Body-composition development during early childhood and energy expenditure in response to physical activity in 1.5-y-old children

Britt Eriksson, Hanna Henriksson, Marie Lof, Ulf Hannestad, and Elisabet Forsum

ABSTRACT
Background: The prevalence of childhood overweight and obesity has increased recently, but the mechanisms involved are incompletely known. Previous research has shown a correlation between the percentage of total body fat (TBF) and physical activity level (PAL). However, the PAL values used may involve a risk of spurious correlations because they are often based on predicted rather than measured estimates of resting energy metabolism.

Objectives: We studied the development of body composition during early childhood and the relation between the percentage of TBF and PAL on the basis of the measured resting energy metabolism.

Design: Body composition was previously measured in 108 children when they were 1 and 12 wk old. When 44 of these children (21 girls and 23 boys) were 1.5 y old, their total energy expenditure and TBF were assessed by using the doubly labeled water method. Resting energy metabolism, which was assessed by using indirect calorimetry, was used to calculate PAL.

Results: Significant correlations were shown for TBF (r = 0.32, P = 0.035) and fat-free mass (r = 0.34, P = 0.025) between values (kg) assessed at 12 wk and 1.5 y of age. For TBF (kg) a significant interaction (P = 0.035) indicated a possible sex difference. PAL at 1.5 y was negatively correlated with the percentage of TBF (r = -0.40, P = 0.0076) and the increase in the percentage of TBF between 12 wk and 1.5 y (r = -0.38, P = 0.0105).

Conclusions: The results indicate that body fatness and physical activity interact during early childhood and thereby influence obesity risk. Our results are based on a small sample, but nevertheless, they motivate additional studies in boys compared with girls regarding the development of body composition during early life. Am J Clin Nutr 2012;96:567–73.

INTRODUCTION
In recent decades, an increasing number of children have developed overweight and obesity (1). This is a serious problem because obesity in childhood tends to persist into adulthood (2), when it is associated with increased risk of diabetes, heart disease, and some forms of cancer (3). Obesity develops over time in response to a positive energy balance, but available knowledge is limited concerning the mechanisms responsible for the recent increase in childhood overweight and obesity. This lack of knowledge is unfortunate because this knowledge may be of use in the prevention and treatment of these conditions. In this context, an interesting question is whether a high amount of body fat in infancy is maintained into childhood. This subject has undergone little investigation because available methods for the assessment of body composition in children are often expensive and demanding for subjects. Despite these difficulties, Wells et al (4) conducted a longitudinal study in children and showed a correlation between the percentage of total body fat (TBF) at 12 wk and the percentage of TBF at 2–3.5 y of age. It has become easier to investigate this area because the air-displacement plethysmography technique (5) became applicable in young infants in 2004. This technique has been used to assess infant body composition in several studies (6), including our own study in 108 Swedish infants (7). We have reinvestigated body composition in 44 of these children at the age of 1.5 y. Because air-displacement plethysmography cannot be applied at this age, we used a stable-isotope methodology to assess body composition. This method requires a procedure that makes it possible to assess total energy expenditure (TEE) by using the doubly labeled water method (8).

Many investigators have studied the relation between the percentage of TBF content and the ratio between TEE and resting energy metabolism, ie, the physical activity level (PAL). A significantly negative relation between the percentage of TBF and estimates of physical activity has often been identified in adults (9, 10) and children (11–17). This may indicate that, as children become fatter, they are less physically active, which results in a positive energy balance that leads to even more fat retention and, thereby, creates a vicious cycle that promotes overweight.

