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Energy requirements and dietary energy recommendations for children and adolescents 1 to 18 years old

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Introduction

In 1981, a group of experts was convened by FAO, WHO and UNU to evaluate the energy and protein requirements of humans, and to make appropriate dietary recommendations. Several key concepts related to energy were asserted in their report (FAO/WHO/UNU, 1985), which included the following:

- The energy requirement is the amount of dietary energy needed to maintain health, growth, and an 'appropriate' level of physical activity.
- 'Appropriate' physical activity includes those activities that an individual must perform to survive in his/her social environment (*occupational activities*), and to pursue his/her physical, intellectual and social desires and wellbeing (*discretionary activities*). For children, this should allow the exploration of the surroundings and the interaction with other children and adults.
- Energy needs are determined by energy expenditure. Therefore, estimates of requirements should be based on measurements of energy expenditure and, for children, an additional allowance for growth.
- Energy requirements can be calculated as multiples of basal metabolic rate (*BMR*). In the absence of direct measurements, BMR can be estimated with mathematical equations derived from published metabolic data.

However, very little information was available on total energy expenditure (*TEE*) of children. Consequently, estimates of energy requirements for 1–10 year old children were based on the reported energy intakes of healthy, well nourished children, with the tacit assumption that they represented habitual intakes. These estimated requirements were derived from an extensive review of published dietary intake data on approximately 6500 children, mostly from developed countries (Ferro-Luzzi & Durnin, 1981).

The FAO/WHO/UNU Expert Committee was also concerned about a perceived secular trend towards sedentary lifestyles in developed countries. Therefore, it was felt prudent to increase by 5% the reported energy intakes of children between 1 and 10 years of age to accommodate a desirable level of physical activity.

After 10 years of age, estimates of energy expenditure expressed as multiples of BMR provided the basis to calculate energy requirements, rather than energy intake data. BMR for boys and girls of a given age and weight were predicted with the mathematical equations derived by Schofield (FAO/WHO/UNU, 1985; Schofield, 1985), and the additional energy expended during the day was calculated based on the assumed energy cost of activities performed by children and adolescents in developed countries. The extra allowance for growth was assumed to be 5.6 kcal (23.4 kJ) per gram of expected weight gain. This corresponded to about 3% of the daily energy requirement at one year of age, with a gradual decrease to about 1% at 15 years.

In deriving these estimates of energy requirements for children and adolescents the FAO/WHO/UNU Expert Committee acknowledged that they exceeded the dietary energy intakes reported for these ages. It was considered that the low intakes reflected an undesirably low level of physical activity, and that dietary recommendations should include enough energy to allow an increase in activity. It should be noted that the spontaneous activity of children and hence energy expenditure can be restricted by energy intake as demonstrated by studies in Guatemala (Torun, 1990*b*).

In the years that followed the 1981 FAO/WHO/UNU Expert Consultation, more has been learned about the energy expenditure of children and adolescents and of the way they distribute their time in activities that demand different levels of energy expenditure, largely due to the application of the doubly-labeled water method, the improved technology and validation of heart-rate monitoring techniques, and the analysis of physiological, nutritional and anthropological studies

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(Schürch & Scrimshaw, 1990). Additional information on food intake and on basal and resting metabolic rates have also allowed a better appraisal of the calculation and validity of energy requirements between 1 and 18 years of age.

This document presents a critical review of that knowledge and makes recommendations for consideration by the group of experts that will revise the 1985 FAO/WHO/UNU report.

Total daily energy expenditure (TEE)

Three types of methods have been used to calculate total daily energy expenditure of free-living children and adolescents. Their advantages and limitations have been reviewed by several authors (e.g. Torun, 1984; Durnin, 1990).

(1) *Doubly-labeled water.* This method has two components: (a) Administration of a marker dose of ^2H and ^{18}O, and measurement of the disappearance of the isotope from the body after several days and (b) Calculation of the food quotient or estimation of the average respiratory quotient during that period of time.

The doubly-labeled water is the most accurate of the three methods. However, there are still some doubts about the appropriateness of the assumptions used for the calculation of energy expenditure. Moreover, the number of children so far studied is very small and restricted to few geographical areas due to the high cost of the isotopes and their analysis. Furthermore, it does not provide information on the patterns of physical activity throughout the day.

(2) *Heart rate monitoring.* This method has three components. (a) Measurement of heart rate while resting and measurement or estimation of the resting and basal metabolic rates. (b) Determination of the relationship between heart rate and oxygen consumption (or energy expenditure) with light, moderate and moderately heavy workloads. This relationship varies among individuals and must be established for every person who will be studied. (c) Minute-by-minute recording of heart rate. Earlier studies used recorders that accumulated all heart beats over some period of time. Average heart rate over 24 h gave unacceptable results due to the poor relationship between heart rate and oxygen consumption at resting and sedentary levels of energy expenditure. However, the method yields acceptable results when the average heart rate is calculated for the period of time when children are awake, and energy expenditure calculated for the remainder of the 24 h from the resting and basal metabolic rates. As shown in Table 1, an analysis of studies by Spurr and collaborators (Spurr *et al*, 1986; Spurr and Reina, 1988*a*) indicated that the results with this heart rate accumulation method did not differ from those obtained in similar children with the minute-by-minute rate recording method.

The heart rate monitoring method has been validated with whole body calorimetry and doubly-labeled water. Comparisons varied on an individual basis, but the mean values for groups of individuals were similar to the other methods (Spurr *et al*, 1988; Ceesay *et al*, 1989; Livingstone *et al*, 1990*a*, 1992*a*; Emons *et al*, 1992). Thus, heart rate monitoring can be used to estimate the energy expenditure of groups of children. Minute-by-minute recording also allows examining the time allocated to different intensities of physical effort.

(3) *Time-motion or activity diary techniques.* These have two components: (a) assessment of time allocation, which has been explored by direct observations with different timing techniques, by activity records or diaries kept by the subjects or caretakers of young children, and by recall interviews with subjects or caretakers and (b) energy costs of the activities that are observed or recorded, measured by indirect calorimetry or estimated from published values. It should be borne in mind that energy costs of activities published for adults do not apply to children under 15 (Torun, 1983, 1990*a*). Many of the results published with the time–motion or diary techniques are questionable due to the inaccuracies inherent in methods based on reporting and in the application of energy cost of activities of adults to calculate energy expenditure of children.

We have based this review and our conclusions on

Table 1 Comparison of total daily energy expenditures (MJ/d) measured with two different heart rate monitoring techniques (three-way analysis of variance with unweighted averages)

Age (y)	n	Control children mean	s.d.	n	Mildly malnourished mean	s.d.
Minute-by-minute heart rate method (Spurr and Reina, 1988a)						
6–8	24	6.6	1.6	21	5.1	1.0
10–12	18	8.4	2.3	23	7.8	2.1
14–16	20	12.1	2.7	26	10.6	2.5
Daytime heart rate accumulation method (Spurr et al., 1986)						
6–8	12	6.4	1.1	9	6.3	0.7
10–12	20	9.2	1.8	19	8.0	1.8
14–16	12	11.5	2.0	16	10.2	2.1

Source	F ratio	Probability
A (Age)	109.283	<0.001
B (Nutritional status)	14.463	<0.001
C (Method)	0.413	0.521
A*B (Age*Nutrition)	0.403	0.668
A*C (Age*Method)	1.495	0.226
B*C (Method*Nutrition)	0.462	0.498
A*B*C (Age*Nutrition*Method)	1.054	0.350

TEE on studies with doubly-labeled water or with appropriate techniques of heart rate monitoring. Some estimates of energy expenditure with time–motion/diary techniques were selected as examples to examine the conclusions based on the other two methods.

Another relatively simple way to estimate total daily energy expenditure (TEE), and therefore requirements, of adults was proposed by the 1985 FAO/WHO/UNU Expert Consultation. Sleeping, occupational, discretional, health-promoting and other miscellaneous activities were assigned an energy cost, expressed as *multiples of basal metabolic rate* (× *BMR*) *or physical activity level* (*PAL*)[1]. A factorial calculation accounting for the time allotted to each of those activities allowed the estimation of the mean PAL in 24 h. For populations engaged in occupational activities of different intensities. TEEs of 1.55, 1.78 and 2.10 × BMR were proposed for men with light, moderate and heavy occupational activities, respectively (FAO/WHO/UNU, 1985). The corresponding factors suggested for women were 1.56, 1.64 and 1.82.

We suggest that a similar approach be used to estimate TEE of groups of children and adolescents with different lifestyles. PAL factors are proposed for those estimates in another section of this document ('Physical activity levels of children and adolescents').

Studies with doubly-labeled water

The doubly-labeled water technique is almost 40 years old, but there are still relatively few data on total energy expenditure in children, due primarily to cost. Until the mid 1970s the cost of the stable isotopes (^{2}H and ^{18}O) involved in the technique was restrictive. Since that time advances in technology, notably the development of highly precise isotope mass ratio spectrometers, made it possible to administer significantly less isotope, thus reducing the cost to a more manageable figure. Unfortunately, the cost of isotopes began to rise steeply in 1990 and once again fewer studies are being undertaken.

Studies that allow consideration of TEE and dietary recommendations have been done with well-nourished children and adolescents in urban centers of the United Kingdom (Prentice *et al*, 1988; Davies *et al*, 1991, 1994), Holland (Saris *et al*, 1989; Emons *et al*, 1992) and the United States (Bandini *et al*, 1990b; Goran *et al*, 1993; Fontvieille *et al*, 1993; Wong, 1994). Table 2 shows their age span and TEE expressed per day, per unit of body weight and PAL.

Figure 1 compares the data from Table 2, expressed as kcal/kg/day, with the FAO/WHO/UNU 1985 recommendations, with and without the allowance for growth. The values for energy expenditure shown in the table and figure do not include the small proportion of energy that should be retained for growth (between 1 and 3%, depending on age).

Current dietary energy recommendations are about 20% higher than energy expenditure of children under 7 years of age in industrialized societies. From 7 years onwards, current recommendations coincide reasonably well with the data from doubly-labeled water studies,

[1] Total energy expenditure expressed as × BMR has been considered to reflect an individual's or population's *physical activity level* (*PAL*). This term has appeared with increasing frequency in the scientific literature. Thus, we will use it as synonym of × BMR.

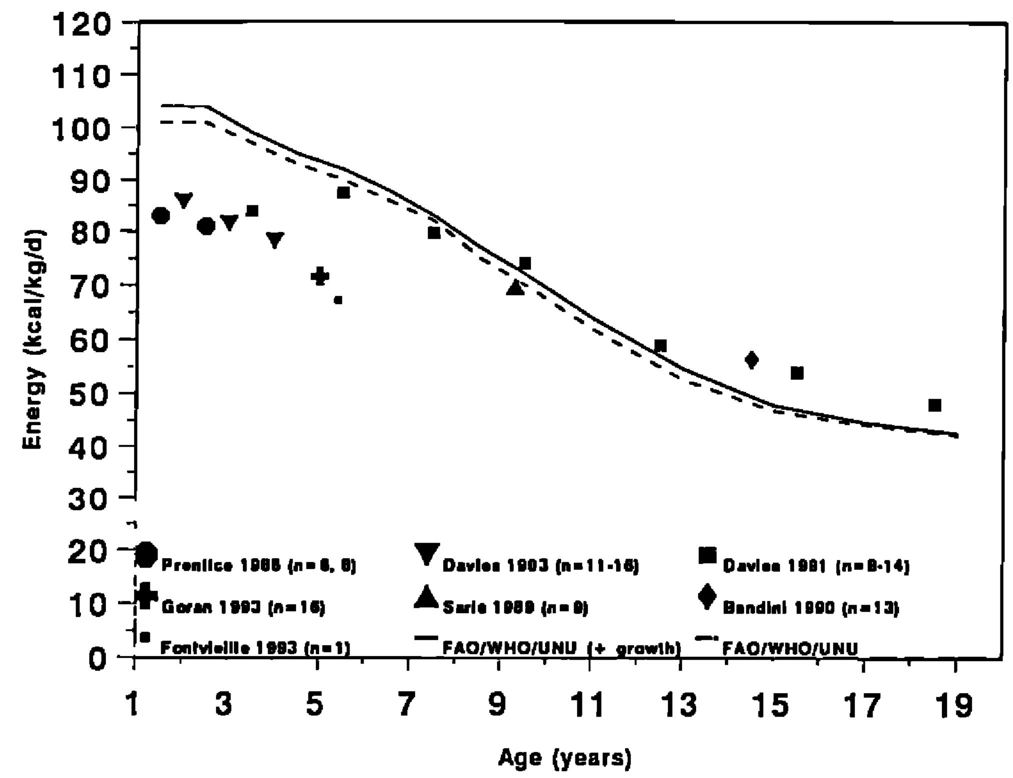


Figure 1a Total energy expenditure estimated with doubly labeled water: boys.

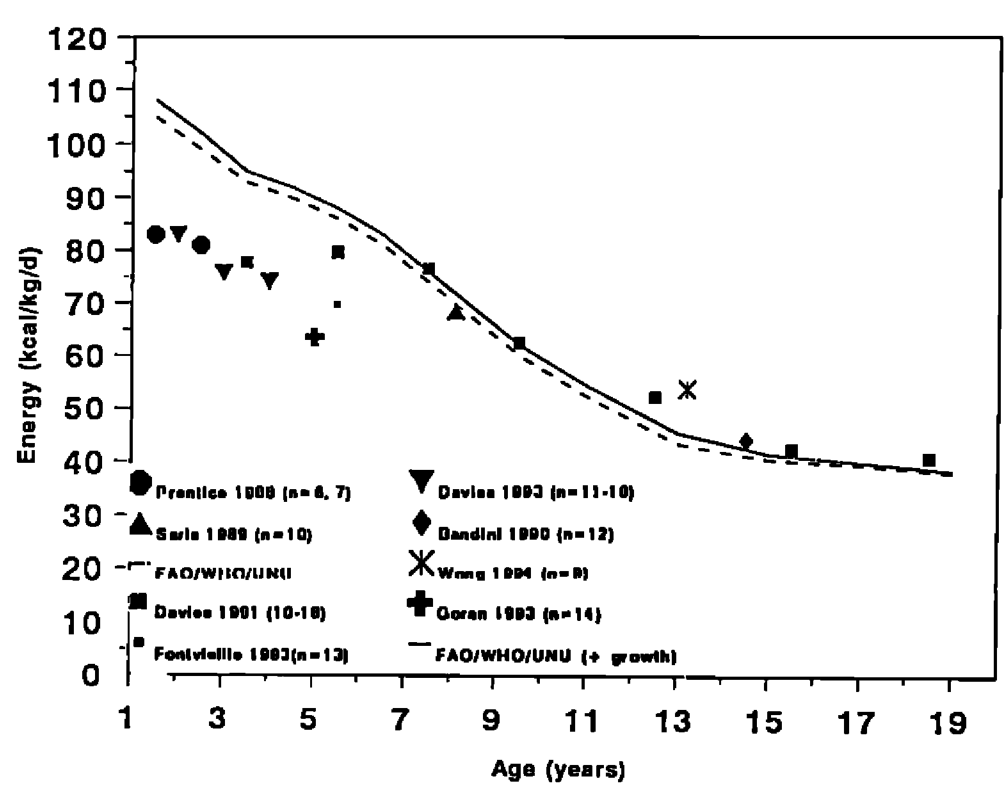


Figure 1b Total energy expenditure estimated with doubly labeled water: girls.

although boys throughout adolescence and girls around puberty seem to require 5–15% more dietary energy.

Within each sex, the PALs in Table 2 show a trend towards uniformity among children between 1 and 5, 6 and 13, and 14 and more years of age. Therefore, the mean PAL values for those three age groups were calculated (Table 3). Since the studies had similar sample sizes within each age group, calculations of the mean PAL weighted for the number of children in each study gave similar results. Measured BMRs were used for calculations in three studies and BMR estimates with Schofield's equations in all others.

On the average, there were no gender differences at 1–5 and 6–13 years. Boys seemed to have higher PAL than girls after that age, but this observation was based on only three data sets from two studies (Bandini *et al*, 1990b; Davies *et al*, 1991). It should also be noted that if PALs were calculated with the equations published by FAO/WHO/UNU (1985) instead of those modified later by Schofield (1985), they would be somewhat lower for girls 1–5 and 6–13 years old than for boys of the same age ranges (1.39 *vs* 1.47 and 1.74 *vs* 1.81, respectively).

It should be kept in mind that the values shown in

Table 2 Groups of children, classified by sex and age, whose total daily energy expenditure has been estimated by the doubly labeled water method (does not include 1–3%, depending on age, that should be retained for growth)

Age[a] (y)	*n*	*Weight* (kg)	*Total energy expenditure* (kcal/d)	(kcal/kg/d)	*PAL*[b]	Reference
Boys						
1–1.9	8[c]			83.0[d]		Prentice *et al* (1988)
1.5–2.49	11	12.6 ± 1.4[e]	1075 ± 305	85.8 ± 26.0	1.49	Davies *et al* (1994)
2–2.9	6[c]			81.0[d]		Prentice *et al* (1988)
2.5–3.49	15	15.0 ± 1.7	1207 ± 181	81.5 ± 15.2	1.41	Davies *et al* (1994)
3–4	13	15.5	1300	83.9 ± 11.5	1.52	Davies *et al* (1991)
3–4.49	16	16.9 ± 2.3	1301 ± 211	78.2 ± 14.5	1.47	Davies *et al* (1994)
4–6	16	20.3 ± 4.3	1438 ± 271	71.5 ± 8.0	1.49	Goran *et al*, (1993)
5.4 ± 0.3	15	21.1 ± 3.9	1415 ± 252	67.1	1.44 (1.36)	Fontvieille *et al* (1993)
5–6	12	18.9	1654	87.5 ± 10.0	1.77	Davies *et al* (1991)
7–8	10	24.6	1958	79.6 ± 9.1	1.84	Davies *et al* (1991)
9.3 ± 1.4	9	30.9 ± 4.3	2151	69.6	1.78 (1.77)	Saris *et al* (1989)
9–10	14	29.5	2180	73.9 ± 12.2	1.86	Davies *et al* (1991)
12–13	8	39.7	2334	58.8 ± 9.8	1.71	Davies *et al* (1991)
14.5 ± 1.5	13	56.4 ± 10.2	3109 ± 506	56.3 ± 6.4	1.88 (1.79)	Bandini *et al* (1990b)
15–16	12	60.1	3233	53.8 ± 7.6	1.88	Davies *et al* (1991)
18–19	12	71.6	3437	48.0 ± 4.3	1.86	Davies *et al* (1991)
Girls						
1–1.9	7[c]			83.0[d]		Prentice *et al* (1988)
1.5–2.49	12	13.0 ± 1.9	1062 ± 212	83.0 ± 19.5	1.46	Davies *et al* (1994)
2–2.9	6[c]			81.0[d]		Prentice *et al* (1988)
2.5–3.49	16	14.9 ± 1.1	1125 ± 211	75.8 ± 15.0	1.38	Davies *et al* (1994)
3–4	18	14.8	1150	77.7 ± 10.3	1.46	Davies *et al* (1991)
3.5–4.49	11	17 ± 2.0	1263 ± 237	74.2 ± 11.0	1.52	Davies *et al* (1994)
4–6	14	21.0 ± 4.7	1344 ± 314	63.5 ± 5.6	1.47	Goran *et al* (1993)
5.5 ± 0.4	13	18.9 ± 2.5	1318 ± 189	69.7	1.51 (1.37)	Fontvieille *et al* (1993)
5–6	16	18.5	1473	79.6 ± 10.5	1.71	Davies *et al* (1991)
7–8	15	26.0	1989	76.5 ± 17.7	1.96	Davies *et al* (1991)
8.1 ± 1.3	10	28.2 ± 2.6	1926	68·3	1.82 (1.69)	Saris *et al* (1989)
9–10	15	29.1	1816	62.4 ± 10.5	1.69	Davies *et al* (1991)
12–13	10	49.3	2569	52.1 ± 7.9	1.90	Davies *et al* (1991)
13.2 ± 1.8	9	43.3 ± 8.9	2321 ± 281	53.6	1.82	Wong, (1994)
14.3 ± 1.0	12	55.7 ± 9.4	2385 ± 446	43.9 ± 7.7	1.66 (1.69)	Bandini *et al* (1990b)
15–16	11	58.0	2453	42.3 ± 6.0	1.67	Davies *et al* (1991)
18–19	11	62.4	2533	40.6 ± 7.6	1.72	Davies *et al* (1991)

[a] Range or mean ± standard deviation.
[b] Physical Activity Level calculated using basal metabolic rates estimated with Schofield's equations (1985) (or, in parenthesis, measured experimentally).
[c] Assuming 50% of the children studied were boys and 50% girls.
[d] Assuming the same values for boys and girls.
[e] Mean ± s.d.

Tables 2 and 3 correspond to studies in a small number of well nourished children with adequate growth patterns, living in societies where food and health services are continuously and readily available.

Table 3 Mean physical activity levels of children in Table 2 grouped by age and sex. (Total energy expenditure measured with doubly labeled water; BMR's were measured or estimated with Schofield's equations)

Age (y)	*Boys*	*Girls*
1–5	1.46 ± 0.06 (6)[a]	1.44 ± 0.06 (6)
6–13	1.79 ± 0.06 (5)	1.80 ± 0.12 (6)
14+	1.84 ± 0.05 (3)	1.69 ± 0.03 (3)

[a] Mean ± s.d. of mean values in Table 2. Number of data sets in parenthesis. Means weighted by the number of children in each study gave similar values.

Studies with heart rate monitoring

Studies to calculate TEE of children and adolescents through heart rate monitoring have also been done only in a few countries, but they include industrialized and developing societies. These studies were done with either daytime heart rate accumulation (Spady, 1980; Torun & Viteri, 1981*a*,*b*; Spurr *et al*, 1986; Spurr & Reina, 1987) or the minute-by-minute heart rate method (Spurr & Reina, 1988*a*,*b*, 1989*a*,*b*; Livingstone *et al*, 1992*a*; Emons *et al*, 1992; Torun *et al*, 1993; Ramirez & Torun, 1994). Table 4 shows their age span and results. All studies involved children living in urban centers. Those in Northern Ireland and Holland involved only between 3 and 6 children in each sex-and-age group, and those in Canada were done with 11 boys and 10 girls. Most studies in Colombia and Guatemala involved 16–34 boys or girls in each age group (median sample size = 20).

Table 4 Groups of children, classified by sex and age, whose total daily energy expenditure was estimated by heart rate monitoring methods (does not include 1–3% energy, depending on age, that should be retained for growth)

Age (y)	*n*	*Weight (kg)*	*Total energy expenditure (kcal/d)*	*Total energy expenditure (kcal/kg/d)*	*PAL*[a]	*Country*	*Condition*[c]	*Method*[d]	*Source*
Boys									
2.5 ± 0.7	6	11.9 ± 1.0	1060	89.1 ± 9.0	1.56[b]	Guatemala	Stunted	Accum	Torun & Viteri (1981*b*)
3.1 ± 0.3	11	12.0 ± 0.8	901	74.8 ± 7.6	1.34	Guatemala	Stunted	Accum	Torun & Viteri (1981*a*)
6.8 ± 0.5	24	21.9 ± 1.6	1581 ± 374	72.3 ± 16.8	1.60	Colombia		M–M	Spurr & Reina (1988*a*)
7.0 ± 0.5	12	21.8 ± 1.4	1541 ± 255	70.2 ± 8.4	1.54[b]	Colombia		Accum	Spurr *et al* (1986)
7.0 ± 0.5	21	19.3 ± 1.7	1207 ± 243	62.7 ± 12.5	1.46	Colombia	Underweight	M–M	Spurr & Reina (1988*a*)
7.4 ± 0.7	9	19.4 ± 2.3	1502 ± 176	81.0 ± 9.7	1.59[b]	Colombia	Underweight	Accum	Spurr *et al* (1986)
7.5 ± 0.3	6	25.4 ± 6.6	1859 ± 388	74.4 ± 12.2	1.64	UK		M–M	Livingstone *et al* (1992*a*)
8.4	5	27.8	2414 ± 394	86.8 ± 14.2	2.13[b]	Holland		M–M	Emons *et al* (1992)
9.3 ± 0.2	5	30.2 ± 9.4	2119 ± 182	74.5 ± 17.7	1.88	UK		M–M	Livingstone *et al* (1992*a*)
9.4 ± 1.0	11	32.1 ± 4.4	2164 ± 199	66.4 ± 9.8	1.86	Canada		Accum	Spady (1980)
10.8 ± 0.5	34	33.3 ± 2.8	2051 ± 400	61.7 ± 13.0	1.75	Guatemala		M–M	Ramirez & Torun (1994)
10.9 ± 0.6	19	25.9 ± 2.6	1918 ± 425	73.6 ± 16.6	1.72[b]	Colombia	Underweight	Accum	Spurr *et al* (1986)
11.0 ± 0.6	20	32.4 ± 3.3	2209 ± 419	68.1 ± 12.7	1.79[b]	Colombia		Accum	Spurr *et al* (1986)
11.1 ± 0.6	14	33.1 ± 2.3	2009 ± 421	60.7 ± 12.7	1.67	Colombia		M–M	Spurr & Reina (1988*b*)
11.1 ± 0.6	23	27.2 ± 2.8	1823 ± 513	67.5 ± 17.2	1.74	Colombia	Underweight	M–M	Spurr & Reina (1988*a*)
11.1 ± 0.6	19	26.6 ± 3.2	1828 ± 378	68.7 ± 14.2	1.77	Colombia	Underweight	M–M	Spurr & Reina (1988*b*)
11.1 ± 0.5	34	28.8 ± 3.1	2015 ± 379	70.1 ± 11.5	1.83	Guatemala	Stunted	M–M	Ramirez & Torun (1994)
11.2 ± 0.5	18	33.3 ± 2.5	2020 ± 542	60.5 ± 15.2	1.74	Colombia		M–M	Spurr & Reina (1988*a*)
12.7 ± 0.3	5	43.8 ± 7.3	2624 ± 315	61.4 ± 12.7	1.76	UK		M–M	Livingstone *et al* (1992*a*)
14.6 ± 0.6	16	34.8 ± 5.1	2445 ± 493	71.4 ± 12.5	1.92	Colombia	Underweight	Accum	Spurr *et al* (1986)
14.7 ± 0.5	12	46.7 ± 3.5	2762 ± 480	58.4 ± 9.0	1.84	Colombia		Accum	Spurr *et al* (1986)
14.8 ± 0.6	20	49.9 ± 3.2	2896 ± 650	58.4 ± 14.4	1.94	Colombia		M–M	Spurr & Reina (1988*a*)
14.8 ± 0.4	26	38.9 ± 5.3	2556 ± 580	65.6 ± 13.7	1.93	Colombia	Underweight	M–M	Spurr & Reina (1988*a*)
15.4 ± 0.4	3	50.7 ± 6.4	2745 ± 33	54.7 ± 6.9	1.71	UK		M–M	Livingstone *et al* (1992*a*)
Girls									
6.6 ± 0.5	21	21.4 ± 1.1	1386 ± 304	63.0 ± 11.5	1.53	Colombia		M–M	Spurr & Reina (1988*a*)
7.0 ± 0.5	16	18.2 ± 1.7	1244 ± 254	67.6 ± 13.5	1.40	Colombia	Underweight	M–M	Spurr & Reina (1988*a*)
7.8 ± 0.3	5	23.5 ± 2.5	1609 ± 260	68.3 ± 5.0	1.55	UK		M–M	Livingstone *et al* (1992*a*)
8.4	5	28.3	2079 ± 191	73.5 ± 6.8	1.96[b]	Holland		M–M	Emons *et al* (1992)
9.4 ± 0.5	4	33.4 ± 3.8	1729 ± 174	52.0 ± 5.2	1.63	UK		M–M	Livingstone *et al* (1992*a*)
9.4 ± 1.2	24	28.3 ± 3.4	1537 ± 340	55.2 ± 13.6	1.43	Colombia		Accum	Spurr & Reina (1987)
9.5 ± 0.8	10	31.6 ± 3.7	1716 ± 243	55.1 ± 11.6	1.52[b]	Canada		Accum	Spady (1980)
9.8 ± 1.0	20	23.7 ± 2.3	1640 ± 284	69.4 ± 10.3	1.70[b]	Colombia	Underweight	Accum	Spurr & Reina (1987)
10.8 ± 0.6	21	27.3 ± 4.0	1584 ± 369	55.1 ± 12.8	1.57	Colombia	Underweight	M–M	Spurr & Reina (1988*a*)
10.9 ± 0.7	11	34.2 ± 3.7	1611 ± 319	46.8 ± 8.9	1.45	Colombia		M–M	Spurr & Reina (1988*a*)
11.4 ± 0.5	23	29.2 ± 3.3	1867 ± 338	63.6 ± 11.6	1.72[b]	Guatemala	Stunted	M–M	Torun *et al* (1993)
11.8 ± 0.6	88[e]	31.1 ± 4.0	2013 ± 400	64.3 ± 11.8	1.81[b]	Guatemala	Stunted	M–M	Torun *et al* (1993)
12.2 ± 0.5	21	33.7 ± 4.4	2170 ± 441	64.5 ± 11.5	1.90[b]	Guatemala	Stunted	M–M	Torun *et al* (1993)
12.5 ± 0.4	5	45.1 ± 4.7	2232 ± 234	49.7 ± 5.4	1.60	UK		M–M	Livingstone *et al* (1992*a*)
14.9 ± 0.6	19	49.3 ± 2.7	1982 ± 452	41.7 ± 9.6	1.61	Colombia		M–M	Spurr & Reina (1988*a*)
15.2 ± 0.5	22	42.0 ± 4.1	1950 ± 585	48.6 ± 14.9	1.61	Colombia	Underweight	M–M	Spurr & Reina (1988*a*)
15.6 ± 0.4	3	55.4 ± 13.2	2365 ± 811	42.9 ± 12.3	1.88	UK		M–M	Livingstone *et al* (1992*a*)

[a] Physical Activity Level calculated using BMR measured by the investigators or estimated mathematically ([b]).
[b] PAL calculated using BMR estimated with Schofield's equations (1985).
[c] Stunted: > 1.5 s.d. below the NCHS median of height-for-age. Underweight: < 95% of weight-for-age and weight-for-height in comparison to Colombian children of upper socioeconomic groups (Rueda-Williamson *et al*, 1969). All others: adequate height and weight for age.
[d] Accum = heart rate accumulation during daytime, and BMR while sleeping; M–M = minute-by-minute recording.
[e] 22 girls measured longitudinally four times at 3-month intervals.

