Energy requirements derived from total energy expenditure and energy deposition during the first 2 y of life[1–4]

Nancy F Butte, William W Wong, Judy M Hopkinson, Carolyn J Heinz, Nitesh R Mehta, and E O'Brian Smith

ABSTRACT

Background: Current recommendations for energy intake of children are derived from observed intakes. Deriving energy requirements on the basis of energy expenditure and deposition is scientifically more rational than is using the observational approach and is now possible with data on total energy expenditure (TEE), growth, and body composition.

Objectives: The objectives of this study were *1*) to define energy requirements during the first 2 y of life on the basis of TEE and energy deposition; *2*) to test effects of sex, age, and feeding mode on energy requirements; and *3*) to determine physical activity.

Design: TEE, sleeping metabolic rate, anthropometry, and body composition were measured in 76 infants. TEE was measured with doubly labeled water, sleeping metabolic rate with respiratory calorimetry, and body composition with a multicomponent model.

Results: Total energy requirements were 2.23, 2.59, 2.97, 3.38, 3.72, and 4.15 MJ/d at 3, 6, 9, 12, 18, and 24 mo, respectively. Energy deposition (in MJ/d) decreased significantly over time ($P = 0.001$) and was lower in breast-fed than in formula-fed infants ($P = 0.01$). Energy requirements were ≈80% of current recommendations. Energy requirements differed by age ($P = 0.001$), feeding group ($P = 0.03$), and sex ($P = 0.03$). Adjusted for weight or fat-free mass and fat mass, energy requirements still differed by feeding group but not by age or sex. Temperament and motor development did not affect TEE.

Conclusion: The TEE and energy-deposition data of these healthy, thriving children provide strong evidence that current recommendations for energy intake in the first 2 y of life should be revised. *Am J Clin Nutr* 2000;72:1558–69.

KEY WORDS Energy requirements, energy expenditure, energy deposition, doubly labeled water, sleeping metabolic rate, physical activity level, infants, toddlers

INTRODUCTION

The energy requirements of infants and young children are the energy intakes that will balance energy expenditure (EE) at a physical activity level (PAL) consistent with normal development and allow for deposition of tissues at a rate consistent with health. In older children and adults, energy requirements are based on basal metabolic rates and an allowance for PAL. Because it was not possible to specify with any confidence the allowance for a desirable PAL in infants and young children, the 1985 FAO/WHO/UNU recommendations for the energy intake from birth to 10 y of age were derived from the observed intakes of healthy, thriving children (1). Energy requirements of infants were based on energy intakes compiled by Whitehead et al (2); 5% was added to compensate for underestimation of intake. Energy requirements of toddlers were estimated from intake data compiled by Ferro-Luzzi and Durnin (3). Implicit in this approach is the assumption that ad libitum intakes reflect desirable intakes. However, energy intakes are not inherently constant but are influenced by external factors. For instance, downward secular trends in the energy intakes of infants have been attributed to changes in breast-feeding rates, the formulation of infant formula, and the timing of food supplementation (2). Energy requirements of young children derived from EE and energy-deposition values would be scientifically more rational than the use of observed intakes. Implicit in the approach based on EE and energy deposition is knowledge of what constitutes developmentally appropriate PALs and normal growth and body composition. Although the energy requirement for growth relative to maintenance is small, except for during the first months of life, satisfactory growth is a sensitive indicator of whether energy needs are being met. To determine the energy cost of growth, the energy content of the newly synthesized tissues must be estimated, preferably from the separate costs of protein and fat deposition.

With the emergence of information on total EE (TEE) by the doubly labeled water (DLW) method, the energy requirements of young children can be estimated on the basis of EE as first shown by Prentice et al (4). DLW measurements of TEE include basal metabolism, thermogenesis, the synthetic cost of growth, and PAL. Although application of the DLW method in young children

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[1] From the US Department of Agriculture/Agricultural Research Service, Children's Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston.

[2] The contents of this article do not necessarily reflect the views or policies of the US Department of Agriculture, and mention of trade names, commercial products, or organizations does not imply endorsement by the US government.

[3] Supported in part by the US Department of Agriculture/Agricultural Research Service under Cooperative Agreement 58-6250-6001. Formulas were donated by Ross Laboratories.

[4] Address reprint requests to NF Butte, Children's Nutrition Research Center, 1100 Bates, Houston, TX 77030. E-mail: nbutte@bcm.tmc.edu.

Received March 10, 2000.
Accepted for publication May 30, 2000.

is subject to errors, the method was validated in infants (5–8). In 1996, the need to revise energy and protein requirements, and the data necessary to do this, were considered (9, 10). It was concluded that current recommendations for energy intake for children aged <2 y were too high; however, revision would require expansion of the database on TEE of children, especially children aged 6–24 mo. An unresolved issue pertinent to the revision of energy recommendations is whether differences in energy utilization observed between breast-fed (BF) and formula-fed (FF) infants in early infancy persist into the second year of life (11).

In this study, energy requirements during the first 2 y of life were derived from the sum of TEE and energy deposition. Factors potentially affecting energy requirements, including sex, age, body size and composition, feeding group, temperament, and motor development, were tested. In addition, PALs consistent with normal development were determined from measurements of TEE and sleeping metabolic rate (SMR).

SUBJECTS AND METHODS

Study design and subjects

Repeated measurements of TEE, SMR, body composition, temperament, and motor development were performed in 76 healthy term infants at the Children's Nutrition Research Center (CNRC) at ages 3, 6, 9, 12, 18, and 24 mo. Body composition was also measured at age 0.5 mo. Feeding practices and morbidity were ascertained at each visit. Seventy-two children completed the 24-mo study. By study design, the infants were either exclusively BF ($n = 40$) or FF ($n = 36$) from birth to 4 mo of age; thereafter, the feeding group was at the discretion of the infants' parents. This study was approved by the Baylor Affiliates Review Board for Human Subject Research and informed, written consent was obtained from each child's mother.

Infants were born healthy at full term to women with unremarkable health histories and pregnancies. The mean maternal age (±SD) was 28.8 ± 4.2 y. Median gravidity and parity were 2 (range: 1–5) and 0 (range: 0–3), respectively. Maternal height and prepregnancy weight averaged 164.3 ± 6.0 cm and 61.1 ± 8.7 kg, respectively. Gestational weight gain was 16.2 ± 5.3 kg. Family income was distributed as follows: <\$20 000, 8%; between \$20 000 and \$34 999, 24%; between \$35 000 and \$49 999, 17%; and >\$50 000, 51%. The above characteristics did not differ by infant feeding group; attained level of education, however, was higher in the BF (16.6 ± 2.6 y) than in the FF (14.4 ± 1.9 y) group ($P = 0.001$).

The infants were admitted to the CNRC Metabolic Research Unit from ≈1000 to 1700 for the series of measurements. Anthropometric measurements were performed ≥1 h after the infants were fed. $^2H_2{}^{18}O$ was administered orally with a syringe ≥30 min after the subjects were fed to avoid regurgitation of the dose. The 15-min whole-body ^{40}K counting and the dual-energy X-ray absorptiometry (DXA) measurements were usually made in the younger infants while they slept and in the older children while they were entertained with a video. The SMR was measured during an afternoon nap.

Infant feeding practices and morbidity

At each visit, infant feeding practices and morbidity were ascertained. The mothers were asked about breast-feeding and use of infant formula, solid foods, beverages, and vitamin-mineral supplements. The mothers were asked to recall any infant illness in the preceding study interval, including the type, duration, and treatment of the illness.

Motor development and temperament

The Bayley Scales of Infant Motor Development were administered by a trained examiner at each age. With correction for the child's age, the raw score was converted to the Psychomotor Development Index (PDI). The temperament of the children was assessed with use of the Carey Temperament Questionnaires (12). The Early Infancy Temperament Questionnaire (12) was used at 3 mo of age. The Infant Temperament Questionnaire was used at 6 and 9 mo of age. The Toddler Temperament Scale (12) was used at 12 and 24 mo of age. These questionnaires consist of 76–97 items on which the mother is asked to rate the actual current behavior of her child in a variety of situations. These responses are converted into category scores from 0 to 6 for 9 characteristics: activity, biological rhythm, initial approach or withdrawal, adaptability, intensity, mood, persistence or attention span, distractibility, and sensory threshold. These categories are used to group infants into 1 of 5 diagnostic clusters: difficult, intermediate-high (difficult), intermediate-low (easy), easy, and slow to warm up.

Anthropometry

The infants were weighed naked on an electronic integrating scale ≥30 min after being fed (Sartorius MC1, LC34; Gottingen, Germany; precision: ±1.0 g). Crown-to-heel length was measured on a recumbent infant board to the nearest 1 mm by 2 trained persons (Holtain Limited, Crymych, United Kingdom). The National Center for Health Statistics (NCHS) growth reference was used to evaluate these children (13).

Multicomponent body-composition model

Body composition was estimated from measurements of total body water, total body potassium, and bone mineral content by using a modified version (14) of the multicomponent model published by Fomon et al (15). Total body water was estimated from deuterium dilution space (N_H) as part of the DLW method at age 3–24 mo. At age 0.5 mo, N_H was calculated from the average of two 3- to 5-h postdose urine samples by the plateau method after an oral dose of 50 mg ^2H_2O/kg body weight. N_H was converted to total body water by dividing by 1.04. Total body potassium was estimated from the ^{40}K naturally present in the child's body by using a whole-body counter (16). For the 15-min count, photons are detected by 12 photon-sensitive NaI(Tl) detectors arranged in 2 arrays above and below the child's body in the low-background whole-body counter. DXA was used to estimate bone mineral content with a Hologic QDR-2000 instrument by using INFANT WHOLE BODY ANALYSIS software (version 5.56-5.71P; Hologic, Inc, Waltham, MA) at ages 0.5, 12, and 24 mo. For the time points at which DXA scans were not performed, bone mineral content was predicted from an equation based on the linear regression of bone mineral content on total body potassium. Energy deposition was computed from the change in protein and fat mass (FM) between adjacent study intervals. The energy equivalents for protein and fat deposition were taken as 23.6 kJ/g protein and 38.7 kJ/g fat, respectively. If body-composition data were missing from one time interval, energy deposition was computed from the change in weight multiplied by the mean energy cost of growth: 20.1, 10.0, 7.9, 10.0, 10.8, and 11.7 kJ/g weight gain at ages 3, 6, 9, 12, 18, and 24 mo, respectively.