1 From the Department of Clinical and Experimental Medicine, Linköping University, Linköping, Sweden. BE and HH contributed equally to this article. 2 The funding bodies had no influence on the study design, collection, analysis, and interpretation of data or the decision to publish the results. 3 Supported by grants from the Swedish Research Council project 15402, AFA Insurance, the Medical Faculty, Linköping University; the County Council of Östergötland, and the Crown Princess Lovisa Foundation. 4 Address correspondence to E Forsum, Department of Clinical and Experimental Medicine, Linköping University, SE 581 85 Linköping, Sweden. E-mail: elisabet.forsum@liu.se. 5 Abbreviations used: AEE, activity energy expenditure; BMR, basal metabolic rate; FFM, fat-free mass; FMI, fat mass index; kD, elimination rate for deuterium; kO, elimination rate for oxygen-18; N0, deuterium dilution space; N0, oxygen-18 dilution space; PAL, physical activity level; PALBMR, physical activity level determined by using the basal metabolic rate; PALSMBR, physical activity level determined by using the sleeping metabolic rate; SMR, sleeping metabolic rate; TBF, total body fat; TEE, total energy expenditure.

Received June 20, 2011. Accepted for publication May 24, 2012. First published online July 25, 2012; doi: 10.3945/ajcn.111.022020.
and obesity. However, in many studies [eg, the study of Tenefors et al (11)], PAL was calculated by using values for resting energy metabolism that were obtained by using equations that were based on body weight. This procedure is common because the measurement of resting energy metabolism in small children is difficult. However, the procedure creates a risk of a spurious correlation between PAL and the percentage of TBF because body weight is also used to calculate the percentage of TBF. In this article, we study the development of body composition during early childhood and relate this development to energy expended in response to physical activity at 1.5 y of age. We also investigate the relation between the percentage of TBF and PAL by using measured as well as predicted resting energy metabolism.

SUBJECTS AND METHODS

Participants

In a previous study (7) in 108 healthy children, body composition was studied at 1 and 12 wk of age. All infants were full-term singletons at birth, and their parents were part of a well-educated, middle-income Swedish population. All parent couples were asked to participate in an examination of their children at the age of 1.5 y, and 45 couples agreed to do so. One child was excluded because of poor health. There was no significant difference between participants and nonparticipants regarding weight, length or BMI (in kg/m²) at 12 wk of age. The study was approved by the Research Ethics Committee in Linköping, Sweden.

Measurement session

A measurement session was scheduled when children were ~1.5 y of age. Parents were asked to collect 2 urine samples and bring them to the measurement session at which time the child was given a dose of stable isotopes mixed with fruit juice. The container was rinsed twice with juice and the child also consumed the washings. The child was allowed to go to sleep to measure the sleeping metabolic rate (SMR) by using a ventilated hood system (Deltatrac Metabolic Monitor; Datex Instrumentorp Corp). Carbon dioxide production and oxygen consumption were measured for 20 min. When the recordings were stable, which occurred after ~10 min, recordings obtained during 12–16 min (average: 14 min) were used to calculate SMR by using the Weir equation (18). Parents were instructed to collect urine samples on days 1, 5, 10, and 15 after the day of dosing and to note the time of sampling. Urine samples were obtained by using baby urine collector bags (B Braun Medical) or cotton balls in the diaper and by using a syringe to recover the urine. Body weight was recorded with the use of a scale (KCC 150; Mettler-Toledo). The length of the child was measured to the nearest centimeter by using a length board.