Table 5 Mean physical activity levels of children in Table 4 grouped by age, sex and height or weight. (Total energy expenditure estimated by heart rate monitoring; BMR's were measured or estimated with Schofield's equations)[a]

Age (years)	*Boys*			*Girls*		
	Adequate wt and ht	*Stunted or underweight*	*All*	*Adequate wt and ht*	*Stunted or underweight*	*All*
(A) Means of mean values in each study[b]						
2 3	—	1.45 (2)	—	—	—	—
6 13	1.72 ± 0.11 (10)[b]	1.68 ± 0.14 (6)	1.71 ± 0.12 (16)	1.53 ± 0.07 (7)	1.66 ± 0.19 (5)	1.58 ± 0.14 (12)
14+	1.83 ± 0.12 (3)	1.92 (2)	1.87 ± 0.10 (5)	1.74 (2)	1.61 (1)	1.70 ± 0.16 (3)
(B) Weighted means[c]						
2–3	—	1.42 (17)	—	—	—	—
6–13	1.65 (149)	1.71 (125)	1.68 (274)	1.50 (80)	1.67 (101)	1.60 (181)
14+	1.89 (35)	1.93 (42)	1.91 (77)	1.65 (22)	1.61 (22)	1.63 (44)

[a] Data of Emons *et al* (1992) excluded due to their unusually high PAL's.
[b] Mean ± s.d. of mean values in Table 4. Number of data sets in parenthesis.
[c] Weighted by the number of children in each study (in parenthesis).

PALs in Table 4 were calculated using measured BMR in most studies; estimates with Schofield's equations (1985) were used in only six of them. Table 5 shows the mean PALs for the same age groups as in Table 3. Although there were large differences in sample sizes (3–34), the means of the mean values in each study were within 5% of the mean values weighted for the number of children in every sex-and-age group.

All Canadian, Dutch and Irish children apparently had adequate weight and height. The Colombian children were from low and low-middle socioeconomic groups of Cali. They were classified as well nourished or as marginally malnourished or underweight when their weight-for-age and weight-for-height was above or below 95% of the Colombian standards for children of upper socioeconomic groups, respectively (Rueda-Williamson *et al*, 1969). Most Guatemalan children were from the lower socioeconomic groups of Guatemala City. While presently well nourished, they were stunted by more than 1.5 s.d. below the NCHS/WHO median of height-for-age. One group of Guatemalan boys (Ramirez and Torun, 1994) was from the middle socioeconomic class and they had adequate height and weight.

Figure 2 compares the data in Table 4, expressed as kcal/kg/day, with the FAO/WHO/UNU 1985 recommendations. Total energy expenditure per unit of body weight was greater among the stunted and underweight children. Since the FAO/WHO/UNU values were derived from data of well nourished, non-stunted children, Figure 3 shows only the values described in Table 4 for such children. They are combined with data from doubly-labeled water in Figure 4.

The higher energy expenditure per unit of body weight often observed in stunted and mildly malnourished children, compared with those of adequate height and weight (Tables 1 and 4), could be partly due to differences in body composition. If so, the differences in TEE would be expected to decrease or disappear when expressed as multiples of BMR (i.e. PAL units). Table 6 shows the PALs of 'normal' and stunted or mildly underweight individuals within the same community. In contrast with TEE per unit of body weight, there was no consistent difference in the PAL of children and adolescents with adequate height and weight, compared with their stunted or slightly underweight counterparts (Tables 5 and 6). This supports the explanation attributing differences to body composition.

However, the differences in TEE could also be related to the children's physical activity patterns. An examination of the minute-by-minute heart rate and its energy equivalence in Guatemalan school-boys of different height and socioeconomic status, showed that during the active hours of the day, the stunted (low income) group spent less time than the taller (middle

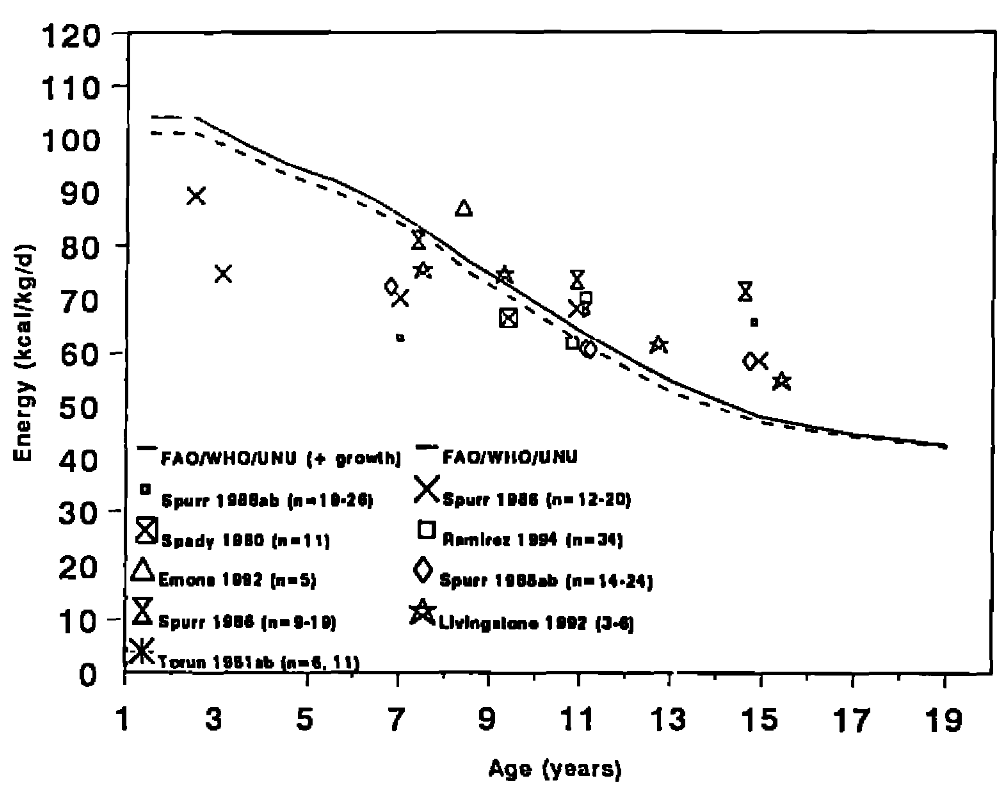


Figure 2a Total energy expenditure estimated by heart rate monitoring: boys.

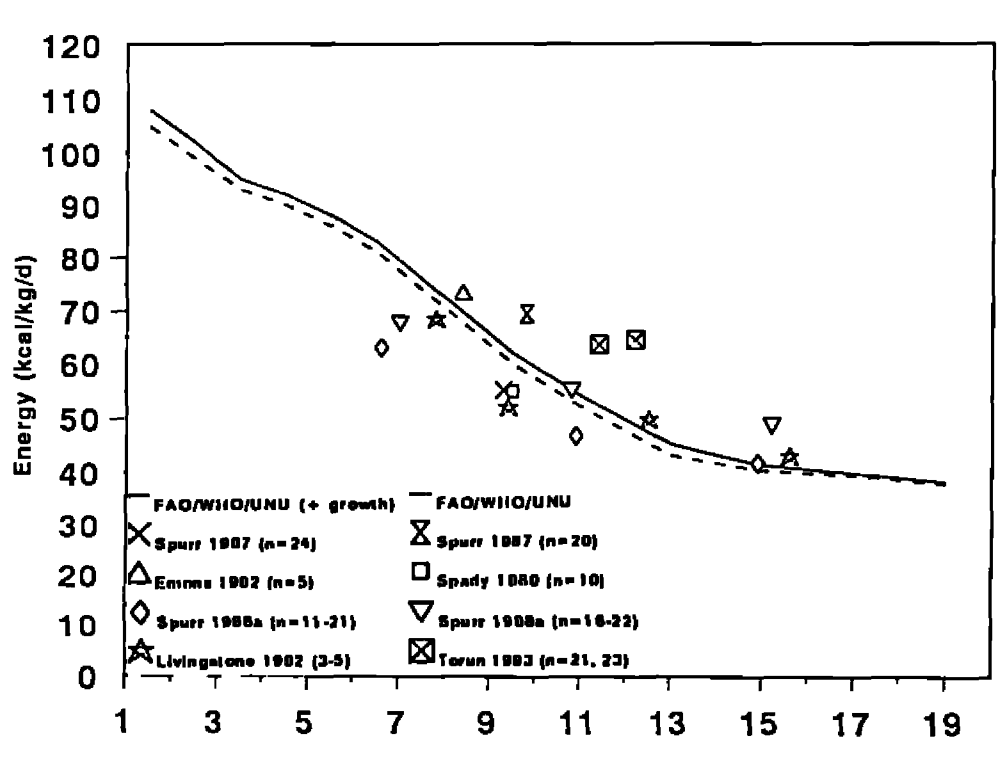


Figure 2b Total energy expenditure estimated by heart rate monitoring: girls.

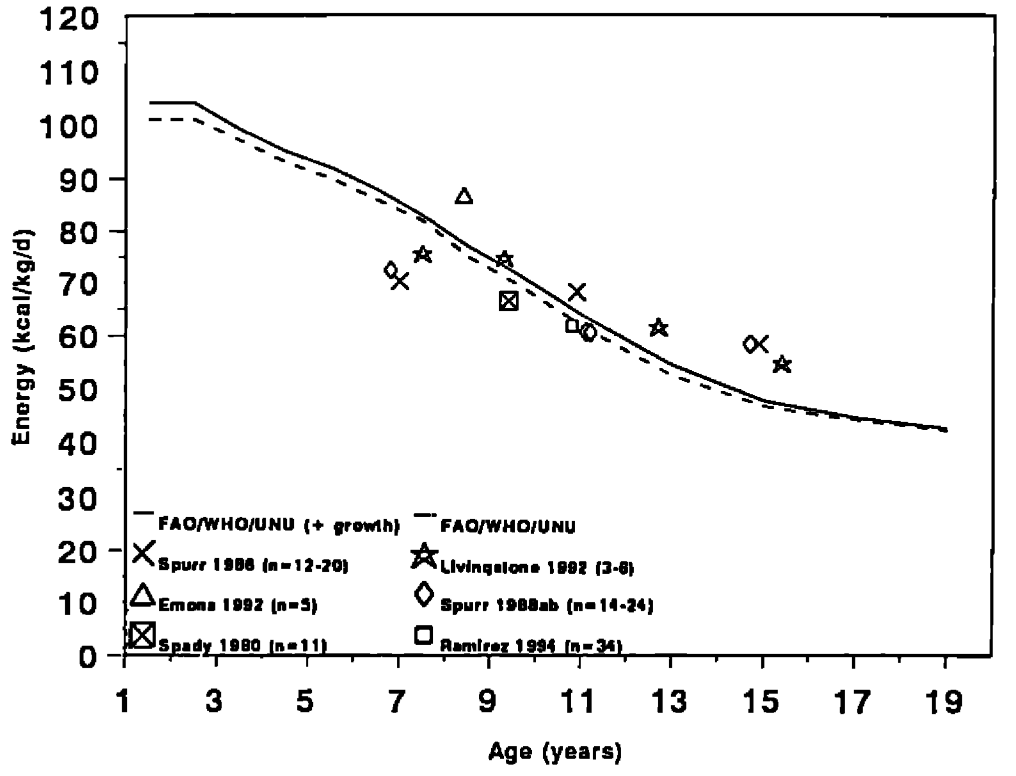


Figure 3a Total energy expenditure estimated by heart rate monitoring, *excluding* stunted and underweight boys.

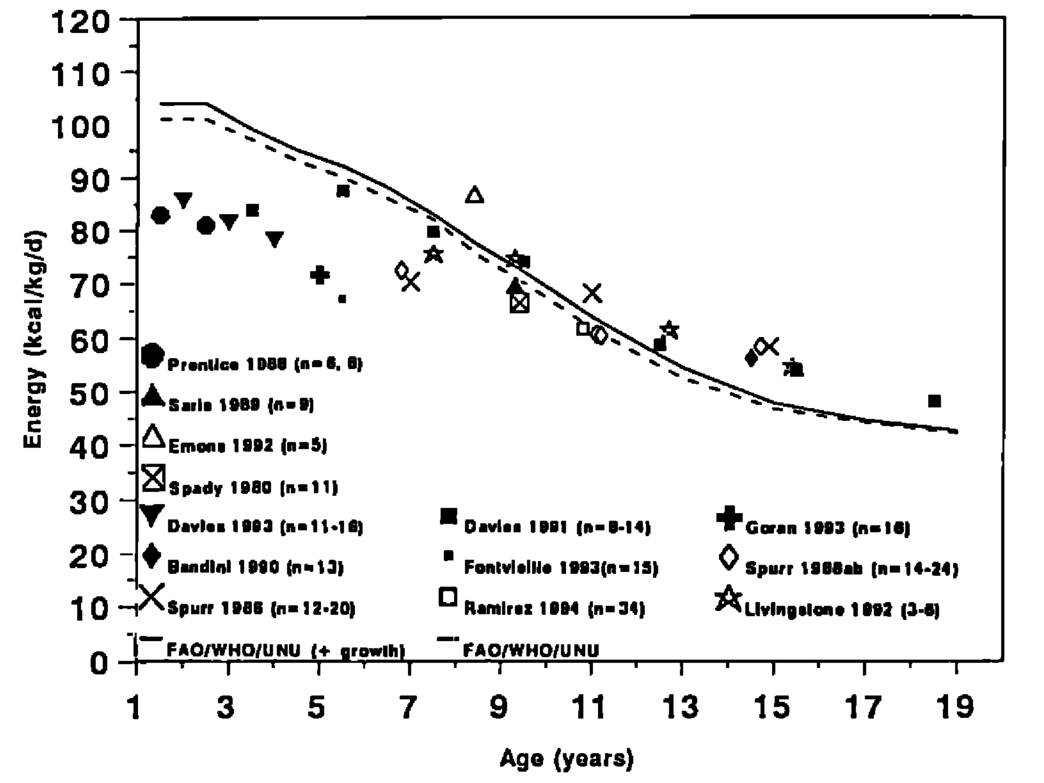


Figure 4a Total energy expenditure estimated with doubly labeled water or by heart rate monitoring, *excluding* stunted and underweight boys. Solid symbols: doubly labeled water.

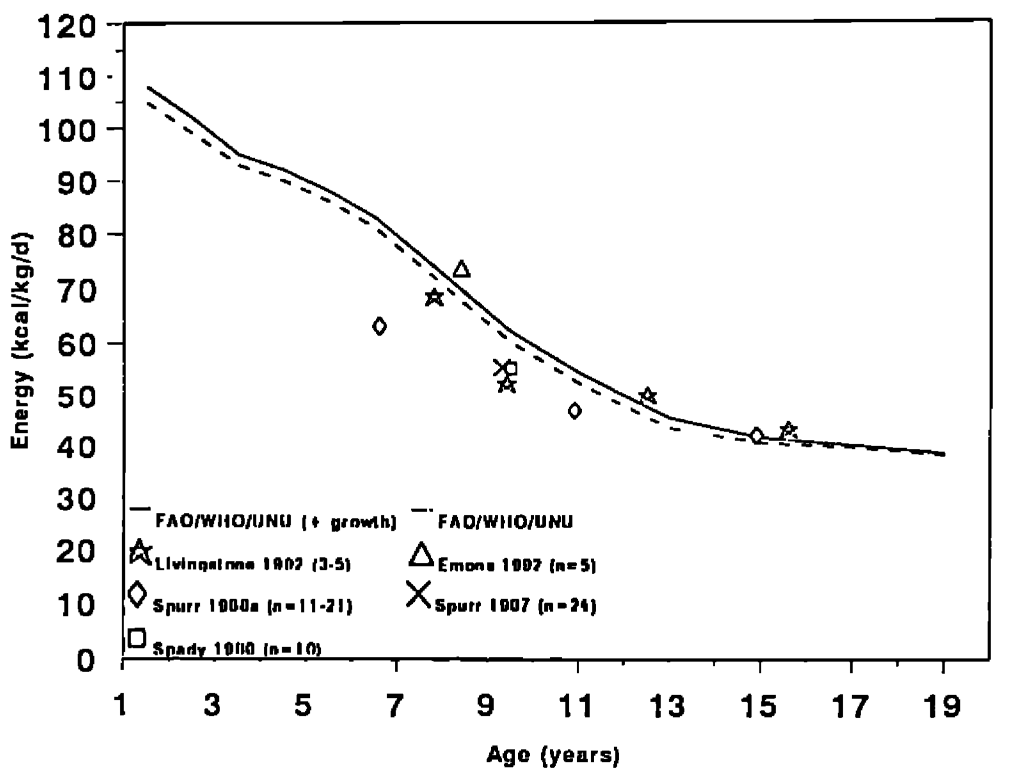


Figure 3b Total energy expenditure estimated by heart rate monitoring, *excluding* stunted and underweight girls.

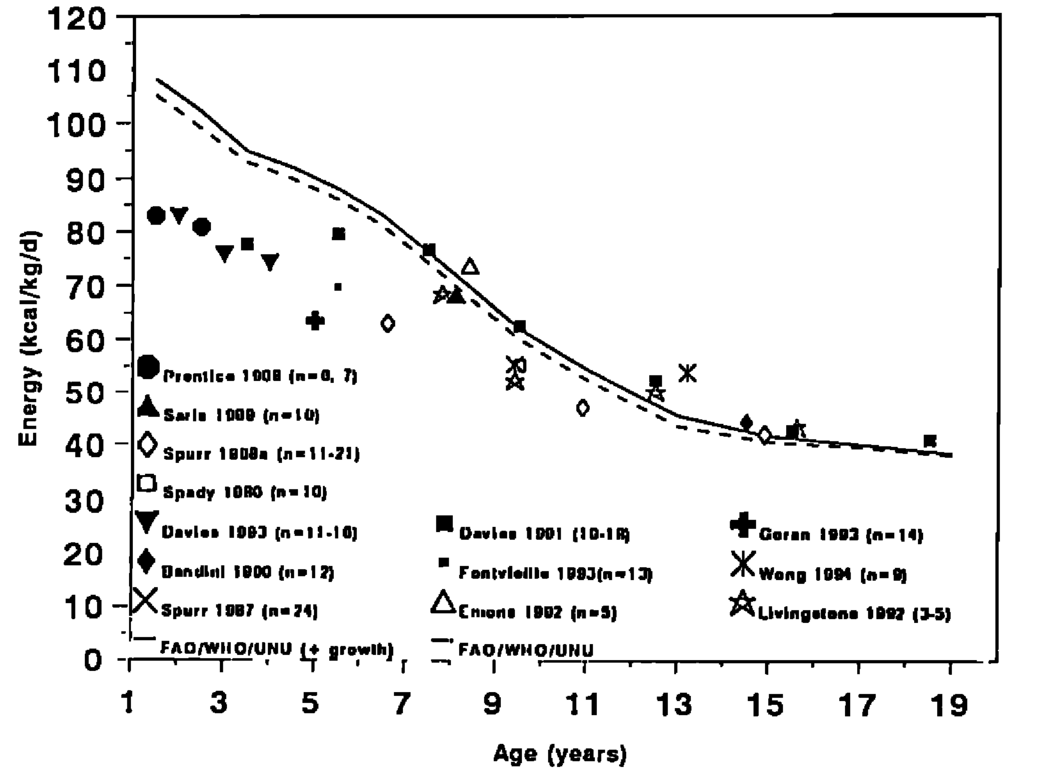


Figure 4b Total energy expenditure estimated with doubly labeled water or by heart rate monitoring, *excluding* stunted and underweight girls. Solid symbols: doubly labeled water.

Table 6 Total daily energy expenditure of well-nourished and of stunted or marginally malnourished children, measured with heart-rate monitoring techniques and expressed as multiples of basal metabolic rate

Age	*n*	*Energy expenditure or PAL*	*Condition*	*Reference*
Boys				
6.9 ± 0.5	41	1.60 ± 0.35	Normal	Spurr & Reina (1989)
7.1 ± 0.6	42	1.46 ± 0.29	Underweight	
11.1 ± 0.6	54	1.74 ± 0.45	Normal	Spurr & Reina (1989)
11.0 ± 0.6	82	1.77 ± 0.47	Underweight	
11.1 ± 0.5	34	1.75 ± 0.35	Normal	Ramirez & Torun (1994)
10.8 ± 0.5	34	1.83 ± 0.31	Stunted	
14.8 ± 0.5	34	1.84 ± 0.50	Normal	Spurr & Reina (1989)
14.8 ± 0.6	47	1.92 ± 0.43	Underweight	
Girls				
7.0 ± 0.7	29	1.53 ± 0.38	Normal	Spurr & Reina (1989)
7.3 ± 0.7	20	1.43 ± 0.16	Underweight	
10.8 ± 0.7	24	1.45 ± 0.21	Normal	Spurr & Reina (1989)
10.8 ± 0.5	32	1.57 ± 0.38	Underweight	
14.9 ± 0.6	19	1.61 ± 0.31	Normal	Spurr & Reina (1989)
15.2 ± 0.5	22	1.61 ± 0.43	Underweight	

Table 7 Groups of children, classified by sex and age, whose total daily energy expenditure was estimated from time-motion observations or activity diaries[a]

Age *(y)*	*n*	*Weight* *(kg)*	*Total energy expenditure* *(kcal/d)*	*(kcal/kg/d)*	*PAL*[b]	*Country*	*Condition*	*Method*[c]	*Source*
Boys									
1.5	12[d]	9.3	725[e,f]	78.5[e,f]	1.39	Gambia	Mild malnutrition	O-Estimated EC	Lawrence *et al* (1991)
2–6	26	12.7 ± 3.2	1026[f]	81[f]	1.35	Guatemala	Stunted	O-Estimated EC	Torun (1990*b*)
4–6	25	17 ± 2	1130	66.5	1.27	Philippines	Normal	O-Estimated EC	Guzman *et al* (1991)
7–9	26	24 ± 3	1499	62.5	1.43	Philippines	Normal	O-Estimated EC	Guzman *et al* (1991)
10–12	25	32 ± 4	1971	61.6	1.61	Philippines	Normal	O-Estimated EC	Guzman *et al* (1991)
12–14	16	31.3 ± 5.6	1810	58.0	1.49	Singapore	Normal	D-Measured EC	Banerjee & Saha (1972)
13–15	24	47 ± 6	2043	43.5	1.37	Philippines	Normal	O-Estimated EC	Guzman *et al* (1991)
14.5 ± 0.4	102	51 ± 10	2626	51.6	1.68	UK	Normal	D-Adult EC	Durnin (1971)
14.6 ± 2.9	75[d]	49.3 ± 12.8	2222 ± 572[f]	45.1[f]	1.45	Canada	Normal	D-Estimated EC	Bouchard *et al* (1983)
16–17	65	69.4 ± 9.5	2766 ± 247	39.9	1.47	Australia	Normal, Students	D-Adult EC	McNaughton *et al* (1970*a*,*b*)
16–17	9	65.0 ± 9.6	2886 ± 235	44.4	1.60	Australia	Normal, Workers	D-Adult EC	McNaughton *et al* (1970*a*)
16–19	32	56 ± 5	2726	48.7	1.71	Philippines	Normal	O-Estimated EC	Guzman *et al* (1991)
18–19	12	72.3 ± 8.1	2714 ± 276	37.4	1.46	Australia	Normal, Students	D-Adult EC	McNaughton *et al* (1970*a*)
18–19	9	68.4 ± 8.4	2740 ± 268	40.1	1.52	Australia	Normal, Workers	D-Adult EC	McNaughton *et al* (1970*a*)
Girls									
1.5	12[d]	9.3	725[e,f]	78.5[e,f]	1.43	Gambia	Mild malnutrition	O-Estimated EC	Lawrence *et al* (1991)
2–6	22	12.7 ± 3.2	1026[f]	81[f]	1.41	Guatemala	Stunted	O-Estimated EC	Torun (1990*b*)
4–6	27	17 ± 2	1058	62.2	1.28	Philippines	Normal	O-Estimated EC	Guzman *et al* (1991)
7–9	24	24 ± 2	1528	63.7	1.57	Philippines	Normal	O-Estimated EC	Guzman *et al* (1991)
13–15	24	46 ± 3	1744	37.9	1.33	Philippines	Normal	O-Estimated EC	Guzman *et al* (1991)
14.5 ± 0.5	90	52 ± 8	2211	42.5	1.59	UK	Normal	D-Adult EC	Durnin (1971)
14.6 ± 2.9	75[d]	49.3 ± 12.8	2222 ± 572[f]	45.1[f]	1.64	Canada	Normal	D-Estimated EC	Bouchard *et al* (1983)
16–17	6	50.9 ± 5.3	1893 ± 195	37.2	1.38	USA	Normal	D-Estimated EC	Bradfield *et al* (1971)
16–17	113	58.3 ± 5.4	2025 ± 167	34.7	1.37	Australia	Normal, Students	D-Adult EC	McNaughton *et al* (1970*a*)
16–17	32	54.8 ± 7.2	2139 ± 237	39.2	1.50	Australia	Normal, Workers	D-Adult EC	McNaughton *et al* (1970*a*)
16–19	32	50 ± 3	1922	38.4	1.49	Philippines	Normal	O-Estimated EC	Guzman *et al* (1991)
18–19	21	58.7 ± 5.4	1949 ± 195	33.2	1.38	Australia	Normal, Students	D-Adult EC	McNaughton *et al* (1970*a*,*b*)
18–19	24	54.3 ± 5.6	2073 ± 159	38.2	1.53	Australia	Normal, Workers	D-Adult EC	McNaughton *et al* (1970*a*,*b*)

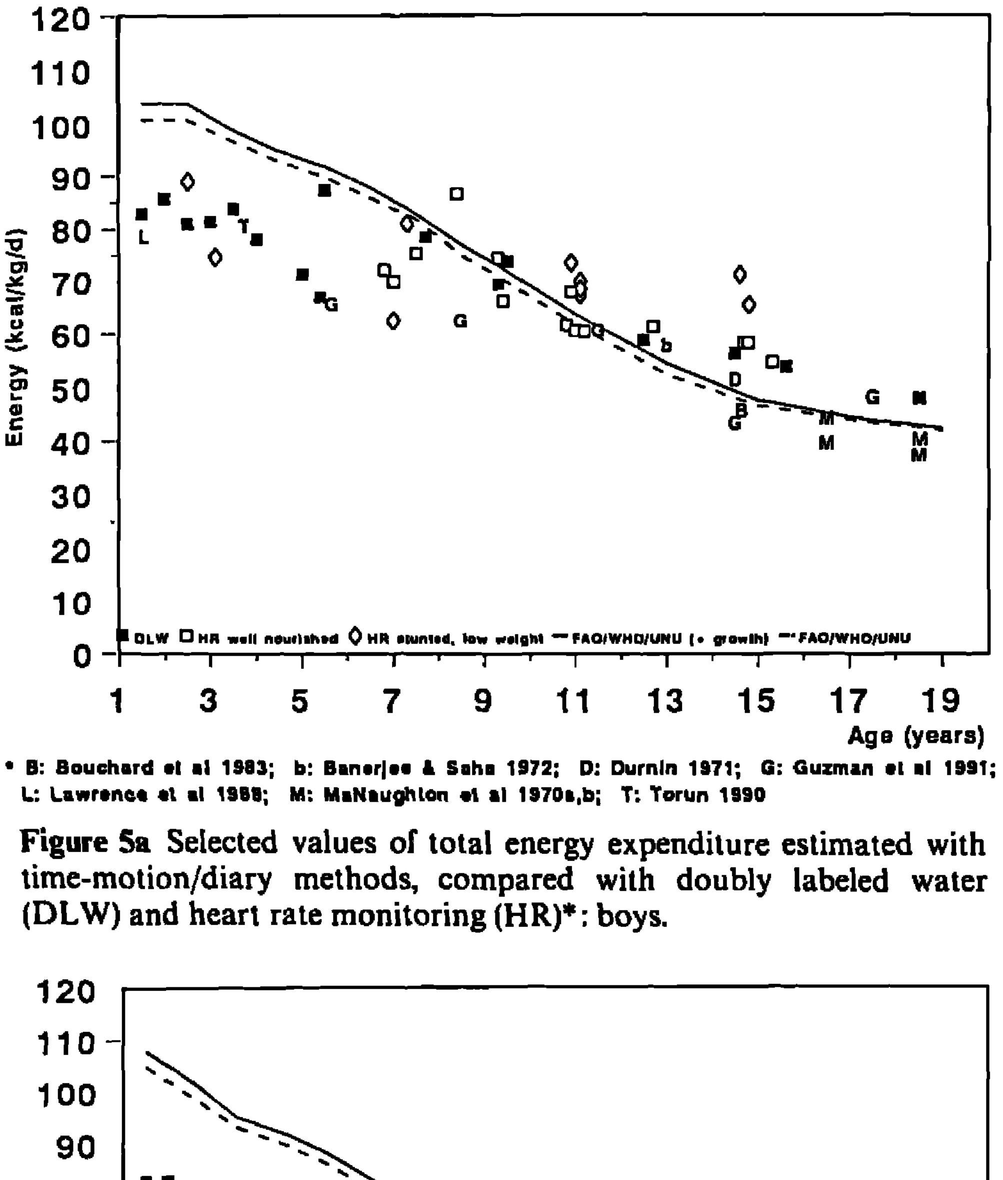
[a] Energy expenditure data published by the authors or calculated from their data by B. Torun.
[b] Physical Activity Level calculated using BMR estimated with Schofield's equations (1985).
[c] O: Observations during daytime and diary or recall interview at night. D: Activity diary. EC: Energy cost of activities.
[d] Assume 50% boys and 50% girls.
[e] Mean of wet (76 kal/kg) and dry (81 kcal/kg) seasons.
[f] Using the same mean values for boys and girls.

income) group in 'sedentary' activities (434 ± 160 *vs* 566 ± 159 min, $P < 0.01$) and more time in 'light' activities that demanded some degree of physical effort (213 ± 136 *vs* 103 ± 94 minutes/day, $P < 0.01$) (Ramirez and Torun, 1994). This was probably due to the different lifestyles imposed by the different socioeconomic conditions of the two groups of children.