Total energy expenditure by the doubly labeled water method

TEE was measured by the DLW method (17). Studies were completed successfully in 351 tests. Parental failure to complete the 10-d urine collection as instructed was the most common cause of unusable data. After collection of a baseline urine sample, the child received by mouth 100 mg ^2H_2O (Cambridge Isotope Laboratories, Andover, MA) and 125 mg $H_2{}^{18}O$ (Cambridge Isotope Laboratories) per kg body weight. One daily urine sample was collected at home for the next 10 d by using cotton balls placed within the child's diaper (18). Urine was expressed from soaked cotton balls with a 50-mL syringe into O-ring-sealed sample vials and then frozen at −20°C. The time of collection was recorded.

Urine samples were analyzed for hydrogen and oxygen isotope ratio measurements by gas isotope ratio mass spectrometry (19). For hydrogen isotope ratio measurements, 10 μL urine without further treatment was reduced to hydrogen gas with 200 mg Zn reagent at 500°C for 30 min (20). The ratios of ^2H to ^1H of the hydrogen gas were measured with a Delta-E gas isotope ratio mass spectrometer (Finnigan MAT, San Jose, CA). For oxygen isotope ratio measurements, 100 μL urine was allowed to equilibrate with 300 mbar CO_2 of known ^{18}O content at 25°C for 10 h with use of a VG ISOPREP-18 water–carbon dioxide equilibration system (VG Isogas, Ltd, Cheshire, United Kingdom). At the end of the equilibration, the ratio of ^{18}O to ^{16}O of the carbon dioxide was measured with a VG SIRA-12 gas isotope ratio mass spectrometer (VG Isogas, Ltd).

N_H and the ^{18}O dilution space (N_O) were calculated as follows:

$$N_H \text{ or } N_O \text{ (mol)} = d \times A \times E_a/a \times E_d \times 18.02 \qquad (1)$$

where d is the dose of ^2H_2O or $H_2{}^{18}O$ (in g), A is the amount of laboratory water (in g) used in the dose dilution, a is the amount of ^2H_2O or $H_2{}^{18}O$ (in g) added to the laboratory water in the dose dilution, E_a is the rise in ^2H or ^{18}O abundance in the laboratory water after the addition of the isotopic water, and E_d is obtained from the zero-time intercepts of the ^2H and ^{18}O decay curves in the urine samples.

Carbon dioxide production ($\dot{V}CO_2$) was calculated from the fractional turnover rates of ^2H (k_H) and ^{18}O (k_O). The isotope dilution spaces and the daily changes in ^{18}O (Q_O) and ^2H (Q_H) dilution spaces were computed from weight velocities as follows:

$$\dot{V}CO_2 \text{ (mol/d)} = 0.4556 \times [(k_O \times N_O - Q_O) - (k_H \times N_H - Q_H)] \qquad (2)$$

In this equation, the in vivo isotope fractional factors of 0.945 [f_1, $^2H_2O_{(liquid)} \leftrightarrow {}^2H_2O_{(gas)}$], 0.990 [$f_2$, $H_2{}^{18}O_{(liquid)} \leftrightarrow H_2{}^{18}O_{(gas)}$], and 1.039 [$f_3$, $H_2{}^{18}O_{(liquid)} + C^{16}O_{2(gas)} \leftrightarrow H_2{}^{16}O_{(liquid)} + C^{18}O_{2(gas)}$] measured at 37°C were used (21). $\dot{V}CO_2$ was converted to TEE with use of the de Weir equation (22) as follows:

$$\text{TEE (MJ/d)} = 22.4 \times (1.106 \times \dot{V}CO_2 + 3.941 \times \dot{V}O_2)/239 \qquad (3)$$

where oxygen consumption ($\dot{V}O_2$) was calculated from the food quotient by using the relation $\dot{V}O_2 = \dot{V}CO_2$/food quotient. Food quotients of 0.87, 0.855, 0.855, 0.855, 0.87, and 0.87 at ages 3, 6, 9, 12, 18, and 24 mo, respectively, were estimated from food records and growth velocity according to Black et al (23).

Sleeping metabolic rate by whole-body respiration calorimetry

A continuous 1- to 2-h measurement of EE during sleep was successful in 391 tests. The infants were fed ad libitum, coaxed to sleep, and then placed in the infant respiratory calorimeter. The design, operation, and calibration of the system was described previously in detail (24). Briefly, the calorimeter is operated in the "push" configuration with inlet flow through the 480 L^3 acrylic-polycarbonate chamber measured by a thermal mass flow meter (model 830; Sierra Instruments, Monterey, CA). A paramagnetic oxygen analyzer (Oxymat 5E; Seimens, Karlsruhe, Germany) and an infrared carbon dixide analyzer (Ultramat 5E; Seimens) were used to measure differences between inflow and outflow oxygen and carbon dioxide concentrations. Chamber temperature and pressure were monitored continuously. $\dot{V}O_2$ and $\dot{V}CO_2$ were calculated from mass balance equations across the chamber. EE was computed from $\dot{V}O_2$ and $\dot{V}CO_2$ with use of the de Weir equation (22). Performance tests with nitrogen and carbon dioxide infusions were done before each study; errors between expected and measured $\dot{V}O_2$ and $\dot{V}CO_2$ were within 2%.

Activity EE (AEE) was estimated from the difference between TEE and SMR. PAL was defined as the ratio of TEE to SMR.

Statistics

MINITAB (release 12, 1998; Minitab Inc, College Station, PA) was used for data description and statistical analyses, including Pearson's correlation coefficients, Student's *t* test, chi-square tests, and linear regression. Repeated-measures analysis of variance with fixed and time-varying covariates (5V; BMDP Statistical Software, Inc, Los Angeles) was used to test the effects of age, sex, and feeding group on growth, body composition, TEE, SMR, and energy requirements. The basic model included grouping factors for initial feeding group (BF or FF) and sex, a time factor (age 3, 6, 9, 12, 18, and 24 mo), and interactions among feeding group, sex, and age. Significant 2- and 3-way interactions were further investigated by subdividing the data by age and reanalyzing for feeding group and sex effects by using one-way analysis of variance.

RESULTS

Subjects

The mean (±SD) birth weight and length of the 76 infants were 3.42 ± 0.44 kg and 50.56 ± 2.24 cm, respectively, and did not differ significantly between the BF ($n = 40$) and FF ($n = 36$) infants. The mean gestational age was 39.1 ± 1.3 wk. The racial distribution by maternal lineage was 55 white, 7 African American, 11 Hispanic, and 3 Asian infants. The average duration of breast-feeding was 11.4 ± 5.8 mo. The percentages of BF children still breast-fed at ages 3, 6, 9, 12, 18, and 24 mo were 100%, 80%, 58%, 38%, 15%, and 5%, respectively. The average duration of formula feeding was 4.4 ± 4.5 mo in the BF group and 11.9 ± 3.8 mo in the FF group. The percentages of BF children given formula at 3, 6, 9, 12, 18, and 24 mo were 0%, 40%, 48%, 30%, 10%, and 2%, respectively. For the FF children, the corresponding percentages were 100%, 100%, 94%, 47%, 6%, and 0%. Seventeen (42%) of the BF infants were not given formula.

Aside from common childhood illnesses, the children were healthy. Maternal recall of the occurrence, type, and duration of infant illness did not differ significantly between the BF and FF infants at any age, with the exception that more illnesses were reported for BF than for FF infants at age 12 mo. The proportion of mothers returning to work, the number of hours worked, and the type of childcare arrangement did not differ significantly between the BF and the FF infants. On average, 62%, 51%, 48%, 51%, 53%, and 37% of the infants stayed at home, whereas others attended daycare centers or private residence facilities at age 3, 6, 9, 12, 18, and 24 mo, respectively.

Anthropometry and body composition

Anthropometric and body-composition measurements are summarized in **Table 1**. Statistical testing was performed with control for initial values at age 0.5 mo. A 3-way interaction among feeding group, sex, and age was detected for weight. Weight was higher in the FF girls than in the BF girls at ages 9 and 12 mo but did not differ significantly among the boys. Length tended to be lower in the BF than in the FF infants ($P = 0.07$). A significant 2-way interaction was encountered for fat-free mass (FFM); it was lower in the BF than in the FF infants at 3 mo. Mean NCHS weight-for-age and weight-for-length z scores differed by age but not by sex or feeding group. Length-for-age z scores differed by age and sex but not by feeding group.

Total energy expenditure

Isotope dilution spaces, fractional turnover rates of ^{2}H and ^{18}O, rates of water turnover, and $\dot{V}CO_2$ measured by DLW are summarized in **Table 2**. Isotope dilution spaces, N_H and N_O, as well as the ratio of N_H to N_O, increased with age. The fractional turnover rates of ^{2}H and ^{18}O decreased from age 3 to 24 mo, but the change was dependent on feeding group. The ratio of k_H to k_O declined significantly with age from 0.86 to 0.78. $\dot{V}CO_2$ differed by age, sex, and feeding group.

