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Energy metabolism in healthy black Kenyan children

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1. Twenty-four healthy black Kenyan children, mean age 29 (SD 19) months, were studied over a 24 h period. Energy expenditure (EE) was determined using a ventilated-hood indirect calorimeter; measuring oxygen consumption and carbon dioxide production. Metabolizable energy intake was measured in twenty children. Anthropometric measurements were used to estimate surface area and lean body-weight.

2. The mean daily intake of metabolizable energy was 338·4 (SE 28·4) kJ/kg; 70% of gross dietary energy being provided by carbohydrate. The level of postprandial EE was significantly ($P < 0.05$) higher than the resting level (12·6 (SE 0·47) and 11·38 (SE 0·37) kJ/kg per h respectively) while the level of the postprandial respiratory quotient (RQ) was similar to the resting level (0·94 (SE 0·02) and 0·98 (SE 0·03 respectively). In 33% of total observations of the resting RQ the value was more than 1·0. These findings suggest that short-term fat storage may be a normal feature of metabolism in children, and also that the energy cost of (postprandial) fat synthesis is increased by a high-carbohydrate diet.

3. Values for the resting metabolic rate and various estimators of body size were compared using regression analysis. It was evident that, in these young children with considerable variation in body composition, body-weight remained a satisfactory metabolic-size estimator.

Concern to improve rates of weight gain in children during recovery from malnutrition or after low birth weight, has stimulated interest in energy metabolism in these unusual circumstances (Ashworth, 1969; Brooke & Ashworth, 1972; Spady *et al.* 1976; Brooke *et al.* 1979; Sauer *et al.* 1979; Chessex *et al.* 1981). The observation by Ashworth (1969) of an enhanced postprandial metabolic rate (MR) during catch-up weight gain was confirmed in later studies (Brooke & Ashworth, 1972; Brooke *et al.* 1979). Ashworth (1969) proposed that this phenomenon, analogous to the heat increment of feeding (Hervey & Tobin, 1983), represents the energy expenditure on biosynthesis, and indicates that growth, i.e. tissue gain, takes place in short spurts after meals. The postprandial increase in the MR was reported to be relatively unimportant after recovery from malnutrition, i.e. at normal growth rates (Brooke & Ashworth, 1972). This accords with the estimate that less than 5% of the metabolizable energy intake of the reference infant, between 9 and 12 months of age, will be deposited in new tissue (calculated from values for the body composition and energy intake of the reference infant from Fomon, 1967, 1974).

Protein turnover exceeds protein deposition (Millward *et al.* 1976) and lipid turnover, i.e. non-protein turnover, together with its necessary energy cost, may also be a feature of normal growth. This will be more difficult to recognize experimentally in those consuming a relatively high fat diet because of the low heat increment of feeding fat (Flatt, 1978) and the unchanging respiratory quotient (RQ) of fat synthesis from fat. By contrast, net lipogenesis after a carbohydrate meal is represented by a higher heat increment, and a shift in the RQ (Acheson *et al.* 1984). The findings presented here, based on a study of Kenyan children, indicate that energy metabolism in children eating a traditional, high-carbohydrate diet (World Health Organization, 1973; Duggan, 1985) is characterized by a high postprandial MR and a persistently high RQ.

SUBJECTS AND METHODS

Energy intake and expenditure were studied in twenty-four black Kenyan children aged between 5 and 79 months (mean 29 (SD 19) months) during an elective overnight admission to the Infectious Diseases Hospital, Nairobi. Twenty children, of whom nineteen were boys (in order to facilitate urine collection), had previously been studied during an acute attack of uncomplicated measles (Duggan *et al.* 1986). The children had all recovered by the time of this, the control study. Convalescence (mean duration 56 (SD 37) d) was monitored at weekly home visits. All children were apyrexial on the day of the study, although one child had mild diarrhoea and another was fractious and anorexic. An additional four children were healthy siblings. The original twenty children were all fully weaned; two of the siblings were still breast-fed.

The children were weighed to within 10 g on a basket beam balance (CMS Weighing Equipment, London) and body length was measured to 1·0 mm on a Harpenden infant measuring table (Holtain Ltd, Crymych, Dyfed). Triceps and subscapular skinfold thicknesses were measured using Tanner Whitehouse skin calipers (Holtain Ltd), and limb, thorax and head dimensions determined to within 1·0 mm with a non-stretch plastic tape, verified against a metre rule. The anthropometric measurements were used to assess nutritional status and to estimate the metabolic body size. A diagnosis of malnutrition was based on a weight deficit of more than 2·0 standard deviations from the weight of a reference child of the same body length, i.e. from the reference mean weight-for-length (Waterlow *et al.* 1977; World Health Organization, 1983). Skinfold thickness and additional limb and trunk circumferential measurements were used to estimate the volume and thus the weight of subcutaneous fat, using the geometric model of Dauncey *et al.* (1977). Lean body-weight was calculated by difference from the total body-weight and the weight of subcutaneous fat. Surface area was estimated from weight and length measurements using the formula of Gehan & George (1970).