Time-motion data and comparison of methods

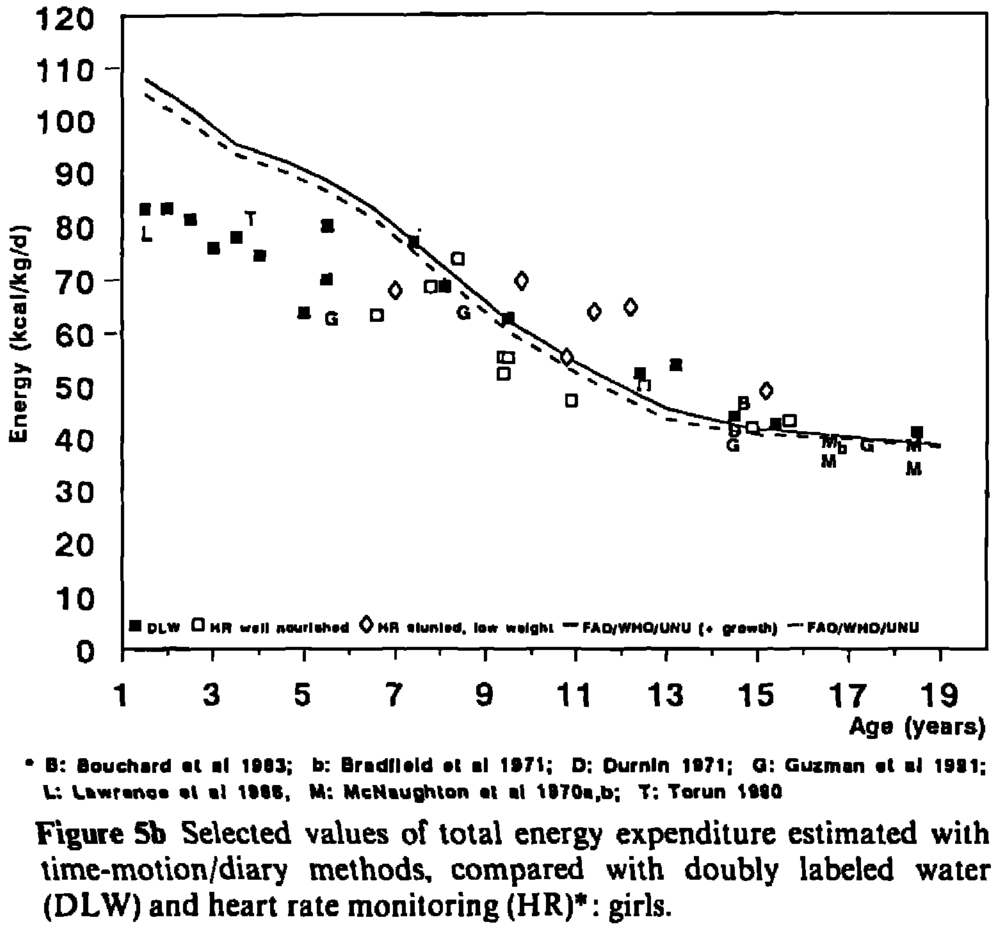
PALs calculated from heart rate studies coincided within 5% with those calculated from doubly-labeled water studies, except for girls 6–13 years old (Tables 3 and 5). Figure 4 also indicates that the estimates of daily energy expenditure per unit of body weight calculated by heart rate monitoring coincide quite well with those based on doubly-labeled water, at least among non-stunted, well nourished boys and girls.

A review of the literature allowed us to identify several studies that estimated total daily energy expenditure of children from *time-motion observations* or *activity diaries* recorded for several days, combined with indirect calorimetry measurements or estimates of the energy cost of the recorded activities. The results of those studies, listed in Table 7, were published as such by the authors or calculated by us from their data.



* B: Bouchard et al 1983; b: Banerjee & Saha 1972; D: Durnin 1971; G: Guzman et al 1991; L: Lawrence et al 1988; M: McNaughton et al 1970a,b; T: Torun 1990

Figure 5a Selected values of total energy expenditure estimated with time-motion/diary methods, compared with doubly labeled water (DLW) and heart rate monitoring (HR)*: boys.



* B: Bouchard et al 1983; b: Bradfield et al 1971; D: Durnin 1971; G: Guzman et al 1991; L: Lawrence et al 1988, M: McNaughton et al 1970a,b; T: Torun 1990

Figure 5b Selected values of total energy expenditure estimated with time-motion/diary methods, compared with doubly labeled water (DLW) and heart rate monitoring (HR)*: girls.

Figure 5 shows all the experimental data from the studies described in Tables 2, 4 and 7. Most time–motion/diary results agree reasonably well with the results from doubly-labeled water and heart rate studies, but there is a tendency to underestimate the energy expenditure of older adolescents, especially boys, with the diary method.

Conclusions

Total daily energy expenditure of free-living children has been measured by a limited number of investigators using doubly-labeled water or adequate heart rate monitoring techniques. Most of those studies have been done in industrialized countries, and none in school-aged children or adolescents in rural areas of developing countries.

The experimental results suggest that current FAO/WHO/UNU recommendations for dietary energy are too high for children under 5, and possibly under 7, years of age. By contrast, current dietary recommendations for adolescent boys and for girls around puberty seem somewhat low.

Energy expenditure per unit of body weight of stunted or mildly underweight, but otherwise healthy, school-children and adolescents in developing countries tends to be higher than among those with adequate height and weight. The causes for this must be explored further. In the meantime it seems convenient to make dietary recommendations based on the ideal weights or PALs of the general population.

The validity of these conclusions must be confirmed by other studies, as they are based on research carried out within a very narrow range of geographic and social environments, and most investigations with doubly-labeled water or heart rate monitoring in industrialized countries involved small numbers of children in each age and sex group. Studies with heart-rate monitoring in developing countries included larger series of children, but they were done mainly among low income urban groups.

Studies are especially needed in rural areas of the developing world and among middle and upper socio-economic groups of children in developing and industrialized cities. The minute-by-minute heart rate monitoring technique seems promising for this purpose, provided that the samples of children studied are of appropriate size. If finances allow it, they should be validated in the field with the doubly-labeled water method.

Time–motion/diary techniques can be useful to confirm the accuracy of the recommendations if the values used for the energy cost of activities are appropriate for children and adolescents (Torun, 1983, 1990*a*). They also provide important information on activity patterns that will allow better estimates of the 24-h PAL, and an understanding of the behavioral determinants of physical activity in children and adolescents.

Estimates of basal metabolic rate to calculate total energy expenditure

To calculate the energy equivalent of a PAL value, it is multiplied by the BMR. The 1985 FAO/WHO/UNU

Expert Consultation endorsed the use of the mathematical equations derived by Schofield, which take into account sex, age and body weight, to estimate a population's mean BMR. Although Schofield revised and modified his equations (Schofield, 1985), those initially published in the FAO/WHO/UNU report on Energy and Protein Requirements are used more often. The two sets of equations give similar values (within $\pm$1–2%), except for girls 3–10 years old, where the FAO/WHO/UNU equations give BMR's 6–7% higher than the revised equations. Thus, the PAL of those girls is lower when calculated with the FAO/WHO/UNU equations. In this review we have used the revised equations (Schofield, 1985).

The PAL approach was recommended by the FAO/WHO/UNU Experts to calculate TEE of adult populations with occupations and lifestyles that involved different PALs. It was used to estimate TEE of children and adolescents 10–18 years old with a pattern of activities that reflected the lifestyle of children in developed countries who spend several hours at school every day (FAO/WHO/UNU, 1985). No calculations were made for those with more energy-demanding lifestyles. This can be corrected, but doubts still remain about the accuracy of the Schofield–FAO/WHO/UNU equations to predict BMR in all races. This has been addressed by authors such as Henry & Rees (1988) and Elia (1992). Table 8 illustrates some of their conclusions about the possibility of over- or underestimating BMR in adults with Schofield's equations.

Accuracy of mathematical estimations of BMR

We explored the accuracy of the Schofield equations to estimate BMR of children and adolescents from various published and unpublished reports. Some studies measured BMR and others measured resting metabolic rate (RMR). The conditions for the latter varied from quasi-basal conditions (supine position, 10–12 h fasting, transported by vehicle to the laboratory, resting 30–60 min prior to the measurement) to measurements done in supine, sitting and standing positions, 2–4 h after a light meal and resting for 15–45 min before the test.

The results for measured BMR are shown in Tables 9 and 10. Those results, however, must be interpreted with some caution. For example, Bandini *et al* (1990b) applied Weir's equation (1948) to correct for the difference in the volumes of inspired and expired air, whereas some of the others apparently did not. When only expired volume is measured and Weir's correction is not applied, BMR is underestimated by about 5%. Some systems that use a ventilated hood and compare the concentration of inhaled and exhaled O_2 and CO_2, such as the diaferometer used by Torun and Viteri (1981*a*), and the system used by Livingstone *et al* (1992*a*), compensate for the difference between inspired and expired air. Saris *et al* (1989) used a whole body indirect calorimeter that could also have compensated for that difference.

Table 8 Percentage by which Schofield equations overestimate (+) or underestimate (−) basal metabolic rate in different ethnic groups (18–60 years old)[a]

Ethnicity	Male: Mean (%)	Male: Sample size	Female: Mean (%)	Female: Sample size
Philippino	+9.6	82	+0.3	16
Indian	+12.7	48	+12.9	7
Japanese	+8.3	123	+7.9	71
Brazilian	+8.1	122	—	—
Chinese	+8.2	232	+3.4	156
Malay	+9.3	62	—	—
Javanese	+5.1	82	—	—
Mayan	+0.0	68	—	—
Chippewa Indian	−18.5	5	−18.5	5

[a] Source: Henry & Rees 1988).

With that methodological caveat in mind, Table 9 shows the BMR of boys and girls of different age groups measured in various countries, and compares them with the BMR calculated with Schofield's equations (1985). There seems to be a difference between developed and developing countries, an age-related trend in the data from the latter, and no major effects related to stunting or mild undernutrition. This can be seen more clearly in Table 10. Except for the Colombian underweight preschool aged boys, the difference or coincidence between measured and calculated BMR was similar for boys and girls of the same age groups, either with adequate weight and height, moderately stunted or mildly underweight.

In terms of age and sex, Schofield's equations overestimated the BMR of well-nourished, stunted or underweight Guatemalan, Colombian and Chinese preschoolers by about 10–12% in boys, and by 6–9% in girls. They coincided with measured BMR in boys and girls 7–16 years old in Holland, the UK and the USA, but overestimated the BMR of Colombian boys of that age by about 5%. That overestimation was not observed in their female counterparts, nor in Chinese girls 12–15 years old. By contrast W Wong (personal communication to B Torun) found that Schofield's equations overestimated by about 6% the BMR of 9–12 year-old hispanic and oriental girls living in Houston, Texas. The equations also overestimated by 9% the BMR of Chinese girls 15–18 years old in Guangzhou, China (Table 10).

In addition to those geographic and/or ethnic differences, Henry indicated that BMR in Beninese and Indonesian children is 8–10% lower than in the U.S. and Europe (personal communication).

More evidence about the tendency of current mathematical equations to overestimate BMR of many children and adolescents is derived from measurements of resting metabolic rates that should have been between about 15 and 20% higher than BMR, considering the conditions under which RMR is measured. For example, unpublished studies by Torun and coworkers in 68 Guatemalan 10–12 year-old boys of two economic income groups and repeated measurements in 24 stunted but well nourished girls of that same age, showed that in both sexes the non-fasting mean RMR measured after 15 min in supine, sitting and standing positions was only 7% greater than their BMR calculated with Schofield's equations. This was about 10% less than expected under the prevailing RMR conditions.

Firouzbakhsh *et al* (1993) reported similar results in 92 boys and 107 girls, 5–16 years old, living in or near Los Angeles, California. RMR measured 2–3 h postprandial and after resting for 15–30 min, coincided with

Table 9 Comparison of measured BMR with BMR calculated from Schofield's equations (1985)

Age	n	Country	Measured (MJ/d)	Calculated (MJ/d)	Difference[a] (%)	Reference
Boys						
2.5—3.8	11[b]	Guatemala	2.81	3.12	+10.9	Torun & Viteri (1981*a*)
2–5	22	Colombia	3.21 ± 0.27	3.59	+11.9	Spurr *et al* (1992)
2–5	17[c]	Colombia	2.61 ± 0.38	3.27	+25.2	Spurr *et al* (1992)
5–6	71	China	3.42 ± 0.30	3.79	+10.8	Ho *et al* (1988)
6–8	43	Colombia	4.05 ± 0.56	4.20	+3.7	Spurr *et al* (1992)
6–8	42[c]	Colombia	3.66 ± 0.47	3.92	+7.0	Spurr *et al* (1992)
7–7.9	6	UK	4.72 ± 0.78	4.52	−4.2	Livingstone *et al* (1992*a*)
9–9.5	5	UK	4.75 ± 0.65	4.98	+4.8	Livingstone *et al* (1992*a*)
9.3 ± 1.4	9	Holland	5.08	4.94	−2.7	Saris *et al* (1989)
10–12	54	Colombia	4.98 ± 0.70	5.19	+4.2	Spurr *et al* (1992)
10–12	80[c]	Colombia	4.37 ± 0.66	4.74	+8.4	Spurr *et al* (1992)
12–12.9	5	UK	6.30 ± 0.83	6.00	−4.8	Livingstone *et al* (1992*a*)
14–16	34	Colombia	6.17 ± 0.74	6.35	+2.9	Spurr *et al* (1992)
14–16	47[c]	Colombia	5.44 ± 0.83	5.57	+2.5	Spurr *et al* (1992)
14.5 ± 1.5	14	USA	7.29 ± 0.77	6.93	−4.9	Bandini *et al* (1990*b*)
15–15.9	3	UK	6.70 ± 0.36	6.51	−2.9	Livingstone *et al* (1992*a*)
Girls						
2–5	20	Colombia	3.10 ± 0.42	3.29	+6.1	Spurr *et al* (1992)
2–5	19[c]	Colombia	2.84 ± 0.38	3.09	+8.8	Spurr *et al* (1992)
5–6	85	China	3.21 ± 0.30	3.50	+9.1	Ho *et al* (1988)
6–8	29	Colombia	3.84 ± 0.51	3.92	+2.1	Spurr *et al* (1992)
6–8	25[c]	Colombia	3.81 ± 0.52	3.64	−4.5	Spurr *et al* (1992)
7–7.9	5	UK	4.36 ± 0.86	4.03	−7.6	Livingstone *et al* (1992*a*)
8.1 ± 1.3	10	Holland	4.80	4.69	−2.4	Saris *et al* (1989)
9–9.9	4	UK	4.43 ± 0.23	4.87	+9.9	Livingstone *et al* (1992*a*)
10–12	29	Colombia	4.85 ± 0.57	4.74	−2.3	Spurr *et al* (1992)
10–12	33[c]	Colombia	4.29 ± 0.82	4.39	+2.3	Spurr *et al* (1992)
12–12.9	16	China	5.26 ± 0.38	5.21	−0.9	Min & Ho (1991)
12–12.9	5	UK	5.85 ± 0.66	5.43	−7.2	Livingstone *et al* (1992*a*)
13–13.9	40	China	5.30 ± 0.43	5.26	−0.8	Min & Ho (1991)
14–14.9	23	China	5.35 ± 0.36	5.48	+2.4	Min & Ho (1991)
14–16	15	Colombia	5.48 ± 0.58	5.69	+3.9	Spurr *et al* (1992)
14–16	19[c]	Colombia	5.19 ± 0.43	5.22	+0.5	Spurr *et al* (1992)
15–15.9	14	China	5.26 ± 0.24	5.57	+5.8	Min & Ho (1991)
16–16.9	13	China	4.99 ± 0.31	5.49	+10.0	Min & Ho (1991)
14.3 ± 1.0	14	USA	6.03 ± 0.56	6.02	−0.2	Bandini *et al* (1990*b*)
15–15.9	3	UK	5.14 ± 1.00	6.00	+16.8	Livingstone *et al* (1992*a*)
17–17.9	20	China	4.82 ± 0.34	5.55	+15.2	Min & Ho (1991)

[a] + indicates that Schofield's formulas give higher values, and − indicates lower values.
[b] Adequate weight but previously malnourished. Height-for-age > 1.5 s.d. below the NCHS median.
[c] Weight-for-age and weight-for-height <95% of Colombian standards (Rueda-Williamson *et al*, 1969)

the calculated BMR within ±8% in all age groups and either sex.

Conclusions
Even though there may be some methodological doubts about their interpretation, the preceding observations and the data shown in Tables 9 and 10 indicate that the mathematical equations endorsed in 1985 by FAO/WHO/UNU to calculate BMR, tend to overestimate the results and, consequently, the TEE of many children and adolescents calculated from estimates of the population's PAL.

It is necessary to decide whether a single set of predictive equations for BMR should be used universally for all children and adolescents, acknowledging an error of certain magnitude in some cases, or whether specific equations must be derived and applied to certain races or to children who live in some parts of the world.

The extensive review of BMR data presently being done by CJK Henry under the auspices of IDECG and with funding from the Nestlé Foundation should help to clarify this issue.

Time allocation to different activities

The habitual physical activity of children and adolescents differs among societies with different cultural characteristics and among groups of different socioeconomic conditions in the same society. For example, while many children in rural areas of developing countries partake in domestic chores or are part of their community's labor force from an early age (Rodgers and Standing, 1981), most children in industrialized countries attend school for several hours, and those in a better socioeconomic situation do not have any work obligations.

Many studies have addressed various aspects of the time allocated by children to their daily activities. These have been performed with diverse objectives by researchers whose main interests are in nutrition, physiology, anthropology, human behavior or economics. Methods have included continuous or spot observations, recall interviews with children or caretakers, subject or observer diaries, and analysis of heart rate patterns. Results have been analyzed and presented as

Table 10 Mean differences between measured BMR in children of different races and BMR calculated from Schofield's equations (1985)

Country Race	Age (y)	Condition[a]	n	Difference[b]	Reference
Boys					
Guatemala Mixed[c]	2–4	Stunted	11	+10.9%	Torun & Viteri (1981*a*)
Colombia/Mixed	2–5		22	+11.9%	Spurr *et al* (1992)
Colombia/Mixed	2–5	Underweight	17	+25.2%	Spurr *et al* (1992)
China/Chinese	5–6		71	+10.8%	Ho *et al* (1988)
Colombia/Mixed	6–16		131	+3.7%	Spurr *et al* (1992)
Colombia/Mixed	6–16	Underweight	169	+6.4%	Spurr *et al* (1992)
Holland, UK, USA/Caucasian	7–16		42	−3.0%	Saris *et al* (1989) Livingstone *et al* (1992*a*) Bandini *et al* (1990*b*)
Girls					
Colombia/Mixed	2–5		20	+6.1%	Spurr *et al* (1992)
Colombia/Mixed	2–5	Underweight	19	+8.8%	Spurr *et al* (1992)
China/Chinese	5–6		85	+9.1%	Ho *et al* (1988)
Colombia/Mixed	6–16		73	+0.2%	Spurr *et al* (1992)
Colombia/Mixed	6–16	Underweight	77	−1.0%	Spurr *et al* (1992)
Holland, UK, USA/Caucasian	7–16		41	−0.3%	Saris *et al* (1989), Livingstone *et al* (1992*a*), Bandini *et al* (1992*b*)
China/Chinese	12–15		79	+0.1%	Min & Ho (1991)
China/Chinese	15–18		47	+9.1%	Min & Ho (1991)

[a] Stunted: >1.5 s.d. below the NCHS median of height-for-age. Underweight: <95% of weight-for-age and weight-for-height in comparison to Colombian children of upper socioeconomic groups (Rueda-Williamson *et al*, 1969). All others: adequate height and weight for age.
[b] + indicates that Schofield's formulas give higher values, and − indicates lower values.
[c] Mixed: various degrees of mixture between caucasian and indigenous.

specific activities or classified according to their purpose or physical effort.

Quantification of total daily time distribution
The variety of methods and the lack of a standard for presenting the data make it difficult to compare across societies and to combine the results of different studies. This is further impaired by the selective nature of some studies that focus on one type of activity, and by incomplete information, such as indicating children's involvement as a percentage of activities performed without information on the time period. We, nevertheless, made an effort to compare and combine information after a critical revision of studies with time allocation data.

From a review of more than 70 studies that had some information, we identified 39 with data of sufficient quality and completeness to quantify children's total daily time allocation (Table 11). We classified activities according to two types of characteristics:

(1) *Intensity of effort and energy expenditure:* (a) sleep, (b) sedentary, (c) light, (d) moderate, (e) heavy. When those categories were used by the investigators, their criteria for classification were respected. When not, we allocated the time to the corresponding category according to the description of the activity or to the children's heart rate, following the criteria shown in Table 12.

(2) *Nature or purpose of the activity:* (a) sleep, (b) school, (c) domestic chores, (d) production (with or without wages), (e) non-work activities. Table 13 gives descriptive examples. 'Recreational activities' are mentioned in some studies. These are non-sedentary leisure activities that involve more effort than the general 'non-work activities'.

Classification of activities according to their physical effort permits making estimates of total daily energy expenditure of children with different lifestyles. Most studies that describe the nature of activities, such as in Table 13, do not indicate the degree of physical effort involved. They must be assigned an energy cost, or at least an intensity of effort, to allow comparing with studies that allocate time according to the level of energy expenditure.

Although the energy cost of some activities listed in Table 13 has been measured by indirect calorimetry, that of many others has not (see review by Torun,

Table 11 Studies used to evaluate and quantify children's time allocation (see 'References' for full bibliographic information)

Acharya & Bennett (1981)	Loucky (1988)
Andersen *et al* (1978)	MacConnie *et al* (1982)
Banerjee & Saha (1972)	McNaughton & Cahn (1970*a*,*b*)
Berio (1984)	Mueller (1984)
Bradfield *et al* (1971)	Munroe *et al* (1983)
Cain (1977)	Munroe & Munroe (1989)
Carbañero (1980)	Nag *et al* (1978)
Colfer (1981)	Niemi *et al* (1981)
Dresen *et al* (1982)	Paolisso & Sackett (1988)
Durnin (1971)	Ramírez & Torún (1994)
Franklin & Harrell (1985)	Rutenfranz *et al* (1974)
Gilliam *et al* (1981)	Saris *et al* (1979)
Grossman (1984)	Seliger *et al* (1974)
Guzmán (1991)	Shephard *et al* (1980)
Hart (1988)	Spady (1980)
Ho *et al* (1988)	Stefanik *et al* (1959)
Huenemann *et al* (1967)	Sunnegardh *et al* (1985)
Johnson *et al* (1956)	Torún *et al* (1993)
Johnson & Johnson (1987)	Turke (1988)

Table 12 Criteria to classify the physical effort of activities according to the children's heart rate

Sedentary	<96
Light	96–120
Moderate	121–145
Heavy	>145

Table 13 Selected examples of activities classified according to their nature or purpose

Sleep	In bed at night; napping.
School	Classroom work; recess; other school activities.
Domestic chores	Child care; cleaning house; washing dishes; laundry; food preparation and cooking; miscellaneous household crafts and tasks; fetching water; fuel collection.
Production	Agricultural activities; household manufacturing and crafts for sale; textile work; hunting, fishing and gathering; trading and selling; wage work.
Non-work activities	Eating; personal care and hygiene; resting; walking and travelling; school homework; play and leisure; social and religious activities.

1990*a*). Furthermore, many tasks involve a variety of specific activities with different energy demands (for example, house cleaning can involve light dusting or heavy sweeping), and pauses of different length may be interspersed with the actual physical endeavor. Consequently, we made an empirical estimation of the physical effort involved in the activity categories of Table 13, based on the energy costs that have been measured, the descriptions available in some studies, our own experience, and the assumption that domestic and productive activities in developing societies involve more physical effort than their equivalents in developed countries or urban centers. This is shown in Table 14. As with all empirical estimations, this can later be modified but it is a starting point to compare studies.

The age groups were classified as 2–5, 5–9, 10–14 and 15–19 years, as this was the age breakdown allowed by most of the reviewed studies. In addition to the overlap between the 2–5 and 5–9 groups, there was some overlap between the other categories, as some studies presented data on children aged 9–11 or 13–15.

Tables 15 and 16 show the factorial distribution of the time allocated by boys and girls, respectively, to activities with different energy demands. They are presented separately for children from industrialized countries, cities in developing countries, and rural areas in the latter, as the activities performed and the energy expenditure involved vary in each of those settings.

Time distributions were calculated as weighted means from several studies, weighting them for the number of

Table 14 Effort empirically assumed to be required by the activities listed in Table 13

	Time spent in physical effort (%) *corresponding to:*			
Time spent in:	*Sedentary*	*Light*	*Moderate*	*Heavy*
School	67	33		
Domestic chores				
cities and industrialized societies		50	50	
rural developing societies		33	67	
Production				
cities and industrialized societies		50	50	
rural developing countries		33	34	33
Non-work activities	30	30	30	10
Recreational activities[a]		30	50	20

[a] Described as such in some studies. They are non-work activities that are not sedentary.

Table 15 Weighted averages of time allocated by boys to activities that require different levels of physical effort[a]

			Mean number of daily hours at:					*Mean daily energy expenditure*
Society	*No. of studies*	*No. of children*[b]	*Sleep*	*Sedentary*	*Light*	*Moderate*	*Heavy*	*PAL*[c]
5–9 Years			(1)[d]	(1.3)	(2.2)	(2.9)	(3.6)	
Industrialized, urban and rural	5	225	10.5	6	4	2	1.5	1.60
Developing, urban	2	81	11	5	3	3	1	1.56
Developing, rural	13	340	10	4	4.5	4	1.5	1.75
10–14 Years			(1)	(1.3)	(2.2)	(2.9)	(3.6)	
Industrialized, urban and rural	9	887	10.5	5.5	4.5	2.5	1	1.60
Developing, urban	3	133	8.5	7.5	4	3.5	0.5	1.62
Developing, rural	12	450	9	4	4.5	4.5	2	1.85
15–19 Years			(1)	(1.3)	(2.2)	(3)	(5)	
Industrialized, urban and rural	5	838	9.5	5	6	3	0.5	1.70
Developing, urban	1	32	8.5	7	6	2.5	0	1.60
Developing, rural	9	200	8	3.5	5	5	2.5	2.13

[a] Sources are listed in Table 11. Averages were weighted on the number of children in each study; refer to the text for explanation of procedure when the exact number of children was not known or it was too large in relation to other studies.
[b] Some numbers of children are approximations, as some studies do not give exact figures.
[c] Expressed as multiples of BMR or Physical Activity Level. Not calculated when time allocation was reported in only one study.
[d] Energy cost of activities, in multiples of BMR, as suggested by Torun (1990*a*).