TEE as measured by the DLW method is summarized in **Table 3**. TEE (in MJ/d) differed by age, sex, and feeding group. TEE was significantly affected by weight, FFM, and FM. Adjusted for weight, TEE still differed by age and feeding group but not by sex. Adjusted for FFM and FM, TEE differed by feeding group but not by age or sex:

$$\begin{aligned}\text{TEE (MJ/d)} = {} & -0.140 + 0.021\ \text{age (mo)} - 0.047\ \text{sex} \\ & + 0.113\ \text{feeding group} \\ & + 0.303\ \text{weight (kg)} \end{aligned} \qquad (4)$$

where $S = 0.460$ and the adjusted $r^2 = 75.8\%$.

$$\begin{aligned}\text{TEE (MJ/d)} = {} & -0.238 + 0.009\ \text{age (mo)} - 0.002\ \text{sex} \\ & + 0.113\ \text{feeding group} + 0.392\ \text{FFM (kg)} \\ & + 0.134\ \text{FM (kg)} \end{aligned} \qquad (5)$$

where $S = 0.446$ and the adjusted $r^2 = 76.7\%$, sex is coded as 1 for boys and 2 for girls, and feeding group is coded as 1 for BF infants and 2 for FF infants.

Sleeping metabolic rate

SMR as measured by respiration calorimetry is shown in **Table 4**. SMR (in MJ/d) differed by sex, age, and feeding group. Adjusted for weight and length or FFM and FM, SMR differed between boys and girls and between BF and FF infants at age 3 mo and 6 mo.

$$\begin{aligned}\text{SMR (MJ/d)} = {} & -1.20 - 0.009\ \text{age (mo)} - 0.061\ \text{sex} \\ & + 0.132\ \text{feeding group} + 0.122\ \text{weight (kg)} \\ & + 0.032\ \text{length (cm)} \\ & - 0.010\ \text{feeding group} \times \text{age} \end{aligned} \qquad (6)$$

where $S = 0.207$ and the adjusted $r^2 = 85.6\%$.

$$\begin{aligned}\text{SMR (MJ/d)} = {} & 0.411 + 0.030\ \text{age (mo)} - 0.053\ \text{sex} \\ & + 0.125\ \text{feeding group} + 0.208\ \text{FFM (kg)} \\ & + 0.075\ \text{FM} - 0.009\ \text{feeding group} \\ & \times \text{age} \end{aligned} \qquad (7)$$

where $S = 0.210$ and the adjusted $r^2 = 85.4\%$, sex is coded as 1 for boys and 2 for girls, and feeding group is coded as 1 for BF infants and 2 for FF infants.

Activity energy expenditure

AEE increased from 0.270 MJ/d at age 3 mo to 1.124 MJ/d at age 24 mo and differed by age ($P = 0.001$) and feeding group ($P = 0.01$) but not by sex (**Figure 1**). Adjusted for weight, AEE differed by feeding group ($P = 0.004$; BF < FF) but not by age or sex. Adjusted for FFM and FM, AEE tended to be lower in BF than in FF infants at age 9 ($P = 0.08$) and 12 mo ($P = 0.07$) (2-way interaction between feeding group and age, $P = 0.05$). PAL differed by age ($P = 0.001$) and feeding group (BF < FF; $P = 0.04$) but not by sex (**Table 5**). PAL increased from 1.2 at age 3 mo to 1.4 at age 24 mo. AEE and PAL were not significantly correlated with body weight, FM, or %FM at any age, except that positive correlations were detected with weight at ages 12 and 18 mo ($r = 0.33$–0.40, $P = 0.02$–0.005).

Bayley motor scores

The Bayley PDI averaged 116 ± 15 and did not differ significantly by age, sex, or feeding group. Because there were no significant differences between feeding groups or sexes, the data are presented by age (**Table 6**). The Bayley PDI was not significantly correlated with TEE, PAL, or AEE at any age. Attainment of the milestones in motor development listed in Table 6 were tested for potential differences in EE. TEE, AEE, and PAL did not differ significantly between the proportion of infants who could or could not perform these milestones, with one exception: at age 6 mo, 5 infants who could not sit alone momentarily had lower TEE, AEE, and PAL ($P = 0.01$) values than did those who could perform this milestone. The proportion of BF and FF infants performing the above milestones did not differ significantly at any age.

Temperament

The category scores for activity, biological rhythmicity, initial approach or withdrawal, adaptability, intensity, mood, persistence or attention span, distractibility, and sensory threshold were not significantly correlated with TEE, AEE, or PAL. The percentages of infants classified into the 5 diagnostic clusters were similar across ages, averaging 17%, 15%, 37%, 27%, and 4% in the difficult, intermediate-high (difficult), intermediate-low (easy), easy and slow to warm up categories, respectively. Infants classified into the 5 diagnostic clusters did not have significantly different TEE, AEE, or PAL values. The proportion of infants classified into the 5 diagnostic clusters did not differ significantly between the BF and FF infants at any age.

Total energy requirements

Total energy requirements estimated from TEE and energy deposition for children aged 3–24 mo are summarized in **Table 7** and shown in **Figure 2**. Energy deposition (MJ/d) decreased significantly over time ($P = 0.001$) and was lower in the BF than in the FF infants ($P = 0.01$). Energy requirements (MJ/d) differed by age ($P = 0.001$), feeding group (BF < FF; $P = 0.03$), and sex (M > F; $P = 0.03$). Adjusted for weight, energy requirements

TABLE 1

Anthropometry and body composition of children aged 0.5–24 mo[1]

	Boys			Girls		
Age and measure	Breast-fed (*n* = 14)	Formula-fed (*n* = 19)	All (*n* = 33)	Breast-fed (*n* = 26)	Formula-fed (*n* = 17)	All (*n* = 43)
0.5 mo						
Weight (kg)	3.88 ± 0.40	3.68 ± 0.46	3.76 ± 0.44	3.65 ± 0.47	3.64 ± 0.42	3.64 ± 0.44
Length (cm)	52.54 ± 1.65	52.15 ± 1.85	52.52 ± 1.74	52.17 ± 1.79	51.70 ± 1.76	51.99 ± 1.77
Fat-free mass (kg)	3.32 ± 0.50	3.37 ± 0.32	3.35 ± 0.40	3.18 ± 0.46	3.02 ± 0.45	3.12 ± 0.45
Length-for-age *z* score[2]	−0.04 ± 0.70	−0.01 ± 0.74	−0.02 ± 0.72	0.21 ± 0.81	−0.04 ± 0.80	0.11 ± 0.81
Weight-for-age *z* score[3]	0.12 ± 0.69	−0.20 ± 0.77	−0.06 ± 0.74	0.16 ± 0.95	0.15 ± 0.95	0.16 ± 0.94
Weight-for-length *z* score[3]	0.11 ± 0.43	−0.29 ± 0.54	−0.12 ± 0.53	−0.28 ± 0.60	−0.06 ± 0.70	−0.20 ± 0.64
3 mo						
Weight (kg)	6.37 ± 0.62	6.30 ± 0.73	6.33 ± 0.68	6.03 ± 0.60	6.04 ± 0.59	6.03 ± 0.59
Length (cm)	60.99 ± 1.74	61.38 ± 1.80	61.21 ± 1.76	60.70 ± 1.82	60.62 ± 1.58	60.67 ± 1.71
Fat-free mass (kg)	4.34 ± 0.35	4.41 ± 0.52[4]	4.37 ± 0.43	4.05 ± 0.53	4.22 ± 0.37[4]	4.11 ± 0.48
Length-for-age *z* score[2]	−0.04 ± 0.55	−0.04 ± 0.66	−0.04 ± 0.60	0.45 ± 0.67	0.29 ± 0.67	0.38 ± 0.66
Weight-for-age *z* score[3]	0.47 ± 0.68	0.26 ± 0.81	0.35 ± 0.76	0.79 ± 0.75	0.70 ± 0.78	0.76 ± 0.75
Weight-for-length *z* score[3]	0.60 ± 0.90	0.32 ± 0.96	0.44 ± 0.92	0.40 ± 0.83	0.46 ± 0.73	0.42 ± 0.78
6 mo[5]						
Weight (kg)	8.09 ± 0.79	8.00 ± 0.85	8.04 ± 0.81	7.49 ± 0.62	7.77 ± 0.72	7.60 ± 0.66
Length (cm)	67.27 ± 1.44	68.44 ± 1.81	67.93 ± 1.74	66.44 ± 1.73	66.72 ± 2.17	66.55 ± 1.90
Fat-free mass (kg)	5.63 ± 0.51	5.62 ± 0.72	5.63 ± 0.60	5.08 ± 0.47	5.42 ± 0.68	5.21 ± 0.57
Length-for-age *z* score[2]	−0.30 ± 0.44	0.15 ± 0.73	−0.05 ± 0.65	0.14 ± 0.66	0.25 ± 0.73	0.18 ± 0.68
Weight-for-age *z* score[3]	0.18 ± 0.79	0.09 ± 0.89	0.13 ± 0.84	0.25 ± 0.64	0.56 ± 0.75	0.37 ± 0.70
Weight-for-length *z* score[3]	0.38 ± 0.91	−0.17 ± 0.89	0.07 ± 0.93	0.15 ± 0.78	0.42 ± 0.65	0.26 ± 0.74
9 mo[6]						
Weight (kg)	9.28 ± 0.96	9.02 ± 0.79	9.13 ± 0.86	8.39 ± 0.63	8.96 ± 0.73[7]	8.62 ± 0.72
Length (cm)	71.99 ± 1.64	72.40 ± 2.03	72.23 ± 1.86	70.72 ± 1.64	71.56 ± 2.05	71.05 ± 1.83
Fat-free mass g)	6.61 ± 0.59	6.82 ± 0.76	6.71 ± 0.67	6.08 ± 0.63	6.23 ± 0.74	6.12 ± 0.66
Length-for-age *z* score[2]	−0.27 ± 0.58	−0.040 ± 0.78	−0.14 ± 0.70	0.02 ± 0.61	0.32 ± 0.77	0.14 ± 0.68
Weight-for-age *z* score[3]	−0.03 ± 0.94	−0.24 ± 0.80	−0.15 ± 0.85	−0.23 ± 0.65	0.34 ± 0.76	−0.01 ± 0.74
Weight-for-length *z* score[3]	0.21 ± 1.05	−0.22 ± 0.77	−0.04 ± 0.91	−0.19 ± 0.61	0.26 ± 0.72	−0.02 ± 0.68
12 mo[8]						
Weight (kg)	10.14 ± 1.10	9.94 ± 0.95	10.03 ± 1.01	9.21 ± 0.72	9.96 ± 0.80[7]	9.50 ± 0.83
Length (cm)	75.81 ± 1.65	76.41 ± 2.43	76.15 ± 2.11	74.96 ± 2.22	75.85 ± 2.22	75.30 ± 2.23
Fat-free mass (kg)	7.56 ± 0.74	7.19 ± 0.67	7.40 ± 0.72	6.78 ± 0.69	7.07 ± 0.65	6.88 ± 0.68
Length-for-age *z* score[2]	−0.20 ± 0.58	0.01 ± 0.89	−0.08 ± 0.77	0.15 ± 0.78	0.33 ± 0.72	0.22 ± 0.76
Weight-for-age *z* score[3]	−0.10 ± 1.00	−0.41 ± 1.05	−0.28 ± 1.02	−0.35 ± 0.69	0.29 ± 0.79	−0.10 ± 0.78
Weight-for-length *z* score[3]	0.12 ± 1.13	−0.40 ± 1.02	−0.17 ± 1.08	−0.41 ± 0.65	0.26 ± 0.87	−0.16 ± 0.80
18 mo[9]						
Weight (kg)	11.56 ± 1.24	11.32 ± 1.04	11.43 ± 1.12	10.68 ± 0.95	11.33 ± 1.17	10.94 ± 1.08
Length (cm)	82.30 ± 1.36	82.81 ± 2.43	82.57 ± 1.99	81.82 ± 2.19	82.18 ± 2.31	81.96 ± 2.22
Fat-free mass (kg)	8.63 ± 0.70	8.46 ± 0.85	8.55 ± 0.76	8.02 ± 0.70	7.94 ± 0.97	7.99 ± 0.80
Length-for-age *z* score[2]	−0.11 ± 0.46	−0.01 ± 0.79	−0.06 ± 0.65	0.19 ± 0.72	0.20 ± 0.70	0.19 ± 0.70
Weight-for-age *z* score[3]	0.02 ± 1.02	−0.20 ± 0.88	−0.10 ± 0.94	−0.16 ± 0.82	0.35 ± 1.02	0.04 ± 0.93
Weight-for-length *z* score[3]	0.12 ± 1.26	−0.22 ± 0.93	−0.06 ± 1.09	−0.31 ± 0.78	0.34 ± 1.04	−0.05 ± 0.93
24 mo[10]						
Weight (kg)	12.67 ± 1.34	12.31 ± 1.06	12.46 ± 1.17	11.80 ± 1.09	12.36 ± 1.28	12.02 ± 1.19
Length (cm)	87.42 ± 2.77	87.69 ± 2.96	87.58 ± 2.84	87.75 ± 2.96	87.56 ± 2.46	87.67 ± 2.62
Fat-free mass (kg)	9.45 ± 0.74	8.77 ± 1.29	9.13 ± 1.06	8.97 ± 1.03	9.03 ± 1.29	8.99 ± 1.10
Length-for-age *z* score[2]	0.39 ± 0.90	0.48 ± 0.84	0.45 ± 0.85	0.81 ± 0.80	0.80 ± 0.76	0.80 ± 0.78
Weight-for-age *z* score[3]	0.08 ± 0.97	−0.22 ± 0.78	−0.10 ± 0.85	−0.15 ± 0.85	0.27 ± 0.98	0.02 ± 0.91
Weight-for-length *z* score[3]	−0.02 ± 0.98	−0.41 ± 0.81	−0.26 ± 0.88	−0.58 ± 0.70	−0.12 ± 0.86	−0.40 ± 0.79

