE 1

Body composition in prepubertal girls with 2 lean parents (LN group), 1 obese and 1 lean parent (LNOB group), or 2 obese parents (OB group)¹

	LN group (n = 30)	LNOB group (n = 44)	OB group (n = 27)
Weight (kg)	27.2 ± 3.6	28.0 ± 4.6	29.6 ± 4.6
Height (cm)	130.4 ± 5.3	130.0 ± 5.6	130.9 ± 5.6
BMI (kg/m ²)	15.9 ± 1.5	16.5 ± 1.8	17.2 ± 1.4 ²
Fat-free mass (kg)	21.0 ± 2.5	21.2 ± 2.6	22.0 ± 3.1
Fat mass (kg)	5.5 ± 1.5	6.1 ± 2.3	6.9 ± 1.8
Percentage body fat (%)	20.6 ± 3.8	21.7 ± 5.4	23.6 ± 3.9

¹ $\bar{x} \pm$ SD.

²Significantly different from LN group, $P < 0.05$ (ANOVA).

for the entire 24-h period. Urine samples were digested with a Kjeltab catalyst (Thompson and Caper, Ltd, Cheshire, United Kingdom) and analyzed by colorimetry. BMR, SMR, and 24-h EE and substrate oxidation were calculated from the $\dot{V}O_2$, $\dot{V}CO_2$, and urinary nitrogen excretion data according to the method of Livesey and Elia (15). Measures of EE were expressed as kJ/min or kJ/d. Errors from 24-h infusions for the calorimeters were $-0.34 \pm 1.24\%$ for $\dot{V}O_2$ and $0.11 \pm 0.98\%$ for $\dot{V}CO_2$ (14).

Doubly labeled water

TEE over the 14-d period was calculated from the fractional turnover rates of deuterium and ¹⁸O after oral ingestion of 100 mg ²H₂O/kg and 125 mg ¹⁸O/kg as water (16). Isotope dilution spaces were used to compute total body water. Baseline urine samples were collected from each girl in the calorimeter. After the girl left the calorimeter, she was given the oral dose of doubly labeled water. Subsequently, one daily urine sample was collected by each girl at home for the next 13 d. The deuterium and ¹⁸O abundances of the urine samples were measured by gas isotope ratio mass spectrometry (GIRMS). An online carbon dioxide–water exchange system was used to prepare deuterium and ¹⁸O samples for oxygen isotopic analysis as C¹⁸O₂. A delta E GIRMS instruments (Finnigan MAT, San Jose, CA) was used exclusively for deuterium isotopic measurements in body water. After reduction of the physiologic fluid for hydrogen gas by using the zinc reduction method (17, 18), 2 GIRMS instruments (VG Sira 12 and VG Prism; VG Isogas Limited, Cheshire, United Kingdom) were used for ¹⁸O measurements of body water by carbon dioxide gas exchange (17). Carbon dioxide production (rCO_2 ; in mol/d) was calculated from the dilution spaces and fractional turnover rates of deuterium and ¹⁸O by using the multipoint slope-intercept method of calculation and the equation

$$rCO_2 = 0.4584 \times (k_o \times N_o - k_h \times N_h) \quad (1)$$

where k_o and k_h are the fractional turnover rates of ¹⁸O and deuterium, respectively, and N_o and N_h are the isotope dilution spaces for ¹⁸O and deuterium, respectively. Fractionated water losses were calculated from estimated ventilatory volume and body surface area, both expressed as functions of carbon dioxide production (19). TEE was calculated by using the Weir equation (20). Assuming that 10% of TEE was due to the thermic effect of food, AEE was calculated as TEE – [BMR + 0.1 TEE]. Physical activity level (PAL) was calculated as TEE/BMR.

Statistical analysis

Data are presented as means. MICROSOFT ACCESS for WINDOWS 95 (version 7.0; Microsoft Corporation, Seattle) was

used for database management. Statistical analyses were performed by using MINITAB for WINDOWS (version 12.2; Minitab, Inc, State College, PA), with significance set at $P < 0.05$. To test whether girls with one lean parent and one obese parent differed according to whether maternal ($n = 23$) or paternal ($n = 21$) obesity was involved, t tests were completed on all variables. No significant differences were observed for any of the variables; therefore, the girls were combined into one group (the LNOB group). Because the present study was part of a longitudinal study, sample size was based on weight gain. Allowing for a 10% attrition rate, we determined that the sample size of 36 in each group would be sufficient to detect a difference of 0.7 SD in outcome variables between girls with lean or obese parents with a 0.05 type 1 error and a power of 0.80. Initially, chi-square analysis was used to determine the ethnic balance among the groups. All variables were then tested for familial obesity effects (LN, LNOB, and OB) and ethnic effects (white, African American, and Hispanic) by using analysis of variance. The model included the grouping factors for familial obesity and ethnicity and the interaction between the 2. For heart rate, respiratory quotient, and EE, analysis of covariance was used. The covariates included weight, or FFM and FM. Multiple comparisons were made by using Tukey's method.