Table 16 Weighted averages of time allocated by girls to activities that require different levels of physical effort[a]

Society	No. of studies	No. of children[b]	Mean number of daily hours at: Sleep	Sedentary	Light	Moderate	Heavy	Mean daily energy expenditure PAL[c]
5–9 Years			(1)[d]	(1.3)	(2.2)	(2.9)	(3.3)	
Industrialized, urban and rural	4	232	10.5	6	4	2	1.5	1.58
Developing, urban	2	81	11.5	5	4	2.5	1	1.56
Developing, rural	13	310	10	4	4.5	4	1.5	1.74
10–14 Years			(1)	(1.3)	(2.2)	(2.9)	(3.3)	
Industrialized, urban and rural	4	700	10	6.5	4	2.5	1	1.58
Developing, urban	2	73[e]	8.5	6	4.5	4.5	0.5	1.70
Developing, rural	12	400	9	3.5	4.5	5	2	1.86
15–19 Years			(1)	(1.3)	(2.2)	(3)	(4.5)	
Industrialized, urban and rural	7	1023	9.5	5.5	6	2.5	0.5	1.65
Developing, urban	1	32	8	7	6.5	2.5	0	1.62
Developing, rural	9	180	8	3	5.5	5.5	2	2.06

[a] Sources are listed in Table 11. Averages were weighted on the number of children in each study; refer to the text for explanation of procedure when the exact number of children was not known or it was too large in relation to other studies.
[b] Some numbers of children are approximations, as some studies do not give exact figures.
[c] Expressed as multiples of BMR or Physical Activity Level. Not calculated when time allocation was reported in only one study.
[d] Energy cost of activities, in multiples of BMR, as suggested by Torun (1990*a*).
[e] In one of the two studies 24 girls were studied longitudinally four times at 3-month-intervals.

children involved, and rounding the time to the nearest half-hour. In studies that only presented the number of households, the number of children was assumed to be either 50 or 33% of those households, depending on other information related to the study. When the number of boys and girls was not given, equal numbers were assumed for each sex. When a study greatly outnumbered the sample size of all others for that sex and age category, only 50% of its sample size was used to calculate the weighted mean in order to reduce the bias of the results towards a single study. For example, 8 of 9 studies on boys 10–14 aged years old in industrialized countries involved between 11 and 171 children, whereas the ninth study involved 360; a weight of 180 was given to that study.

Tables 15 and 16 show that, compared with children in industrialized societies, children in developing rural areas sleep less at night, participate longer in moderate and/or heavy physical activities, and have a greater energy expenditure in relation to their basal metabolic rate. There are very few studies on children in cities from developing countries, but their physical activity falls between the other two groups, resembling more that of children in industrialized countries than that of their rural counterparts. Within the same type of society, there were no striking differences between boys (Table 15) and girls (Table 16).

In terms of the nature or purpose of the activities, children of school age in industrialized countries spend between 4.5 and 7.5 h at school during school-days. In developing countries, children in urban areas spend similar amounts of time at school, although many from the lower socioeconomic groups do not attend school at all, especially after 12 years of age. School attendance is less among their rural counterparts, who average between 0.5 and 2 h per day (Table 17).

Table 17 also shows that children in rural traditional societies of developing countries begin domestic and productive work at preschool age, and from 10 years onwards they have an important daily workload. Girls are involved in domestic work longer than boys and, after 9 years of age, boys spend more time than girls in production and wage-earning chores.

Estimations of total daily energy expenditure

Total daily energy expenditure was estimated from the time allocations in Tables 15 and 16, and the energy costs of sedentary, light, moderate and heavy activities suggested by Torun (1990*a*), as shown in those tables; the energy cost of sleep was assumed to equal basal metabolic rate. The results, expressed as PAL or multiples of BMR, are shown in the last column of those tables.

Table 17 Time allocated to school attendance, domestic work, productive work and non-work activities by children of native, traditional, rural populations from several countries[a]

	Time allocated to (rounded to 0.5 h): School	Domestic work	Production work	Non-work and sleep
2–5 Years				
Boys	<0.5	0.5	0.5	23
Girls	<0.5	1	<0.5	23
5–9 Years				
Boys	1	0.5	1.5	21
Girls	1	1.5	1.5	20
10–14 Years				
Boys	2	1	4	17
Girls	2	2.5	2.5	17
15–19 Years				
Boys	1.5	1	6	15.5
Girls	1.5	3.5	3.5	15.5

[a] Bangladesh (Cain, 1977), Borneo (Colfer, 1981), Botswana (Mueller, 1984), Guatemala (Loucky, 1988), Indonesia (Nag *et al*, 1978; Hart, 1988), Ivory Coast (Berio, 1984), Kenya (Munroe *et al*, 1983; Munroe & Munroe, 1989), Papua/New Guinea (Grossman, 1984), Panama (Franklin & Harrell, 1985), Peru (Munroe *et al*, 1983; Johnson & Johnson, 1987), Philippines (Carbañero, 1980), Nepal (Nag *et al*, 1978; Acharya & Bennett, 1981), Venezuela (Paolisso & Sackett, 1987), Western Caroline Islands (Turke, 1988).

PALs were converted into kcal/kg/day applying Schofield's equations (Schofield, 1985) to the body weight at the mid-point of the age intervals shown in Table 18 (i.e. 7.5, 12.5 and 17.5 y). The NCHS/WHO median weight for age was used for children in industrialized countries, and it was assumed that the average weights for children in urban and rural developing areas corresponded to the 30th and 20th centiles of the NCHS values, respectively. The remarkable agreement with the estimates of total daily energy expenditure by the doubly-labeled water and heart rate methods (Figure 6) suggests that the criteria for classification of activities shown in Tables 13 and 14 and the factors used to assign them an energy cost (Tables 15 and 16) were good estimates.

Tables 15, 16 and 18 suggest that total energy expenditure expressed as PAL is similar for boys and girls within each age group and geographic/developmental category. In industrialized countries, it is constant between 5 and 14 years (and similar to cities in developing countries), and it increases by about 5% after that age. In rural developing societies, daily energy expenditure increases with age, as a reflection of children's increasing involvement in energy-demanding chores.

An analysis of the estimates of total daily energy expenditure shown in Table 18 indicates that, based on multiples of BMR, children of 5–9, 10–14 and 15–19 years spend about 10, 15 and 25% more energy in rural developing societies than in industrialized countries. When expressed as kcal/kg, the corresponding increments in energy expenditure are about 15, 25 and 30% for the three age groups, respectively.

Table 18 Estimates of total daily energy expenditure of children based on the data shown in Tables 15 and 16, and the median weights assumed for the age span

Age (y)	*Assumed weight*[a] *(kg)*	*Estimated daily energy expenditure*	
		PAL	*(kcal/kg/day)*[b]
Boys			
Industrialized countries			
5 9	24.0	1.60	69.9
10–14	42.3	1.60	53.2
15–19	67.8	1.70	46.6
Developing cities			
5 9	22.5	1.56	70.4
10–14	38.6	1.62	56.3
Developing rural areas			
5–9	21.6	1.75	80.5
10–14	36.5	1.85	66.1
15–19	60.3	2.13	60.9
Girls			
Industrialized countries			
5–9	23.3	1.58	65.0
10–14	43.8	1.58	46.1
15–19	56.7	1.65	42.2
Developing cities			
5–9	21.6	1.56	66.8
10–14	40.0	1.70	52.2
Developing rural areas			
5–9	20.7	1.74	76.2
10–14	37.6	1.86	59.2
15–19	50.4	2.06	55.9

[a] Children in industrialized countries: NCHS median for mid-point of age range (i.e., 7.5, 12.5 and 17.5 y); children in developing urban centers: 30th centile; children in rural societies: 20th centile.
[b] Basal metabolic rate was converted to kcal/kg/day using the formulas suggested by Schofield (1985).

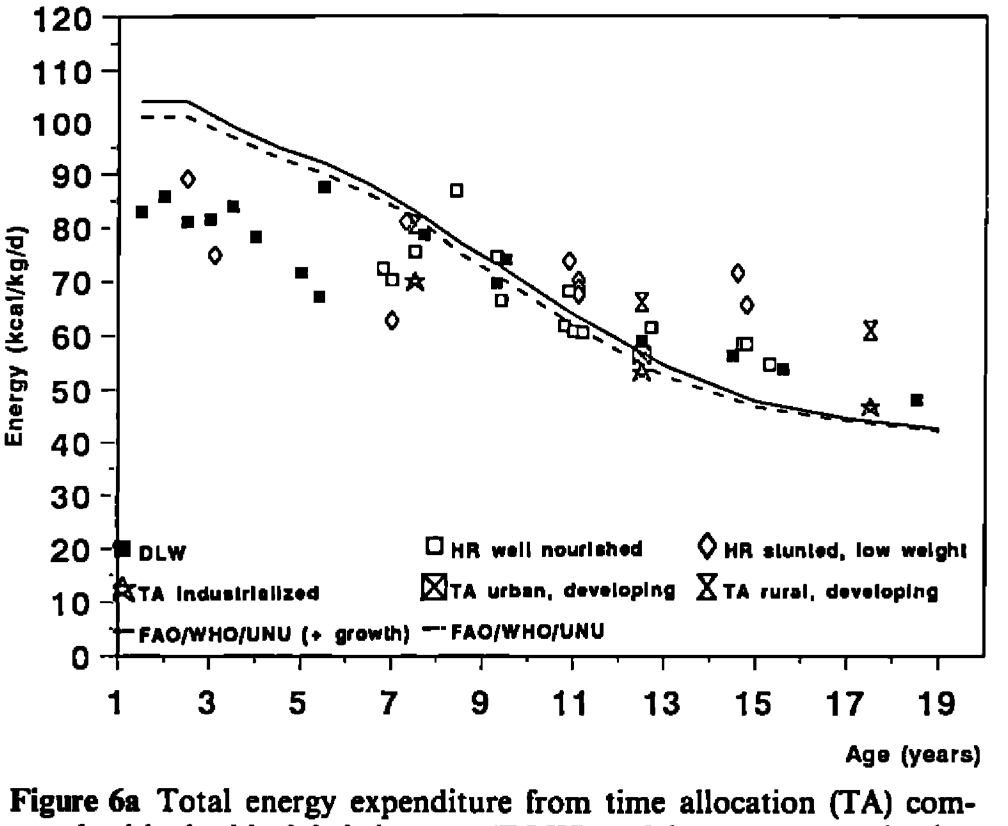


Figure 6a Total energy expenditure from time allocation (TA) compared with doubly labeled water (DLW) and heart rate monitoring (HR): boys.

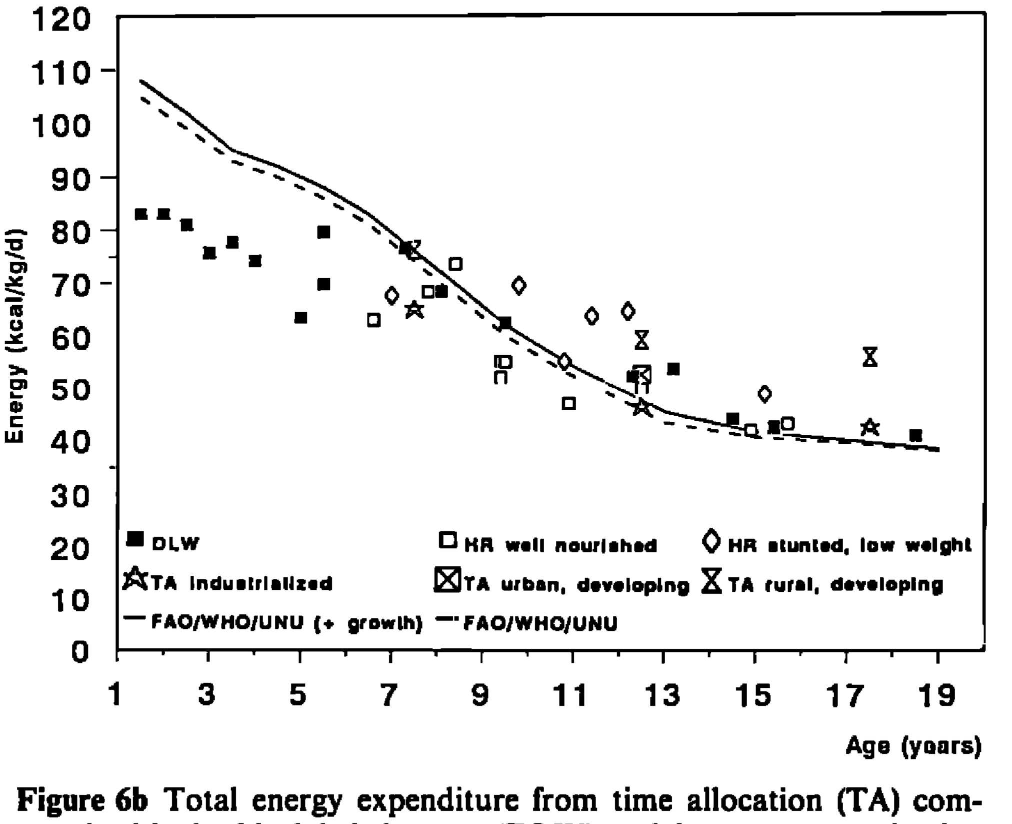


Figure 6b Total energy expenditure from time allocation (TA) compared with doubly labeled water (DLW) and heart rate monitoring (HR): girls.

Conclusions

We believe that more insightful information on children's time allocation and its energy cost is lying unanalyzed in existing databases of nutritional, physiological and anthropological studies. Efforts must be made to retrieve, analyze and present them in a standard manner to allow making better estimates of children's energy expenditure and requirements, as well as of the behavioural and social implications of their time distribution.

The data that we were able to analyze indicates that, beginning at least at 5 years of age, children in rural areas of developing countries spend more time in activities that require more physical effort than children in cities or industrialized countries.

It seems that time allocation of physical activity is similar in urban areas of industrialized and developing countries, but more information is needed from the latter to confirm this notion. Information is also needed on the time allocated to activities by children and adolescents of different socioeconomic groups.

Table 19 Mean 24-hour physical activity levels of children and adolescents in industrialized countries and in cities of developing countries (based on data in Tables 2, 4, 7, 15 and 16)[a]

Age (y)	Method[b]	Boys		Girls	
1–5	DLW		1.46 (86)[c]		1.44 (84)
	HR (St)		1.42 (17)		
	TM (St)		1.36 (38)		1.42 (34)
6–13	DLW		1.79 (53)		1.80 (75)
	HR	1.71 (149)	1.71 (274)	1.50 (80)	1.59 (181)
	HR (St)	1.71 (125)		1.67 (101)	
	TM		1.51 (67)		1.57 (24)
	TA		1.60 (1326)		1.59 (1086)
14–18	DLW		1.84 (37)		1.69 (34)
	HR		1.81 (15)	1.65 (22)	1.63 (44)
	HR (St)			1.61 (22)	
	TM		1.57 (304)		1.58 (253)
	TA		1.70 (870)		1.65 (1055)

[a] Excluding studies with mean PAL < 1.40 for children over 5 years, and > 1.90 for all ages.
[b] DLW: doubly labeled water; HR: heart rate monitoring; TA: time allocation; TM: time-motion/diary. (St): stunted or mildly underweight; otherwise, normal.
[c] Weighted mean. Number of children in parenthesis.

The conversion of time allocation data to energy expenditure gives reasonable results when activities such as those listed in Table 13 are assigned the intensity of effort shown in Table 14, and the energy equivalents shown in Tables 15 and 16 are applied to sleep, sedentary, light, moderate and heavy activities.

When time allocation is converted into energy expenditure expressed as PAL, there is practically no difference between boys and girls within the same type of society.

Physical activity levels of children and adolescents

The occupational and habitual activities of adults are classified as light, moderate and heavy, and taken into account to calculate and recommend dietary energy intakes. The data presented in this document supports the suggestion that the same approach must be applied to children from 5 years of age onwards.

To do so, estimates must be made of the 24-hour PAL of children and adolescents with different lifestyles. This is usually associated with their geographic habitat (urban or rural, industrialized or developing country) and socioeconomic conditions.

An analysis of the PALs calculated in this review for children studied with doubly-labeled water, heart rate monitoring, time–motion/diary techniques and time allocation estimates allows making practical suggestions. Table 19 summarizes those calculations for *industrialized countries* and *cities in developing countries*, calculated as weighted means for the total number of boys or girls included in all studies with a specific technique. Studies with mean PAL < 1.40 for children over 5 years old were excluded, as well as those with PAL > 1.90 at all ages, as those figures are very unlikely to represent the *habitual* activity level of children in cities and industrialized countries. The mean PALs of normal and stunted children calculated from heart rate monitoring methods were combined as they were derived from otherwise healthy children, and in most cases they agreed within 4%.

There is hardly any information of TEE of children and adolescents living in *rural developing countries*. Therefore, we only estimated their PAL from time allocation data, as described in the preceding section and shown in Tables 15, 16 and 18.

The estimates of PALs from studies on time–motion/diary records and time allocation data involve a series of assumptions on the energy cost of activities and tasks to calculate TEE. Thus, it seems more reasonable to use the data derived from doubly-labeled water and heart rate monitoring studies to suggest PALs to estimate the energy expenditure and requirements of children and adolescents from different populations. Such PALs, based on the data in Table 19, are shown in Table 20. Assuming that those levels of physical activity correspond to children and adolescents who are neither extremely sedentary nor active and are consuming dietary energy *ad libitum*, we suggest that they are are equivalent to a *moderate* PAL.

The mean coefficient of variance (CV) of the studies with doubly-labeled water and heart rate monitoring in boys and girls 1–5, 6–13 and > 14 years old shown in Tables 3 and 5 is 6%. We calculated the PAL of *light* and *heavy* lifestyles by subtracting or adding twice the CV (i.e. 12%) from the moderate PAL of children and adolescents over 5 years old (Table 20). It is unlikely that infants and preschoolers have a heavy physical lifestyle. Consequently, for that age group it is suggested that the mean of the PALs shown in Table 19 (measured

Table 20 Physical activity levels suggested to estimate total daily energy expenditure from the mean basal metabolic rate of children and adolescents

Age (y)	Sex	Habitual physical activity: Light	Moderate	Heavy
1–5	M, F	1.44	1.61	
6–13	M	1.54	1.75	1.96
14–18	M	1.60	1.82	2.04
6–13	F	1.48	1.68	1.88
14–18	F	1.46	1.66	1.86

Table 21 Data from Table 20 rounded to the closest 0.05 PAL units

Age (y)	Sex	*Habitual physical activity* Light	Moderate	Heavy
1–5	M, F	1.45	1.60	—
6–13	M	1.55	1.75	1.95
14–18	M	1.60	1.80	2.05
6–13	F	1.50	1.70	1.90
14–18	F	1.45	1.65	1.85

by DLW or HR) be applied to a 'light' lifestyle, and the additional 12% (twice the mean CV) be applied to a 'moderate' PAL.

To facilitate remembering those PAL factors, it is further suggested to round them to the closest 0.05 PAL units, as shown in Table 21.

As more information on TEE and BMR of boys and girls with different lifestyles becomes available and the questions related to the mathematical equations to estimate BMR are cleared, the PALs shown in Table 21 may be modified. In the meantime, their use is suggested as a first approximation to estimate energy requirements in population groups where actual data is unavailable. Table 22 shows those estimates for boys and girls with median weights-for-age corresponding to the NCHS standards. Figure 7 compares them with measurements using doubly labeled water and heart rate monitoring, expressed as kcal/kg/day.

Dietary energy intake

The most important criteria in choosing a method for collecting food intake data in children and adolescents are: (a) the technique should not interfere with the subject's dietary pattern; (b) the data should be representative of *usual* or *habitual* intake and (c) the technique should be suitable for application in large study groups.

The methods most frequently used in childhood and adolescent population groups are similar to those

Table 22 Estimates of total daily energy expenditure from the physical activity levels suggested in Table 21 and basal metabolic rates calculated with Schofield's equations

Age (y)	Weight[a] (kg)	*Habitual physical activity*[b] Light (kcal/d)	Light (kcal/kg/d)	Moderate (kcal/d)	Moderate (kcal/kg/d)	Heavy (kcal/d)	Heavy (kcal/kg/d)
Boys							
1	10.4	854	82.1	942	90.6	[c]	[c]
2	12.3	1018	82.7	1123	91.3	[c]	[c]
3	14.6	1211	83.0	1337	91.6	[c]	[c]
4	16.7	1281	76.6	1413	84.6		
5	18.7	1346	72.0	1486	79.4		
6	20.7	1510	72.9	1704	82.3	1899	91.7
7	22.9	1587	69.3	1792	78.2	1996	87.2
8	25.3	1671	66.1	1887	74.6	2102	83.1
9	28.1	1770	63.0	1998	71.1	2227	79.2
10	31.4	1885	60.0	2126	67.7	2370	75.5
11	35.3	1988	56.3	2245	63.6	2501	70.9
12	39.8	2112	53.1	2384	59.9	2657	66.8
13	45.0	2254	50.1	2545	56.6	2836	63.0
14	50.8	2491	49.0	2803	55.2	3192	62.8
15	56.7	2659	46.9	2991	52.7	3406	60.1
16	62.1	2811	45.3	3163	50.9	3602	58.0
17	66.3	2930	44.2	3296	49.7	3755	56.6
18	68.9	3004	43.6	3379	49.1	3849	55.9
Girls							
1	9.8	783	79.9	865	88.2	[c]	[c]
2	11.8	953	80.7	1051	89.1	[c]	[c]
3	14.1	1120	79.4	1236	87.6	[c]	[c]
4	16.0	1176	73.5	1297	81.1		
5	17.7	1226	69.3	1352	76.4		
6	19.5	1323	67.8	1499	76.9	1676	85.9
7	21.8	1393	63.9	1579	72.4	1764	80.9
8	24.8	1484	59.8	1682	67.8	1880	75.8
9	28.5	1597	56.0	1810	63.5	2023	71.0
10	32.5	1706	52.5	1933	59.4	2160	66.5
11	37.0	1783	48.2	2021	54.6	2259	61.0
12	41.5	1874	45.1	2123	51.2	2373	57.2
13	46.1	1966	42.6	2228	48.3	2490	54.0
14	50.3	1982	39.4	2256	44.8	2529	50.3
15	53.7	2048	38.1	2331	43.4	2613	48.7
16	55.9	2091	37.4	2379	42.6	2668	47.7
17	56.7	2107	37.2	2397	42.3	2688	47.0
18	56.6	2105	37.2	2395	42.3	2685	47.4

[a] Median weight for age, NCHS/WHO.
[b] PAL factors shown in Table 21.
[c] Assume values similar to moderate physical activity in children 1–3 years old.

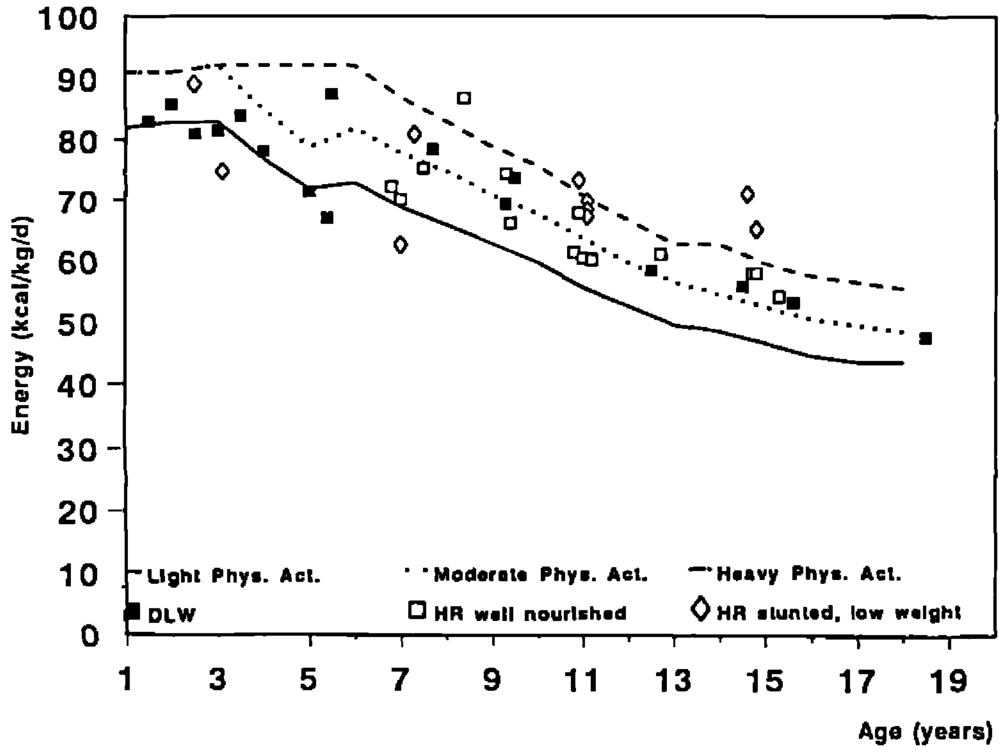


Figure 7a Energy expenditure calculated from estimates of habitual physical activity, compared with measurements using doubly labeled water and heart rate monitoring. *Including* data of stunted and underweight children: boys.

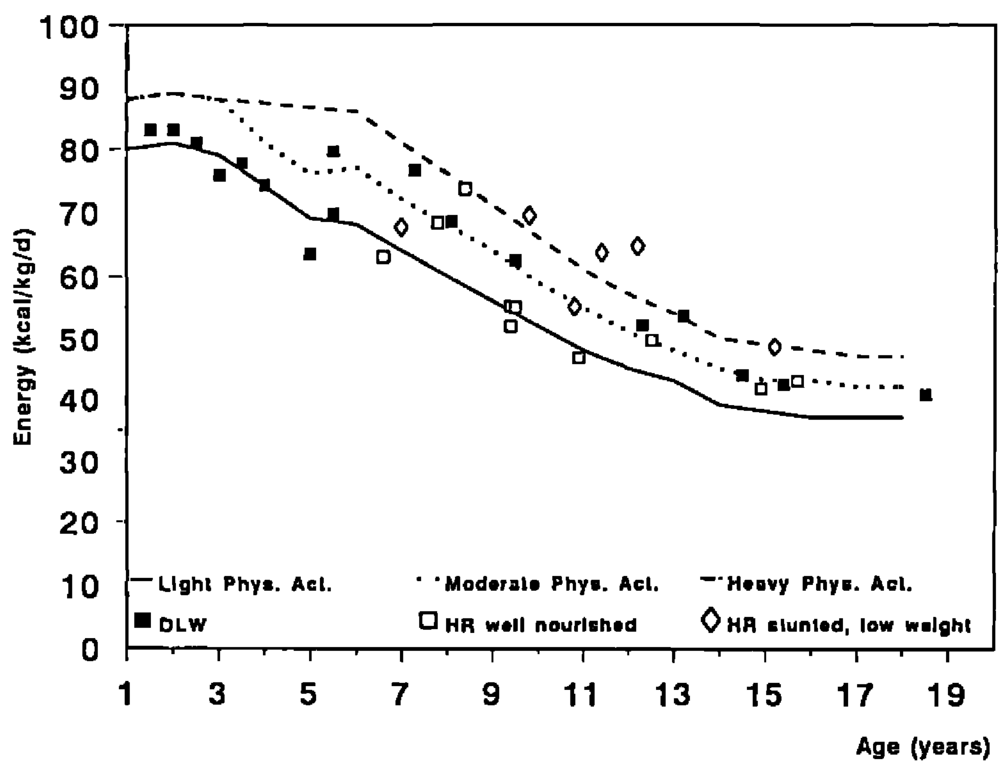


Figure 7b Energy expenditure calculated from estimates of habitual physical activity, compared with measurements using doubly labeled water and heart rate monitoring. *Including* data of stunted and underweight children: girls.

applied in adult studies, namely:

(1) *Retrospective or food recall methods*, which depend on dietary information given from memory by the child/adolescent and/or parent/child carer. Several specific types of data collection fall within this category, including those aimed at quantifying actual intake for a precise time (usually the previous day, or *24-h recall*) and those designed to elicit information about usual consumption patterns for a longer, less precisely defined time period (*diet history* or *food frequency* methods). More than one 24-h recall should be made on different days of the week, especially when there are cultural cyclic changes in food intake (e.g. weekdays compared with weekends). Recalls of more than 24 h are sometimes performed but the accuracy with which subjects and/or parents can remember food consumption is debatable, particularly if food intake patterns are highly unstructured or unstable. In the food frequency method, subjects and/or parents/child carers report by interview or self-administered questionnaire, the frequency of consumption of particular foods during a specified time span (week, month, year). A quantitative component is added by including the size and number of portions most frequently consumed for each food.