[1] $\bar{x}$ ± SD.

[2] Significant age ($P = 0.001$) and sex ($P = 0.02$) effects for length-for-age *z* score.

[3] Significant age effects ($P = 0.001$) for weight-for-age and weight-for-length *z* scores.

[4] Significant 2-way interaction for fat-free mass ($P = 0.01$); formula-fed > breast-fed at 3 mo.

[5] *n* = 18 formula-fed boys.

[6] *n* = 25 breast-fed and 16 formula-fed girls.

[7] Significant 3-way interaction for weight ($P = 0.04$); formula-fed girls > breast-fed girls at 9 and 12 mo.

[8] *n* = 18 formula-fed boys and 16 formula-fed girls.

[9] *n* = 16 formula-fed boys, 25 breast-fed girls, and 16 formula-fed girls.

[10] *n* = 12 breast-fed and 17 formula-fed boys.

TABLE 2

Isotope dilution spaces, fractional turnover rates of ^{2}H and ^{18}O, and rates of water and carbon dioxide production measured by the doubly labeled water method in children aged 3–24 mo[1]

	Boys			Girls		
Age and measure	Breast-fed ($n = 14$)	Formula-fed ($n = 12$)	All ($n = 26$)	Breast-fed ($n = 25$)	Formula-fed ($n = 16$)	All ($n = 41$)
3 mo						
N_H (kg)[2]	3.78 ± 0.30	3.84 ± 0.48	3.80 ± 0.39	3.54 ± 0.52	3.68 ± 0.33	3.59 ± 0.46
N_O (kg)[2]	3.71 ± 0.34	3.79 ± 0.49	3.75 ± 0.41	3.50 ± 0.52	3.60 ± 0.38	3.54 ± 0.47
N_H/N_O[2]	1.02 ± 0.02	1.01 ± 0.03	1.02 ± 0.02	1.01 ± 0.03	1.02 ± 0.03	1.02 ± 0.03
k_H (d^{-1})	0.23 ± 0.03	0.24 ± 0.04	0.23 ± 0.03	0.23 ± 0.03	0.24 ± 0.04	0.24 ± 0.03
k_O (d^{-1})	0.27 ± 0.04	0.28 ± 0.04	0.27 ± 0.04	0.27 ± 0.03	0.29 ± 0.04	0.28 ± 0.03
k_H/k_O[2]	0.85 ± 0.03	0.86 ± 0.04	0.86 ± 0.03	0.86 ± 0.03	0.84 ± 0.03	0.85 ± 0.03
$\dot{V}CO_2$ (L/d)[3]	73 ± 16	78 ± 17	75 ± 17	70 ± 13	80 ± 17	74 ± 15
6 mo[4]						
N_H (kg)	4.82 ± 0.48	4.76 ± 0.64	4.79 ± 0.55	4.32 ± 0.40	4.59 ± 0.60	4.42 ± 0.49
N_O (kg)	4.76 ± 0.50	4.68 ± 0.62	4.72 ± 0.55	4.27 ± 0.40	4.50 ± 0.64	4.35 ± 0.50
N_H/N_O	1.01 ± 0.02	1.02 ± 0.02	1.02 ± 0.02	1.01 ± 0.02	1.02 ± 0.03	1.02 ± 0.02
k_H (d^{-1})[5]	0.22 ± 0.03	0.22 ± 0.04	0.22 ± 0.04	0.21 ± 0.02	0.24 ± 0.03	0.22 ± 0.02
k_O (d^{-1})[5]	0.26 ± 0.03	0.26 ± 0.04	0.26 ± 0.04	0.26 ± 0.02	0.28 ± 0.03	0.26 ± 0.03
k_H/k_O	0.84 ± 0.03	0.84 ± 0.03	0.84 ± 0.03	0.83 ± 0.04	0.84 ± 0.04	0.83 ± 0.04
$\dot{V}CO_2$ (L/d)[3]	104 ± 19	104 ± 16	104 ± 18	97 ± 20	108 ± 15	100 ± 19
9 mo						
N_H (kg)	5.51 ± 0.48	5.72 ± 0.66	5.60 ± 0.56	5.10 ± 0.56	5.19 ± 0.68	5.13 ± 0.59
N_O (kg)	5.44 ± 0.58	5.58 ± 0.61	5.50 ± 0.58	5.02 ± 0.56	5.11 ± 0.71	5.05 ± 0.60
N_H/N_O	1.02 ± 0.04	1.03 ± 0.02	1.02 ± 0.03	1.02 ± 0.02	1.02 ± 0.03	1.02 ± 0.03
k_H (d^{-1})	0.21 ± 0.05	0.21 ± 0.03	0.21 ± 0.04	0.21 ± 0.03	0.22 ± 0.04	0.22 ± 0.03
k_O (d^{-1})	0.26 ± 0.06	0.26 ± 0.03	0.26 ± 0.05	0.26 ± 0.03	0.27 ± 0.04	0.26 ± 0.04
k_H/k_O	0.83 ± 0.05	0.82 ± 0.04	0.82 ± 0.04	0.83 ± 0.03	0.82 ± 0.03	0.83 ± 0.03
$\dot{V}CO_2$ (L/d)[3]	122 ± 18	132 ± 18	126 ± 18	113 ± 17	124 ± 17	116 ± 18
12 mo						
N_H (kg)	6.31 ± 0.61	5.91 ± 0.52	6.14 ± 0.60	5.58 ± 0.62	5.81 ± 0.58	5.65 ± 0.61
N_O (kg)	6.16 ± 0.59	5.80 ± 0.49	6.00 ± 0.57	5.48 ± 0.66	5.63 ± 0.55	5.53 ± 0.62
N_H/N_O	1.02 ± 0.02	1.02 ± 0.03	1.02 ± 0.03	1.02 ± 0.03	1.03 ± 0.02	1.02 ± 0.03
k_H (d^{-1})[5]	0.20 ± 0.04	0.21 ± 0.06	0.20 ± 0.05	0.20 ± 0.03	0.24 ± 0.04	0.21 ± 0.04
k_O (d^{-1})[5]	0.24 ± 0.05	0.26 ± 0.07	0.25 ± 0.06	0.24 ± 0.03	0.29 ± 0.04	0.26 ± 0.04
k_H/k_O	0.81 ± 0.03	0.81 ± 0.03	0.81 ± 0.03	0.81 ± 0.04	0.82 ± 0.03	0.82 ± 0.04
$\dot{V}CO_2$ (L/d)[3]	140 ± 26	142 ± 27	141 ± 26	128 ± 21	136 ± 23	131 ± 22
18 mo[6]						
N_H (kg)	7.06 ± 0.57	6.90 ± 0.74	6.99 ± 0.64	6.56 ± 0.61	6.47 ± 0.89	6.53 ± 0.72
N_O (kg)	6.91 ± 0.59	6.67 ± 0.71	6.80 ± 0.64	6.42 ± 0.64	6.29 ± 0.87	6.37 ± 0.72
N_H/N_O	1.02 ± 0.02	1.03 ± 0.02	1.03 ± 0.02	1.02 ± 0.02	1.03 ± 0.02	1.02 ± 0.02
k_H (d^{-1})[5]	0.18 ± 0.04	0.20 ± 0.06	0.19 ± 0.05	0.17 ± 0.04	0.20 ± 0.05	0.18 ± 0.05
k_O (d^{-1})[5]	0.23 ± 0.04	0.25 ± 0.06	0.24 ± 0.05	0.22 ± 0.04	0.25 ± 0.06	0.23 ± 0.05
k_H/k_O	0.79 ± 0.04	0.79 ± 0.04	0.79 ± 0.04	0.79 ± 0.04	0.80 ± 0.04	0.79 ± 0.04
$\dot{V}CO_2$ (L/d)[3]	165 ± 24	164 ± 17	164 ± 20	145 ± 28	153 ± 31	148 ± 29
24 mo[7]						
N_H (kg)	7.92 ± 0.92	6.98 ± 1.08	7.52 ± 1.07	7.32 ± 0.83	7.27 ± 1.10	7.30 ± 0.92
N_O (kg)	7.76 ± 0.82	6.63 ± 1.12	7.28 ± 1.09	7.17 ± 0.77	7.10 ± 1.04	7.14 ± 0.86
N_H/N_O	1.02 ± 0.02	1.04 ± 0.02	1.03 ± 0.03	1.02 ± 0.02	1.02 ± 0.03	1.02 ± 0.02
k_H (d^{-1})[5]	0.16 ± 0.03	0.21 ± 0.03	0.18 ± 0.04	0.17 ± 0.03	0.19 ± 0.06	0.18 ± 0.04
k_O (d^{-1})[5]	0.20 ± 0.03	0.27 ± 0.04	0.23 ± 0.05	0.22 ± 0.03	0.24 ± 0.07	0.23 ± 0.05
k_H/k_O	0.78 ± 0.05	0.78 ± 0.03	0.78 ± 0.04	0.79 ± 0.04	0.79 ± 0.04	0.79 ± 0.04
$\dot{V}CO_2$ (L/d)[3]	176 ± 24	172 ± 29	741 ± 25	168 ± 27	179 ± 34	172 ± 29