Stable-isotope methodology and energy expenditure

Each subject was given an accurately weighed dose of isotopes (0.14 g D2O  and 0.35 g H218O/kg body weight). Urine samples were stored in glass vials with an internal aluminum-lined screw-cap sealing at +4 °C until sample collection was completed, after which they were stored at −20 °C until analyzed. Isotope enrichment was analyzed by using an isotope ratio mass spectrometer fitted with a carbon dioxide, deuterium, and water equilibrium device (Deltaplus XL; Thermoquest). The procedure described by Thielecke and Noack (19) was followed except that equilibration times for deuterium and carbon dioxide were 360 and 840 min, respectively. The mass spectrometric response was standardized by using Vienna standard mean ocean water and water samples with known enrichments. Dose and urine samples from each subject were always analyzed simultaneously within the same equilibrium device when a linear mass spectrometric response was also confirmed. The deuterium dilution space (ND) and oxygen-18 dilution space (N0) were calculated by using zero time enrichments obtained from the exponential isotope disappearance curves that provided estimates for elimination rates for deuterium (kD) and oxygen-18 (kO). Carbon dioxide production was calculated according to the method of Davies et al (20), with the assumption that 25% of total water losses were fractionated. TEE was calculated from the carbon dioxide production by using the Weir formula (18), with assumption of a food quotient of 0.85 (21). The basal metabolic rate (BMR) was calculated by using equations that were based on body weight for boys and girls <3 y of age (22). Activity energy expenditure (AEE) was calculated as TEE minus SMR. PAL determined by using the SMR (PALSMR) was calculated as TEE divided by SMR, and PAL determined by using the BMR (PALBMR) was calculated as TEE divided by BMR. Total body water was the average of ND divided by 1.041 and N0 divided by 1.007 (8). Analytic precision was 0.22 ppm for deuterium and 0.03 ppm for oxygen-18. When samples from one adult subject were analyzed 9 times, the following CVs were obtained: TEE (1.2%), total body water (0.3%), and kD and kO (≤0.3% or less). These values were all well within recommended criteria (8).

Body composition

At 1 and 12 wk of age, body composition was calculated from body density, which was assessed by means of air displacement plethysmography with the use of Pea Pod (COSMED) (5) with software 3.0.1 and was based on the fat-free mass (FFM) density model of Fomon et al (23), which represents the best model currently available (6). At 1.5 y of age, FFM was calculated as total body water divided by 0.784 (23). To obtain TBF, FFM was deducted from body weight. Fat mass index (FMI; in kg/m²) was calculated as TBF divided by length squared, and fat-free mass index (in kg/m²) was calculated as FFM divided by length squared.

Statistics

Values are given as means ± SDs. Student’s t test for paired and unpaired observations was used to compare groups. Linear regression and correlation analyses were also used. Multiple regression analysis including sex as an independent variable was used to identify significant interactions. The comparison of correlation coefficients was based on Fisher’s z transformation. Significance (2-sided) was accepted when P < 0.05. Analyses were performed with Statistica Software version 10 (STAT SOFT, Scandinavia AB).
FATNESS AND PHYSICAL ACTIVITY IN EARLY CHILDHOOD

RESULTS

Subjects

Body weights, lengths, and gestational ages at birth of boys and girls in the study are shown in Table 1. At 1 wk of age, 39 children were completely breastfed, whereas 4 children received breast milk and formula. One child was fed formula only. Corresponding numbers at 12 wk of age were 33, 7, and 4 children, respectively. When measured at 1.5 y of age, all children were weaned. Ages, body weights, lengths, weight-for-age z scores, length-for-age z scores, and body compositions of all children in the study, as well as for boys and girls separately at the 3 time points, are shown in Table 2. N D and N D;N D, k D, k O, carbon dioxide production, and total body water at 1.5 y of age for boys and girls in the study are shown in Table 3.

Body-composition results

As shown in Table 2, TBF increased from 13.5% to 25.9% between 1 and 12 wk of age (P < 0.001; paired t test). The corresponding increase between 12 wk and 1.5 y of age was smaller (from 25.9% to 27.9%) but remained significant (P = 0.0075; paired t test). The percentage of TBF for each child in the study at all 3 measurements is shown in Figure 1. For all children, this value increased between 1 and 12 wk of age. However, between 12 wk and 1.5 y of age increases (29 children) and decreases (15 children) in the percentage of TBF were observed. When body fatness was assessed by using FMI, increases and decreases between 12 wk and 1.5 y of age were shown for 30 and 14 children, respectively. No significant differences between boys and girls were shown regarding these changes in body fatness. The change in the percentage of TBF (the percentage of TBF at 1.5 y minus the percentage of TBF at 12 wk) was 2.0 ± 4.7% (range: −6.5 to 14.1%; n = 44). This change was correlated with PAL-SMR (Figure 2) and AEE (MJ · d⁻¹ · kg⁻¹) (r = −0.41, P = 0.0054). The corresponding change in FMI (FMI at 1.5 y minus FMI at 12 wk) was 0.57 ± 0.109 (range: −1.46 to 3.89; n = 44) and was correlated with PAL-SMR (r = −0.34, P = 0.026) and AEE (MJ · d⁻¹ · kg⁻¹) (r = −0.37, P = 0.015).