RESULTS

Subject characteristics

A total of 52 white, 30 African American, and 19 Hispanic girls were enrolled in the study. There were no significant differences in mean age (8.5 ± 0.4 y) or ethnic distribution among the LN, LNOB, and OB familial groups.

Weight, height, BMI, and body-composition data for the 3 familial groups are shown in **Table 1**. Weight, height, FFM, FM, and percentage body fat were not significantly different among the familial groups; however, there was a significant difference in BMI among the groups: the LN group had a significantly lower mean BMI than did the OB group. The BMI for the siblings of the children in the study were in the ranges of 13.7–24.6, 11.2–34.5, and 12.8–30.8 for the LN, LNOB, and OB groups, respectively. Ethnic effects were observed for weight, height, and FFM ($P < 0.05$). The African American girls weighed significantly more and had a significantly greater FFM than did the white girls and were significantly taller and had a significantly greater FFM than did the Hispanic girls.

By design, the body size and composition of the girls' parents differed. The mothers' weights and BMIs were significantly different among all 3 familial groups (both $P < 0.001$). The BMIs of the mothers of girls in the LN, LNOB, and OB groups were 22.5 ± 1.8 , 28.5 ± 7.7 , and 34.7 ± 7.1 , respectively. Percentage body fat was also significantly different among all groups of mothers ($32.5 \pm 5.6\%$ in mothers of girls in the LN group, $39.6 \pm 8.5\%$ in mothers of girls in the LNOB group, and $46.3 \pm 6.9\%$ in mothers of girls in the OB group; $P < 0.0001$), as were FM and FFM ($P < 0.0001$).

The weights of the girls' fathers were significantly different only between the LN and OB groups ($P < 0.01$); however, the BMI of the fathers was significantly different among all familial groups (24.6 ± 3.3 in the LN group, 27.1 ± 4.5 in the LNOB group, and 31.1 ± 3.1 in the OB group; $P < 0.0001$). The fathers' percentage body fat was also significantly different among the

TABLE 2

Energy expenditure (EE) measured by 24-h respiration calorimetry in prepubertal girls with 2 lean parents (LN group), 1 obese and 1 lean parent (LNOB group), or 2 obese parents (OB group)¹

	LN group (n = 30)	LNOB group (n = 44)	OB group (n = 27)
Basal			
Heart rate (beats/min)	85 ± 10 (71–104)	86 ± 10 (69–111)	87 ± 10 (68–110)
Activity (counts/min)	22 ± 18 (0–68)	24 ± 16 (1–56)	26 ± 20 (0–72)
Respiratory quotient	0.83 ± 0.04 (0.73–0.92)	0.82 ± 0.03 (0.77–0.89)	0.81 ± 0.04 (0.72–0.88)
EE			
(kJ/min)	3.113 ± 0.339 (2.594–3.837)	3.163 ± 0.293 (2.460–3.799)	3.268 ± 0.318 (2.799–4.113)
(kJ/d)	4481 ± 490 (3736–5523)	4552 ± 418 (3544–5473)	4707 ± 456 (4033–5920)
Sleep			
Heart rate (beats/min)	75 ± 8 (63–91)	77 ± 8 (59–95)	77 ± 8 (62–93)
Activity (counts/min)	14 ± 19 (4–106)	11 ± 6 (4–34)	11 ± 4 (5–20)
Respiratory quotient	0.84 ± 0.02 (0.81–0.89)	0.85 ± 0.03 (0.78–0.89)	0.84 ± 0.02 (0.77–0.87)
EE (kJ/min)	2.732 ± 0.251 (2.142–3.117)	2.812 ± 0.251 (2.222–3.318)	2.849 ± 0.301 (2.155–3.452)
Sound sleeping EE (kJ/min)	2.510 ± 0.239 (1.879–2.887)	2.615 ± 0.402 (1.946–4.644)	2.586 ± 0.272 (1.967–3.142)
24-h			
Heart rate (beats/min)	90 ± 7 (75–102)	90 ± 7 (71–111)	92 ± 8 (73–104)
Activity (counts/min)	225 ± 59 (149–416)	210 ± 32 (143–273)	231 ± 41 (152–304)
Nonprotein respiratory quotient	0.88 ± 0.02 (0.83–0.93)	0.88 ± 0.03 (0.82–0.94)	0.87 ± 0.02 (0.81–0.91)
EE			
(kJ/min)	4.180 ± 0.414 (3.280–5.088)	4.217 ± 0.414 (3.414–5.372)	4.397 ± 0.464 (3.339–5.268)
(kJ/d)	5975 ± 590 (4694–7268)	6058 ± 619 (4879–7686)	6284 ± 657 (4770–7510)
Activity-related EE (kJ/d)	757 ± 393 (0–1293)	720 ± 477 (–213 to 2096)	925 ± 548 (–38 to 2134)
Physical activity level	1.35 ± 0.10 (1.14–1.48)	1.34 ± 0.11 (1.16–1.62)	1.36 ± 0.11 (1.19–1.58)