[1] $\bar{x}$ ± SD. N_H, ^{2}H dilution space; N_O, ^{18}O dilution space; k_H, fractional turnover rate of ^{2}H; k_O, fractional turnover rate of ^{18}O; $\dot{V}CO_2$, carbon dioxide production.

[2] Significant age effects for N_H, N_O, N_H/N_O, and k_H/k_O, $P = 0.001$, at 3, 6, 9, 12, 18, and 24 mo.

[3] Significant age ($P = 0.001$), sex ($P = 0.02$), and feeding-group ($P = 0.05$) effects for $\dot{V}CO_2$ at 3, 6, 9, 12, 18, and 24 mo.

[4] $n = 13$ breast-fed boys, 11 formula-fed boys, 24 breast-fed girls, and 12 formula-fed girls.

[5] Significant 2-way interactions for k_H and k_O, $P = 0.04$–0.06; formula-fed > breast-fed at 6, 12, 18, and 24 mo.

[6] $n = 12$ breast-fed boys, 10 formula-fed boys, 23 breast-fed girls, and 14 formula-fed girls.

[7] $n = 11$ breast-fed boys, 8 formula-fed boys, 21 breast-fed girls, and 12 formula-fed girls.

TABLE 3

Total energy expenditure measured by the doubly labeled water method in children aged 3–24 mo[1]

	Boys			Girls		
TEE	Breast-fed	Formula-fed	All	Breast-fed	Formula-fed	All
(MJ/d)[2]						
3 mo	1.72 ± 0.39	1.84 ± 0.40	1.78 ± 0.39	1.65 ± 0.30	1.89 ± 0.39	1.74 ± 0.36
6 mo	2.49 ± 0.47	2.47 ± 0.39	2.48 ± 0.42	2.32 ± 0.47	2.57 ± 0.38	2.40 ± 0.45
9 mo	2.93 ± 0.44	3.16 ± 0.43	3.03 ± 0.44	2.70 ± 0.41	2.96 ± 0.41	2.78 ± 0.42
12 mo	3.36 ± 0.63	3.41 ± 0.66	3.38 ± 0.63	3.08 ± 0.50	3.27 ± 0.54	3.14 ± 0.52
18 mo	3.90 ± 0.56	3.86 ± 0.40	3.88 ± 0.48	3.43 ± 0.67	3.60 ± 0.73	3.50 ± 0.69
24 mo	4.16 ± 0.56	4.05 ± 0.68	4.11 ± 0.60	3.98 ± 0.63	4.22 ± 0.80	4.06 ± 0.69
$(\text{MJ}\cdot\text{kg}^{-1}\cdot\text{d}^{-1})$[3]						
3 mo	0.27 ± 0.06	0.30 ± 0.05	0.28 ± 0.06	0.28 ± 0.04	0.31 ± 0.05	0.29 ± 0.05
6 mo	0.30 ± 0.06	0.32 ± 0.05	0.31 ± 0.05	0.31 ± 0.05	0.33 ± 0.05	0.31 ± 0.05
9 mo	0.32 ± 0.06	0.36 ± 0.03	0.34 ± 0.05	0.32 ± 0.04	0.33 ± 0.04	0.32 ± 0.04
12 mo	0.33 ± 0.04	0.35 ± 0.05	0.34 ± 0.04	0.33 ± 0.05	0.33 ± 0.06	0.33 ± 0.05
18 mo	0.34 ± 0.03	0.35 ± 0.05	0.34 ± 0.04	0.32 ± 0.06	0.32 ± 0.05	0.32 ± 0.05
24 mo	0.33 ± 0.03	0.33 ± 0.05	0.33 ± 0.04	0.33 ± 0.05	0.34 ± 0.06	0.34 ± 0.05
$(\text{MJ}\cdot\text{kg FFM}^{-1}\cdot\text{d}^{-1})$[4]						
3 mo	0.40 ± 0.09	0.42 ± 0.07	0.41 ± 0.08	0.41 ± 0.08	0.44 ± 0.08	0.42 ± 0.08
6 mo	0.44 ± 0.07	0.44 ± 0.07	0.44 ± 0.07	0.46 ± 0.08	0.47 ± 0.07	0.46 ± 0.08
9 mo	0.45 ± 0.08	0.46 ± 0.03	0.45 ± 0.06	0.44 ± 0.06	0.48 ± 0.07	0.46 ± 0.06
12 mo	0.44 ± 0.05	0.47 ± 0.08	0.46 ± 0.06	0.46 ± 0.06	0.47 ± 0.09	0.46 ± 0.07
18 mo	0.45 ± 0.05	0.46 ± 0.06	0.46 ± 0.05	0.43 ± 0.07	0.45 ± 0.07	0.44 ± 0.07
24 mo	0.43 ± 0.04	0.46 ± 0.07	0.45 ± 0.06	0.44 ± 0.06	0.46 ± 0.08	0.45 ± 0.07

[1] $\bar{x}$ ± SD. Sample sizes indicated in Table 2.

[2] Significant age ($P = 0.001$), sex ($P = 0.02$), and feeding-group ($P = 0.05$) effects.

[3] Significant age ($P = 0.01$) and feeding-group ($P = 0.02$) effects.

[4] Significant feeding-group ($P = 0.02$) effect.

differed by feeding group (BF < FF; $P = 0.004$) and tended to differ by age ($P = 0.08$) but not by sex. Adjusted for FFM and FM, energy requirements differed by feeding group (BF < FF; $P = 0.004$) but not by age or sex:

$$\begin{aligned}\text{Energy requirements (MJ/d)} = {}& 0.321 + 0.013 \text{ age (mo)} \\ & - 0.047 \text{ sex} \\ & + 0.139 \text{ feeding group} \\ & + 0.277 \text{ weight} \qquad (8)\end{aligned}$$

$S = 0.469$ and the adjusted $r^2 = 69.7\%$.

$$\begin{aligned}\text{Energy requirements (MJ/d)} = {}& 0.241 + 0.002 \text{ age (mo)} \\ & - 0.007 \text{ sex} \\ & + 0.142 \text{ feeding group} \\ & + 0.358 \text{ FFM (kg)} \\ & + 0.118 \text{ FM (kg)} \qquad (9)\end{aligned}$$

where $S = 0.457$ and the adjusted $r^2 = 70.4\%$, sex is coded as 1 for boys and 2 for girls, and feeding group is coded as 1 for BF infants and 2 for FF infants.