Correlation coefficients of relations obtained when variables assessed at 12 wk of age were correlated with the same variables assessed at 1.5 y of age are shown in Table 4, which includes values for sexes combined as well as for boys and girls separately. For sexes combined, these correlations were significant for body weight and length, TBF (kg), FMI, BMI, and FFM. A multiple regression analysis with the value at 1.5 y of age as the dependent variable and the value at 12 wk of age and sex as independent variables showed no significant interaction when body weight and length, FMI, BMI, and FFM were analyzed. However, for TBF (kg), a significant (P = 0.035) interaction was observed. For this variable, correlation coefficients for boys and girls were 0.04 (P = 0.84) and 0.60 (P = 0.0041), respectively, but were not significantly (P = 0.0512) different (Table 4). No significant correlations were shown for body weight, TBF, or FMI for either boys or girls when relations between values assessed at 1 wk and 1.5 y of age were studied (data not shown). At the age of 1.5 y, BMI was correlated with the percentage of TBF for boys (r = 0.51, P = 0.012) and girls (r = 0.50, P = 0.022) as well as with FMI for boys (r = 0.84, P < 0.001) and girls (r = 0.77, P < 0.001).

Energy-expenditure results

TEE, SMR, BMR, AEE, PAL-SMR, and PAL-BMR are shown in Table 5 for all children in the study as well as for boys and girls separately. A significant difference between SMR and BMR was shown for boys (P = 0.034) but not for girls or for sexes combined. When values for boys and girls (n = 44) were used, we showed that SMR (kJ/d) correlated significantly with FFM (kg) (r = 0.49, P = 0.0079), TBF (kg) (r = 0.41, P = 0.0055), and body weight (r = 0.52, P < 0.001). Significant correlations were shown between PAL-SMR and the percentage of TBF (r = 0.72, P < 0.001; n = 44) and, as shown in Figure 3, between PAL-SMR (y) and the percentage of TBF (x). For the latter relation, multiple regression analysis, with PAL-SMR as the dependent variable and the percentage of TBF and sex as independent variables, showed no significant interaction, and correlation coefficients for boys and girls were not significantly different. However, the relation between PAL-SMR and the percentage of TBF was significant for boys (r = −0.46, P = 0.028; n = 23) but not for girls (r = −0.28, P = 0.22; n = 21). When PAL-BMR was used as the dependent variable, correlations with the percentage of TBF were significant for boys (r = −0.63, P = 0.0014) and girls (r = −0.81, P < 0.001). When FMI was used as an estimate of body fatness, the following results were obtained: PAL-BMR and FMI were significantly correlated (r = −0.67, P < 0.001; n = 44), whereas PAL-SMR and FMI were not significantly correlated (r = −0.29; n = 44). The correlation between PAL-BMR and FMI was significant for boys (r = −0.59, P = 0.0032; n = 23) and girls (r = −0.77, P < 0.001, n = 21). AEE (MJ/d) and PAL-SMR were not correlated with body weight (kg) (n = 44). When AEE (kJ · d⁻¹ · kg⁻¹) was regressed on the percentage of TBF, a significant (r = −0.54, P < 0.001; n = 44) linear relation was obtained (y = −5.64x + 251). The corresponding relation between AEE (kJ · d⁻¹ · kg⁻¹) and FMI was also significant (r = −0.42, P = 0.0041; n = 44; y = −17.3x + 178).