¹ $\bar{x} \pm SD$; range in parentheses.

familial groups (18.9 ± 5.6% in fathers of girls in the LN group, 24.0 ± 8.6% in fathers of girls in the LNOB group, and 28.7 ± 5.2% in fathers of girls in the OB group; $P < 0.0001$), as was FM ($P < 0.0001$). The FFM of the fathers was not significantly different among familial groups.

Respiration calorimetric measurements

Energy intake

In the LN, LNOB, and OB groups, respectively, the percentages of energy from protein (14.6 ± 0.9%, 14.8 ± 1.1%, and 14.5 ± 0.8%), carbohydrate (55.7 ± 2.0%, 55.4 ± 2.6%, and 55.7 ± 1.8%), and fat (31.1 ± 1.6%, 31.4 ± 1.5%, and 31.2 ± 1.4%) while the girls were in the calorimeter did not differ significantly. Energy intake was not significantly different from 24-h EE in the calorimeter. Energy intakes (6159 ± 628, 6142 ± 820, and 6167 ± 925 kJ/d) and energy balance (138 ± 678 kJ, 71 ± 703 kJ, and –172 ± 841 kJ) also did not differ significantly among the LN, LNOB, and OB groups, respectively.

Energy expenditure

Mean heart rate, activity, respiratory quotient, and EE for the basal, sleep, and 24-h periods while the girls were in the calorimeter, by familial group, are shown in **Table 2**. Adjusted for weight (or FM and FFM), there were no significant differences in heart rate, activity, respiratory quotient, or EE for the basal, sleep, and 24-h periods among familial groups. Adjusted for FFM and FM, the mean (±SE) BMRs were 4422 ± 95, 4552 ± 55, and 4619 ± 75 kJ/d in the LN, LNOB, and OB groups, respectively. For the sleep period, these adjusted values were 2.705 ± 0.041, 2.818 ± 0.024, and 2.793 ± 0.031 kJ/min in the LN, LNOB, and OB groups, respectively. Adjusted for FFM,

FM, and energy balance, 24-h EE was also not significantly different among familial groups (6084 ± 117, 6067 ± 92, and 6243 ± 113 kJ/d in the LN, LNOB, and OB groups, respectively). AEE and activity (counts/min as recorded by the motion sensor) and PAL while in the calorimeter (24-h EE/BMR) were also not significantly different among the LN, LNOB, and OB groups.

There were no significant differences among the ethnic groups in heart rate, activity, or respiratory quotient during the basal, sleep, or 24-h periods. However, ethnic differences were observed for BMR and SMR when these were adjusted for weight ($P < 0.05$) or FM and FFM ($P < 0.02$). BMR and SMR were significantly lower in the African American girls (4448 ± 70 kJ/d and 2.73 ± 0.03 kJ/min, respectively) than in the white girls (4678 ± 53 kJ/d and 2.83 ± 0.022 kJ/min, respectively) when adjusted for weight ($P < 0.03$) or FM and FFM ($P < 0.01$). Twenty-four-hour EE was also significantly different among ethnic groups when adjusted for FM and FFM ($P < 0.02$) and approached significance when adjusted for weight ($P = 0.07$). The Hispanic girls had a significantly greater 24-h EE than did the African American girls ($P < 0.01$). AEE and PAL in the calorimeter were also significantly different among ethnic groups ($P < 0.05$); Hispanic girls had a higher AEE ($P = 0.05$) and PAL ($P < 0.03$) than did white girls.