DISCUSSION

In this study, energy requirements during the first 2 y of life were derived from measurements of TEE and energy deposition. The energy requirements of infants and young children should support a rate of growth and body composition consistent with health. The NCHS growth reference was used to evaluate the adequacy of growth of these infants (13). Although the NCHS growth reference has its shortcomings (25), it has been used extensively to compare growth performance of study populations. Although weight velocity (g/d) was higher in FF than in BF infants aged between 3 and 6 mo, and higher in FF than in BF girls aged between 6 and 9 mo (26), the mean NCHS *z* scores for weight-for-age, length-for-age, and weight-for-length of the BF and FF groups did not differ significantly and were well within 1 SD of the reference mean. The growth performance of these infants was comparable with that of other BF and FF infant populations in whom socioeconomic and environmental constraints would not be expected to limit growth (27, 28). A pooled analysis of growth data on BF infants from the United States, Canada, and Europe showed consistently downward trends after 2–3 mo in NCHS weight-for-age, length-for-age, and weight-for-length *z* scores to means of −0.5, −0.29, and −0.32, respectively, at age 12 mo (28). In our study, the growth pattern was similar in the BF and FF groups. Growth in both groups was faster than the NCHS reference in the first 3 mo, declined between the ages of 3 and 12 mo, and then plateaued. Length-for-age *z* scores hovered around 0 for the first 18 mo in both groups and then increased at 24 mo as a result of a disjunction in the reference where 2 databases were merged. Relative to the NCHS reference and compared with other BF and FF study populations, the growth of these children was satisfactory. The assessment of body composition is more problematic because in vivo body-composition measurements have been made in fewer studies of infants and toddlers. The FM of our children peaked at ≈30% at age 3–6 mo and then decreased to ≈25% FM in the second year of life (14). Our values for FM and %FM were 9% higher than the Fomon reference (15) but were comparable with the results of recent studies that used total-body electrical conductivity and ^{18}O dilution (29–31).

The body-composition data also were used to compute the energy cost of growth. The energy content of the newly synthesized tissues is theoretically more accurate when the separate

TABLE 4

Sleeping metabolic rate measured by respiration calorimetry in children aged 3–24 mo[1]

	Boys			Girls		
Age and measure	Breast-fed	Formula-fed	All	Breast-fed	Formula-fed	All
3 mo[2]						
$\dot{V}O_2$ (L/min)	0.050 ± 0.005	0.054 ± 0.005	0.052 ± 0.005	0.047 ± 0.004	0.052 ± 0.004	0.049 ± 0.005
$\dot{V}CO_2$ (L/min)	0.041 ± 0.004	0.046 ± 0.004	0.044 ± 0.005	0.040 ± 0.004	0.044 ± 0.004	0.041 ± 0.004
RQ	0.82 ± 0.06	0.86 ± 0.02	0.84 ± 0.04	0.84 ± 0.04	0.83 ± 0.04	0.84 ± 0.04
SMR (kJ/min)	1.02 ± 0.10	1.11 ± 0.10	1.07 ± 0.11	0.96 ± 0.09	1.06 ± 0.09	1.00 ± 0.10
(MJ/d)[3]	1.47 ± 0.15	1.59 ± 0.14	1.54 ± 0.15	1.38 ± 0.13	1.53 ± 0.12	1.43 ± 0.15
$(\text{MJ}\cdot\text{kg}^{-1}\cdot\text{d}^{-1})$[4]	0.23 ± 0.02	0.25 ± 0.02	0.24 ± 0.02	0.23 ± 0.02	0.26 ± 0.02	0.24 ± 0.02
$(\text{MJ}\cdot\text{kg FFM}^{-1}\cdot\text{d}^{-1})$[4]	0.34 ± 0.03	0.36 ± 0.02	0.35 ± 0.03	0.34 ± 0.04	0.37 ± 0.02	0.35 ± 0.04
6 mo[5]						
$\dot{V}O_2$ (L/min)	0.65 ± 0.007	0.069 ± 0.006	0.068 ± 0.007	0.061 ± 0.005	0.066 ± 0.005	0.063 ± 0.006
$\dot{V}CO_2$ (L/min)	0.056 ± 0.006	0.060 ± 0.008	0.058 ± 0.007	0.052 ± 0.005	0.056 ± 0.005	0.054 ± 0.005
RQ	0.86 ± 0.05	0.87 ± 0.07	0.86 ± 0.06	0.86 ± 0.04	0.86 ± 0.04	0.86 ± 0.04
SMR (kJ/min)	1.34 ± 0.14	1.42 ± 0.13	1.39 ± 0.14	1.25 ± 0.11	1.35 ± 0.10	1.29 ± 0.11
(MJ/d)[3]	1.92 ± 0.21	2.05 ± 0.19	2.00 ± 0.21	1.79 ± 0.15	1.94 ± 0.14	1.85 ± 0.16
$(\text{MJ}\cdot\text{kg}^{-1}\cdot\text{d}^{-1})$[4]	0.24 ± 0.02	0.26 ± 0.02	0.25 ± 0.02	0.24 ± 0.02	0.26 ± 0.03	0.25 ± 0.02
$(\text{MJ}\cdot\text{kg FFM}^{-1}\cdot\text{d}^{-1})$[4]	0.35 ± 0.03	0.36 ± 0.03	0.35 ± 0.03	0.35 ± 0.03	0.36 ± 0.04	0.36 ± 0.03
9 mo[6]						
$\dot{V}O_2$ (L/min)	0.079 ± 0.009	0.078 ± 0.005	0.078 ± 0.007	0.070 ± 0.007	0.074 ± 0.006	0.072 ± 0.007
$\dot{V}CO_2$ (L/min)	0.070 ± 0.008	0.069 ± 0.006	0.069 ± 0.007	0.063 ± 0.007	0.062 ± 0.006	0.063 ± 0.006
RQ	0.89 ± 0.05	0.88 ± 0.06	0.88 ± 0.05	0.90 ± 0.05	0.84 ± 0.03	0.88 ± 0.05
SMR (kJ/min)	1.63 ± 0.18	1.60 ± 0.11	1.61 ± 0.14	1.45 ± 0.15	1.52 ± 0.13	1.47 ± 0.14
(MJ/d)	2.34 ± 0.26	2.31 ± 0.15	2.32 ± 0.20	2.08 ± 0.22	2.18 ± 0.18	2.12 ± 0.21
$(\text{MJ}\cdot\text{kg}^{-1}\cdot\text{d}^{-1})$	0.25 ± 0.03	0.26 ± 0.02	0.26 ± 0.02	0.25 ± 0.02	0.25 ± 0.02	0.25 ± 0.02
$(\text{MJ}\cdot\text{kg FFM}^{-1}\cdot\text{d}^{-1})$	0.35 ± 0.05	0.34 ± 0.02	0.34 ± 0.04	0.35 ± 0.04	0.35 ± 0.03	0.35 ± 0.03
12 mo[7]						
$\dot{V}O_2$ (L/min)	0.087 ± 0.008	0.086 ± 0.008	0.086 ± 0.008	0.085 ± 0.007	0.082 ± 0.009	0.084 ± 0.008
$\dot{V}CO_2$ (L/min)	0.078 ± 0.009	0.075 ± 0.009	0.076 ± 0.009	0.074 ± 0.007	0.070 ± 0.007	0.072 ± 0.007
RQ	0.89 ± 0.05	0.87 ± 0.04	0.88 ± 0.04	0.87 ± 0.04	0.85 ± 0.02	0.86 ± 0.04
SMR (kJ/min)	1.79 ± 0.18	1.76 ± 0.18	1.77 ± 0.17	1.74 ± 0.14	1.68 ± 0.19	1.72 ± 0.16
(MJ/d)	2.58 ± 0.26	2.54 ± 0.25	2.55 ± 0.25	2.50 ± 0.20	2.42 ± 0.27	2.47 ± 0.23
$(\text{MJ}\cdot\text{kg}^{-1}\cdot\text{d}^{-1})$	0.25 ± 0.02	0.27 ± 0.03	0.26 ± 0.03	0.27 ± 0.02	0.25 ± 0.02	0.26 ± 0.02
$(\text{MJ}\cdot\text{kg FFM}^{-1}\cdot\text{d}^{-1})$	0.34 ± 0.03	0.36 ± 0.03	0.35 ± 0.03	0.37 ± 0.03	0.34 ± 0.02	0.36 ± 0.03
18 mo[8]						
$\dot{V}O_2$ (L/min)	0.096 ± 0.009	0.099 ± 0.005	0.098 ± 0.007	0.09 ± 0.010	0.092 ± 0.010	0.091 ± 0.010
$\dot{V}CO_2$ (L/min)	0.085 ± 0.010	0.087 ± 0.006	0.086 ± 0.008	0.083 ± 0.010	0.080 ± 0.010	0.082 ± 0.010
RQ	0.88 ± 0.04	0.88 ± 0.05	0.88 ± 0.04	0.91 ± 0.04	0.88 ± 0.03	0.90 ± 0.04
SMR (kJ/min)	1.98 ± 0.19	2.04 ± 0.10	2.01 ± 0.15	1.88 ± 0.22	1.88 ± 0.20	1.88 ± 0.21
(MJ/d)	2.85 ± 0.27	2.93 ± 0.15	2.89 ± 0.21	2.70 ± 0.31	2.71 ± 0.29	2.71 ± 0.30
$(\text{MJ}\cdot\text{kg}^{-1}\cdot\text{d}^{-1})$	0.25 ± 0.03	0.26 ± 0.02	0.26 ± 0.03	0.25 ± 0.02	0.24 ± 0.02	0.25 ± 0.02
$(\text{MJ}\cdot\text{kg FFM}^{-1}\cdot\text{d}^{-1})$	0.33 ± 0.04	0.36 ± 0.03	0.34 ± 0.04	0.34 ± 0.03	0.33 ± 0.03	0.34 ± 0.03
24 mo[9]						
$\dot{V}O_2$ (L/min)	0.103 ± 0.009	0.098 ± 0.008	0.100 ± 0.009	0.097 ± 0.012	0.096 ± 0.012	0.096 ± 0.012
$\dot{V}CO_2$ (L/min)	0.093 ± 0.009	0.086 ± 0.009	0.088 ± 0.009	0.085 ± 0.010	0.083 ± 0.012	0.084 ± 0.010
RQ	0.91 ± 0.01	0.88 ± 0.04	0.89 ± 0.04	0.88 ± 0.03	0.86 ± 0.03	0.87 ± 0.03
SMR (kJ/min)	2.12 ± 0.19	2.01 ± 0.17	2.05 ± 0.18	1.99 ± 0.24	1.97 ± 0.24	1.98 ± 0.24
(MJ/d)	3.06 ± 0.27	2.89 ± 0.25	2.95 ± 0.26	2.86 ± 0.35	2.84 ± 0.35	2.85 ± 0.34
$(\text{MJ}\cdot\text{kg}^{-1}\cdot\text{d}^{-1})$	0.25 ± 0.02	0.23 ± 0.02	0.24 ± 0.02	0.24 ± 0.02	0.24 ± 0.03	0.24 ± 0.02
$(\text{MJ}\cdot\text{kg FFM}^{-1}\cdot\text{d}^{-1})$	0.33 ± 0.04	0.32 ± 0.04	0.32 ± 0.04	0.32 ± 0.03	0.32 ± 0.05	0.32 ± 0.04

[1] $\bar{x}$ ± SD. $\dot{V}O_2$, oxygen consumption; $\dot{V}CO_2$, carbon dioxide production; RQ, respiratory quotient; SMR, sleeping metabolic rate; FFM, fat-free mass.

