Diet composition and body composition in preschool children\textsuperscript{1,2}

Lisa-Marie Atkin and Peter SW Davies

\textbf{ABSTRACT}

\textbf{Background:} In studies of adult humans and in animal models, dietary intakes of the macronutrients, particularly fat, are related to body composition; however, data on children are more scarce.

\textbf{Objective:} We sought to determine whether diet composition is related to percentage body fat in children aged 1.5–4.5 y.

\textbf{Design:} In 77 preschool children, a 4-d weighed-food record was used to determine intakes of total energy and energy from each macronutrient. An oxygen-18 dilution method was used to calculate percentage body fat. Habitual physical activity level was determined by calculating the ratio of total energy expenditure (from stable isotope analyses) to predicted basal metabolic rate. Dietary intake and body-composition data were analyzed to evaluate whether diet composition was related to body fat. Further analyses incorporating physical activity level were performed.

\textbf{Results:} Percentage body fat was not significantly correlated with dietary intake variables (total energy or percentage of energy from fat, carbohydrate, or protein) and did not differ significantly among 3 increasing levels of each dietary intake variable by analysis of variance. In multiple regression analysis, physical activity level was related to body fat whereas diet composition was not.

\textbf{Conclusions:} We found no relations between dietary intakes of total energy, fat, carbohydrate, or protein and percentage body fat in children. The relation between fat intake and body fat may develop over time and may not be evident in preschool children. Energy expenditure, in particular physical activity level, may have a greater influence on body composition in early childhood.


\textbf{KEY WORDS} Children, preschool children, diet composition, body composition, obesity, overweight, stable isotopes, dietary fat, body fat, nutrition assessment, energy intake, energy expenditure, physical activity, obesity prevention

\textbf{INTRODUCTION}

The prevalences of overweight and obesity appear to be increasing at an alarming rate in the Western world (1–3). In response to this pandemic situation, many countries have implemented public health campaigns aimed at the treatment and prevention of obesity. At the population level it is not yet clear whether these programs, which typically focus on lifestyle modification, have been successful. However, at the level of the individual, it is well established that obesity is challenging to treat and has a high relapse rate (4, 5). As a consequence, in the past decade, efforts have turned toward prevention strategies with the belief that they may offer a more effective solution to the problem of obesity.

It is evident that the deposition of excess adipose tissue results from a positive energy balance. However, a significant body of research findings suggests that the macronutrient composition of the diet affects the composition of the human body. In particular, it appears that the proportion of fat ingested, compared with carbohydrate and protein, influences the amount of body fat. The greater energy density of lipids (38 \text{kJ/g} as opposed to 17 \text{kJ/g} for the other macronutrients) may be one way in which fat exerts its obesity-promoting effect. Thus, a higher-fat diet necessarily results in a higher energy intake, which leads to a positive energy balance if energy expenditure is not increased proportionately. This can be seen in the study of Westerterp et al (6), who found that the fat content of the diet had an effect on body fat mass only as a function of its alteration of energy intake.

Numerous small-animal models have shown convincingly that dietary fat is positively correlated with body fat content (7–11), even under conditions of constant energy intake (12, 13). Further, a dose-response relation between fat intake and body fat deposition has been shown (14). In humans, studies on adults provide compelling evidence of an association between ingested fat and adiposity (15, 16). This evidence is strengthened by findings indicating that this association remains when fat intake is described as a percentage of energy intake (17–19) and when confounding variables are controlled for (20–22).

In children, however, the evidence is inconclusive; some studies found a positive relation between fat intake and body fat (23–26) whereas others did not (27, 28). Interestingly, some investigators reported a significant correlation between dietary fat and adiposity indicators in boys but not in girls (29, 30). Moreover, the effects of growth and development may interact with diet composition or physical activity, or both, in ways that are not yet well understood. Given that 26–41\% of obese preschool children become obese adults (31), it is important to more fully elucidate the factors that contribute to the deposition of excess adipose tissue in childhood.

\textsuperscript{1}From the School of Human Movement Studies, Faculty of Health, Queensland University of Technology, Kelvin Grove, Australia.