The relation between 24-h EE and FFM gave an r value of 0.80 ($P < 0.0001$) for the entire sample. The correlations between FFM and 24-h EE for the familial groups were $r = 0.76$ for the LN group, $r = 0.77$ for the LNOB group, and $r = 0.84$ for the OB group (all $P < 0.005$, **Figure 1**). There were no significant differences among familial groups in the slopes of FFM versus 24-h EE.

Heart rate, activity, respiratory quotient, and EE during the various activities are presented in **Table 3**. There were no significant differences in heart rate and respiratory quotient during

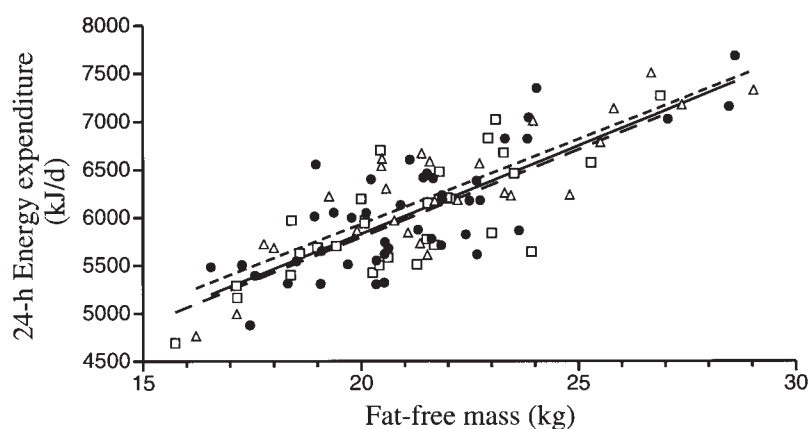


FIGURE 1. Relation between 24-h energy expenditure measured by respiration calorimetry and fat-free mass in prepubertal girls with 2 lean parents (\square), 1 lean and 1 obese parent (\bullet), or 2 obese parents (\triangle).

any of the activities (playing video games, watching television or a movie, doing arts and crafts, doing schoolwork, and exercising) among the familial groups. Activity counts were not significantly different among familial groups during video games, arts and crafts, or schoolwork. Workloads during the exercise sessions did not differ significantly by familial group. Heart rate, respiratory quotient, and activity counts during the video games, television or a movie, arts and crafts, schoolwork, and exercise did not differ among white, African American, and Hispanic girls. EE was not significantly different by familial group during video games, television or a movie, and arts and crafts. Significant familial group effects were observed for EE during schoolwork when covaried for FM and FFM but not when covaried for weight. The OB group had a higher EE than did the LNOB group while doing schoolwork. EE during exercise at both intensities was not significantly different among the LN, LNOB, and OB groups. There were no ethnic effects for EE during the video games, television or a movie, or exercise.

Relations between body composition (FFM and percentage body fat) and EE during the specific activities in the calorimeter were examined. The positive correlations (r) between FFM and EE during television or a movie, during video games, during arts and crafts, during schoolwork, during exercise at a low intensity, and during exercise at a high intensity were 0.64, 0.52, 0.69, 0.65, 0.43 and 0.45, respectively (all $P < 0.0001$). The positive correlations between percentage body fat and EE during television or a movie, during video games, during arts and crafts, and during schoolwork were 0.26, 0.34, 0.29, and 0.27, respectively (all $P < 0.05$).

By using data from the entire sample of girls, comparisons among the activities completed in the calorimeter had some interesting results. BMR was lower than EE when the girls were watching television or a movie ($P < 0.0001$). EE while watching television or a movie was significantly lower than EE while playing video games, doing schoolwork, or doing arts and crafts ($P < 0.0001$). EE during video games was similar to EE during schoolwork. However, EE during arts and crafts was significantly greater than EE while playing video games or doing schoolwork ($P < 0.001$).