(2) *Prospective or food record methods*, which require that all food items consumed be recorded at the time of consumption. Intakes are quantified by *direct weighing* of the food, by estimates using *household measures* or by *collection of duplicate diets*. Quantitative assessment of usual food intake can be obtained by increasing the number of measurement days. Seven days are generally assumed to represent a good compromise between precision, subject/parental cooperation, cultural dietary patterns and investigator workload.

Each of these methods has advantages and drawbacks when applied to children and adolescents. Ultimately, all survey methods are dependent on the motivation, compliance and ability of subjects and/or parents/child carers to report accurately habitual food intake.

Food intake data must then be converted into energy equivalents. This is often done disaggregating recipes into their food components and calculating their metabolizable energy as reported in food composition tables. Care must be taken to make all necessary conversions for the proper use of food composition data. A common error is applying to 'cooked' or 'wet' weight of foods the energy values for 'raw' or 'dry' foods that appear in composition tables, without applying adequate conversion factors.

A more accurate approach is to perform chemical or calorimetric analyses of samples of foods that are ready to be eaten. This is particularly useful to calculate the energy provided by food recipes that are unlikely to appear in food composition tables or that may be subject to variations. When the energy content of food is measured by bomb calorimetry, appropriate corrections must be made to calculate metabolizable energy.

Validity of energy intakes in children and adolescents
Most dietary intake studies in children assume that the data obtained are representative of habitual food consumption, and many recent studies concluded that energy intakes (EI) have declined in industrialized countries and more privileged groups in developing countries in response to a secular trend towards lower levels of activity in children and adolescents. However, studies in adults using doubly-labeled water (DLW) measurements of total energy expenditure (TEE) to validate EI have demonstrated that intake data may underestimate habitual food intake to a greater extent than has been appreciated (Prentice *et al*, 1986; Livingstone *et al*, 1990*b*; Schoeller, 1990). It is conceivable, therefore, that the reportedly low intakes of children may be artifacts of dietary survey methodology, rather than indicative of a diminution in energy expenditure.

Validation studies have been reported to assess the accuracy of EI in children and adolescents, using DLW measurements of TEE. These include studies of EI by 4-day weighted dietary record (*WDR*) in 1.5–4.5 year olds ($n = 81$) (Davies *et al*, 1994), by 7-day WDR in 7, 9, 12, 15 and 18 year olds ($n = 58$), by diet history (*DH*) in 3, 5, 7, 9, 12, 15 and 18 year olds (Livingstone *et al*, 1992*b*) and by 14-day estimated food records in non-

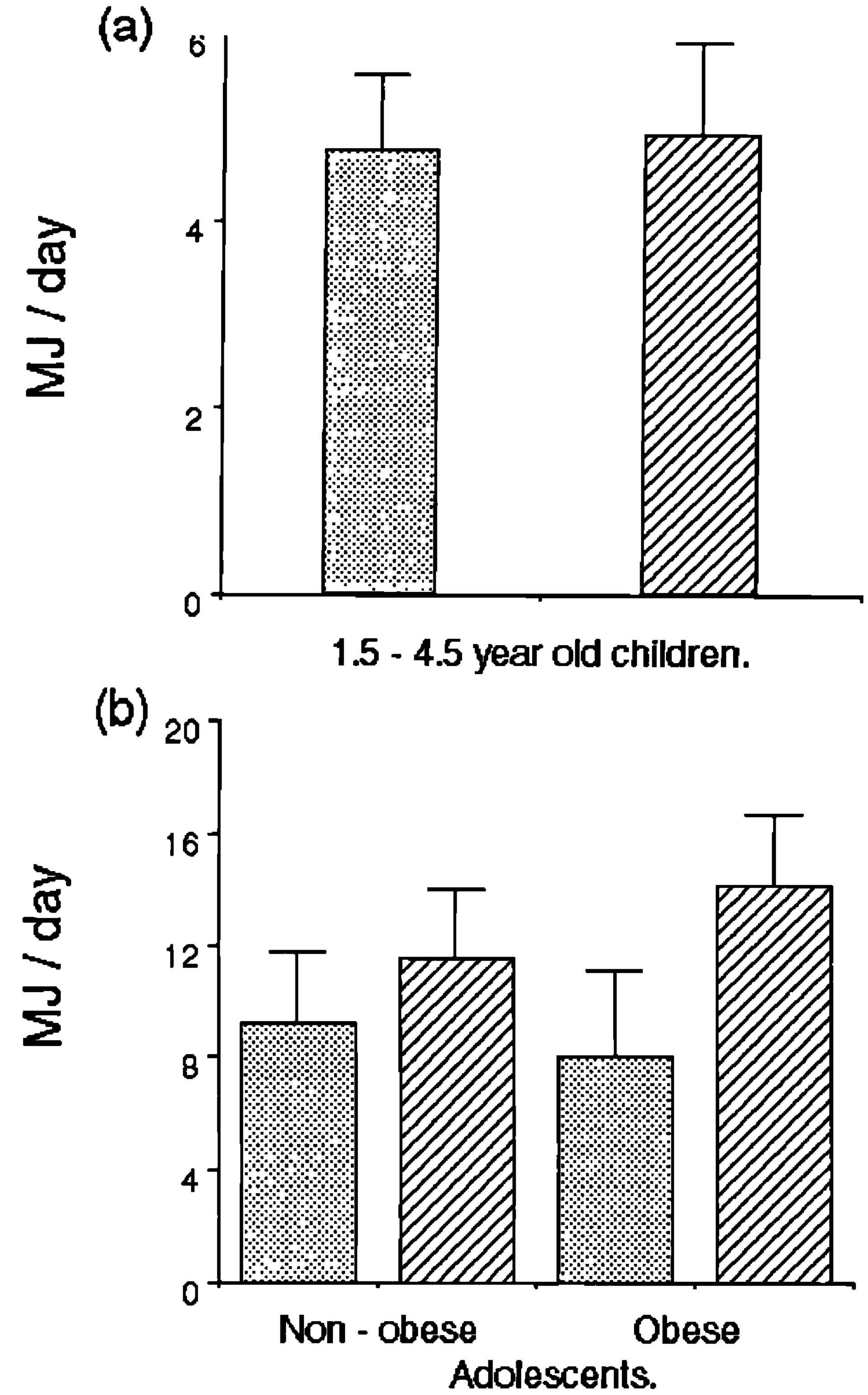


Figure 8 Comparison (±s.d.) of reported habitual energy intake (▒) and energy expenditure (▨) in (a) 1.5 4.5 year old children (Davies *et al*, 1994) and (b) non-obese and obese adolescents (Bandini *et al*, 1990*a*).

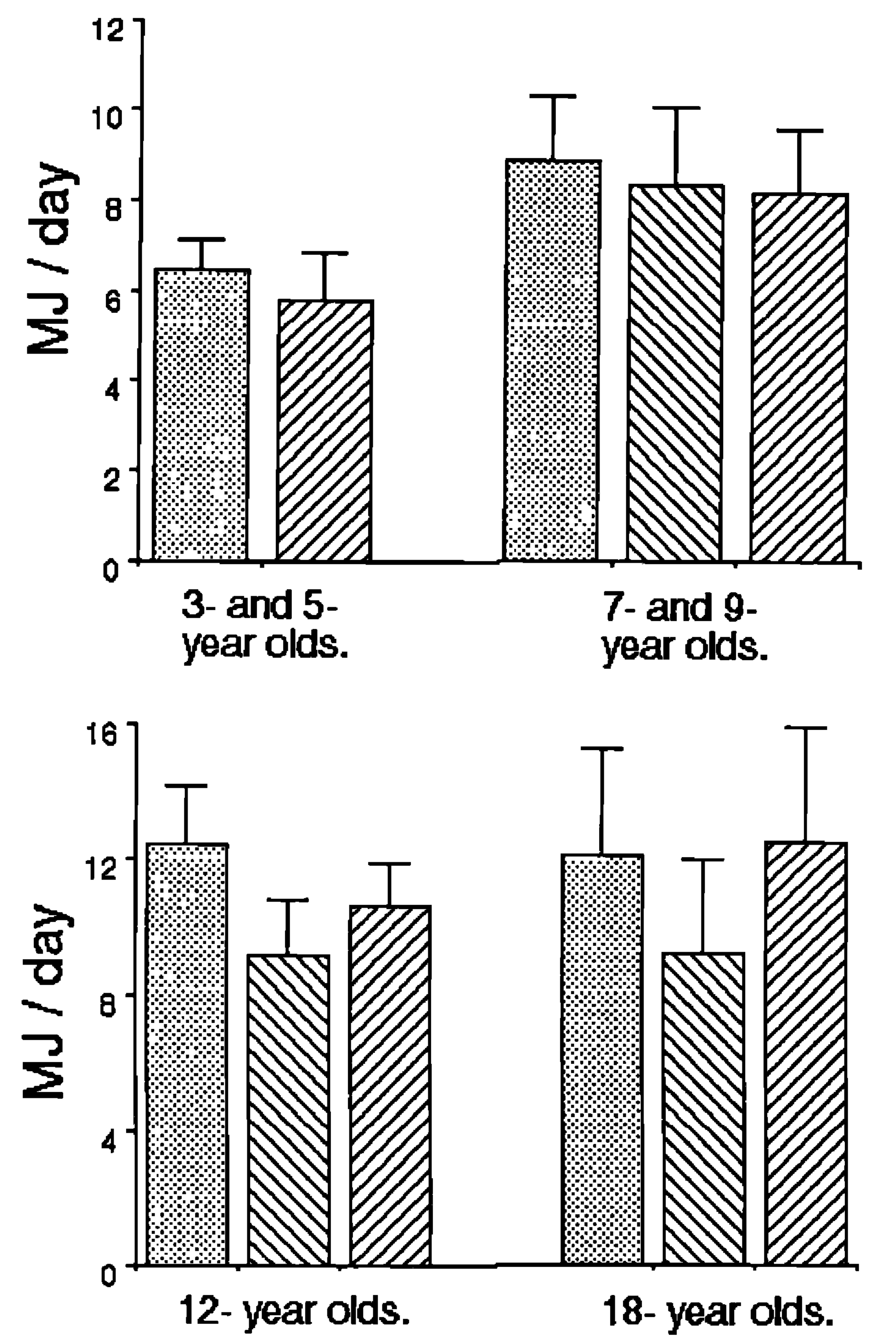


Figure 9 Comparison (±s.d.) of reported habitual energy intake by diet history (▒) and weighed dietary record (▧) and energy expenditure (▨) in 3—18 year old subjects (Livingstone *et al*, 1992*b*).

obese and obese adolescents ($n = 55$) (Bandini *et al*, 1990*a*).

The results shown in Figures 8–10 indicate that bias in dietary reporting does not operate uniformly across age groups and that it is influenced by the particular methodology used.

In children aged 1.5–4.5 years, mean EI calculated by 4-day WDR were not significantly different from mean TEE (+3%) (Figure 8a). Similarly, the mean EI by 7-day WDR of 7 and 9 year olds were in close correspondence with simultaneous measurements of TEE (+2%) (Figure 10a), but in adolescents and young adults there was increasing divergence between EI and TEE as age increased: mean EI were significantly lower than TEE in 12 year olds (−14%) and in 15 and 18 year olds (−24%, $P < 0.01$) (Figure 10a). Using 14-day estimated intake records, Bandini *et al* (1990*a*) also showed a substantial underestimation of EI by adolescents, with the negative bias being most apparent in obese subjects (Figure 8b). After adjustment for changes in body composition, mean estimated EI were 80 ± 23% (non-obese) and 54 ± 32% (obese) of TEE values ($P < 0.001$).

The age-related discrepancy differed in the study to validate EI by diet history in 3–18 year olds. There was a bias towards overestimation of EI in the younger children by this technique: as age increased, mean differences were +12%, +9%, +11% and −1% (Figures 9 and 10b).

These validation studies can be criticized because they only involved a small number of subjects in various age groups. However, all of them indicate that a bias in dietary reporting is highly probable. Thus, considerable caution needs to be applied when interpreting energy intake data sets as a basis for deriving energy requirements. Moreover, the magnitude and direction of the errors in children's EI are likely to be different from those found in adults. These biases are highly relevant to the problem of determining appropriate energy intakes for nitrogen balance studies (see Appendix).

Age is an important variable that affects compliance in dietary reporting. The results presented suggest that the mean EI assessed by weighed dietary records are more likely to represent usual food intake in younger than in older subjects. This could be due to the fact that in young children overall control of food intake and responsibility for dietary reporting are shared by parents and other adults concerned with child caring. Younger children also have less unsupervised access to food in- and out-of-home. On the other hand, by early adolescence the responsibility for reporting shifts more to the subjects themselves. Consequently, their greater food requirements in combination with unstructured eating patterns and a significant degree of out-of-home

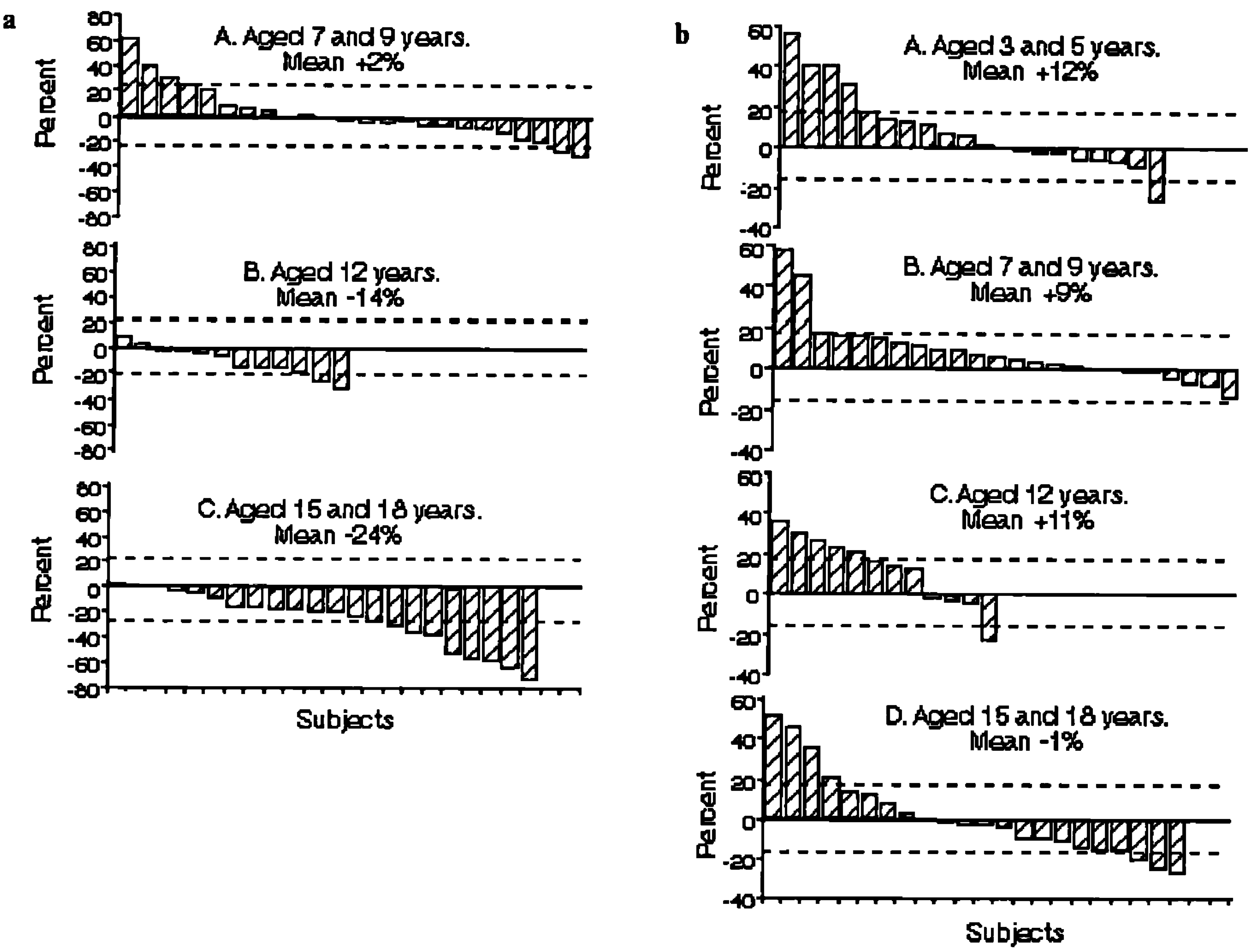


Figure 10a Individual differences between energy expenditure measured by the doubly labeled water method and energy intakes as measured by 7-day weighed dietary records expressed as a percentage of energy expenditure in children aged 7 and 9 years (A), 12 years (B) and 15 and 18 years (C).

Figure 10b Individual differences between energy expenditure measured by the doubly labeled water method and energy intakes as measured by diet history expressed as a percentage of energy expenditure in children aged 3 and 5 years (A), 7 and 9 years (B), 12 years (C) and 15 and 18 years (D) (From data of Livingstone et al, 1992*b*).

eating suggest that under-reporting (by WDR) may be partly due to forgetfulness and lack of compliance with a demanding protocol.

Obesity is another important factor. In common with obese adults (Prentice *et al*, 1986), obese adolescents have been found to under-report EI significantly more than their non-obese counterparts (Bandini *et al*, 1990*a*). Preoccupation with body weight and image, which may lead to real or apparent dietary restraint, seems to be well developed in girls with normal and low weight by the age of 12 years. Similar, although less marked trends, have been observed in adolescent boys (Livingstone *et al*, 1992*b*).

The *method* used to assess EI also may influence the results. Validation studies with various EI methods across the entire age range of childhood and adolescence are lacking. Only one study has validated simultaneously EI by WDR and DH with TEE (Livingstone *et al*, 1992*b*). Although EI by DH were biased towards overestimation in most age groups and individual measurements lacked precision, mean intakes assessed by DH seemed more representative of habitual EI across the age range than WDR. The apparent superiority of DH in overcoming an age-related bias in dietary reporting is contrary to expectations and needs to be evaluated carefully. Since DH is not a standardized instrument and it only measures memory and perception of usual diet, it is subjective and children may tend to exaggerate the intake of 'good' foods and under-estimate 'bad' foods. Accuracy in reporting is also dependent on motivation, intelligence, an adequately developed concept of time, ability to recognize foods, the complexity and stability of food patterns and the age at which children can reliably report their own food intake without control or supervision of adults.

Other factors which are likely to influence reporting accuracy and about which little is known, include *social class* and *educational background.*

In addition to the credibility of food intake reports, assessment of EI can be distorted by the use of inadequate *food composition tables* and/or overlooking the conversion of *cooked* and *processed foods* into their *raw ingredients*[2].

Dietary energy intake data of children and adolescents

A selection of dietary intake studies reported in the literature from about 1980 onwards are reviewed here since earlier studies were evaluated extensively by Ferro-Luzzi & Durnin (1981), as the basis for the 1985 FAO/WHO/UNU estimated requirements. Since 1980, a vast number of dietary intake studies on children and adolescents have been reported and the studies cited in

[2] The world-wide food composition data network being developed by INFOODS offers electronic access to information on prepared and processed foods often not available in local food composition tables (for information: http://www.crop.cri.nz/crop/infoods/infoods.htmi).

this review are by no means an exhaustive compilation. Many studies were excluded based on the following criteria:

(1) When energy intakes were reported for wide age bands (e.g. 11–16 years) and the mean age was not recorded.
(2) When energy intakes were reported combined for boys and girls over 10 years old.
(3) When data were presented in a format which could not be readily interpreted for the purposes of this review (e.g., in graphs). Unfortunately, many studies in developing countries were excluded for this reason.
(4) When the children studied were generally malnourished or obese, and their mean weight-for-height differed from the NCHS/WHO standards by more than 2 s.d. Many reports were based on representative study populations and therefore included children with a range of body weights.
(5) Only studies of healthy children were included, since many disease states are likely to affect energy intakes and requirements.

Tables 23 and 24 give details of the studies that were reviewed. Forty-eight involved children approximately 1–10 years old, and 41 studies included children and adolescents approximately 10–18 years old.

Tables 25–30 show the energy intakes of the children, by ascending age. Boys and girls under 5 years are listed together in Table 25, as many studies did not separate the results for each sex. The same is true of the six studies in Table 30. When body weights were not reported, median weights (NCHS) at the mid-point of the age range were assumed and, in Tables 25 and 30, averaged for boys and girls. Energy intake data are presented as absolute values, in relation to body weight, and as multiples of the estimated BMR. The latter were calculated from the mean weights using the equations proposed by Schofield to FAO/WHO/UNU (1985).

Comparison with total energy expenditure and dietary recommendations

When energy intakes are used to assess requirements or to estimate whether the mean intake satisfies a population's dietary recommendations, the possibility of bias must be acknowledged and the data should be analyzed and interpreted accordingly. Information that is incompatible with fundamental principles of energy physiology should not be accepted, as it cannot represent long-term usual intake or is due to methodological bias or inadequate reporting. Goldberg *et al* (1991) and Black *et al* (1991) suggested a screening of EI data of adult populations, calculating them as multiples of BMR. For example, a value below 1.27 × BMR, considered as the *survival requirement* for adults (FAO/WHO/UNU, 1985), is unacceptable as representative of habitual intake.

Following that logic, we used the PALs shown in Table 21 to establish reasonable limits to evaluate dietary energy surveys among children and adolescents. Mean results lower than two times the coefficient of variation (i.e. 12%) below the PAL corresponding to light habitual activity, or higher than two times the CV above the PAL for heavy habitual activity were considered unlikely to represent the usual intake of healthy children. Since the PALs for boys or girls 6–13 and 14–18 years old in Table 21 are reasonably close, the acceptable limits for those age groups were averaged to simplify the evaluation of the results in Tables 25–30. Further corrections for the energy needs for growth were not made, as they are only about 3% at age 1 and less than 1% in late adolescence.

Thus, Tables 31–33 were prepared from the data in Tables 25–30 that were between 1.28 and 1.79 × BMR for children 1–5 years, between 1.39 and 2.24 × BMR for boys 6–18, and between 1.30 and 2.10 × BMR for girls 6–18. Mean energy intakes expressed as MJ/d, kJ/kg/d and × BMR, were weighted for the number of children in each study. When a study included more than 500 or 1000 children of a given age and sex, only 30% or 20% of the number, respectively, were used to calculate the weighted means to avoid an extreme bias toward the results of that study.

As Table 31 and Figure 11 show, energy intake per unit of body weight is fairly constant for both boys and girls between 3 and 7 years of age, after which it decreases gradually until age 15 (girls) or 16 (boys).

Compared with total energy expenditure assessed with doubly-labeled water and heart rate monitoring, energy intake tends to overestimate requirements under 8–10 years and to underestimate them after that age. Those trends also apply to the 1985 FAO/WHO/UNU energy recommendations, but the overestimation is markedly higher under 6 years of age. This is partly due to the 5% additional dietary energy recommended in 1985 for children 1–10 years old to accommodate 'a desirable level of physical activity'.

The reported EI of children 1–5 years old is about 13% lower than FAO/WHO/UNU requirements (Figure 11, Table 31). Although the wide range between data sets could reflect real differences in intake, unrepresentative study samples, or artifacts in dietary survey methodology, mean intakes fell short of FAO/WHO/UNU requirements in about 80% of the data sets.

The influence of *sex* on dietary energy intake is illustrated in Figure 12 and Tables 31–33. Girls have lower EI than boys, whether expressed in absolute terms or relative to their body weights or their estimated BMR, and the difference becomes greater in adolescence. These findings are consistent with their lower total energy expenditure (Tables 2–7 and 20, and Figure 5).

Conclusions

Recent trends in EI of children and adolescents suggest that if the groups studied are representative of their age and sex, and the EI data are valid measures of habitual intake, then:

(a) Habitual energy intakes of 1–6 year old children are lower than current recommendations. Increasing reported energy intakes by 5% to accommodate a 'desirable level of physical activity' may be unrealistic.
(b) Energy requirements for physical activity may be more variable in adolescent males but lower in the adolescent females, than has been assumed when deriving factorially estimated energy requirements.

For methodological and economic reasons it seems inevitable that we will continue to rely partly on reported EI data as a basis of estimating energy requirements for most populations. However, it is clear that these data can no longer be tacitly accepted as representative

Table 23 Dietary surveys of children aged approximately 1–10 years

Source	Country	Sex	Age (y)	No. of subjects	Method[a]	Time of year	Socio-economic status[b]	Urban/rural[c]	Race/ethnic background
Bellu *et al* (1991)	Italy	M & F	1	164	24-h recall	?	?	U	?
Boggio & Klepping (1981)	France	M & F	5–6, 9–11, 14–16	376	7-d weighed record	?	M	U	?
Boulton (1981)	Australia	M & F	2, 3–5, 8–18	198, 486, 235	Diet history, 4-d record	12 months	M	U	Mixed
Brault-Dubuc & Mongeau (1989)	Canada	M & F	6–16	402 (L)[d]	7-d record	12 months	M	U	?
Catassi *et al* (1988)	Italy	M & F	0.5–2.5	90	3-d weighed record	?	?	?	?
Cunningham & Lee (1990)	Republic of Ireland	M & F	8–18	538	Diet history	12 months	M	U & R	Caucasian
Davies *et al* (1994)	United Kingdom	M & F	1.5–4.5	81	4-d weighed record	Autumn	M	U	?
Deheeger *et al* (1991)	France	M & F	2	323	5-d record, diet history	?	M	U	?
Duggan *et al* (1991)	United Kingdom	M & F	0.3–3.3	97	5-d weighed record	?	L	U	Asian
Durnin (1984)	United Kingdom	M & F	5–6, 10–11	430	5-d weighed record	?	M	U	?
Eastwood *et al* (1990)	Mexico	M & F	2.8–3.9, 4.0–5.0	45	1-d weighed record	?	L	R	Mixed
Griffiths *et al* (1987)	United Kingdom	M & F	3–4	37	7-d weighed record & duplicate analysis	?	?	?	?
Hagman *et al* (1986)	Sweden	M & F	2–3, 4–5, 8–9, 13–14	1020	7-d record, diet history, 24-h recalls	12 months	M	U & R	?
Hitchcock *et al* (1984)	Australia	M & F	1–3	205 (L)[e]	7-d record	12 months	M	U	?
Ho *et al* (1988)	China	M & F	5–6	60	7-d weighed record	?	M	U	Chinese
Hoffmans *et al* (1986)	Netherlands	M & F	0.3–1.5	124 (L)[f]	24 h-recall	Spring	M	U	?
Ikemoto *et al* (1989)	Japan	M & F	1–2	10	Chemical analysis	12 months	?	?	?
Jenner *et al* (1988)	Australia	M & F	8–10	884	Food frequency questionnaire	April–Aug	M	U	?
Knuiman *et al* (1983)	Finland, Netherlands, Italy, Phillipines and Ghana	M	8–9	589	7-d record or 7-d recall	Feb–May	M	U & R	Mixed
Livingstone *et al* (1992*b*)	United Kingdom	M & F	3–18	78	7-d weighed record, diet history	Oct–July	M	U & R	Causasian
Leung *et al* (1984)	Canada	M & F	3–4	189	4-d record	?	M	U	?
Lopez-Jaramillo *et al* (1992)	Ecuador	M	9	114	2 × 24 h recalls	?	LU	U	Ecuadorian
Magarey & Boulton (1984)	Australia	M & F	4	178	3-d record	June–Sept	M	U	Mixed

Table 23 (*continued*)

Source	*Country*	*Sex*	*Age (y)*	*No. of subjects*	*Method*[a]	*Time of year*	*Socio-economic status*[b]	*Urban/ rural*[c]	*Race ethnic background*
Martinez (1982)	Canada	M & F	6–7	193	3-d record	?	M	U & R	?
McKillop & Durnin (1982)	United Kingdom	M & F	1 2	143	5-d weighed record	?	M	U	?
Morgan & Zabik (1981)	USA	M & F	5–12	657	7-d record	Autumn	—	—	—
Morrison *et al* (1980)	USA	M & F	6–19	949	24-h recall	12 months	M	U	Black & White
Nelson *et al* (1990)	United Kingdom	M & F	7–12	194	7-d weighed record	April–July	?	U & R	?
Narasinga *et al* (1983)	India	M & F	2 6	128	Diet questionnaire	12 months	U	?	Asian
Neiderud *et al* (1992)	Sweden & Greece	M & F	2–8	152	24-h recall	Aug–Nov	?	U & R	Mixed
Oliveria *et al* (1992)	USA	M & F	3–5	91	4 × 3-d record	12 months	M	U	Caucasian
Palti *et al* (1979)	Israel	M & F	2.5–4	98 (L)[g]	24-hr recall	December–April	M	U	Mixed
Pao *et al* (1985)	USA	M & F	1–18	2826	24-h recall, 2-d record	Spring	M	U & R	Mixed
Parizkova *et al* (1986)	Czechoslovakia	M & F	3–5	22	7-d record	?	?	U	?
Paul *et al* (1990)	United Kingdom	M & F	1–3	48 (L)[h]	7-d weighed record	?	M	?	?
Payne & Belton (1992)	United Kingdom	M & F	2–5	153	7-d weighed record	May–April	M	U & R	?
Persson & Calgren (1984)	Sweden	M & F	4–5, 8–9	477	7-d record	?	M	?	?
Räsänen *et al* (1985)	Finland	M & F	3–18	1251	24-h recall	Autumn	M	U & R	?
Räsänen *et al* (1991)	Finland	M & F	9–18	1200	2 × 24-h recalls	Autumn	M	U & R	?
Räsänen & Ylonen (1992)	Finland	M & F	1.5	46	3-d record	August–November	M	U	?
Salas *et al* (1990)	Spain	M & F	2–9	121	2 × 24-h recall	?	M	U	Caucasian
Salz *et al* (1993)	USA	M & F	6–9	195	24-h recall	?	M	U & R	Caucasian
Sawaya *et al* (1988)	Saudi Arabia	M & F	1.1–2.0, 2.1 3.0, 3.1–4.0, 4.1 5.0	540	24-h recall	?	?	U R[i]	Arab
Sunnegardh *et al* (1986)	Sweden	M & F	8–9, 13–14	666	24-h recall, 7-d record, diet history	?	M	U & R	?
Treiber *et al* (1990)	USA	M & F	3–5	55	2 × 24-h recall	?	M	U	Black and White
Vanderkooy *et al* (1987)	Canada	M & F	4 5	108	3-d weighed record	May–Sept	MU	U & R	Caucasian
Van Steenbergen (1984)	Kenya	M & F	1–3, 4 6	56	2-d weighed record	wet & dry	L	R	Akamba
Walker *et al* (1990)	Jamaica	M & F	0.75 2.0	191	4 × 24-h recall	?	L	U	Jamaican, black

[a] Records – estimated (household measures) records, weighed records = weighed intake.
[b] Socioeconomic status: M = mixed, L = lower, LU = lower and upper, MU = middle and upper, U = upper.
[c] Urban Rural: U = urban, R = rural.
[d] L – longitudinal Brault-Dubuc & Mongeau (1984): 402 children studied in two cohorts starting at age 6 and 10 years with yearly measurements made for 7 years.
[e] Hitchcock *et al* (1984): 205 children recruited. Measurements made at 1 year (n = 125), $1\frac{1}{2}$ years (n = 142), 2 years (n = 146) and 3 years (n = 145).
[f] Hoffmans *et al* (1986): 124 children studied. Measurements made at 16 months and 28 months.
[g] Palti *et al* (1979): 98 children studied. Three measurements made (1st study n = 98; 2nd study n = 82; 3rd study n = 75).
[h] Paul *et al* (1990): 48 children recruited at 2 months. Measurements made at 12 months (n = 29), 15 months (n = 25), 18 months (n = 22), 24 months (n = 22) and 36 months (n = 31).
[i] Described by authors as semi-rural.