\textsuperscript{2}Address reprint requests to PSW Davies, School of Human Movement Studies, Faculty of Health, Queensland University of Technology, Victoria Park Road, Kelvin Grove, QLD 4059, Australia. E-mail: ps.davies@qut.edu.au.

Received July 29, 1999.

Accepted for publication December 10, 1999.
Attempts to determine whether a relation between ingested fat and body fat exists have been complicated by important methodologic limitations. It can be difficult to obtain an accurate measure of energy intake under free-living conditions, and most studies in children have relied on self-report by using food records or dietary recalls. In addition, in many of these studies, anthropometric measurements were used to determine the degree of adiposity; these methods are similarly characterized by potential inaccuracy.

In a previous study, we found no correlation between diet composition and body size in a large sample of children (n = 1444) aged 1.5–4.5 y (27). We used age- and sex-adjusted body mass index (BMI), which was a good index of body size but was potentially inaccurate as an index of body composition. In the study reported here, we sought to address these methodologic concerns by using a 4-d weighed-food record in conjunction with an isotopic method of assessing percentage body fat to examine the possible relation between diet composition and body composition in children.

SUBJECTS AND METHODS

Subjects

The data analyzed here were provided by the Feasibility Study for the National Diet and Nutrition Survey of Children aged 1.5 to 4.5 y in Great Britain. Eight distinct geographic areas were chosen as recruitment sites, with a plan to select 12 children from each area for a predicted total sample size of 96 subjects. Subjects were identified by 1 of 3 methods: approaching randomly selected addresses, obtaining referrals from those households contacted, or locating families via community playgroups. Care was taken to include a wide range of families with socioeconomic diversity. A total of 202 households were approached for recruitment. Only 1 child per household could be enrolled. In these households, 146 eligible children were identified, but 53 of these children could not comply with all aspects of the study and thus were excluded from the project. Hence, the survey included 93 children aged 1.5–4.5 y. Quota sampling was used to ensure an even distribution by age and sex in 3 groups (1.50–2.49 y, 2.50–3.49 y, and 3.50–4.49 y).

Ethics approval was obtained from the National Health Service Local Research Ethical Committee in each health district involved. The procedures were explained to the children, and their parents’ written, informed consent was obtained before the study began.

Food records

The child’s mother or primary caregiver kept a weighed-food record for a period of 4 consecutive days including a Saturday and a Sunday. Comprehensive instructions on how to weigh and record all food and drinks consumed were provided by the fieldworker before the recording period began. Fieldworkers were fully trained and all had previously worked on other studies that used similar methods. The need for detail and accuracy was emphasized to the mother or primary caregiver, and strategies for managing various challenging situations were explained. These included how to handle leftovers, fluids, spilled and wasted food, child-care arrangements, and eating outside the home. Digital scales were used for weighing food (Soehnle 200; Soehnle Waagen GmbH, Murrhardt, Germany).

The fieldworker revisited the subject’s home ≈24 h after the food record began to check all aspects of the recording procedure, give encouragement, and motivate the families as appropriate. At the end of the 4-d period, a Meals Check Sheet that summarized the number of meals, snacks, and drinks consumed every day was completed by the fieldworker for each child. This served to highlight any inconsistencies over the recording period, which then allowed the fieldworker to identify and correct possible recording errors.

After the 4-d recording procedure, the food record was coded by the fieldworker according to the food code list and associated nutrient database compiled by the Nutrition Branch of the Ministry of Agriculture, Fisheries, and Food. Any missing details and anomalies were recognized at this stage and the appropriate fieldworker contacted the informant to probe for additional information.

The consulting nutritionist checked the coding and also ensured that spilled and wasted foods and leftovers had been measured and subtracted from the record correctly. Computer edits to ascertain the completeness and consistency of the information were performed before the food record was linked to the nutrient database for conversion of food items to their constituent nutrients. The database used nutrient values obtained from McCance and Widdowson’s The Composition of Foods (32) and its supplements (33–35). Additional nutrient values were obtained from published scientific literature and from manufacturers’ data. Each food in the database had assigned values for energy and 44 nutrients. Further edit checks at this stage identified unusually high or low nutrient values; these cases were checked individually and any coding errors were corrected.