[2] $n = 12$ breast-fed boys, 17 formula-fed boys, 25 breast-fed girls, and 15 formula-fed girls.

[3] Significant sex effect ($P = 0.001$) and 2-way interaction ($P = 0.01$); formula-fed > breast-fed at 3 and 6 mo.

[4] Significant sex effect ($P = 0.04$), and 2-way interaction ($P = 0.02$); formula-fed > breast-fed at 3 and 6 mo.

[5] $n = 14$ breast-fed boys, 18 formula-fed boys, 26 breast-fed girls, and 17 formula-fed girls.

[6] $n = 13$ breast-fed boys, 17 formula-fed boys, 22 breast-fed girls, and 15 formula-fed girls.

[7] $n = 10$ breast-fed boys, 17 formula-fed boys, 22 breast-fed girls, and 13 formula-fed girls.

[8] $n = 13$ breast-fed boys, 15 formula-fed boys, 21 breast-fed girls, and 13 formula-fed girls.

[9] $n = 8$ breast-fed boys, 13 formula-fed boys, 22 breast-fed girls, and 12 formula-fed girls.

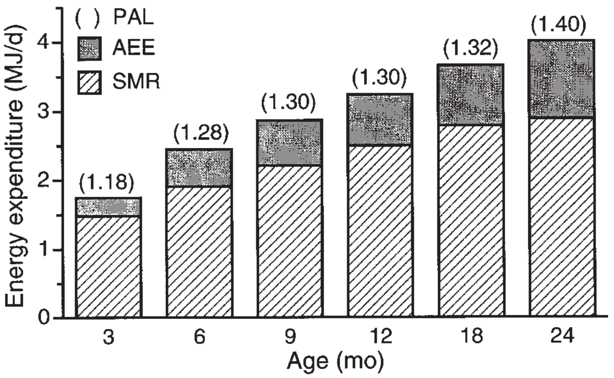

FIGURE 1. Sleeping metabolic rate (SMR), activity energy expenditure (AEE), and physical activity level (PAL) of children aged 3–24 mo. *n* = 67, 60, 56, 57, 59, and 52 for ages 3, 6, 9, 12, 18, and 24 mo, respectively.

costs of protein and fat deposition are taken into account because the composition of weight gain varies with age. The mean energy cost of growth in this study was 20 kJ/g at 3 mo and ≈10 kJ/g weight gain thereafter. Much of our understanding of the energy cost of growth has been derived from preterm infants or children recovering from malnutrition (32). Typically, the energy cost of growth in these studies range from 10 to 25 kJ/g. On the basis of the changes in body composition of Fomon's term infant reference (15), the energy cost of growth fell from 19 to 8 kJ/g in the first year of life. In practicality, the energy cost of growth is an issue only during the first half of infancy, during which energy deposition contributes significantly to energy requirements. At ages 3 and 6 mo, the energy cost of growth constituted 22% and 6%, respectively, of total energy requirements; thereafter, it contributed negligibly (2–3%) to total energy requirements.

Our TEE values agree with measurements in children aged 3–24 mo from the United Kingdom, the United States, the Netherlands, The Gambia, Mexico, and Peru (4, 11, 29, 33–43). In these studies, mean TEE values were ≈0.30 $\text{MJ} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$ at 3 mo and ≈0.33 $\text{MJ} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$ from 6 mo onward. In the present study, TEE was found to be a function of age, sex, and feeding group. Differences in TEE between ages could be accounted for by weight or FFM and FM. Differences between boys and girls were accounted for by FFM and FM. Together, these factors accounted for 76% of the variability in TEE. The differences in TEE observed between feeding groups, however, were not explained by these factors, or by other plausible factors measured in this study. Motor development, temperament, morbidity, the return of mothers to work, and child-care arrangements did not explain the difference in TEE between feeding groups. Differences in TEE between BF and FF infants were reported previously by us (11) and others (44, 45).

SMR was also a function of sex, age, and feeding group; however, the latter was dependent on age. Significant differences between the BF and FF infants were evident at 3 and 6 mo only. Lower SMRs in BF infants in early infancy confirmed prior observations (33, 46). Weight and length or FFM and FM explained 85% of the variability in SMR. We compared our SMR measurements with BMR predicted from weight and length using the Schofield equation (47). Predicted BMRs were equal to 0.88 SMR at 3–12 mo, 0.93 SMR at 18 mo, and 1.00 SMR at 24 mo. Schofield compiled ≈300 measurements from Benedict and Talbot (48, 49), Clagett and Hathaway (50), Harris and Benedict (51), and Karlberg (52) to develop predictive models based on weight and length (47). Experimental conditions varied across studies in which indirect calorimetry was used to measure SMR or resting metabolic rate rather than BMR. Benedict performed measurements on sleeping infants 1–1.5 h after a feeding of sweetened water. Clagett's measurements were done while the infants slept or after an early morning feeding. The 94 measurements in the Harris and Benedict study were in infants during the first week of life, when basal metabolism is known to be lower. The 60 infants in Karlberg's series were fasted and sedated with hexobarbital during the measurements. The influence of neonatal age and sedation might explain the lower values predicted by the Schofield equation compared with our values.

Also implicit in this approach to energy requirements is an understanding of what constitutes developmentally appropriate PALs. As expected, PAL increased significantly with age from 1.2 at 3 mo to 1.4 at 24 mo. According to the Bayley PDI, the motor skills of these infants were developmentally on target. The Bayley PDI was not significantly correlated with TEE, PAL, or AEE at any age. We did not detect any significant difference in EE as the children attained milestones such as crawling or walking. Once the coordination and strength are in place to master these skills, the child may be more energetically efficient than during the learning period. We anticipated an effect of infant temperament on PALs, but neither the category scores for activity, biological rhythmicity, initial approach or withdrawal, adaptability, intensity, mood, persistence or attention span, distractibility, and sensory threshold nor the diagnostic temperament clusters were related to TEE, AEE, or PAL. The fact that we did not detect an effect of temperament may have been due to the lower number of infants in the outermost categories of difficult and slow to warm up. This is in contrast with findings by Wells and Davies (53) of

TABLE 5
Physical activity level (PAL) of children aged 3–24 mo[1]

	Boys			Girls		
	Breast-fed	Formula-fed	All	Breast-fed	Formula-fed	All
PAL (TEE/SMR)						
3 mo	1.17 ± 0.27	1.14 ± 0.18	1.16 ± 0.22	1.20 ± 0.22	1.20 ± 0.19	1.20 ± 0.21
6 mo	1.28 ± 0.20	1.24 ± 0.17	1.26 ± 0.18	1.30 ± 0.24	1.32 ± 0.15	1.30 ± 0.21
9 mo	1.29 ± 0.25	1.37 ± 0.15	1.33 ± 0.21	1.25 ± 0.16	1.36 ± 0.19	1.29 ± 0.18
12 mo	1.27 ± 0.18	1.35 ± 0.28	1.31 ± 0.23	1.24 ± 0.15	1.40 ± 0.29	1.29 ± 0.21
18 mo	1.37 ± 0.24	1.33 ± 0.17	1.35 ± 0.21	1.26 ± 0.27	1.38 ± 0.28	1.30 ± 0.28
24 mo	1.31 ± 0.10	1.49 ± 0.18	1.40 ± 0.17	1.39 ± 0.28	1.43 ± 0.20	1.40 ± 0.26

[1] $\bar{x}$ ± SD; sample sizes indicated in Table 2. TEE, total energy expenditure; SMR, sleeping metabolic rate.

TABLE 6
Bayley scales of infant motor development and Carey Temperament Questionnaires

	Age					
	3 mo (*n* = 76)	6 mo (*n* = 75)	9 mo (*n* = 74)	12 mo (*n* = 74)	18 mo (*n* = 71)	24 mo (*n* = 72)
Psychomotor Development Index	114 ± 17[1]	119 ± 14	117 ± 15	109 ± 14	113 ± 17	118 ± 19
Milestones (% of children performing)						
Turns from back to side	20	100	100	100	100	100
Sits alone momentarily	3	93	100	100	100	100
Rolls from back to stomach	3	86	100	100	100	100
Prewalking progression	0	34	94	100	100	100
Pulls to standing position	0	31	94	100	100	100
Walks with help	0	0	65	98	98	100
Walks alone	0	0	4	83	98	100
Stands up	0	0	3	70	98	100
Walks up stairs with help	0	0	0	11	91	98
Jumps off floor, both feet	0	0	0	0	16	78
Walks up stairs alone	0	0	0	1	14	58
Jumps from second step	0	0	0	0	1	29
Carey Diagnostic Clusters (% children)						
Difficult	4.2	14 ± 9	31 ± 4	13	22	13 ± 6
Intermediate-high (difficult)	15 ± 5	14 ± 9	21 ± 4	13	10 ± 2	16 ± 7
Intermediate-low (easy)	38	39 ± 2	27 ± 1	39 ± 1	35 ± 6	42 ± 4
Easy	40 ± 8	24 ± 3	14 ± 3	31 ± 9	25 ± 4	24 ± 2
Slow to warm up	1 ± 4	6 ± 8	5 ± 7	2 ± 9	6 ± 8	3

[1] $\bar{x}$ ± SD.