Table 24 Dietary surveys of children and adolescents aged approximately 10–18 years

Source	*Country*	*Sex*	*Age (y)*	*No. of subjects*	*Method*[a]	*Time of year*	*Socio-economic status*[b]	*Urban/rural*[c]	*Race/ethnic background*
Adamson *et al* (1992)	United Kingdom	M & F	11–12	379	2 × 3-d records	January–July	M	U & R	?
Baghurst *et al* (1983)	Australia	M & F	14–15, 18	490	Food frequency	?	M	U	Mixed
Barber *et al* (1985)	Great Britain	F	15–18	448	14-d diary	?	?	U	Caucasian
Bergstrom *et al* (1993)	Sweden	M & F	13–16, 16–18	731	7-d record	Sept–December January–May	M	U & R	?
Boulton (1981)	Australia	M & F	2	198	Record and diet history	12 months	M	U	Mixed
			3–5	486	4-d record	12 months			
			8–18	235	4-d record	12 months			
Boggio & Klepping (1981)	France	M & F	5–6, 9–11, 14–16	376	7-d weighed record	?	M	U	?
Brault-Dubuc & Mongeau (1989)	Canada	M & F	6–17	402 (L)[d]	7-d record	12 months	M	U	?
Bull (1985)	United Kingdom	M & F	15–18	382	14-d record	Spring–Summer	M	U & R	?
Crawley (1993)	United Kingdom	M & F	16–17	4760	4-d record	April–July	M	U & R	?
Cunningham & Lee (1990)	Republic of Ireland	M & F	8–18	538	Diet history	12 months	M	U & R	Caucasian
Department of Health (1989)	United Kingdom	M & F	10–11, 14–15	2697	7-d weighed record	January–June	M	U & R	?
Durnin (1984)	United Kingdom	M & F	5–6, 10–11	430	5-d weighed record	?	M	U	?
Frank *et al* (1985)	USA	M & F	10–11, 13–14	491	24-h recall	?	?	?	Black & White
Greger *et al* (1978)	USA	F	12–13	184	Diet recalls, diet history	Autumn & Spring	?	?	?
Hagman *et al* (1986)	Sweden	M & F	2–3, 4–5, 8–9, 13–14	1020	7-d record, diet history, 24-h recalls	12 months	M	U & R	?
Hackett *et al* (1984)	United Kingdom	M & F	11–14	375	5 × 3-d records	?	M	U & R	?
Jenner *et al* (1992)	Australia	M & F	11–12	1215	2-d records	April–August	M	U	?
Johnson & Jensen (1984)	USA	M & F	10–11	60	7-d records, 24-h recalls	?	M	?	Mixed
Kaufman *et al* (1982)	Israel	M & F	17–18	1178	24-h recall	?	M	U	Mixed
Livingstone *et al* (1992*b*)	United Kingdom	M & F	3–18	78	7-d weighed record, diet history	October–July	M	U & R	Caucasian

Table 24 (*continued*)

Source	Country	Sex	Age (y)	No. of subjects	Method[a]	Time of year	Socio-economic status[b]	Urban/rural[c]	Race/ethnic background
McCoy *et al* (1984)	USA	F	12, 14, 16	1247	2 × 24-h recalls	February–May	M	U & R	Black & White
Michaud *et al* (1991)	France	M & F	15–19	481	1-d record	?	M	U	?
Morgan & Zabik (1981)	USA	M & F	5–12	657	7-d record	Autumn	MU	?	?
Morrison *et al* (1980)	USA	M & F	6–19	949	24-h recall	12 months	M	U	Black & White
Nelson *et al* (1990)	United Kingdom	M & F	7–12	194	7-d weighed record	April–July	?	U & R	?
Pao *et al* (1985)	USA	M & F	1–18	2826	24-h recall, 2-d record	Spring	M	U & R	Mixed
Perusse *et al* (1984)	Canada	M & F	11–17	580	3-d weighed record	?	?	U & R	?
Post *et al* (1987)	Netherlands	M & F	12–18	233	Diet history	Jan–April	MU	U	?
Räsänen *et al* (1985)	Finland	M & F	3–18	1768	2 × 24-h recalls	Autumn	M	U & R	?
Räsänen *et al* (1991)	Finland	M & F	9–18	1200	2 × 24-h recalls	Autumn	M	U & R	?
Rodriguez (1991)	Guatemala	M	10–11	140	3 × 24-h recalls	July–Sept	LM	U	Mixed
van den Reek *et al* (1986)	USA	F	12–15	8	7-d weighed duplicate method	Summer	U	U	White
Seone & Roberge (1983)	Canada	M & F	10–18	500	3-d weighed record	?	?	?	?
Skinner *et al* (1985)	USA	M & F	16–18	225	24-h recall	?	?	U & R	Black & White
Story (1986)	USA	M & F	13–17	277	3 × 24-h recall	?	L	R	Cherokee
Strain *et al* (1994)	United Kingdom	M & F	12–13, 15–16	1016	Diet history	12 months	M	U & R	Caucasian
Sunnegardh *et al* (1986)	Sweden	M & F	8–9, 13–14	666	24-h recall, Diet history, 7-d record	?	M	U & R	?
Tan *et al* (1989)	New Zealand	M & F	12 14	501	3 × 24-h recalls	Autumn	M	U	?
Tayter *et al* (1989)	USA	M & F	10–12	39	3 d-record	?	M	?	Caucasian
Torun et al (1993)	Guatemala	M	10–12	24 (L)[e]	3 × 24 h recalls every 3 months	12 months	L	U	Mixed
Woodward *et al* (1984)	Tasmania	M & F	12 16	1055	1-d diet record	?	M	U & R	?

[a] Records = estimated (household measures) records, weighed records = weighed intake.
[b] Socioeconomic status: M = mixed, L = lower, LU = lower and upper, MU = middle and upper, U = upper.
[c] Urban/Rural: U = urban, R = rural.
[d] L-Longitudinal. Brault-Dubuc & Mongeau (1989): 402 children studied in two cohorts starting at age 6 and 10 years with yearly measurements made for 7 years.
[e] Torun *et al* (1994): 24 girls studied four times at 3-month intervals.

Table 25 Energy intakes of children aged approximately 1–5 years

Source	Age (y)	N	Weight (kg) Mean	Weight (kg) s.d.	BMR[a] (MJ/d)	Energy intake (EI) (MJ/d) Mean	Energy intake (EI) (MJ/d) s.d.	Energy intake (EI) (kJ/kg/d) Mean	Energy intake (EI) (kJ/kg/d) s.d.	× BMR[b]
Bellu *et al* (1991)	1	164 (76M, 88F)	9.81	1.28	2.26	4.15	1.29	423	131	1.84[c]
Catassi *et al* (1988)	1–1.25	12	10.75	1.4	2.50	4.11	0.99	382	92	1.64
	1.25–1.50	10	11.90	1.0	2.79	4.12	0.65	349	55	1.48
	1.50–2.00	18	12.30	1.7	2.90	4.21	0.93	344	76	1.45
Davies *et al* (1993)	1.5 2.5	23	12.85	1.67	3.04	4.20	0.63	327	49	1.38
Duggan *et al* (1991)	1–1.5	13	11.00	(M)[d]	2.57	3.89[e]	1.26	354	115	1.51
	1.5–2.0	9	11.00	(M)	2.57	3.71	1.06	337	96	1.44
Hitchcock *et al* (1984)	1	62 (M)	11.0	(M)	2.57	4.15	0.85	377	77	1.55
		63 (F)	11.0	(M)	2.57	3.98	0.83	362	75	1.93[c]
	1.5	72 (M)	11.0	(M)	2.57	4.96	0.89	451	81	1.74
		70 (F)	11.0	(M)	2.57	4.47	1.00	406	91	1.56
Hoffmans *et al* (1986)	1–2	124	11.2	—	2.62	4.08	1.06	366	107	1.56
Ikemoto *et al* (1989)	1–2	10	11.0	1.6	2.57	3.90	0.41	377	40	1.52
McKillop & Durnin (1982)	1–2	73 (M)	11.6	—	2.72	4.79	1.02	413	—	1.76
		70 (F)	10.9	—	2.56	4.59	0.96	420	—	1.79
Pao *et al* (1985)	1–2	246	11.0	(M)	2.57	4.90	1.43	445	130	1.91[c]
Paul *et al* (1990)	1.0	15 (M)	10.00	1.23	2.31	3.72	0.60	370	60	1.61
	1.0	14 (F)	9.07	0.98	2.09	3.39	0.48	370	50	1.62
	1.25	13 (M)	10.37	1.07	2.41	3.90	0.77	380	50	1.62
	1.25	12 (F)	9.70	0.68	2.25	3.63	0.46	370	50	1.73
	1.50	11 (M)	10.87	1.47	2.53	4.02	0.93	370	70	1.59
	1.50	11 (F)	10.45	1.00	2.44	3.68	0.61	350	60	1.51
Räsänen & Ylonen (1992)	1–2	23 (M)	11.0	(M)	2.57	5.20	0.83	473	75	2.02[c]
		23 (F)	11.0	(M)	2.57	4.57	0.92	415	84	1.78
		46 (Total)	11.0	(M)	2.57	4.89	0.93	445	85	1.90[c]
Sawaya *et al* (1988)	1.1 2	178	11.15	—	2.62	3.62	—	325	—	1.38
Van Steenbergen (1984)	1–3	22	12.25		2.90	4.16	1.74	340	142	1.44
Walker *et al* (1990)	0.75–2	129 stunted	8.43		1.92	3.99	1.87	473	213	2.07[c]
	0.75–2	62 non-stunted	11.45		2.69	4.07	1.50	356	130	1.51
Boulton (1981)	2.0	102 (M)	12.94	1.67	3.06	5.08	0.99	400	80	1.66
		95 (F)	12.65	2.91	3.00	4.73	1.03	390	90	1.58
		197 (Total)	12.78	2.69	3.02	5.02	1.86	400	140	1.66
Catassi *et al* (1988)	2.0–2.5	18	14.90	3.3	3.56	4.53	0.93	307	63	1.27[c]
Davies *et al* (1994)	2.5–3.5	31	14.96	1.40	3.57	4.64	0.74	310	49	1.30

Table 25 (*continued*)

Source	Age (y)	N	Weight (kg) Mean	Weight (kg) s.d.	BMR[a] (MJ/d)	Energy intake (EI) (MJ/d) Mean	Energy intake (EI) (MJ/d) s.d.	Energy intake (EI) (kJ/kg/d) Mean	Energy intake (EI) (kJ/kg/d) s.d.	× BMR[b]
Deheeger *et al* (1991)	2.0	131 (M)	12.1	1.6	2.85	5.51	1.34	452	110	1.93[c]
		192 (F)	12.2	1.9	2.87	5.85	1.08	480	89	2.04[c]
Duggan *et al* (1991)	2–3.25	10	13.5	(M)	3.20	4.35	1.62	322	120	1.36
Eastwood *et al* (1990)	2.75–3.9	45	15.05		3.49	6.48	1.66	430		1.85[c]
Hagman *et al* (1986)	2–3	41 (M)	15.1	—	3.61	5.80	—	384	—	1.61
		41 (F)	15.4	—	3.70	5.55	—	360	—	1.50
Hitchcock *et al* (1984)	2	74 (M)	13.5	(M)	3.20	5.35	1.01	396	75	1.67
		72 (F)	13.5	(M)	3.22	4.85	1.17	359	87	1.51
Hoffmans *et al* (1980)	2–3	124	13.8	—	3.28	4.74	1.39	344	107	1.45
Narasinga *et al* (1993)	2 3	9 (M)	13.4	—	3.18	5.44	—	407	—	1.71
		10 (F)	11.7	—	2.76	4.72	—	403	—	1.71
Neiderud *et al* (1992)	2–3	11 Greek Imm	13.5	(M)	3.20	6.08	—	450	—	1.90[c]
		13 Swedish	13.5	(M)	3.20	4.99	—	370	—	1.56
		20 Greek	13.5	(M)	3.20	5.63	—	417	—	1.76
Palti *et al* (1979)	2.5	98	13.2	—	3.12	4.58	13.38	347	105	1.47
Paul *et al* (1990)	2.0	13 (M)	12.20	1.20	2.87	4.22	0.78	350	60	1.47
		9 (F)	11.61	0.83	2.74	4.03	0.50	350	40	1.47
Payne & Belton (1992)	2 3	31 (M)	14.0	1.5	3.33	4.50	0.76	321	54	1.35
		42 (F)	13.5	1.4	3.22	4.39	0.83	325	61	1.36
Salas *et al* (1990)	2 5	61	15.0	(M)	3.48	6.68	1.39	445	93	1.92[c]
Sawaya *et al* (1988)	2.1 3	97	13.25	—	3.32	4.06	—	306	—	1.22[c]
Davies *et al* (1994)	3.5 4.5	27	16.94	2.10	3.66	5.42	0.64	320	38	1.48
Eastwood *et al* (1990)	2.8–3.9	45	15.05	—	3.49	6.48	1.66	430	—	1.85[c]
Griffiths *et al* (1987)	3–4	15 (M)	16.0	2.0	3.58	4.60	0.82	289	42	1.28
		22 (F)	15.4	1.5	3.52	5.48	1.07	360	71	1.56
Hitchcock *et al* (1984)	3–4	73 (M)	16.5	(M)	3.62	5.74	1.00	348	61	1.59
		72 (F)	16.5	(M)	3.63	5.55	0.94	336	57	1.53
Leung *et al* (1984)	3–4	189	16.5	(M)	3.62	5.80	1.20	352	73	1.60
Livingstone *et al* (1992*b*)	3 4	8	16.4	1.5	3.61	5.91	0.55	360	34	1.64
Narasinga *et al* (1983)	3–4	23 (M)	14.9	—	3.47	6.33	—	425	—	1.82[c]
		13 (F)	15.0	—	3.49	5.81	—	387	—	1.66
Oliveria *et al* (1992)	3 5	55 (M)	16.5	(M)	3.62	6.71	0.95	407	58	1.85[c]
		36 (F)	16.5	(M)	3.63	6.14	1.23	372	75	1.69
		91 (Total)	16.5	(M)	3.62	6.48	1.10	393	67	1.79

Table 25 (*continued*)

Source	Age (y)	N	Weight (kg) Mean	Weight (kg) s.d.	BMR[a] (MJ/d)	Energy intake (EI) (MJ/d) Mean	Energy intake (EI) (MJ/d) s.d.	Energy intake (EI) (kJ/kg/d) Mean	Energy intake (EI) (kJ/kg/d) s.d.	× BMR[b]
Palti *et al* (1979)	3	82	14.1	—	3.40	5.09	1.25	360	89	1.50
Pao *et al* (1985)	3–5	404	16.5	(M)	3.62	5.99	1.62	363	98	1.65
Paul *et al* (1990)	3	20 (M)	14.53	1.56	3.44	4.96	0.78	340	50	1.44
		13 (F)	14.16	1.35	3.41	4.62	0.50	330	50	1.35
Parizkova *et al* (1986)	3–5	22	19.3	2.50	3.89	7.25	2.03	376	105	1.86[c]
Payne & Belton (1992)	3–4	31 (M)	16.3	1.6	3.60	5.01	0.89	307	55	1.39
		38 (F)	15.4	1.7	3.52	4.76	0.71	309	46	1.35
Räsänen *et al* (1985)	3–4	153 (M)	15.7	(median)[f]	3.55	6.40	1.70	408	108	1.80[c]
		128 (F)	15.2	(median)[f]	3.50	5.80	1.20	382	79	1.66
Sawaya *et al* (1988)	3.1–4	158	15.4	—	3.53	4.62	—	300	—	1.31
Treiber *et al* (1990)	3–5	66	16.35	—	3.62	6.84	1.78	418	—	1.89[c]
Eastwood *et al* (1990)	4.0–5.0	22	17.25	—	3.71	6.30	1.19	365	—	1.70
Hagman *et al* (1986)	4–5	154 (M)	18.8	—	3.84	6.90	—	367	—	1.80[c]
		152 (F)	18.6	—	3.82	6.45	—	347	—	1.69
Magaray & Boulton (1984)	4–5	93 (M)	17.9	—	3.76	5.94	—	331	—	1.58
		85 (F)	17.7	—	3.74	5.44	—	307	—	1.45
Narasinga *et al* (1983)	4–5	17 (M)	17.3	—	3.70	6.62	—	383	—	1.79
		6 (F)	15.6	—	3.54	5.90	—	378	—	1.67
Palti *et al* (1979)	4	75	16.5	—	3.62	4.96	0.95	301	58	1.37
Payne & Belton (1992)	4–5	35 (M)	18.0	1.9	3.77	5.30	0.79	294	44	1.41
		30 (F)	17.6	2.2	3.73	5.06	0.89	288	51	1.36
Persson & Calgren (1984)	4–5	Total sample of 477 (including 8–9 y)	16.5	(M)	3.62	6.67	1.23	404	75	1.84[c]
Sawaya *et al* (1988)	4.1–5	107	17.25	—	3.71	4.93	—	286	—	1.33
Vanderkooy *et al* (1987)	4–5	62 (M)	18.6	—	3.82	6.23	1.64	335	57	1.63
		44 (F)	18.0	—	3.77	5.38	1.47	299	53	1.43
Van Steenbergen (1984)	4–6	34	18.2	—	3.79	5.04	2.03	277	111	1.33

[a] BMR = Predicted basal metabolic rate (FAO/WHO/UNU, 1985).
[b] Mean energy intakes expressed as a multiple of mean predicted BMR.
[c] Excluded from Table 31 because × BMR was < 1.28 or > 1.79.
[d] (M) = Median (NCHS) weights at mid-year.
[e] Mean energy intakes (MJ/d) calculated from recorded energy intake (kJ/kg/d) and median (NCHS) weights.
[f] Median weights reported.

Table 26 Energy intakes of boys aged approximately 5–10 years

Source	Age (y)	N	Weight (kg) Mean	Weight (kg) s.d.	BMR[a] (MJ/d)	Energy intake (MJ/d) Mean	Energy intake (MJ/d) s.d.	Energy intake (kJ/kg/d) Mean	Energy intake (kJ/kg/d) s.d.	× BMR[b]
Boggio & Klepping (1981)	5–6	51	19.5	2.2	3.91	6.89	1.12	353	57	1.76
Durnin (1984)	5–6	93	19.5	(Median)[c]	3.91	6.90	—	354	—	1.76
Livingstone *et al* (1992*b*)	5–6	6	17.9	2.5	3.76	6.57	0.83	367	46	1.75
Narasinga *et al* (1983)	5–6	12	17.4	—	3.71	6.63	—	381	—	1.79
Brault-Dubuc & Mongeau (1989)	6–7	102	20.6	2.52	4.01	8.91	1.73	438	99	2.22
Martinez (1982)	6–7	89	22.4	—	4.18	8.03	2.05	358	92	1.92
Morrison *et al* (1980)	6–9	95 (white)[d]	23.8	(M)[e]	4.31	8.10	2.51	340	105	1.88
		35 (black)	23.8	(M)	4.31	6.97	2.90	293	122	1.62
Räsänen *et al* (1985)	6–7	139	21.6	(M)	4.11	7.90	1.90	366	88	1.92
Salz *et al* (1983)	6–9	102	25.8	—	4.50	8.27	2.22	321	101	1.84
Brault-Dubuc & Mongeau (1989)	7–8	84	22.9	3.1	4.23	9.04	1.84	401	95	2.14
Livingstone *et al* (1992*b*)	7–8	6	25.4	6.6	4.46	9.75	1.93 (WDR)[f]	384	76	2.19
					4.46	9.41	1.50 (DH)	370	59	2.11
Nelson *et al* (1990)	7–10	25	27.0	(M)	4.62	7.59	1.43	281	31	1.64
Boulton (1981)	8–9	17	31.9	—	5.08	8.93	1.81	280	60	1.76
Brault-Dubuc & Mongeau (1989)	8 9	98	25.4	3.7	4.46	9.43	1.73	375	63	2.11
Hagman *et al* (1986)	8 9	144	27.3	—	4.64	8.90	—	326	—	1.92
Jenner *et al* (1988)	8–10	434	30.1	—	4.91	7.45	1.80	248	60	1.52
Knuiman *et al* (1983)	9	133 (Finland)	30.0	5.0	4.90	9.25	1.63	310	54	1.89
	9	117 (Netherlands)	30.0	5.0	4.90	8.75	1.38	293	46	1.79
	9	109 (Italy)	30.0	7.0	4.90	9.25	2.13	310	71	1.89
	9	114 (Philippines)	22.0	3.0	4.14	7.98	1.93	364	88	1.93
	9	116 (Ghana)	24.0	3.0	4.33	7.10	1.40	297	59	1.64
Lopez-Jaramillo *et al* (1992)	9	78 (LSC)[g]	25.5	—	4.47	5.20	1.15	204	45	1.16[i]
		36 (USC)	27.0	—	4.62	6.43	0.96	238	36	1.39
Sunnegardh *et al* (1986)	8–9	159	27.3	3.8	4.64	8.40	2.50 (24-h R)[h]	308	92	1.81
		142	27.3	3.8	4.64	8.90	1.20 (DR)	326	44	1.92
Boulton (1981)	9.11	23	31.6	—	5.05	8.85	1.15	280	60	1.75
Brault-Dubuc & Mongeau (1989)	9–10	103	27.8	3.9	4.69	9.74	1.91	355	77	2.08
Livingstone *et al* (1992*b*)	9–10	6	30.2	8.4	4.92	8.95	1.36 (WDR)	296	45	1.82
					4.92	9.94	1.38 (DH)	329	46	2.02
Räsänen *et al* (1985)	9–10	162	29.9	(M)	4.89	9.10	2.30	304	77	1.86
Räsänen *et al* (1991)	9–10	119	27.0	(M)	4.89	8.30	2.40	307	89	1.70

[a] BMR = Predicted basal metabolic rate (FAO/WHO/UNU, 1985).
[b] Mean energy intakes expressed as a multiple of mean predicted BMR.
[c] Median weight report.
[d] White = white children, black = black children.
[e] (M) = Median (NCHS) weights at mid-year.
[f] WDR = weighed dietary record, DH = diet history.
[g] LSC = lower social class, USC = upper social class.
[h] 24-h R = 24-h recall, DR = diet records (estimated from household measures).
[i] Excluded from Table 31 because × BMR was < 1.39.

Table 27 Energy intakes of girls aged approximately 5 10 years

Source	Age (y)	N	Weight (kg) Mean	Weight (kg) s.d.	BMR[a] (MJ/d)	Energy intake (MJ/d) Mean	Energy intake (MJ/d) s.d.	Energy intake (kJ/kg/d) Mean	Energy intake (kJ/kg/d) s.d.	× BMR[b]
Boggio & Kleping (1981)	5–6	52	19.2	2.5	3.88	6.62	1.19	345	62	1.71
Durnin (1984)	5–6	110	18.4	(Median)[c]	3.80	6.00	—	326	—	1.58
Livingstone *et al* (1992*a*,*b*)	5–6	6	18.1	2.2	3.78	6.54	0.64	361	35	1.73
Narasinga *et al* (1983)	5–6	9	16.9	—	3.66	5.91	—	350		1.61
Brault-Dubuc & Mongeau (1989)	6–7	93	19.0	2.7	3.86	7.86	1.51	416	84	2.04
Martinez (1982)	6–7	104	21.6	—	4.10	7.28	1.38	337	64	1.78
Morrison *et al* (1980)	6–9	79 (white)[d]	23.8	(M)[e]	4.31	8.11	2.34	341	98	1.88
		37 (black)	23.8	(M)	4.31	6.08	2.64	255	111	1.41
Räsänen *et al* (1985)	6–7	145	20.5	(M)	4.00	6.80	1.30	332	63	1.70
Salz *et al* (1983)	6–9	93	25.6	—	4.48	7.87	2.12	308	87	1.76
Brault-Dubuc & Mongeau (1989)	7 8	73	21.0	2.81	4.05	8.25	1.43	398	82	2.04
Livingstone *et al* (1992*a*,*b*)	7–8	6	23.5	2.2	4.28	6.62	0.82 (WDR)[f]	282	35	1.55
					4.28	7.56	1.20 (DH)	322	51	1.77
Nelson *et al* (1990)	7 10	26	27.0	(M)	4.61	6.92	1.39	256	51	1.50
Boulton (1981)	8 9	17	29.8	—	4.87	7.74	1.12	260	30	1.59
Brault-Dubuc & Mongeau (1989)	8 9	95	23.4	4.8	4.27	8.21	1.37	358	80	1.92
Hagman *et al* (1986)	8 9	152	28.7	—	4.77	7.85	—	274	—	1.65
Jenner *et al* (1988)	8 10	450	29.3	—	4.83	6.92	1.85	236	63	1.43
Sunnegardh *et al* (1986)	8 9	167	28.6	6.6	4.76	7.70	2.60 (24-h R)[g]	269	91	1.62
		153	28.6	6.6	4.76	8.00	1.20 (DR)	280	42	1.68
Boulton (1981)	9 11	24	34.6		5.32	7.62	2.06	220	70	1.43
Brault-Dubuc & Mongeau (1989)	9 10	94	26.6	4.6	4.57	8.38	1.43	321	65	1.83
Livingstone *et al* (1992*a*)	9–10	6	32.2	3.6	5.10	7.95	1.26 (WDR)	247	39	1.56
					5.10	8.63	0.43 (DH)	268	13	1.69
Räsänen *et al* (1985)	9 10	154	30.3	(M)	4.92	7.70	—	254	—	1.57
Räsänen *et al* (1991)	9–10	109	27.0	(M)	4.92	7.80	2.20	289	81	1.59

[a] BMR = Predicted basal metabolic rate (FAO/WHO UNU, 1985).
[b] Mean energy intakes expressed as a multiple of mean predicted BMR.
[c] Median weight reported.
[d] White = white children, black = black children.
[e] (M) = Median (NCHS) weights at mid-year.
[f] WDR = weighed dietary record, DH = diet history.
[g] 24-h R = 24-h recall, DR = diet records (estimated from household measures).