Body composition

Body composition was assessed by measurement of total body water. A stable, nontoxic isotope of oxygen (18O) was administered orally in flavored water at a dose of 0.125 g/kg body wt. The dose was given through a straw from a 100-mL bottle. If the child was unable to drink through a straw, a child’s cup (with a lid that has a small spout with holes in it) was used instead. We measured and adjusted for all spills. The weight of the dose consumed by each subject was determined and expressed to 2 decimal places.

A single predose urine sample was obtained to allow calculation of the natural concentration of 18O. A timed urine sample (≈15 mL) was then collected in a plastic screw-top container daily for the next 10 d. For children in diapers, mothers used a standard procedure of collecting urine with cotton wool balls and syringes and putting it into smaller containers. The 4-d weighed-food record was conducted during the 10-d urine-collection period.

The isotopic enrichment of the urine samples was measured relative to a local standard by using isotope ratio mass spectrometry (Aqua-Sira; VG Isotech, Cheshire, UK). This permitted calculation of total body water with a modified version of the equation described by Halliday and Miller (36) as recommended for all such studies (37). The equation is as follows:

$$N = [(T \times A)/a] \times [(E_a - E_r)/E_t]$$

(1)

where N is the dilution space (g), A is the amount of isotope administered (g), a is the weight (g) of that portion of the dose reserved for mass spectrometer analysis, T is the amount of tap water (g) in which a is diluted preceding analysis, and $E_a$, $E_r$, and $E_t$ are the isotopic enrichments (δ units) of the portion of
the dose, the tap water, and the antilog of the intercept of the regression line of the postdose urine sample minus the predose urine sample. The dilution space was reduced by 1% to adjust for the exchange of isotope (18O) with nonaqueous oxygen (38–40). Measurement of total body water in the mass spectrometry laboratory had been established with an accuracy of 3% and a precision of 1% (41).

The resulting values for total body water were used to calculate fat-free mass with the age- and sex-specific reference values of Fomon et al (42), thereby allowing us to determine fat mass from body weight. The percentage body fat was calculated from fat mass and body weight.

**Physical activity level**

The doubly labeled water technique was used to measure total energy expenditure (TEE). Two stable isotopes (18O and 2H) were administered orally in the form of water at doses of 0.125 g H218O/kg body wt and 0.05 g 2H2O/kg body wt. A single urine sample was collected before dosing to allow measurement of the natural concentrations of 18O and 2H. A timed urine sample was then collected daily for 10 d according to the procedure described above for measurement of total body water. Isotopic enrichment of the urine samples was analyzed relative to a local standard by isotope ratio mass spectrometry. The methods used to calculate TEE are described in detail elsewhere (43).

We used digital scales (Soehnle Quantratonic; Soehnle Waagen GmbH) to measure body weight of the children in minimal clothing; weight was recorded to the nearest 100 g. Height was measured to the nearest millimeter by using a portable, modified, digital telescopic stadiometer, as described previously (27). Basal metabolic rate (BMR) was predicted from body weight and height by using separate equations for boys and girls and for subjects younger and older than 3 y (44). These prediction equations are based on measurements of >1000 children; the standard error is ~257 kJ/d. Physical activity level was calculated as the ratio of TEE to BMR.

**Statistical analysis**

Associations between dietary intake variables and percentage body fat were examined by determining Pearson’s product-moment correlation coefficients. The sample then was divided into tertiles on the basis of the amount of intake for each dietary variable (total energy and percentage of energy from carbohydrate, fat, and protein). Thus, for each intake variable, tertile 1 had the lowest amount of intake, tertile 2 had the middle amount, and tertile 3 had the highest amount. The mean percentage body fat was ascertained for each tertile. A one-way analysis of variance was performed to test whether percentage body fat differed between the tertiles. Multiple regression analysis was used to model the relations between dietary intake variables, habitual physical activity level (TEE/BMR), and body composition. The data are presented as means ± SD unless stated otherwise. Significance was set at *P* < 0.05. Statistical analyses were performed by using MINITAB (version 5.21; minitab Inc, State College, PA).