TABLE 7
Total energy requirements estimated from total energy expenditure and energy deposition of children aged 3–24 mo[1]

	Boys			Girls		
Age and measure	Breast-fed	Formula-fed	All	Breast-fed	Formula-fed	All
Energy deposition (MJ/d)						
3 mo	0.49 ± 0.16	0.48 ± 0.12	0.48 ± 0.14	0.50 ± 0.12	0.47 ± 0.11	0.49 ± 0.12
6 mo	0.17 ± 0.12	0.13 ± 0.05	0.15 ± 0.09	0.12 ± 0.12	0.21 ± 0.08	0.16 ± 0.11
9 mo	0.07 ± 0.10	0.12 ± 0.08	0.10 ± 0.10	0.06 ± 0.10	0.11 ± 0.08	0.08 ± 0.10
12 mo	0.07 ± 0.12	0.12 ± 0.10	0.10 ± 0.11	0.08 ± 0.08	0.10 ± 0.06	0.08 ± 0.07
18 mo	0.08 ± 0.05	0.09 ± 0.06	0.08 ± 0.06	0.07 ± 0.05	0.07 ± 0.05	0.07 ± 0.05
24 mo	0.06 ± 0.06	0.06 ± 0.05	0.06 ± 0.05	0.07 ± 0.05	0.07 ± 0.05	0.07 ± 0.05
Energy requirements (MJ/d)						
3 mo	2.21 ± 0.42	2.29 ± 0.47	2.24 ± 0.44	2.15 ± 0.36	2.35 ± 0.46	2.23 ± 0.41
6 mo	2.66 ± 0.51	2.59 ± 0.39	2.63 ± 0.45	2.45 ± 0.49	2.80 ± 0.35	2.57 ± 0.47
9 mo	2.99 ± 0.44	3.36 ± 0.40	3.14 ± 0.45	2.76 ± 0.42	3.06 ± 0.38	2.85 ± 0.43
12 mo	3.43 ± 0.71	3.54 ± 0.75	3.47 ± 0.71	3.18 ± 0.53	3.38 ± 0.54	3.25 ± 0.53
18 mo	4.01 ± 0.53	3.96 ± 0.45	3.98 ± 0.48	3.51 ± 0.69	3.67 ± 0.74	3.57 ± 0.70
24 mo	4.25 ± 0.60	4.12 ± 0.68	4.19 ± 0.62	4.05 ± 0.64	4.28 ± 0.80	4.14 ± 0.70
Energy requirements (MJ · kg^{-1} · d^{-1})						
3 mo	0.35 ± 0.06	0.37 ± 0.06	0.36 ± 0.06	0.36 ± 0.05	0.39 ± 0.06	0.37 ± 0.06
6 mo	0.32 ± 0.06	0.34 ± 0.05	0.33 ± 0.06	0.32 ± 0.05	0.36 ± 0.05	0.34 ± 0.05
9 mo	0.33 ± 0.06	0.38 ± 0.02	0.35 ± 0.05	0.33 ± 0.05	0.34 ± 0.03	0.33 ± 0.04
12 mo	0.34 ± 0.04	0.36 ± 0.06	0.35 ± 0.05	0.34 ± 0.05	0.34 ± 0.05	0.34 ± 0.05
18 mo	0.35 ± 0.03	0.36 ± 0.05	0.35 ± 0.04	0.33 ± 0.06	0.32 ± 0.05	0.33 ± 0.05
24 mo	0.34 ± 0.04	0.34 ± 0.05	0.34 ± 0.04	0.34 ± 0.05	0.35 ± 0.06	0.34 ± 0.05
Energy requirements (MJ · kg FFM^{-1} · d^{-1})						
3 mo	0.51 ± 0.09	0.51 ± 0.08	0.51 ± 0.08	0.54 ± 0.10	0.56 ± 0.09	0.54 ± 0.10
6 mo	0.47 ± 0.08	0.46 ± 0.07	0.47 ± 0.07	0.48 ± 0.09	0.52 ± 0.06	0.49 ± 0.08
9 mo	0.46 ± 0.07	0.48 ± 0.02	0.47 ± 0.06	0.45 ± 0.06	0.50 ± 0.06	0.47 ± 0.06
12 mo	0.45 ± 0.06	0.50 ± 0.09	0.47 ± 0.07	0.47 ± 0.06	0.48 ± 0.09	0.47 ± 0.07
18 mo	0.46 ± 0.04	0.47 ± 0.06	0.46 ± 0.05	0.44 ± 0.07	0.46 ± 0.07	0.44 ± 0.07
24 mo	0.44 ± 0.04	0.47 ± 0.07	0.46 ± 0.06	0.45 ± 0.06	0.47 ± 0.08	0.46 ± 0.07

[1] $\bar{x}$ ± SD; sample sizes indicated in Table 2.

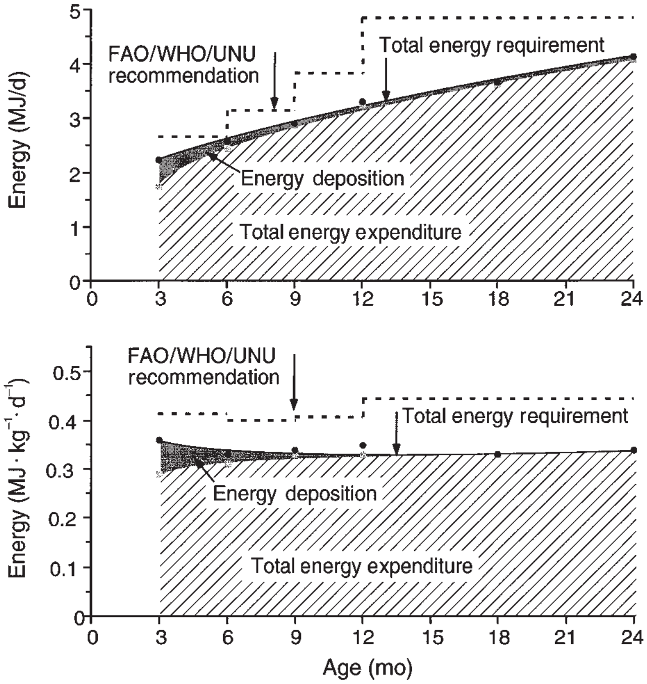

FIGURE 2. Total energy expenditure, energy deposition, and total energy requirements of children aged 3–24 mo compared with the 1985 FAO/WHO/UNU recommendations (1).

a positive correlation between AEE and distress to limitations on the Rothbart Temperament Questionnaire.

Total energy requirements for the children in the present study were a function of age, sex, and feeding group. Naturally, total energy requirements (in MJ/d) increased as the children grew and were higher in boys than in girls; however, weight or FFM and FM accounted for the differences between ages and sexes. The effect of feeding group on energy requirements was apparent throughout the 2 y, primarily because of the higher TEE in the FF than in the BF infants. Energy requirements (in MJ $\cdot$ kg^{-1} $\cdot$ d^{-1}) were 7%, 8%, 9%, 3%, 1%, and 2% higher in the FF than in the BF infants at ages 3, 6, 9, 12, 18, and 24 mo, respectively. Although we did not detect an interaction between feeding group and age, our data strongly suggest that differences in energy requirements between feeding groups diminish beyond the first year of life.

Our estimations of the total energy requirements were slightly lower than those estimated by Prentice et al (4). Their estimates were 0.40, 0.36, 0.35, 0.35, and 0.34 MJ $\cdot$ kg^{-1} $\cdot$ d^{-1} at ages 3, 6, 9, 12, and 24 mo, respectively. The discrepancies between databases may be attributed to differences in the proportion of BF and FF infants, the estimated energy deposition for growth, or the wide spectrum of nutritional statuses attributable to the inclusion of infants from the United Kingdom, the United States, Peru, and The Gambia.

Total energy requirements of our infants were ≈80% of the 1985 FAO/WHO/UNU recommendations for energy intake of infants and toddlers. The 1985 FAO/WHO/UNU recommendations were based on observed energy intakes of infants compiled by Whitehead et al (2) from the literature predating 1940 and up to 1980. Modeling of the data indicated a highly significant curvilinear relation between energy intake per kg body weight and age. The authors attributed the sharp fall in energy intake from age 0 to 6 mo to the rapidly decelerating rate of growth and ascribed the rise in energy intake from age 6 to 12 mo to an increase in PAL. Because of the concern that the data represented earlier infant feeding practices, we compiled data published after 1980 (9). Although we did not find evidence of a strong secular trend in energy intakes of infants, the more recent data were 2–15% lower than the 1985 FAO/WHO/UNU recommendations, in part because of the extra 5% allowance added to the recommendations to correct for underestimation of energy intake. In contrast with the 1985 FAO/WHO/UNU recommendations, our data do not display a curvilinear pattern. Energy requirements gradually increased from 0.29 to 0.33 MJ $\cdot$ kg^{-1} $\cdot$ d^{-1}.

In conclusion, energy requirements during the first 2 y of life were estimated from measurements of TEE and energy deposition. Whether these estimations would balance energy expenditure at a PAL consistent with normal development and allow for deposition of tissues at a rate consistent with health is uncertain. Without normative standards, evaluating the growth, body composition, and PAL of young children is judgmental. Remarkable similarity in mean TEE values among studies conducted in the United Kingdom, the United States, the Netherlands, The Gambia, Mexico, and Peru (4, 11, 29, 33–43) lends support to the validity of the data and provides strong evidence that current recommendations for energy intake during the first 2 y of life should be revised.

We thank the women who participated in this study and acknowledge the contributions of Marilyn Navarrete for subject recruitment; Sopar Seributra and Sandra Kattner for nursing and dietary support; Maurice Puyau, Firoz Vohra, Judy Joo Posada, JoAnn Pratt, Zahira Colon, Kiyoko Usuki, Shide Zhang, and Deborah Roose for technical assistance; Anne Adolph for data management; Leslie Loddeke for editorial review; and Idelle Tapper for secretarial assistance.

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