Table 28 (*continued*

Source	Age (y)	N	Weight (kg) Mean	Weight (kg) s.d.	BMR[a] (MJ/d)	Energy intake (EI) (MJ/d) Mean	Energy intake (EI) (MJ/d) s.d.	Energy intake (EI) (kJ/kg/d) Mean	Energy intake (EI) (kJ/kg/d) s.d.	× BMR[b]
Brault-Dubuc & Mongeau (1989)	14 15	49	50.0	8.8	6.36	11.60	2.46	238	49	1.82
Department of Health (1989)	14–15	513[c]	55.7	9.5	6.77	10.40	2.30	187	41	1.54
Post *et al* (1987)	14–15	95	48.9	—	6.28	12.20	1.95	249	40	1.94
Woodward *et al* (1984)	14–15	132	54.0	(Median)	6.65	12.10	(Median)	224	—	1.82
Brault-Dubuc & Mongeau (1989)	15–16	46	57.0	8.34	6.87	12.29	2.84	218	50	1.79
Bull (1985)	15–18	198	62.0	(M)	7.23	10.10	—	163	—	1.40
Cunningham & Lee (1990)	15–18	73	63.9	—	7.37	14.0	4.5	219	70	1.90
Livingstone *et al* (1992*a*,*b*)	15–16	6	56.4	9.1	6.83	11.33	1.88 (WDR)	201	33	1.66
					6.83	13.91	2.20 (DH)	247	39	2.04
Michaud *et al* (1991)	15–19	198	63.7	8.5	7.36	12.39	3.80	195	60	1.68
Pao *et al* (1985)	15–18	365	61.9	(M)	7.23	10.92	3.55	176	57	1.51
Post *et al* (1987)	15–16	102	55.6	—	6.77	12.5	3.03	225	54	1.85
Räsänen *et al* (1985)	15 16	139	58.0	(M)	6.94	11.8	3.70	203	64	1.70
Räsänen *et al* (1991)	15–16	118	58.0	(M)	6.94	11.8	4.30	203	74	1.70
Strain *et al* (1994)	15–16	252	59.0	9.4	7.01	13.10	(Median)	222	—	1.87
Woodward *et al* (1984)	15–16	132	60.0	(Median)	7.09	11.9	(Median)	198	—	1.68
Bergstrom *et al* (1993)	16–18	211	66.4	8.4	7.55	10.50	2.70	158	41	1.39
Boulton (1981)	16–17	15	65.8	—	7.51	11.84	4.35	180	60	1.50
Brault-Dubuc & Mongeau (1989)	16–17	29	59.8	8.25	7.07	11.72	3.02	198	51	1.66
Crawley (1993)	16 17	2006[c]	62.7	(M)	7.31	11.40	2.69	182	43	1.56
Morrison *et al* (1980)	16–19	82 (white)	64.0	(M)	7.37	13.20	4.25	207	67	1.79
		14 (black)	64.0	(M)	7.37	13.11	5.57	205	87	1.78
Post *et al* (1987)	16–17	76	61.0	—	7.16	12.80	3.49	210	57	1.79
Seone & Roberge (1983)	16 18	69	63.9	—	7.37	12.31	2.82	193	44	1.67
Skinner *et al* (1985)	16–18	114	64.0	(M)	7.38	12.80	5.20	200	81	1.73
Kaufman *et al* (1982)	17–18	627[c]	61.3	—	7.18	10.38	3.91	169	64	1.45
Post *et al* (1987)	17–18	28	63.8	—	7.36	13.00	3.17	204	50	1.77
Livingstone *et al* (1992*b*)	18–19	5	78.5	14.1	7.83	10.72	3.46 (WDR)	137	44	1.37[j]
					7.83	15.52	2.26 (DH)	198	29	1.98
Räsänen *et al* (1985)	18–19	124	65.0	(M)	7.45	12.50	3.20	192	49	1.68
Räsänen *et al* (1991)	18–19	93	65.0	(M)	7.45	12.50	3.80	192	58	1.68

[a] BMR = Predicted basal metabolic rate (FAO/WHO/UNU, 1985).
[b] Mean energy intakes expressed as a multiple of mean predicted BMR.
[c] Only 30% (for *n* > 500) or 20% (for *n* > 1000) used to calculate weighted means in Table 32.
[d] Median values reported.
[e] White = white children, black = black children.
[f] (M) = Median weight for height from Baldwin's standards (FAO/WHO/UNU, 1985).
[g] WDR = Weighted dietary record, DH = diet history.
[h] Woodward *et al* (1984). Total sample size = 1055. Sample sizes for specific groups were not reported but are assumed to be evenly distributed by age group (*n* = 4) and sex.
[i] 24-hr R = 24-h recall.
[j] Excluded from Table 32 because × BMR was < 1.39.

Table 28 Energy intakes of boys aged approximately 10–18 years

Source	Age (y)	N	Weight (kg) Mean	Weight (kg) s.d.	BMR[a] (MJ/d)	Energy intake (EI) (MJ/d) Mean	Energy intake (EI) (MJ/d) s.d.	Energy intake (EI) (kJ/kg/d) Mean	Energy intake (EI) (kJ/kg/d) s.d.	× BMR[b]
Boggio & Klepping (1981)	9 11	37	31.3	4.5	4.99	8.34	1.04	266	33	1.67
Brault-Dubuc & Mongeau (1989)	10	104	31.4	5.5	5.00	10.58	2.20	344	80	2.12
Cunningham & Lee (1990)	8–12	85	34.1	—	5.20	9.70	3.20	284	94	1.87
Department of Health (1989)	10–11	902[c]	36.8	7.7	5.40	8.67	1.51	236	41	1.61
Durnin (1984)	10–11	102	33.0	(Median)[d]	5.11	8.40	—	255	—	1.64
Frank *et al* (1985)	9–11	184	35.0	—	5.26	9.80	—	280	—	1.86
Morrison *et al* (1980)	10 12	101 (white)[e]	34.5	(M)[f]	5.23	10.15	3.68	294	107	1.94
	10 12	31 (black)	34.5	(M)	5.23	8.33	4.13	241	120	1.59
Pao *et al* (1985)	9–11	196	31.0	(M)	4.99	8.29	2.41	267	—	1.66
Rodriguez (1991)	10–11	140	34.2	8.0	5.22	7.38	1.92	222	59	1.41
Seone & Roberge (1983)	10–12	99	35.8	—	5.32	9.08	1.69	254	47	1.71
Tayter *et al* (1989)	10–12	20	35.3	—	5.30	9.18	—	260	—	1.73
Adamson *et al* (1992)	11–12	184	40.5	—	5.67	8.61	1.76	213	—	1.52
Hackett *et al* (1984)	11–12	193	39.0	—	5.56	8.90	—	229	—	1.60
Boulton (1981)	11–12	8	39.0	—	5.56	8.57	2.02	220	80	1.54
Brault-Dubuc & Mongeau (1989)	11–12	96	34.6	6.76	5.24	10.26	2.06	305	60	1.96
Jenner *et al* (1992)	11–12	626[c]	42.0	—	5.78	8.60	2.30	205	55	1.49
Nelson *et al* (1990)	11–12	76	37.0	(M)	5.41	7.74	1.67	209	45	1.43
Perusse *et al* (1984)	11–17	304	49.8	14.7	6.34	11.00	2.91	221	58	1.74
Boulton (1981)	12–13	15	42.7	—	5.83	10.25	1.78	240	70	1.76
Brault-Dubuc & Mongeau (1989)	12–13	79	37.6	6.8	5.45	10.63	1.87	290	50	1.95
Cunningham & Lee (1990)	12 15	93	49.3	—	6.31	11.30	3.30	229	67	1.79
Livingstone *et al* (1992*b*)	12–13	6	44.5	6.7	5.96	10.15	1.08 (WDR)[g]	228	24	1.70
					5.96	11.82	2.64 (DH)	266	59	1.98
Pao *et al* (1985)	12–14	296	44.0	(M)	5.92	9.49	2.91	216	—	1.60
Post *et al* (1987)	12 13	26	38.4	—	5.51	11.70	2.55	305	66	2.12
Räsänen *et al* (1991)	12 13	116	40.9	(M)	5.69	10.20	3.60	249	88	1.79
Strain *et al* (1994)	12 13	251	43.0	9.4	5.85	11.0	(Median)	256	—	1.88
Tan *et al* (1989)	12–14	246	44.0	(M)	5.92	10.2	2.9	232	66	1.72
Woodward *et al* (1984)[h]	12–13	132[h]	41.0	(Median)	5.70	9.9	(Median)	241	—	1.74
Boulton (1981)	13–14	12	52.6	—	6.55	10.0	2.54	190	30	1.53
Brault-Dubuc & Mongeau (1989)	13 14	61	42.6	7.2	5.82	10.70	2.05	257	48	1.84
Frank *et al* (1985)	13–14	78	49.8	—	6.34	11.03	—	221	—	1.74
Hagman *et al* (1986)	13–14	166	50.5	—	6.40	12.10	—	240	—	1.89
Morrison *et al* (1980)	13–15	94 (white)	49.8	(M)	6.34	12.06	5.55	242	111	1.90
		40 (black)	49.8	(M)	6.34	10.87	5.08	218	102	1.72
Post *et al* (1987)	13–14	73	43.4	—	5.88	11.60	1.71	267	39	1.97
Sunnegardh *et al* (1986)	13 14	171	49.8	11.8	6.34	10.8	3.9 (24-h R)[i]	217	78	1.70
		166			6.34	12.3	3.9 (DH)	247	78	1.94
Seone & Roberge (1983)	13–15	103	52.5	—	6.54	10.91	2.23	208	42	1.67
Story (1986)	13–17	139	66.4	—	7.58	9.57	4.94	144	75	1.26[j]
Woodward *et al* (1984)	13–14	132	48.0	(Median)	6.21	11.70	(Median)	244		1.88
Baghurst & Record (1983)	14–15	77	52.6	(M)	6.55	11.95	—	227	—	1.82
Bergstrom *et al* (1993)	14–16	155	54.3	10.2	6.67	8.90	2.20	164	41	1.33[j]
Boulton (1981)	14–16	25	62.3	—	7.26	11.84	3.24	190	60	1.63
Boggio & Klepping (1981)	14–16	73	56.7	12.2	6.96	10.94	2.56	193	45	1.57

Table 28 (*continued*

Source	Age (y)	N	Weight (kg) Mean	Weight (kg) s.d.	BMR[a] (MJ/d)	Energy intake (EI) (MJ/d) Mean	Energy intake (EI) (MJ/d) s.d.	Energy intake (EI) (kJ/kg/d) Mean	Energy intake (EI) (kJ/kg/d) s.d.	× BMR[b]
Brault-Dubuc & Mongeau (1989)	14–15	49	50.0	8.8	6.36	11.60	2.46	238	49	1.82
Department of Health (1989)	14–15	513[c]	55.7	9.5	6.77	10.40	2.30	187	41	1.54
Post *et al* (1987)	14–15	95	48.9	—	6.28	12.20	1.95	249	40	1.94
Woodward *et al* (1984)	14–15	132	54.0	(Median)	6.65	12.10	(Median)	224	—	1.82
Brault-Dubuc & Mongeau (1989)	15 16	46	57.0	8.34	6.87	12.29	2.84	218	50	1.79
Bull (1985)	15–18	198	62.0	(M)	7.23	10.10	—	163	—	1.40
Cunningham & Lee (1990)	15–18	73	63.9	—	7.37	14.0	4.5	219	70	1.90
Livingstone *et al* (1992*a*,*b*)	15–16	6	56.4	9.1	6.83	11.33	1.88 (WDR)	201	33	1.66
					6.83	13.91	2.20 (DH)	247	39	2.04
Michaud *et al* (1991)	15–19	198	63.7	8.5	7.36	12.39	3.80	195	60	1.68
Pao *et al* (1985)	15–18	365	61.9	(M)	7.23	10.92	3.55	176	57	1.51
Post *et al* (1987)	15–16	102	55.6	—	6.77	12.5	3.03	225	54	1.85
Räsänen *et al* (1985)	15 16	139	58.0	(M)	6.94	11.8	3.70	203	64	1.70
Räsänen *et al* (1991)	15–16	118	58.0	(M)	6.94	11.8	4.30	203	74	1.70
Strain *et al* (1994)	15–16	252	59.0	9.4	7.01	13.10	(Median)	222	—	1.87
Woodward *et al* (1984)	15–16	132	60.0	(Median)	7.09	11.9	(Median)	198	—	1.68
Bergstrom *et al* (1993)	16 18	211	66.4	8.4	7.55	10.50	2.70	158	41	1.39
Boulton (1981)	16–17	15	65.8	—	7.51	11.84	4.35	180	60	1.50
Brault-Dubuc & Mongeau (1989)	16–17	29	59.8	8.25	7.07	11.72	3.02	198	51	1.66
Crawley (1993)	16 17	2006[c]	62.7	(M)	7.31	11.40	2.69	182	43	1.56
Morrison *et al* (1980)	16 19	82 (white)	64.0	(M)	7.37	13.20	4.25	207	67	1.79
		14 (black)	64.0	(M)	7.37	13.11	5.57	205	87	1.78
Post *et al* (1987)	16–17	76	61.0	—	7.16	12.80	3.49	210	57	1.79
Seone & Roberge (1983)	16–18	69	63.9	—	7.37	12.31	2.82	193	44	1.67
Skinner *et al* (1985)	16–18	114	64.0	(M)	7.38	12.80	5.20	200	81	1.73
Kaufman *et al* (1982)	17–18	627[c]	61.3	—	7.18	10.38	3.91	169	64	1.45
Post *et al* (1987)	17–18	28	63.8	—	7.36	13.00	3.17	204	50	1.77
Livingstone *et al* (1992*b*)	18–19	5	78.5	14.1	7.83	10.72	3.46 (WDR)	137	44	1.37[j]
					7.83	15.52	2.26 (DH)	198	29	1.98
Räsänen *et al* (1985)	18–19	124	65.0	(M)	7.45	12.50	3.20	192	49	1.68
Räsänen *et al* (1991)	18–19	93	65.0	(M)	7.45	12.50	3.80	192	58	1.68

[a] BMR = Predicted basal metabolic rate (FAO/WHO/UNU, 1985).
[b] Mean energy intakes expressed as a multiple of mean predicted BMR.
[c] Only 30% (for $n > 500$) or 20% (for $n > 1000$) used to calculate weighted means in Table 32.
[d] Median values reported.
[e] White = white children, black = black children.
[f] (M) = Median weight for height from Baldwin's standards (FAO/WHO/UNU, 1985).
[g] WDR = Weighted dietary record, DH = diet history.
[h] Woodward *et al* (1984). Total sample size = 1055. Sample sizes for specific groups were not reported but are assumed to be evenly distributed by age group ($n = 4$) and sex.
[i] 24-hr R = 24-h recall.
[j] Excluded from Table 32 because × BMR was < 1.39.

Table 29 Energy intakes of girls aged approximately 10–18 years

Source	Age (y)	N	Weight (kg) Mean	Weight (kg) s.d.	BMR[a] (MJ/d)	Energy intake (EI) (MJ/d) Mean	Energy intake (EI) (MJ/d) s.d.	Energy intake (EI) (kJ/kg d) Mean	Energy intake (EI) (kJ/kg d) s.d.	× BMR[b]
Boggio & Klepping (1981)	9–11	38	31.0	5.0	4.68	7.38	1.53	238	49	1.58
Brault-Dubuc & Mongeau (1989)	10	103	30.9	6.8	4.68	9.02	1.99	300	79	1.93
Cunningham & Lee (1990)	8–12	63	34.7	—	4.87	8.40	2.80	242	81	1.72
Department of Health (1989)	10–11	821[c]	37.1	7.4	4.99	7.69	1.61	207	43	1.54
Durnin (1984)	10–11	125	34.4	Median[d]	4.86	7.70	—	224	—	1.58
Frank *et al* (1985)	9–11	159	35.0	—	4.89	8.64	—	247	—	1.77
Morrison *et al* (1990)	10–12	103 (white)[f]	36.0	(M)[e]	4.94	8.85	2.90	246	81	1.79
	10–12	44 (black)	36.0	(M)	4.94	7.10	4.02	197	112	1.44
Pao *et al* (1985)	9 11	222	32.0	(M)	5.08	7.69	2.03	240	—	1.51
Seone & Roberge (1983)	10–12	72	37.4	—	5.01	7.91	1.70	211	45	1.58
Tayter *et al* (1989)	10–12	19	37.0	—	5.01	7.86	—	212	—	1.57
Torun *et al* (1994)	10 12	72	29.59	3.55	4.63	6.42 (24-h R)[g]	1.56	218	53	1.39
						5.97 (FFQ)	1.76	204	61	1.29[h]
Adamson *et al* (1992)	11 12	195	41.9	—	5.24	8.25	1.95	197	—	1.57
Hackett *et al* (1984)	11–12	212	39.9		5.14	8.27	—	207	—	1.61
Boulton (1981)	11–12	15	41.8	—	5.23	7.53	3.02	180	40	1.44
Brault-Dubuc & Mongeau (1989)	11 12	85	34.5	7.2	4.86	9.16	1.96	274	57	1.88
Jenner *et al* (1992)	11–12	589[c]	42.9	—	5.29	7.50	2.10	175	49	1.42
Nelson *et al* (1990)	11 12	67	38.7	(M)	5.08	7.45	1.20	193	31	1.47
Pérusse *et al* (1984)	11 17	276	46.4	11.2	5.47	8.47	2.57	183	47	1.55
Boulton (1981)	12 13	7	49.9	—	5.64	6.98	1.61	140	70	1.24[h]
Brault-Dubuc & Mongeau (1989)	12 13	71	38.9	7.2	5.09	9.55	1.93	253	50	1.88
Cunningham & Lee (1990)	12 15	114	51.7		5.74	9.10	3.0	176	58	1.59
Greger *et al* (1978)	12 13	183 (fall)	48.0	12.0	5.55	8.46	2.45	176	51	1.52
		184 (spring)	52.0	30.0	5.75	8.08	2.35	155	45	1.41
Livingstone *et al* (1992*a,b*)	12 13	6	44.8	3.9	5.39	8.57	1.59 (WDR)[i]	191	35	1.59
					5.39	12.08	1.47 (DH)	270	33	2.24[h]
McCoy *et al* (1984)	12 13	441	44.0	(M)	5.35	8.43	—	192	—	1.58
Pao *et al* (1985)	12 14	295	46.5	(M)	5.47	7.76	2.58	167	—	1.42
Post *et al* (1987)	12 13	31	42.2	—	5.25	9.80	1.67	232	40	1.87
Räsänen (1985)	12–13	166	44.0	(M)	5.35	8.20	2.30	186	52	1.53
Räsänen (1991)	12 13	119	44.0	(M)	5.35	8.50	2.60	193	59	1.59
Van den Reek (1986)	12 15	8	47.0	9.0	5.50	6.20	1.94	132	41	1.13[h]
Strain *et al* (1994)	12–13	259	44.0	9.0	5.35	9.2	(Median)	209	—	1.72
Tan *et al* (1989)	12 14	255	46.5	(M)	5.47	7.8	2.1	168	45	1.43
Woodward *et al* (1984)	12 13	132[j]	43.0	(Median)	5.29	8.9	(Median)	207	—	1.68
Boulton (1981)	13 14	15	62.4		6.28	7.49	2.04	120	40	1.19[h]
Brault-Dubuc & Mongeau (1989)	13 14	50	44.0	7.99	5.35	9.08	1.62	213	37	1.70
Frank *et al* (1985)	13 14	70	48.6	—	5.58	8.35	—	172	—	1.50
Hagman *et al* (1986)	13 14	170	50.3	—	5.67	9.65	—	192	—	1.70
Morrison *et al* (1980)	13 15	78 (white)	49.3	(M)	5.61	8.55	2.68	173	54	1.52
		32 (black)	49.3	(M)	5.61	7.83	2.78	159	56	1.40
Post *et al* (1987)	13–14	98	48.0	—	5.55	9.60	1.98	200	41	1.73
Seone & Roberge (1983)	13 15	92	50.5	—	5.68	8.61	1.63	170	32	1.52
Sunnegardh *et al* (1986)	13 14	169	50.9	9.2	5.70	8.10	2.60 (24-h R)	159	51	1.42
					5.70	9.90	2.60 (DH)	194	51	1.74
Story (1986)	13 17	138	62.8	—	6.32	7.57	2.89	120	46	1.20[h]
Woodward *et al* (1984)	13–14	132	49.0	(Median)	5.60	9.00	(Median)	184	—	1.61
Baghurst *et al* (1983)	14–15	69	51.4	(M)	5.72	9.36	—	182	—	1.64
Bergstrom *et al* (1993)	14–16	189	53.7	8.2	5.84	7.10	1.60	132	30	1.22[h]

Table 29 *(continued)*

Source	Age (y)	N	Weight (kg) Mean	Weight (kg) s.d.	BMR[a] (MJ/d)	Energy intake (EI) (MJ/d) Mean	Energy intake (EI) (MJ/d) s.d.	Energy intake (EI) (kJ/kg/d) Mean	Energy intake (EI) (kJ/kg/d) s.d.	× BMR[b]
Boulton *et al* (1981)	14 16	27	57.5	—	6.03	6.90	1.84	120	30	1.14[h]
Boggio & Klepping (1981)	14–16	125	51.2	7.50	5.71	8.48	1.97	166	38	1.49
Brault-Dubuc & Mongeau (1989)	14–15	37	48.3	7.30	5.56	8.96	2.31	191	48	1.61
Department of Health (1989)	14 15	461	53.7	9.20	5.84	7.85	1.74	146	32	1.34
McCoy *et al* (1984)	14–15	440	51.4	(M)	5.72	8.40	—	163	—	1.47
Post *et al* (1987)	14–15	129	52.0	—	5.75	9.60	2.27	185	44	1.67
Woodward *et al* (1981)	14 15	132	51.0	(Median)	5.70	9.2	(Median)	180	—	1.61
Barber *et al* (1985)	15 18	448	56.4	—	6.00	8.6	—	152	—	1.43
Brault-Dubuc & Mongeau (1989)	15–16	32	49.9	4.98	5.64	9.16	2.17	187	43	1.62
Bull (1985)	15 18	184	53.8	(M)	5.84	7.80	—	145	—	1.34
Cunningham *et al* (1990)	15 18	110	57.2	—	6.02	8.90	2.50	156	44	1.48
Livingstone *et al* (1992*b*)	15 16	6	57.2	9.2	6.02	6.84	1.78 (WDR)	120	31	1.14[h]
					6.02	9.34	1.70 (DH)	163	30	1.55
Michaud *et al* (1991)	15–19	283	54.6	6.2	5.88	8.40	2.73	154	50	1.43
Pao *et al* (1985)	15–18	374	53.8	(M)	5.84	7.39	2.73	137	51	1.27[h]
Post *et al* (1987)	15 16	130	54.9		5.90	9.50	2.28	173	42	1.61
Räsänen *et al* (1985)	15 16	152	53.0	(M)	5.80	7.60	2.20	143	42	1.31
Räsänen *et al* (1991)	15–16	112	53.0	—	5.80	8.60	3.30	162	62	1.48
Strain *et al* (1994)	15–16	254	57.0	8.5	6.01	9.10	(Median)	160	—	1.51
Woodward *et al* (1984)	15 16	132	52.0	(Median)	5.75	8.50	(Median)	163	—	1.48
Bergstrom *et al* (1993)	16 18	176	58.4	8.7	6.08	7.10	1.90	122	33	1.17[h]
Boulton (1981)	16–17	12	55.9		5.95	6.15	1.41	110	30	1.03[h]
Brault-Dubuc & Mongeau (1989)	16 17	18	52.0	5.60	5.75	9.11	2.18	178	42	1.58
Crawley (1993)	16 17	2754[c]	54.0	(M)	5.85	8.80	2.10	163	39	1.50
Morrison *et al* (1980)	16–19	71 (white)	54.0	(M)	5.85	8.68	3.41	161	63	1.48
		13 (black)	54.0	(M)	5.85	8.10	5.00	150	93	1.38
Post *et al* (1987)	16 17	99	57.4	—	6.03	9.30	1.99	162	35	1.54
Seone & Roberge (1983)	16–18	65	54.4	—	5.87	7.96	2.18	146	40	1.36
Skinner *et al* (1985)	16–18	111	54.0	(M)	5.85	8.60	3.77	159	70	1.47
Kaufman *et al* (1992)	17–18	551[c]	55.7	—	5.94	6.71	2.89	120	52	1.13[h]
Post *et al* (1987)	17 18	32	57.9	—	6.05	9.80	2.83	169	49	1.62
Livingstone *et al* (1992*b*)	18 19	5	63.9	16.2	5.98	7.84	1.74 (WDR)	123	27	1.31
					5.98	10.13	1.58 (DH)	159	25	1.69
Räsänen *et al* (1985)	18–19	148	54.4	—	5.87	7.70	2.50	142	46	1.31
Räsänen *et al* (1991)	18 19	116	54.4	—	5.87	7.40	2.50	136	46	1.26[h]

[a] BMR – Predicted basal metabolic rate (FAO WHO UNU, 1985).
[b] Mean energy intakes expressed as a multiple of mean predicted BMR.
[c] Only 30% (for $n > 500$) or 20% (for $n > 1000$) used to calculate weighted means in Table 33.
[d] Median values reported.
[e] (M) = Median weight for height from Baldwin's standards [FAO/WHO/UNU, 1985]
[f] White = white children, black = black children.
[g] 24-h R = 24-hour recall, FFQ = food frequency questionnaire.
[h] Excluded from Table 33 because × BMR was < 1.30 or > 2.10.
[i] WDR = weighed dietary record, DH = diet history.
[j] Woodward *et al* (1981). Total sample size = 1055. Sample sizes for specific groups were not reported but are assumed to be evenly distributed by age group ($n = 4$) and sex.

Table 30 Combined energy intakes for male and female subjects aged 5–10 years

Source	Age (y)	N	Weight (kg) Mean	Weight (kg) s.d.	BMR[a] (MJ/d)	Energy intake (MJ/d) Mean	Energy intake (MJ/d) s.d.	Energy intake (kJ/kg/d) Mean	Energy intake (kJ/kg/d) s.d.	× BMR[b]
Ho *et al* (1988)	5–6	60	17.5	—	3.73	5.36	—	312	—	1.44
Morgan & Zabik (1981)	5 6	162	20.5	(M)[c]	4.00	8.09	—	395	—	2.02
Pao *et al* (1985)	6–8	428	22.4	(M)	4.18	7.17	1.89	320	—	1.72
Salas *et al* (1990)	6–9	60	23.8	(M)	4.31	8.63	1.60	363	67	2.00
Morgan & Zabik (1981)	7 8	168	23.6	(M)	4.29	8.75	—	371	—	2.04
Persson & Calgren (1984)	8–9	(Total sample of 477 including 4 5 olds)	27.6	(M)	4.67	8.22	1.56	298	57	1.76
Morgan & Zabik (1981)	9 10	165	30.1	(M)	4.91	9.30	—	309	—	1.89

[a] BMR = Predicted basal metabolic rate (FAO/WHO/UNU, 1985).
[b] Mean energy intakes expressed as a multiple of mean predicted BMR.
[c] (M) = Median (NCHS) weights at mid-year (FAO/WHO/UNU, 1985).