**RESULTS**

Results from 16 subjects were excluded from the analyses because they had unacceptable data arising from either poor parental compliance in urine sample collection or analytic problems. Further, if the propagation of error analysis yielded errors >5% for the estimation of 18O dilution space, the data were discarded. Hence, the final cohort consisted of 77 subjects. Selected physical characteristics of the children are shown in Table 1.

The dietary intake data are shown in Table 2. Average energy intake was 4759 kJ/d for the total sample. Mean values for diet composition indicated that carbohydrate provided 57.4% of energy, fat provided 30.5%, and protein provided 12.1%.

There were no significant correlations between percentage body fat and any of the intake variables. The correlation between percentage of dietary energy from fat and percentage body fat was 0.11 for the total sample (*n* = 77), 0.08 for boys (*n* = 39), and 0.10 for girls (*n* = 38). The results of the correlation analyses are shown in Table 3.

The results of the one-way analysis of variance that tested whether percentage body fat differed by tertiles of intake for each dietary variable are shown in Table 4. There were no significant differences in percentage body fat among the 3 tertiles for total energy intake or percentage of energy from carbohydrate, fat, or protein. Thus, no association was found between percentage body fat and dietary intake, whether intake was expressed as total energy or as amounts of macronutrients, for the total sample and for each sex.

The results of the multiple regression analysis are shown in Table 5. It is clear that the habitual level of physical activity had an influence on body composition, in contrast with energy and macronutrient intakes, which did not affect body composition.

### Table 1

Subject characteristics

<table>
<thead>
<tr>
<th></th>
<th>Total sample</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(<em>n</em> = 77)</td>
<td>(<em>n</em> = 39)</td>
<td>(<em>n</em> = 38)</td>
</tr>
<tr>
<td>Age (y)</td>
<td>3.08 ± 0.81</td>
<td>3.09 ± 0.82</td>
<td>3.08 ± 0.81</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>95.8 ± 7.6</td>
<td>96.7 ± 7.4</td>
<td>94.9 ± 7.8</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>15.0 ± 2.4</td>
<td>15.0 ± 2.5</td>
<td>14.9 ± 2.3</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>16.3 ± 1.3</td>
<td>16.1 ± 1.4</td>
<td>16.5 ± 1.2</td>
</tr>
<tr>
<td>Percentage body fat (%)</td>
<td>24.0 ± 5.9</td>
<td>23.1 ± 6.0</td>
<td>24.9 ± 5.7</td>
</tr>
<tr>
<td>TEE (kJ/d)</td>
<td>4981 ± 963</td>
<td>5115 ± 1009</td>
<td>4845 ± 906</td>
</tr>
<tr>
<td>BMR (kJ/d)</td>
<td>3321 ± 355</td>
<td>3451 ± 337</td>
<td>3191 ± 328</td>
</tr>
<tr>
<td>PAL (TEE/BMR)</td>
<td>1.51 ± 0.28</td>
<td>1.49 ± 0.28</td>
<td>1.52 ± 0.27</td>
</tr>
</tbody>
</table>

*Significantly different from boys, *P* < 0.01 (independent *t* test).

### Table 2

Energy and macronutrient intakes

<table>
<thead>
<tr>
<th></th>
<th>Total sample</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(<em>n</em> = 77)</td>
<td>(<em>n</em> = 39)</td>
<td>(<em>n</em> = 38)</td>
</tr>
<tr>
<td>Energy (kJ/d)</td>
<td>4759 ± 835</td>
<td>4918 ± 864</td>
<td>4596 ± 782</td>
</tr>
<tr>
<td>Carbohydrate (g/d)</td>
<td>162.7 ± 30.3</td>
<td>169.0 ± 28.3</td>
<td>156.3 ± 31.2</td>
</tr>
<tr>
<td>(% of energy)</td>
<td>57.4 ± 6.2</td>
<td>57.8 ± 5.4</td>
<td>57.0 ± 7.0</td>
</tr>
<tr>
<td>Fat (g/d)</td>
<td>43.6 ± 10.6</td>
<td>44.6 ± 11.6</td>
<td>42.6 ± 9.6</td>
</tr>
<tr>
<td>(% of energy)</td>
<td>30.5 ± 4.3</td>
<td>30.1 ± 4.0</td>
<td>31.0 ± 4.5</td>
</tr>
<tr>
<td>Protein (g/d)</td>
<td>34.4 ± 10.5</td>
<td>35.6 ± 10.3</td>
<td>33.0 ± 10.8</td>
</tr>
<tr>
<td>(% of energy)</td>
<td>12.1 ± 2.8</td>
<td>12.1 ± 2.4</td>
<td>12.0 ± 3.2</td>
</tr>
</tbody>
</table>