Substrate oxidation

There were no significant differences in the nonprotein respiratory quotient or in carbohydrate and fat oxidation among

familial groups or among ethnic groups. Adjusted for energy balance, carbohydrate oxidation (expressed as a percentage of non-protein EE) was $59.6 \pm 7.6\%$ in the LN group, $59.2 \pm 9.2\%$ in the LNOB group, and $57.1 \pm 7.8\%$ in the OB group; fat oxidation was $40.4 \pm 7.6\%$ in the LN group, $40.8 \pm 9.2\%$ in the LNOB group, and $42.9 \pm 7.8\%$ in the OB group.

Doubly labeled water

Of the 101 girls, complete data were available for 97. The deuterium-to-oxygen ratios for the LN, LNOB, and OB groups were 1.034 ± 0.02 , 1.036 ± 0.02 , and 1.036 ± 0.01 , respectively. As shown in **Table 4**, TEE, AEE, PAL, TEE, and AEE adjusted for weight or FFM and FM were not significantly different among familial groups. Adjusted for FFM and FM, the mean (\pm SE) TEE was 7201 ± 397 , 7293 ± 172 , and 7305 ± 235 kJ/d in the LN, LNOB, and OB groups, respectively.

Ethnic effects were observed for TEE ($P < 0.05$). The African American girls had a lower free-living TEE than did the white girls when this variable was adjusted for weight (6853 ± 213 compared with 7623 ± 158 kJ/d, $P = 0.01$) or FM and FFM ($P = 0.01$). No significant ethnic effects were observed for free-living AEE or PAL.

The relation between free-living TEE and FFM was $r = 0.42$ for the entire sample (**Figure 2**). There were no significant differences among familial groups in the slopes or intercepts of FFM versus TEE. The correlations between FFM and TEE within the groups were significant only in the LN group ($r = 0.49$) and the OB group ($r = 0.56$) (both $P < 0.01$). The relations between TEE and percentage body fat were not significant in any of the groups. AEE was significantly related to FFM in the OB group only ($r = 0.38$, $P < 0.05$). There were also no significant relations between AEE and percentage body fat in any of the familial groups.

DISCUSSION

In this study, we sought to determine whether EE differed among normal-weight-for-height, multiethnic girls of 2 lean parents, 1 lean and 1 obese parent, or 2 obese parents. We found that EE during rest, sleep, exercise of 2 different intensities, schoolwork, arts and crafts, video games, and television or a movie and over a 24-h period was similar among prepubertal girls with either lean or obese parents. Free-living TEE and AEE were also

TABLE 3

Energy expenditure (EE) for specific activities in prepubertal girls with 2 lean parents (LN group), 1 obese and 1 lean parent (LNOB group), or 2 obese parents (OB group)¹

Activity	LN group (n = 30)	LNOB group (n = 44)	OB group (n = 27)
Video games			
Heart rate (beats/min)	93 ± 9	92 ± 9	92 ± 10
Activity (counts/min)	204 ± 113	188 ± 90	214 ± 69
Respiratory quotient	0.90 ± 0.03	0.89 ± 0.04	0.87 ± 0.04
EE (kJ/min)	4.422 ± 0.502	4.439 ± 0.577	4.678 ± 0.544
Arts and crafts			
Heart rate (beats/min)	104 ± 10	104 ± 10	103 ± 12
Activity (counts/min)	271 ± 102	262 ± 75	296 ± 92
Respiratory quotient	0.88 ± 0.05	0.87 ± 0.05	0.88 ± 0.05
EE (kJ/min)	4.757 ± 0.586	4.757 ± 0.711	5.092 ± 0.682
Schoolwork			
Heart rate (beats/min)	98 ± 10	99 ± 10	98 ± 11
Activity (counts/min)	221 ± 116	204 ± 75	230 ± 73
Respiratory quotient	0.86 ± 0.05	0.88 ± 0.06	0.88 ± 0.04
EE (kJ/min)	4.364 ± 0.485	4.448 ± 0.519	4.749 ± 0.590 ²
Television or movie			
Heart rate (beats/min)	88 ± 8	87 ± 9	88 ± 10
Activity (counts/min)	48 ± 45	39 ± 37	51 ± 39
Respiratory quotient	0.92 ± 0.05	0.90 ± 0.05	0.92 ± 0.04
EE (kJ/min)	3.791 ± 0.444	3.891 ± 0.452	3.908 ± 0.548
Exercise (≈40% $\dot{V}O_{2peak}$)			
Workload (W)	15 ± 5	13 ± 5	15 ± 5
Heart rate (beats/min)	130 ± 11	128 ± 16	124 ± 12
Respiratory quotient	0.93 ± 0.04	0.92 ± 0.04	0.92 ± 0.03
EE (kJ/min)	9.950 ± 2.021	9.665 ± 2.013	9.728 ± 1.582
Exercise (≈60% $\dot{V}O_{2peak}$)			
Workload (W)	33 ± 8	32 ± 6	34 ± 5
Heart rate (beats/min)	142 ± 13	142 ± 18	142 ± 15
Respiratory quotient	0.95 ± 0.05	0.94 ± 0.03	0.94 ± 0.03
EE (kJ/min)	12.636 ± 1.937	12.155 ± 2.385	12.757 ± 1.200