DISCUSSION

A comparison of the weights and lengths of children in the current study with appropriate reference data (24) showed that, regarding body size, the children in the current study were considered typical Swedish children at birth and at 12 wk and 1.5 y of age. However, when the average percentage of TBF of children in the current study at 1.5 y of age was compared with data in available reference data sets, values for girls in the current study were 4% (25) and 25% (23) higher. These figures were also higher for boys in the current study, with corresponding figures of

<table>
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<th>TABLE 1</th>
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<td>Body weight, length, and gestational age at birth of the children in the study¹</td>
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<tr>
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<th>Girls (n = 21)</th>
<th>Boys (n = 23)</th>
<th>All (n = 44)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight (g)</td>
<td>3710 ± 480</td>
<td>3810 ± 520</td>
<td>3760 ± 500</td>
</tr>
<tr>
<td>Length (cm)</td>
<td>51 ± 2</td>
<td>51 ± 2</td>
<td>51 ± 2</td>
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<tr>
<td>Gestational age (wk)</td>
<td>40.3 ± 1.1</td>
<td>40.2 ± 1.4</td>
<td>40.3 ± 1.3</td>
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¹ All values are means ± SDs. There was no significant difference between boys and girls by using Student’s t test.
16% (25) and 37% (23). Thus, apparently our population was considerably fatter than reference children. However, during the second year of life, such data are very limited, and more studies are required to define optimal body composition in young children.

In this study, body fatness was assessed in different ways during infancy and childhood, but all body-composition data were calculated by using the model of Fomon et al (23), which provides data for infants and for children 1 y of age. We assumed that the difference between TEE and SMR represented a valid estimate of energy expended in response to physical activity, although it included energy expended in response to tissue synthesis and the thermic effect of food. At the age of 1.5 y, children gain an average of 6–8 g body weight/d. When this figure was used to calculate energy expenditure because of tissue synthesis (26), the latter figure was only ~1% of TEE. The thermic effect of food represents only 5–10% of TEE (27). Our estimates of AEE may have been slightly too high, but meaningful corrections of AEE values in individuals for energy expended in response to tissue synthesis and the thermic effect of food are not possible. Our estimates of TEE agreed with comparable estimates in children (28, 29). Our estimates of SMR were similar to the BMR calculated by using prediction equations (22) for girls but not for boys, which was possibly a result of limitations in data used to establish these equations. In this article, we conducted many statistical tests, which create a risk of a type I error. Thus, although not all of our significant results were important for our conclusions, we emphasize that our results need confirmation before firm conclusions can be drawn.

We have previously reported poor correlations between BMI and the percentage of TBF in infants (7). Our current results showed that, at 1.5 y of age, BMI explains only ~25% of the variation in the percentage of TBF. The limitations of BMI as an estimate of body fatness have been pointed out (30), and there is considerable discussion about the best way to express results when describing human body fatness. It has been proposed that FMI may have advantages over the percentage of TBF (30), and therefore, in this article, we used FMI as well as the percentage of TBF as estimates of body fatness.

Available reference data (23, 25) showed that healthy infants gain body fat during the first months of life. The percentage of TBF reaches a maximum between 3 and 6 mo of age and