*Significantly different from boys, *P* < 0.05. Statistical analyses were performed by using MINITAB (version 5.21; minitab Inc, State College, PA).
DISCUSSION
The problem of overweight and obesity is a growing public health concern affecting numerous countries. Research in the latter half of the 20th century that investigated the etiology, pathophysiology, and treatment of obesity has produced a body of knowledge, yet effective methods for both treating and preventing obesity remain elusive.

The amount of fat ingested has been implicated as a causal or facilitating factor in the deposition of body fat. Thus, it is proposed that dietary fat can directly or indirectly manipulate human adipose tissue. One explanation for this is the greater energy density of dietary fat, which ensures that a high-fat diet will always contain more energy than a low-fat diet of similar volume. Further, the metabolic efficiency of the macronutrients differs markedly. In conditions of energy excess, fat is stored at an energy cost of only 3%, in contrast with 28% for carbohydrate and 24% for protein (45). Other purported theories for the association between dietary fat and body fat, which have been discussed in detail elsewhere, include passive overconsumption (46) and the depressed response of fat oxidation to ingestion (47–51).

To examine the proposed relation between ingested fat and body fat, these 2 variables must be measured accurately. It is unquestionably difficult to assess dietary intake accurately in a free-living population. Dietary survey techniques have inherent limitations that can be further complicated by suboptimal application and implementation. The weighed-food record is a putative gold standard for assessing individual dietary intake (52) because it minimizes many potential errors. However, it is well established that even this method is prone to bias in reporting of food intake by adults (53–55). Livingstone et al (56) showed an age-dependent effect of reporting bias with a 7-d weighed diet record. They found that in 7- and 9-y-old children, energy intake data showed good agreement with energy expenditure as measured by doubly labeled water, thus affirming the validity of the weighed record. In contrast, older subjects (aged 12, 15, and 18 y) showed systematic negative bias in dietary reporting (56), as Bandini et al (57, 58) also found with a nonweighed diet record.

The most compelling evidence supporting the validity of the weighed-food record in the age group studied here (1.5–4.5 y) comes from a study that used the same method and population. In a comparison of TEE measured by doubly labeled water and energy intake from the 4-d weighed record, Davies et al (59) found an average difference of only 3%. Thus, although the weighed-food record has had some limitations in adolescents and adults, the evidence to date indicates that it is a valid measure of energy intake in prepubertal children.

Previous studies that examined the possible relation between diet composition and body composition commonly used BMI because of its low cost, ease of use, and feasibility as a measurement technique for population groups in large-scale or epidemiologic studies. Support for the use of BMI as an adiposity indicator comes from investigations that found good correlations with body-fat measures obtained by densitometry (60–62). However, BMI does not provide a measure of body composition, and substantially more accurate methods for assessing percentage body fat are available. The isotope dilution method measures total body water. Given that lipids are hydrophobic and thus the body’s fat mass is anhydrous, fat-free mass can be calculated from total body water. By using the two-compartment model, fat mass and percentage body fat can then be calculated. The accuracy of the isotope dilution method for measuring total body water is excellent (38). Moreover, the precision of this method, when performed with an isotopic ratio mass spectrometer, is 1–2% (63, 64).

We used this sound methodology to assess diet composition and body composition, yet found no significant relation between the amount of fat ingested (expressed as a proportion of energy intake) and percentage body fat. To thoroughly explore any potential association, the sample was divided into tertiles based on the percentage of dietary energy from fat. The mean percentage body fat for each tertile was then subjected to one-way analysis of variance. The lack of any significant difference in this analysis supports the assertion that the amount of dietary fat consumed was not associated with adiposity in this cohort of children aged 1.5–4.5 y.