¹ $\bar{x} \pm SD$. $\dot{V}O_{2peak}$, peak oxygen uptake.

²Significantly different from LNOB group when covaried for fat mass and fat-free mass, $P < 0.05$ (analysis of covariance).

similar. Thus, the mean EE for basal-energy-requiring processes and physical activity did not differ between normal-weight prepubertal girls with a familial predisposition to obesity and those without a family history of obesity.

Our findings are similar to those of Goran et al (11), who studied prepubertal girls and boys, but are in contrast with results of other studies in children with lean or obese parents (9, 10). Goran et al (11) reported no significant differences in TEE and AEE as measured by doubly labeled water but a lower REE in children with 1 obese parent than in children with 2 lean or 2 obese parents. That study, however, did not separate normal-weight and overweight children. Griffiths and Payne (9) used heart rate monitoring to measure TEE in a small sample of young children. Wurmser et al (10) measured resting metabolic rate only. Thus, possible reasons for these discrepancies in the literature are sample size, measurement techniques, age or pubertal status, and obesity in the children at the time of study. Our study used 2 sophisticated measures of EE and, therefore, we evaluated thoroughly the components of EE. The 24-h protocol was designed to test for possible differences in EE during specific activities among girls with and without a predisposition to obesity.

Ethnicity appears to be an important determinant of REE, SEE, and free-living TEE in children. We confirmed lower

BMRs, SMRs, and free-living TEEs in the African American girls, as reported previously (21–23) but in contrast with one report (24). Yanovski et al (23), who studied girls of a similar age (9.3 y), found a 385-kJ/d lower BMR in African American girls than in white girls. Our study was not designed to test specifically for ethnic effects; we therefore could not state anything conclusive about the Hispanic group because the sample size was too small. However, it is quite clear that the African American girls consistently had a lower EE than did the white girls. Our finding of a lower TEE was most likely due to the lower BMR and SMR observed in the African American girls, because AEE did not differ significantly among the ethnic groups. These lower rates of EE may play an important role in the development of obesity, which is increasingly prevalent in African American girls (1) and women (25).

The nonprotein respiratory quotient and substrate oxidation measured in the calorimeter were not significantly different among the familial groups or the ethnic groups. Direct comparisons of our results with those of similarly designed studies (10, 11) cannot be made because such studies did not include the respiratory quotient. Other researchers compared postabsorptive fat oxidation of obese and nonobese children (26, 27). Significantly higher fat oxidation was reported in obese children, but not when



TABLE 4

Energy expenditure (EE) measured by doubly labeled water in prepubertal girls with 2 lean parents (LN group), 1 obese and 1 lean parent (LNOB group), or 2 obese parents (OB group)¹

	LN group (n = 29)	LNOB group (n = 43)	OB group (n = 25)
Total EE (kJ/d)	7138 ± 1159 (5284–9309)	7376 ± 1280 (5443–10104)	7519 ± 1310 (5351–9640)
Activity-related EE (kJ/d)	1933 ± 866 (699–3774)	2105 ± 1121 (–46 to 4402)	2130 ± 875 (795–3682)
Physical activity level	1.59 ± 0.21 (1.30–2.04)	1.63 ± 0.27 (1.10–2.15)	1.61 ± 0.20 (1.33–2.01)

¹ $\bar{x} \pm SD$; range in parentheses.

adjusted for FFM (26). Postabsorptive fat oxidation was also higher in obese adolescents than in control subjects and remained higher after adjustment for FFM (27).