| TABLE 2 |
| Age, body weight, weight-for-age z score, length, length-for-age z score, and body composition at 1 and 12 wk and 1.5 y of age of the children in the study† |
| | 1 wk | 2 wk | 1.5 y |
| | Girls (n = 21) | Boys (n = 23) | All (n = 44) | Girls (n = 21) | Boys (n = 23) | All (n = 44) | Girls (n = 21) | Boys (n = 23) | All (n = 44) |
| Age (d) | 8 ± 2 | 7 ± 2 | 7 ± 2 | 86 ± 4 | 85 ± 3 | 85 ± 4 | 561 ± 12 | 554 ± 14 | 557 ± 14 |
| Body weight (kg) | 3.7 ± 0.5 | 3.8 ± 0.5 | 3.7 ± 0.5 | 6.0 ± 0.7 | 6.3 ± 0.5 | 6.2 ± 0.6 | 11.7 ± 1.4 | 12.1 ± 1.1 | 11.9 ± 1.2 |
| Weight-for-age z score | 0.54 ± 0.40 | 0.47 ± 0.30 | 0.50 ± 0.30 | 0.43 ± 0.10 | 0.27 ± 0.34 | 0.34 ± 0.89 | 0.10 ± 0.13 | 0.14 ± 0.92 | 0.12 ± 1.02 |
| Length (m) | 0.52 ± 0.02 | 0.52 ± 0.02 | 0.52 ± 0.02 | 0.61 ± 0.02 | 0.62 ± 0.02 | 0.61 ± 0.02 | 0.83 ± 0.03 | 0.83 ± 0.02 | 0.83 ± 0.03 |
| Length-for-age z score | 0.49 ± 0.12 | 0.26 ± 0.10 | 0.37 ± 0.10 | 0.26 ± 0.08 | 0.21 ± 0.05 | 0.23 ± 0.77 | 0.45 ± 1.13 | 0.02 ± 0.82 | 0.12 ± 0.99 |
| TBF (%) | 2.16 ± 0.35 | 0.45 ± 0.21 | 0.52 ± 0.19 | 1.56 ± 0.35 | 1.65 ± 0.40 | 1.61 ± 0.38 | 3.23 ± 0.68 | 3.45 ± 0.62 | 3.34 ± 0.65 |
| BMI (kg/m²) | 13.8 ± 1.0 | 13.7 ± 1.2 | 13.7 ± 1.1 | 16.2 ± 1.4 | 16.5 ± 1.6 | 16.3 ± 1.5 | 17.0 ± 1.1 | 17.6 ± 1.6 | 17.3 ± 1.4 |
| TBF (kg) | 3.13 ± 0.35 | 3.30 ± 0.37 | 32.2 ± 0.37 | 4.43 ± 0.38 | 4.66 ± 0.35 | 4.55 ± 0.38 | 8.50 ± 0.86 | 8.66 ± 0.72 | 8.58 ± 0.78 |
| FFM (kg) | 11.7 ± 0.7 | 12.0 ± 0.8 | 11.9 ± 0.8 | 12.0 ± 0.8 | 12.1 ± 0.9 | 12.1 ± 0.8 | 12.3 ± 0.7 | 12.6 ± 1.0 | 12.4 ± 0.9 |

†All values are means ± SDs. FFM, fat-free mass; FFMI, fat-free mass index; FMI, fat mass index; TBF, total body fat.
2Calculated as FFMI divided by length squared.
3Calculated as TBF divided by length squared.
4Calculated as FFM divided by length squared.
6Significantly different (P < 0.05) from the corresponding value for boys by using Student’s t test.
7All values are means ± SDs. There was no significant difference between girls and boys by using Student’s t test. kDp, elimination rate for deuterium; kD, elimination rate for oxygen-18; NDp, deuterium dilution space; ND, oxygen-18 dilution space.
decreases slowly during the second half of the first year of life. In our children, the average change in the percentage of TBF between 12 wk and 1.5 y of age was an increase with a large variation between individuals. Longitudinal studies (4, 17, 31) indicated that body fatness during early childhood may be the result of interactions between body composition and physical activity. Our results presented in Figure 2 show a relation between the change in body fatness and physical activity. In Figure 2, PAL-SMR represents the independent variable, which suggested that a high level of physical activity leads to fat loss. However, it is also conceivable that a fat loss leads to increased physical activity, which suggested that fat loss should be the independent variable. In fact, both alternatives may be correct, and thus, we conclude that the data in Figure 2 show that children who were physically active at 1.5 y of age had decreased their body fatness more than did less active children. It is likely that this at least partially reflects a variation in development regarding physical capacity, such as in the ability to walk. However, it seems reasonable to assume that children who were physically active at 1.5 y of age were also active earlier in life. If so, our observation can be reconciled with findings that suggested that lean individuals, because of their genetic disposition, are likely to be more physically active than obese subjects are (32). As shown in Table 4, estimates of body composition at 12 wk were correlated with the same estimates at 1.5 y of age. For TBF (kg), we observed a significant interaction, and correlation coefficients for this relation were significant for girls but not for boys. Thus, although the correlation coefficients for boys and girls were not significantly different, these results indicated that a sex difference in body-composition development during early life may be present, which is a topic that requires additional studies.