There is suggestion in the literature that protein intake, not fat intake, may be associated with the development of adiposity in childhood (65). It has been proposed that a high protein intake during early childhood stimulates insulin-like growth factor I production, thereby triggering precocious adipocyte multiplication (66). In the present study, we did not find any association between dietary protein intake and percentage body fat. However, if protein intake does in fact influence obesity development only as a function of early adiposity rebound, then it would not have been possible to reveal such a relation in this cross-sectional study.

### TABLE 3

<table>
<thead>
<tr>
<th></th>
<th>Total sample (n = 77)</th>
<th>Boys (n = 39)</th>
<th>Girls (n = 38)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (kJ/d)</td>
<td>-0.03</td>
<td>0.15</td>
<td>-0.17</td>
</tr>
<tr>
<td>Carbohydrate (% of energy)</td>
<td>-0.08</td>
<td>-0.02</td>
<td>-0.13</td>
</tr>
<tr>
<td>Fat (% of energy)</td>
<td>0.11</td>
<td>0.08</td>
<td>0.10</td>
</tr>
<tr>
<td>Protein (% of energy)</td>
<td>0.03</td>
<td>-0.10</td>
<td>0.14</td>
</tr>
</tbody>
</table>

None of the correlations were significant.

### TABLE 4

<table>
<thead>
<tr>
<th></th>
<th>1 (n = 26)</th>
<th>2 (n = 25)</th>
<th>3 (n = 26)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total energy (kJ)</td>
<td>25.3 ± 6.6</td>
<td>22.9 ± 7.1</td>
<td>23.8 ± 3.4</td>
<td>0.357</td>
</tr>
<tr>
<td>Carbohydrate (% of energy)</td>
<td>24.9 ± 6.5</td>
<td>24.0 ± 4.4</td>
<td>23.2 ± 6.6</td>
<td>0.572</td>
</tr>
<tr>
<td>Fat (% of energy)</td>
<td>23.6 ± 6.7</td>
<td>23.1 ± 6.4</td>
<td>25.4 ± 4.4</td>
<td>0.346</td>
</tr>
<tr>
<td>Protein (% of energy)</td>
<td>22.5 ± 5.7</td>
<td>26.0 ± 5.5</td>
<td>23.7 ± 6.2</td>
<td>0.105</td>
</tr>
</tbody>
</table>

X ± SD. Tertile 1 had the lowest intake and tertile 3 had the highest.
Dietary carbohydrate expressed as a percentage of energy intake is often inversely related to body fat (20), including in childhood obesity (23, 26, 67). A high-carbohydrate diet is thought to function in various ways to produce this effect. With regard to energy intake, carbohydrates have a lower energy density than lipids. Further, polysaccharides are characterized by slower rates of digestion and absorption, a greater satiating ability, and effective feedback control of oxidation. In this cohort of 1.5–4.5- y-old children, there was no association between carbohydrate intake and percentage body fat.

Thus, in a comprehensive investigation of the influence of macronutrients on body fat, no significant relations were found for the total sample, for each sex, or for tertiles of intakes for each macronutrient. To nullify any possible mathematical bias arising from expression of macronutrients as percentages of energy intake, all analyses were also performed for macronutrient intakes in g/d. Again, no significant relations or differences were found.

If macronutrient intakes do not affect body composition when analyzed cross-sectionally, then the question remains, does energy intake influence body fat at this age? There was no correlation between total energy consumption in kJ/d and percentage body fat (Table 3), nor was there a difference in percentage body fat among the 3 tertiles of energy intake (Table 4). Although we acknowledge the inherent difficulty in obtaining energy intake measures in free-living individuals, as argued previously, the 4-d weighed-food record used here affords confidence in the data presented. Because we also used the isotope dilution method to assess body composition, we are satisfied that methodologic weaknesses have been minimized. Hence, in this sample of 77 preschool children, intakes of energy and the constituent macronutrients were not associated with percentage body fat. The inquiry then necessarily turns to the other element in the energy-balance equation.