Table 31 Energy intakes of subjects (sexes combined) aged 1–5 years, and of boys and girls aged 5–10 years compared with current FAO/WHO/UNU (1985) estimated requirements

Age (y)	Studies n	Subjects n	Energy intake[a] (MJ/d) Mean	(MJ/d) s.d.	(kJ/kg/d) Mean	(kJ/kg/d) s.d.	(kcal/kg/d) Mean	(kcal/kg/d) s.d.	× BMR Mean	FAO/WHO/UNU (1985) requirements (MJ/d)	FAO/WHO/UNU (1985) requirements (kJ/kg/d)	Percentage difference (%)[b] (MJ/d)	Percentage difference (%)[b] (kJ/kg/d)
Sexes combined													
1 2	12	927	4.17	0.82	375	74	90	18	1.54	4.80	439	−13.1	−14.6
			(Range 3.39–4.96)		(Range 325–451)				(Range 1.38–1.79)				
2–3	11	835	4.92	1.08	367	81	88	19	1.51	5.70	418	−13.7	−12.2
			(Range 4.03–5.80)		(Range 310–407)				(Range 1.30–1.76)				
3 5	22	2460	5.76	1.15	345	67	82	16	1.53	6.50	397	−11.4	−13.1
			(Range 4.60–6.90)		(Range 277–408)				(Range 1.31–1.80)				
Boys													
5 6	6	273[c]	7.06	1.05	363	53	87	13	1.80	7.57	385	−6.7	−5.7
			(Range 5.36–8.09)		(Range 312–395)				(Range 1.44–2.02)				
6–7	4	544	7.82	1.88	360	87	86	21	1.90	7.94	368	−1.5	−2.2
			(Range 7.17 8.91)		(Range 320 438)				(Range 1.92 2.22)				
7 8	6	436	8.41	2.29	352	100	84	24	1.94	8.32	347	+1.1	+1.4
			(Range 6.97–9.58)		(Range 293–401)				(Range 1.62–2.14)				
8 9	7	996	8.13	1.79	289	62	69	15	1.72	8.66	322	−6.1	−10.2
			(Range 7.45 9.43)		(Range 248–375)				(Range 1.64–2.11)				
9 10	7	1085	8.75	1.81	314	66	75	16	1.83	8.99	301	−2.7	+4.3
			(Range 7.10–9.74)		(Range 280–364)				(Range 1.64–2.08)				
Girls													
5 6	6	288	6.64	0.96	349	50	83	12	1.72	6.81	368	−2.5	−5.2
			(Range 5.36–8.09)		(Range 312–395)				(Range 1.44–2.02)				
6–7	4	556	7.21	1.52	342	66	82	16	1.78	7.11	347	+1.4	−1.4
			(Range 6.80 7.86)		(Range 320–416)				(Range 1.70–2.04)				
7–8	6	402	8.05	2.13	343	93	82	22	1.88	7.40	318	+8.8	+7.9
			(Range 6.08–8.25)		(Range 255–398)				(Range 1.41–2.04)				
8 9	7	1026	7.47	1.69	266	62	64	15	1.58	7.65	268	−2.4	−0.7
			(Range 6.92–8.21)		(Range 236 358)				(Range 1.50–1.92)				
9 10	6	469	8.14	1.75	283	67	68	16	1.68	7.86	259	+3.6	+9.3
			(Range 7.62 8.38)		(Range 220–321)				(Range 1.43–1.83)				

[a] Energy intake data (MJ/d, kJ/kg/d, × BMR) expressed as weighted means. s.d. estimated from $\sqrt{\left(\frac{\Sigma CV^2}{n}\right)}$ (n = number of studies). For studies where s.d. was not reported the mean CV of other studies in that group was assumed.

[b] Percentage difference = (energy intake − FAO/WHO/UNU estimated requirement)/estimated requirement × 100.

[c] Sample sizes for 5 10 year olds include studies listed in Table 30 and assume equal numbers of boys and girls.

Table 32 Energy intakes of boys aged 10–18 years compared with current FAO/WHO/UNU (1985) estimated requirements

Age (y)	Studies n	Subjects n	Energy intake[a] (MJ/d) Mean	s.d.	(kJ/kg/d) Mean	s.d.	(kcal/kg/d) Mean	s.d.	× BMR Mean	FAO/WHO/UNU (1985) requirements (MJ/d)	(kJ/kg/d)	× BMR	Percentage difference (%)[b] (MJ/d)	(kJ/kg/d)	× BMR
10—11	10	1981	8.86	2.62	255	76	61	18	1.68	8.95	278	1.76	−1.0	−8.3	−4.5
			(Range 7.38–10.58)		(Range 222–344)				(Range 1.41–2.12)						
11—12	7	1203	8.74	1.97	220	58	53	14	1.55	9.37	254	1.73	−6.7	−13.4	−10.4
			(Range 7.74–10.26)		(Range 205–305)				(Range 1.43–1.96)						
12—13	9	1167	10.47	2.59	240	61	57	15	1.76	9.66	237	1.69	+8.4	+1.3	+4.1
			(Range 9.49–11.0)		(Range 216–305)				(Range 1.60–2.12)						
13—14	10	1023	11.37	3.28	233	64	56	15	1.80	10.20	217	1.67	+11.5	+7.4	+7.2
			(Range 10.00–12.10)		(Range 190–267)				(Range 1.53–1.97)						
14—15	8	1268	11.11	2.50	208	50	50	12	1.70	10.83	206	1.65	+2.6	+0.1	+2.4
			(Range 10.40–12.20)		(Range 187–249)				(Range 1.54–1.94)						
15—16	7	795	12.34	3.25	212	57	51	14	1.75	11.29	195	1.62	+9.3	+8.7	+8.0
			(Range 11.33–13.10)		(Range 198–225)				(Range 1.66–1.87)						
16—17	10	3143	11.49	3.51	184	55	44	13	1.57	11.71	187	1.60	−1.9	−1.6	−1.9
			(Range 10.10–14.00)		(Range 163–219)				(Range 1.40–1.90)						
17—18	5	968	11.22	3.53	179	56	43	13	1.55	12.00	184	1.60	−6.5	−2.7	−3.1
			(Range 10.38–13.20)		(Range 169–207)				(Range 1.45–1.79)						

[a] Energy intake data (MJ/d, kJ/kg/d, × BMR) expressed as weighted means. s.d. estimated from $\sqrt{\left(\frac{\Sigma CV^2}{n}\right)}$ (n = number of studies). For studies where s.d. was not reported the mean CV of other studies in that group was assumed.

[b] Percentage difference = (Energy intake − FAO/WHO/UNU estimated requirement)/estimated requirement × 100.

Table 33 Energy intakes of girls aged 10 18 years compared with current FAO/WHO/UNU (1985) estimated requirements

			Energy intake[a]							*FAO/WHO/UNU (1985) requirements*			*Percentage difference* (%)[b]		
			(MJ d)		*(kJ kg d)*		*(kcal/kg d)*		× *BMR*						
Age (*y*)	*Studies* *n*	*Subjects* *n*	*Mean*	*s.d.*	*Mean*	*s.d.*	*Mean*	*s.d.*	*Mean*	*(MJ/d)*	*(kJ/kg d)*	× *BMR*	*(MJ/d)*	*(kJ/kg/d)*	× *BMR*
10—11	9	1750	7.94	2.46	226	72	54	17	1.60	7.99	237	1.65	−0.6	−4.6	−3.0
			(Range 7.09 9.02)		(Range 197–300)				(Range 1.44–1.93)						
11 12	8	1254	7.81	2.16	194	45	46	11	1.51	8.28	215	1.63	−5.7	−9.8	−7.4
			(Range 6.54–9.16)		(Range 175–274)				(Range 1.41–1.88)						
12 13	11	2142	8.41	2.16	186	53	44	13	1.55	8.57	196	1.60	−1.9	−5.1	−3.1
			(Range 7.80 9.80)		(Range 168–253)				(Range 1.42–1.88)						
13 14	9	1005	8.88	2.39	179	48	43	11	1.58	8.87	181	1.58	0.0	−1.1	0.0
			(Range 7.83–9.65)		(Range 159–213)				(Range 1.40–1.73)						
14—15	8	1669	8.47	2.19	166	42	40	10	1.49	9.03	176	1.57	−6.2	−5.7	−5.1
			(Range 7.85 9.60)		(Range 146–191)				(Range 1.34 1.67)						
15 16	7	818	8.72	2.39	161	45	38	11	1.48	8.95	169	1.54	−2.6	−4.7	−3.9
			(Range 7.60 9.50)		(Range 143–187)				(Range 1.31–1.62)						
16—17	8	3789	8.62	2.53	156	46	37	11	1.46	8.91	166	1.53	−3.3	−6.0	−4.6
			(Range 7.80 9.30)		(Range 145 178)				(Range 1.34 1.58)						
17 18	3	399	8.55	3.32	156	61	37	15	1.45	8.95	165	1.52	−4.4	−5.4	−4.6
			(Range 8.10 9.80)		(Range 150–169)				(Range 1.38–1.62)						

[a] Energy intake data (MJ/d, kJ/kg/d, × BMR) expressed as weighted means. s.d. estimated from $\sqrt{\left(\frac{\Sigma CV^2}{n}\right)}$ (n = number of studies). For studies where s.d. was not reported the mean CV of other studies in that group was assumed.

[b] Percentage difference = (energy intake − FAO/WHO UNU estimated requirement)/estimated requirement × 100.

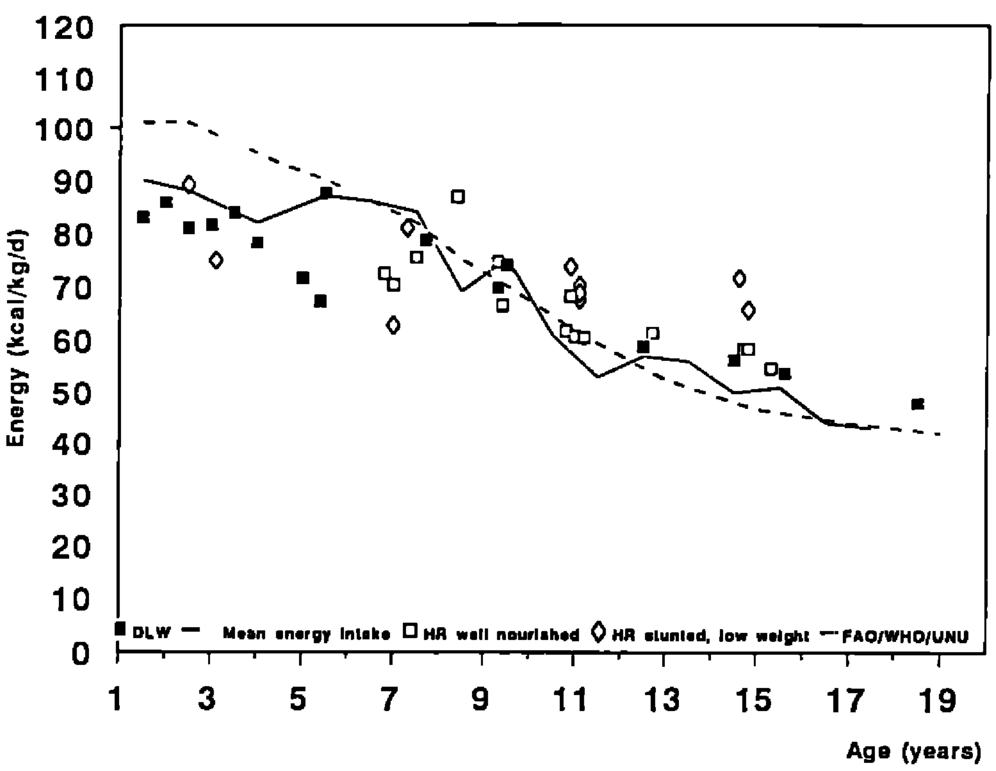


Figure 11a Energy intake compared with expenditure estimated by doubly labeled water and heart rate monitoring, *including* stunted and underweight children, and current recommendations: boys (solid line: mean energy intake; interrupted line: FAO/WHO/UNU recommendations).

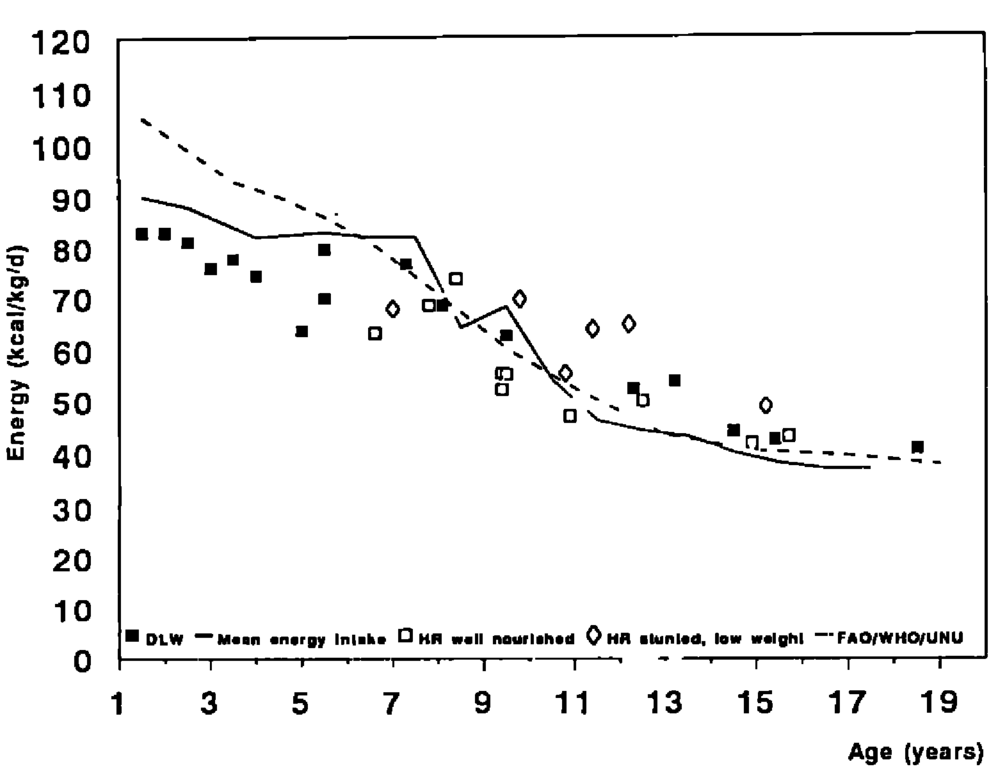


Figure 11b Energy intake compared with expenditure estimated by doubly labeled water and heart rate monitoring, *including* stunted and underweight children, and current recommendations: girls (solid line: mean energy intake; interrupted line: FAO/WHO/UNU recommendations).

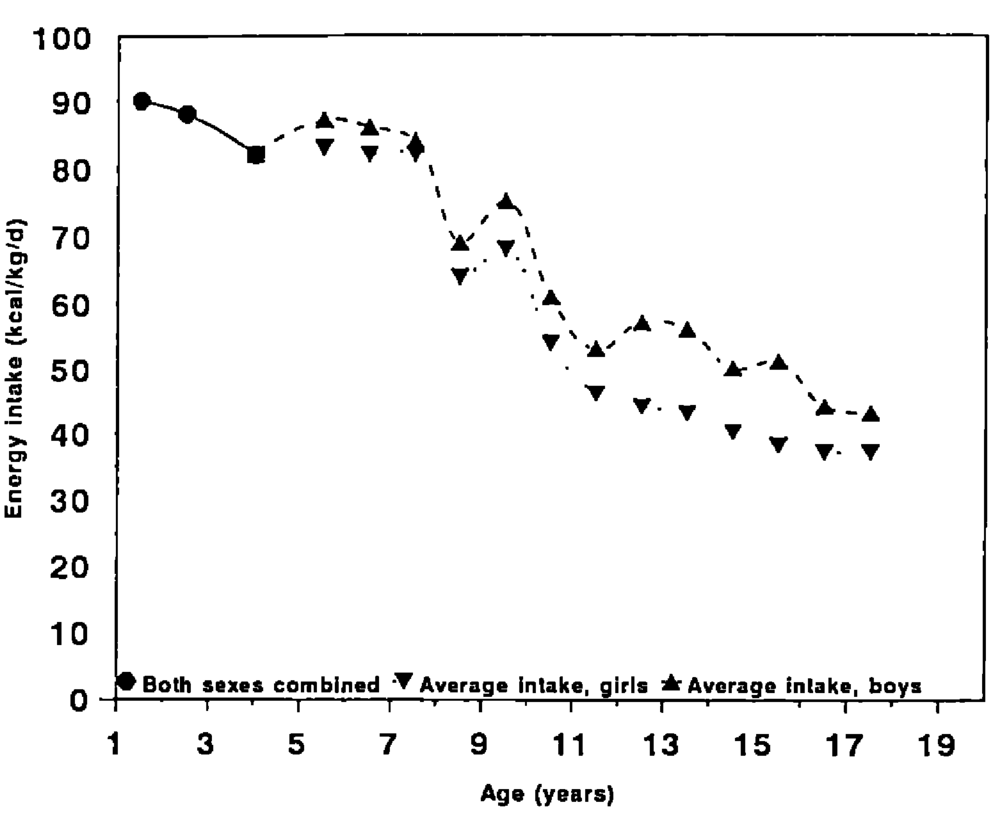


Figure 12 Comparison of average dietary energy intakes of boys and girls.

of usual intake. Therefore, the following recommendations need to be considered:

(a) At present there are too few studies in which energy intake and energy expenditure have been studied in the same population to know the nature and extent of bias involved in these measurements. This will require more extensive validation studies of energy and nutrient intakes that take into account differences in methodology, social status, education, age, and geographical region in both developing and industrialized countries. From these studies guidelines may emerge for detecting patterns of bias and the characteristics of individuals contributing to it.
(b) Variation among individuals within the same population can be appropriately characterized by a mean and standard deviation whose validity will depend upon the adequacy of the sample. However, the nature and extent of differences in mean values among different populations make it unlikely that they can be appropriately characterized by a single mean and standard deviation, no matter how many populations are sampled. It may be better to express a range of mean values for this purpose.
(c) Research must be done to find ways of minimizing the psychological basis of under- and over-reporting in these age groups.
(d) Appropriate 'cut-off' values based on fundamental principles of energy physiology should be used to determine the acceptance of energy intake results. This will require an extensive data base of basal and total daily energy expenditures (BMR and TEE) in association with objective measures of physical activity. In the meantime, the following estimates of multiples of BMR are suggested as provisional cut-off points: 1–5 years (boys and girls): 1.28–1.79 × BMR; 6–18 years: 1.39–2.24 × BMR (boys) and 1.30–2.10 × BMR (girls).

These recommendations will not guarantee valid data and cannot eliminate the considerable differences among populations, but may lead to the design of more effective instruments for assessing energy intake and requirements of children and adolescents.

General conclusions and recommendations

1. Dietary recommendations to satisfy the energy requirements of children and adolescents should be based on their *energy expenditure* and requirements for *growth.* Their *habitual physical activity and lifestyle* must be taken into account, as energy expenditure should be consistent with the attainment and maintenance of long-term good health, and the performance of economically necessary and socially desirable physical activity.

   Energy for socially desirable activities is particularly important as part of the normal process of a child's development, for activities such as exploration of the surroundings, learning and behavioural adjustments to other children and adults (FAO/WHO/UNU, 1985).
2. There is a major *contrast between lifestyles* of children and adolescents in *rural developing societies* and in *developed countries.* Whereas the former engage in physically-demanding *obligatory or occupational activities* from an early age, the latter tend to be

quite sedentary (Cooper *et al*, 1984; Verschuur & Kemper, 1985; Atomi *et al*, 1986; Armstrong *et al*, 1990; Gortmaker *et al*, 1990). *Discretional activities* are also probably quite different in those two settings: in developing rural areas, children walk more to move around and to socialize, while those in developed countries travel in motor vehicles and spend a significant period of time sitting and watching television (Dietz and Gortmaker, 1985; Gortmaker *et al*, 1990).

More studies are needed in children and adolescents who live in *cities of developing countries.* Available evidence suggests that those in the middle and upper socioeconomic groups are relatively sedentary, with a lifestyle that resembles that of children in developed countries more than that of their rural counterparts. Habitual activities related to energy expenditure in the lower socioeconomic groups have hardly been studied.

3. Recommendations to fulfill energy requirements of children and adolescents should be made according to *two or three levels of intensity of habitual physical activity*, in a manner similar to that recommended for adults in the 1985 FAO/WHO/UNU Report. Provisional physical activity levels are suggested in Table 21.
4. The 1985 recommendation for *5% additional dietary energy intake* to 'allow a desirable level of physical activity' among all children under 10 years of age *seems unwarranted.* Furthermore, scientific evidence accumulated in the last decade suggests that *current FAO/WHO/UNU recommendations* for dietary energy are *too high* for children under 5, and possibly under 7, years of age.
5. Current recommendations seem *somewhat low for adolescent boys and for girls around puberty.* This is *more so in rural areas of the developing world*, where recommendations for girls throughout adolescence and for boys and girls of school age may also be too low when expressed per unit of body weight or as multiples of BMR.
6. *Healthy but stunted or slightly underweight* boys and girls in developing countries seem to have a higher energy requirement per unit of body weight than their well-nourished, non-stunted counterparts. The differences in absolute terms and PAL units are less consistent. It seems reasonable to recommend for them the *same total dietary energy intakes* as for well-nourished, non-stunted children of the same age and sex, provided that they are encouraged and have opportunities to be *physically active.*
7. Dietary energy recommendations must be accompanied by strong *recommendations for physical activity* compatible with the achievement and maintenance of *health, prevention of obesity* and adequate *social and psychological development.* The minimum amount of exercise required by children for a healthy life has not been exactly determined. Provisional recommendations can be made, similar to those for adults, based on Simons-Morton *et al*'s (1988) review of recommendations for physical activity for children: exercise involving dynamic movement of large muscle groups for at least 20 min, three or more times a week, at an intensity that raises and maintains heart rate at 140 or more beats per minute.

There are some contradictory and non-conclusive results on the role of physical activity for the prevention of obesity, but as Gortmaker *et al* (1990) point out, obesity seems to have a stronger relationship with *inactivity* than with vigorous physical activity.

Methodological considerations

8. The use of *doubly-labeled water* provides, at present, the most exact quantitative measurements of TEE of free-living children and adolescents. However, financial and technical constraints limit its application in samples large enough to represent boys and girls of all ages living in a wide variety of social and geographic settings. *Minute-by-minute heart rate monitoring* techniques seem promising for this purpose, especially if they are validated in the field with doubly-labeled water measurements.
9. *Time–motion* or *activity diary techniques* can provide useful information to confirm or monitor the accuracy of dietary recommendations. Sampling must be adequate in size, physiological and anthropological characteristics, and appropriate factors must be applied to quantify the energy expended in the observed/recorded/timed activities. These techniques also provide an important insight on the *pattern of habitual activities* of children and adolescents.
10. There is a need to obtain more information on the *energy cost of activities and tasks* in which children and adolescents from different societies typically engage, in order to increase and improve existing databases (e.g. Torun, 1990*a*). *Standardized procedures* must be established to *define those activities and tasks* and to *measure their energy cost.*
11. *Time allocation studies* can help to define the appropriate level of habitual physical activity for specific (geographic, ethnic, social) groups of children and adolescents. There is, however, a need to *develop standardized procedures* for the collection of time allocation data in different societies across all age groups.
12. The use of *multiples of BMR*, or *physical activity levels* (*PAL*), is useful in physiological and practical terms to calculate the energy expenditure and estimate the energy requirements of population groups. PALs for children and adolescents with different lifestyles have been suggested in this paper.
13. It seems that a single set of *mathematical equations* cannot be used across *all races and geographic regions* to calculate the BMR of boys or girls of a specific age group. To avoid making important errors in the estimation of energy requirements and recommendations, this issue must be cleared. If necessary, specific sets of mathematical equations should be derived for some races or countries.
14. *Dietary energy intake* studies tend to overestimate energy requirements of children under 8 and to underestimate those of children over 12 years of age. Nevertheless, they may be useful to estimate requirements of a healthy, well growing population when total energy expenditure cannot be measured or calculated. However, to accept the data as representative of *habitual and appropriate intake*, it is necessary that it should be: (a) derived from *adequate population samples*; (b) validated by studies

that take into account the *method used for data collection*, as well as the *anthropological, geographic and health characteristics* of the population and (c) screened and edited to *exclude information that is incompatible with fundamental principles of energy physiology* in population groups (e.g. exclusion of data below or above cut-off points compatible with long-term *habitual* eating patterns of a healthy population). Provisional cut-off points, calculated as multiples of BMR, are suggested in this paper.

Other conclusions and recommendations

15. Other specific conclusions, including recommendations for important and much needed research, are included at the end of each section in this document.

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Discussion

Initially, the discussion dealt with the selection of studies and data that form the basis of the paper and recommendations of Torun *et al.* For methodological reasons, Ferro-Luzzi questioned the validity of older energy expenditure data based on heart rate measurements. She also argued that the life-styles of children are changing so rapidly, also in developing countries, that time allocation studies made more than 10 years ago may no longer reflect today's situation. Torun explained and justified the selection criteria that were used in greater detail and argued that, in general, there was a reasonably good fit between data obtained by different methods at different points in time. Shetty supported this view and emphasized the relatively good fit even with data that were collected in the 1970s and formed the basis of the 1985 report.

There was general agreement that energy requirements should be based on data on energy expenditures of normal children. Some of the data in the paper of Torun *et al* were from children from developing countries who were of low height-for-age (stunted), but otherwise 'normal', healthy, and adequately nourished (in terms of BMI and weight-for-height) at the time the measurements were taken. There was some debate as to whether data of such children should be included in the data base or not, particularly since energy expenditures of stunted children, expressed per kg body weight, are higher than those of non-stunted children of the same weight. In the end, the prevailing view was that in making recommendations one could not ignore that large proportions of children in developing countries are stunted, but otherwise healthy and normal, and that it seems therefore justified to include such data (Torun, Scrimshaw). Another argument was that recommending the feeding of stunted but otherwise healthy children additional energy to catch up in height (i.e. by determining their dietary energy requirements on the basis of ideal rather than actual weight, as one does with protein) will only tend to make them obese (Scrimshaw, Torun), and as long as dietary recommendations to satisfy energy requirements are made by age groups in absolute terms (i.e. energy units per day) and not by kg body weight or lean body mass, there will be no substantial difference between stunted and non-stunted children.

Several discussants speculated on the reasons why energy expenditures per kg body mass or LBM tend to be higher in stunted children than in children of normal height. Behavioral and life-style differences could be responsible for some of the differences found in DLW studies. This argument is supported by heart-rate and time–motion studies tending to show that stunted children from lower socioeconomic classes are likely to have a different life-style. Using minute-by-minute records and estimating the time spent in various categories of activities. Torun found that poorer children spent less time in sedentary and more time in light activities. Spurr found no differences in activity between well nourished and marginally nourished Colombian children during the school year, but the better nourished children were more active in leisure activities during the summer holidays. Comparing heart rates of children from the UK and developing countries, Prentice found that UK children had higher heart rates.

Torun argued in his paper and in the discussion that, in general, studies show differences in life-style requiring more energy-demanding activities from children of rural populations in developing countries. To Schürch this conclusion appeared to be a reflection of the assumptions made rather than an inference from empirical data. Table 14 shows that it is assumed that children living in rural areas of developing countries spend a greater proportion of their time in domestic chores and production activities requiring greater effort. These assumptions are used to calculate mean daily EE in terms of PAL factors from which it is then concluded that energy expenditures are higher in rural than in urban and industrial environments. This argument seems to a large extent circular.

Body mass and LBM are both very heterogeneous, i.e. composed of different tissues with different energy requirements. If their proportions differ between children of low and normal height this could explain some of the differences observed in calorimetric studies (Young). The results of a few small studies that tried to test this hypothesis remain inconclusive, and more work is needed to clarify this issue. Differences in body proportions have been observed: stunted Peruvian children, for instance, tend to have reduced limb length relative to the size of their trunks (Reeds), and the secular trend in Japanese to become taller reflects primarily an increase in leg length (Butte).

Several participants (e.g. Ferro-Luzzi & Torun) emphasized how difficult it was to measure the energy cost of activities in children and argued for the development of instruments that are better adapted to children.

Much of the discussion dealt with the introduction of PAL indices and their values reflecting the different life-styles of different groups of children. Torun integrated a section on this issue into the final version of his paper. He also defined cut-off points in terms of PAL values. Dietary intake data, for instance, lying below or above these cut-offs were considered physiologically improbable and excluded from the data base.

Some discussants expressed concern about the current trend towards increasingly sedentary life-styles not only in adults, but also among children. Should proposed PAL values reflect actual or desirable levels of activity? Butte and Durnin expressed doubts that we have enough information to be prescriptive; others feared that by recommending higher PAL values without being able to ensure that children actually do increase their level of physical activity may well lead to recommendations that are inappropriately high.

Hautvast commented on the dietary intakes presented in Figure 10, and showing that energy intakes appear to be higher than energy expenditures in infants and lower than energy expenditures in adolescents. This appears quite plausible considering that dietary intakes during the first years of life are mainly based on reports of 'caretakers, who are more likely to over-report intakes, whereas adolescents, trying to stay slim, may under-report intakes. Torun also finds this interpretation quite plausible, particularly because adolescent girls reported intakes that were further below predicted values than the intakes reported by adolescent boys. Torun added further that the discrepancy between intakes and expenditures tends to be greater in data from the US (Dietz) than from the UK (Livingstone). Prentice emphasized that only a few of the columns in Figure 10 exceed the range representing the estimated limits of precision, given the inaccuracies of both methods.

Waterlow raised the question of how accurate recommendations needed to be. The answer obviously depends on the use to which recommendations are to be put. To assess the adequacy of food available to countries or populations, FAO and other organizations use food balance sheets and estimates of population structure and food wastage which are notoriously inaccurate; in this context it appears unnecessary to try to formulate recommendations with an accuracy below 5 kcal/kg. Of greater concern are cumulative effects of errors. Reed pointed out that the energy equivalent of an excess of 5 kcal/kg/d for a year in a 14 year old weighing 40 kg amounts to about 8 kg. Clugston mentioned that WHO is often approached by governments and agencies who use these recommendations to calculate energy requirements of populations. Since children are often 40% of the population of poor countries, the accuracy of requirements is quite important for such calculations. Since a large proportion of children in poor countries are undernourished, Clugston encouraged IDECG to examine further the energy (and other dietary) requirements of stunted and wasted children.