Tennefors et al (11) observed a negative correlation \( r = -0.81, P < 0.001 \) between PAL (y) and the percentage of TBF (x) in children aged 9 and 14 mo and considered the possibility that this may indicate the presence of a vicious cycle, in which a high body fatness limits physical activity and, thereby, promotes additional retention of body fat. However, Tennefors et al (11) pointed out that the observed correlation may be spurious because they calculated PAL by using equations that were based on body weight. Our findings showed that the correlation between PAL and the percentage of TBF tended to be weaker but was still present when a measured estimate of the resting energy metabolism, SMR, was used to calculate PAL. The relations between physical activity (PAL-SMR and AEE in kJ \( \cdot d^{-1} \cdot kg^{-1} \)) and body fatness were nonsignificant or weaker when FMI, rather than the percentage of TBF, was used. An interpretation of this observation is difficult because most studies (9, 10, 12, 14–17) have only reported results for the percentage of TBF. In addition to the amount of body fat, the percentage of TBF is affected by the amount of FFM. Thus, it may be speculated that...
a high FFM is a factor that counteracts the development of obesity.

With the use of our results that were based on PALSMR, the following calculation can be made: at the age of 1.5 y, TBF varied between 21% and 35%, which represented a difference in PAL and, thus, in energy expenditure of ~800 kJ/d, with the assumption of an average figure (2.89 MJ/d) for resting energy metabolism. During 1 y, 800 kJ/d is equivalent to the energy content of ~7 kg body fat, which should be compared with the amount of fat retained by the reference boy (169 g) or girl (258 g) during the second year of life (23). Thus, the proposed mechanism (11) may represent a powerful stimulus to retain fat already at 1.5 y of age. Furthermore, although we showed no significant difference between sexes, we observed that when a measured estimate of resting metabolic rate was used, the relation between the percentage of TBF and PAL was significant in boys but not in girls. This result is in agreement with previous studies (10, 15, 16) that suggested that the negative relation between physical activity and body fatness tends to be stronger in boys than in girls. In particular, a report by Rush et al (15) is of interest because it used measured estimates of resting energy metabolism, was conducted in children, and identified a significant relation in boys but not in girls. Although our sample was small, we consider these results to be interesting because, to our knowledge, such observations have not previously been made as early in life as in the current study.

In conclusion, this study shows a relation between physical activity at 1.5 y of age and the change in body fatness between 12 wk and 1.5 y of age, which is an observation that can be reconciled with the notion that lean individuals, because of their genetic disposition, are likely to be more physically active than obese individuals are (32). Furthermore, we identified a relation between the percentage of TBF and PALSMR at 1.5 y of age, which is a relation that was significant in boys but not in girls. Our results also suggest that sexes may differ regarding body-composition development between 12 wk and 1.5 y of age. However, our findings, in particular the sex-specific results, were based on a small sample and, therefore, need confirmation. Our results indicate that body fatness and physical activity interact during early childhood, which, thereby, influence obesity risk.

We thank all of the parents and children who participated in the study. The authors’ responsibilities were as follows—BE and HH: were responsible for data collection and contributed to the data analysis and manuscript preparation; ML: participated in data collection and contributed to the analysis; UH: was responsible for the operation of the mass spectrometer; EF: was responsible for the study design and contributed to the data analysis and manuscript preparation; and all authors: reviewed the manuscript. None of the authors had a conflict of interest.