Energy expenditure in children appears to have declined markedly over the past 30 y (68). Evidence of this trend can be found in numerous studies of young children, which showed that rates of TEE are substantially lower (69–72) than current recommendations for energy intake (73). In the sample of children studied here, a comparison of TEE with current energy intake guidelines showed that TEE was 10–12% below the energy intake recommendations (74). It is reasonable to suggest that a reduction in physical activity levels is most likely responsible for this phenomenon because it is difficult to imagine that there has been a major change in resting metabolic rate or thermoregulation during this period. Moreover, it is unlikely that the energy cost of growth in children (2% of energy intake) has changed in the past few decades. Indeed, studies that reported low TEE in preschool children attributed much of this to low activity-related energy expenditure (69, 70). Additionally, Salbe et al (75) reported in 1997 that levels of physical activity in 5-y-old children were 20–30% lower than those currently recommended by the World Health Organization.

Cross-sectional (76) and longitudinal (77) data indicate that physical inactivity is linked to obesity in children. We previously reported finding a significant negative correlation between body fat (measured by isotope dilution) and physical activity levels in the same cohort studied here (43). In the current study, we conducted a more comprehensive evaluation of energy balance by subjecting total energy intake, macronutrient intakes, and PAL to multiple regression analysis to determine their contributions to percentage body fat. The results of this analysis confirm the apparent influence of physical activity, in contrast with dietary intake, on body composition in this age group.

In the study reported here, we failed to find a relation between ingested fat and body fat in a sample of 77 preschool-age children. This is in agreement with other investigations of children at this age (27, 78), but in contrast with several studies of older children and adults. This suggests that perhaps the relation between fat intake and adiposity develops over a certain time period and that the age group studied here (1.5–4.5 y) was too young to show such an effect. If this is the case, then the need to target nutritional education strategies aimed at obesity prevention is evident. The results of this study may also be interpreted as indicating that habitual physical activity is more influential than diet composition in determining percentage body fat in young children. This hypothesis, in conjunction with the findings of Davies et al (43) and others (76, 77, 79–81) indicating that physical activity is inversely related to adiposity indexes, identifies the importance of physical activity in the prevention of overweight and obesity.

Future research, however, should examine the longitudinal effect of macronutrient intakes on adiposity development. The sum of evidence thus far indicates that dietary fat intake does affect body composition in older children, adolescents, and adults. The apparent lack of such a relation in younger children is interesting and suggests that there may be a critical period in development during which physiologic processes or environmental factors, or both, facilitate such an effect. A longitudinal investigation would permit examination of these issues.

At this time, it would be premature to conclude that a low level of physical activity is a cause rather than a consequence of obesity in young children. However, given that the evidence and intuitive thought point toward the probability that this is the case, an investigation into the effect of physical activity level over time will be of great benefit in our attempts to better understand obesity. Further, there is some indication that qualitative aspects of physical activity, as opposed to energy expenditure per se, are related to adiposity in prepubertal children (82); therefore, an examination of this issue would be valuable.

Awareness of the causes of excess adiposity will allow the development and implementation of prevention strategies, which is becoming urgent in industrialized countries. Prepubertal children are an important population in which to encourage lifestyle habits that will reduce the risk of obesity in adolescence and adulthood.

### TABLE 5

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Coefficient</th>
<th>r ratio</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>27.4</td>
<td>0.98</td>
<td>NS</td>
</tr>
<tr>
<td>Total energy intake (kJ)</td>
<td>−0.0007</td>
<td>−0.22</td>
<td>NS</td>
</tr>
<tr>
<td>Carbohydrate intake (% of energy)</td>
<td>0.043</td>
<td>0.16</td>
<td>NS</td>
</tr>
<tr>
<td>Fat intake (% of energy)</td>
<td>0.240</td>
<td>0.60</td>
<td>NS</td>
</tr>
<tr>
<td>Physical activity level</td>
<td>−8.18</td>
<td>−3.45</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

1. Protein intake (% of energy) was removed from the model because of its high collinearity with carbohydrate intake (% of energy) (r = −0.82). However, protein intake was not significant (t = −0.16; P = 0.88) in the model when carbohydrate intake was forced out of the regression equation.
REFERENCES