The energy costs of specific activities common to girls of the age group we studied were measured in the calorimeter to test for differences among familial groups and to determine which activities were associated with the highest EE. The exercise sessions of 2 different intensities were conducted to test for energetic efficiency. We found that EE did not differ during these activities between girls with lean parents and girls with obese parents. However, EE did differ depending on the type of activity. In our sample of girls, only the EE during the basal state was significantly lower than the EE while watching television or a movie. Watching television or a movie was associated with a lower EE than was any of the other activities (video games, schoolwork, and arts and crafts), which clearly classifies it as a sedentary activity. Interestingly, playing video games was associated with a similar EE as was doing schoolwork. Arts and crafts were associated with the highest EE of all the other activities, excluding exercise; EE during arts and crafts was significantly higher than EE during video games, schoolwork, or television or a movie. The variation in EE during these activities indicates how total daily EE can differ depending on how children spend their free time. Rather than the energy cost of specific activities being a major determinant of obesity, the actual time spent in various activities is a more likely contributor to the development of obesity. The time spent in sedentary behaviors, such as watching television, was shown to be positively related to body fatness (28, 29). Decreasing the time spent in these sedentary activities was shown to be effective in reducing adiposity (30).

One way to examine energy expended in physical activity is the PAL. We reported PAL for the calorimetric studies and in the free-living situation. The low PALs in the calorimeter reflect the confinement, even though exercise sessions were included. Despite the imposed structure (ie, 30-min sessions of specific activities), there was a wide range of PALs in the calorimeter (1.14–1.62), consistent with the wide variation in the amount of free spontaneous movement of the girls.

Motion sensors in the calorimeters were used to monitor spontaneous activity. The data from the motion sensors for the 24-h period showed a wide range of activity (mean values over the 24-h period: 143–416 counts/min) in the entire group, indicating that some girls were moving around the room or fidgeting more than others. In an overfeeding study (31), two-thirds of the increase in TEE was due to activation of nonexercise activity thermogenesis, which is associated with fidgeting, maintenance of posture, and physical activities of daily living.

In the free-living situation, the PALs of the girls were on average much higher than they were in the calorimeter, which was expected. There was an even wider range of PALs in the group overall (1.1–2.48), indicating that some girls were very sedentary and some were highly active in the free-living situation.

As a group, prepubertal girls predisposed to familial obesity did not have lower BMRs, AEEs, or TEEs than did girls without familial obesity. The nonsignificant differences in EE, however, do not preclude the possibility that lower EE contributes to the development of obesity in some at-risk persons. Obesity is a complex entity arising from the interaction of multiple genetic and environmental factors. The striking range in AEE and TEE under confined and free-living conditions points to girls at risk

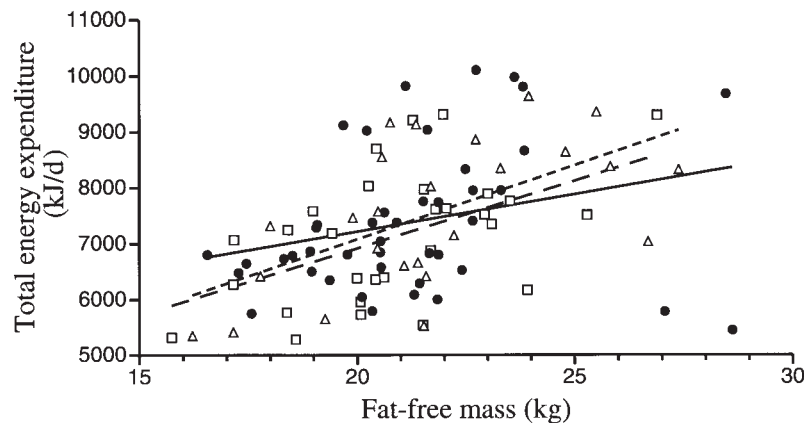



FIGURE 2. Relation between free-living total energy expenditure measured by doubly labeled water and fat-free mass in prepubertal girls with 2 lean parents (□), 1 lean and 1 obese parent (●), or 2 obese parents (△).

at the lower end of the distribution. Although we did not study food intake in these girls, the fact that we did not find significant differences in mean EE implicates the regulation of food intake as one of the causal factors in the development of obesity in predisposed children. Children with lower rates of EE and poor regulation of food intake would be at risk of obesity. We chose to study such girls at a normal weight because we are observing the girls as part of a longitudinal study to determine whether EE for maintenance and physical activity, in combination with a predisposition to obesity, contributes to subsequent rates of weight and fat gain. In conclusion, REE, SEE, 24-h EE, and AEE under confined and free-living conditions were not significantly lower in multiethnic prepubertal girls with a familial predisposition to obesity than in girls without a familial predisposition to obesity. 

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