### Table 4

<table>
<thead>
<tr>
<th>Boys (n = 23)</th>
<th>Girls (n = 21)</th>
<th>All (n = 44)</th>
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<tbody>
<tr>
<td>r</td>
<td>P</td>
<td>r</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>0.07</td>
<td>0.74</td>
</tr>
<tr>
<td>Length (cm)</td>
<td>0.52</td>
<td>0.012</td>
</tr>
<tr>
<td>TBF (kg)</td>
<td>0.04</td>
<td>0.84</td>
</tr>
<tr>
<td>TBF (%)</td>
<td>0.12</td>
<td>0.58</td>
</tr>
<tr>
<td>FMI (kg/m²)</td>
<td>0.16</td>
<td>0.46</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>0.29</td>
<td>0.18</td>
</tr>
<tr>
<td>FFM (kg)</td>
<td>0.22</td>
<td>0.32</td>
</tr>
<tr>
<td>FFMI (kg/m²)</td>
<td>0.30</td>
<td>0.16</td>
</tr>
</tbody>
</table>

1 Comparisons on the basis of Fisher’s z transformation showed no significant difference between r values for boys and girls, although for TBF (kg), r = 0.0512. r and P values were calculated by using correlation analysis. FFM, fat-free mass; FFMI, fat-free mass index; FMI, fat mass index; TBF, total body fat.

2 Multiple regression analysis with TBF (kg) at 1.5 y of age as the dependent variable and TBF (kg) at 12 wk of age and sex as independent variables showed significant interaction (P = 0.035), indicating a difference between boys and girls with regard to slope.

3 Calculated as TBF divided by length squared.

4 Calculated as TEE divided by SMR.

5 Calculated as PALSMR (calculated as the total energy expenditure divided by sleeping metabolic rate), TBF, total body fat; PAL, physical activity level; PALBMR, PAL determined by using the basal metabolic rate; PALSMR, PAL determined by using the sleeping metabolic rate; SMR, sleeping metabolic rate; TEE, total energy expenditure.

6 Predicted by using body weight (22).

7 Calculated as TEE minus PALBMR.

8 Calculated as TEE divided by PALSMR.

9 Calculated as TEE divided by BMR.

### Table 5

<table>
<thead>
<tr>
<th>Boys (n = 23)</th>
<th>Girls (n = 21)</th>
<th>All (n = 44)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEE (MJ/d)</td>
<td>3.93 ± 0.42</td>
<td>4.06 ± 0.41</td>
</tr>
<tr>
<td>SMR (MJ/d)</td>
<td>2.74 ± 0.25</td>
<td>3.02 ± 0.32</td>
</tr>
<tr>
<td>BMR (MJ/d)</td>
<td>2.73 ± 0.34</td>
<td>2.89 ± 0.27</td>
</tr>
<tr>
<td>AEE (kJ·d⁻¹·kg⁻¹)</td>
<td>1.19 ± 0.39</td>
<td>1.04 ± 0.41</td>
</tr>
<tr>
<td>PALBMR</td>
<td>1.44 ± 0.17</td>
<td>1.35 ± 0.16</td>
</tr>
<tr>
<td>PALSMR</td>
<td>1.45 ± 0.18</td>
<td>1.41 ± 0.15</td>
</tr>
</tbody>
</table>

1 All values are means ± SDs. AEE, activity energy expenditure; BMR, basal metabolic rate; PAL, physical activity level; PALBMR, PAL determined by using the basal metabolic rate; PALSMR, PAL determined by using the sleeping metabolic rate; SMR, sleeping metabolic rate; TEE, total energy expenditure.

2 Measured by using indirect calorimetry.

3 Significantly different from the corresponding value for boys by using Student’s t test (P = 0.0025).

4 Predicted by using body weight (22).

5 Calculated as TEE minus PALBMR.

6 Calculated as TEE divided by SMR.

7 Calculated as TEE divided by BMR.

### Figure 3

PALSMR (calculated as the total energy expenditure divided by the sleeping metabolic rate) at the age of 1.5 y (y) regressed on the percentage of TBF at the same age (x). Correlation and regression analysis showed a significant relation between x and y (r = −0.40, P = 0.0076; n = 44; y = 1.94−0.0197x). PALSMR, physical activity level determined by using the sleeping metabolic rate; TBF, total body fat.
REFERENCES