Energy balance (24 h) was measured on twenty children, and MR alone on the four siblings. A weighed duplicate diet was collected over 24 h together with all faeces and urine passed during this period. The energy content of food and faeces was determined by bomb calorimetry, using duplicate or triplicate analysis. The energy content of urine was calculated from its nitrogen content (Duggan *et al.* 1986). The results were used to calculate the metabolizable energy intake. For the first eight children, the weight and energy content of individual food items had been separately determined; for the remainder, all weighed duplicate meals were saved in a single container. Information on the foods in the eight separately-collected diets were further analysed using food tables (Harvey, 1951; Oyenuga, 1968; Paul & Southgate, 1978) in order to estimate the nutrient composition of the energy intake. The hospital toddler-diet varied little from day-to-day, consisting of maize porridge for breakfast, and midday and evening meals of rice, beans and minced meat, with two snacks of sweet milky tea and bread.

The MR was measured by the ventilated-hood method of indirect calorimetry. The unit, whose construction and initial calibration is described in detail elsewhere (Duggan *et al.* 1985) is capable of measuring both oxygen consumption and carbon dioxide production. The circuit consists of a clear plastic head-box, large enough to accommodate the head and shoulders of a child, in a series with a gas mixer, a wet gas meter and a vacuum pump. Mixed expired and ventilating air drawn through the apparatus by the pump, is sampled in parallel at the exit port of the gas meter, dried, filtered and delivered at constant pressure to the two analysers: a paramagnetic O_2 analyser (Servomex OA 580; Taylor Servomex Ltd, Crowborough) and an infrared CO_2 analyser (Morgan 801D; Morgan Scientific Instruments, Gillingham). The amplified signals from the analysers are continually recorded as a net deflection from the baseline which is set for room air. The circuit is sufficiently simple to be set up in a hospital side ward. It is sufficiently accurate to give 103 (SE 1·01)% recovery of O_2 and 100·9 (SE 2·9)% recovery of CO_2 (*n* 9) when respiratory exchange is mimicked by delivering a known volume of a verified mixture of CO_2 in N_2 into a ventilated empty head-box (Duggan *et al.* 1985).

The analysers were calibrated before use on each occasion, using four-point and six-point calibration for the O_2 and CO_2 analysers respectively. Calibration gases were produced by a precision gas blender (Signal Instruments, Camberley) which was calibrated by Haldane gas analysis. Recalibration for 3-h periods during each 24 h study involved spanning 20–21% O_2 concentration for the O_2 analyser and a full six-point calibration spanning 0·5–1·0% for the CO_2 analyser. During clinical use, the ventilating gas flow was adjusted to maintain the net deflections of both O_2 and CO_2 (from the regularly rechecked baseline) between 0·5 and 1·0% (Duggan, 1985).

The MR was calculated from the respiratory gas exchange using Weir's (1949) formula. Between one and six measurements of MR were made on each child over the 24 h period of observation, the main constraints being regular interruptions for meals, non-compliance of children and occasional electrical power failure. All recorded measurements were based on a period of at least 20 min steady-state observation, the time of completion of which was recorded to the nearest 0·5 h. Two such observations were theoretically possible within the 2 h time intervals illustrated in Table 3 and Figs. 1–4 (see later). In order to eliminate bias due to unequal numbers of observations, an individual mean was calculated for each stated time interval. This resulted in a total of fifty-seven values for the variation of MR in relation to meals and sixty-six for its diurnal variation. Forty-seven of sixty-nine measurements were made on sleeping children, the remainder on children in a state of quiet alertness. Thirty-six (52%) measurements were made at least 4 h after a meal, i.e. in resting metabolism; the remainder are defined as postprandial measurements.

The parents of all children gave informed verbal consent, and the study was approved by the Medical Research Ethical Committee of Kenyatta National Teaching Hospital.

RESULTS

The age and anthropometric measurements of the children are illustrated in Table 1. Eight of the original twenty children had been diagnosed as malnourished on the basis of a significant weight-for-length deficit at the time of measles, but only one remained significantly wasted after convalescence.

Energy intake. The mean 24 h intake of gross energy was equivalent to 374·2 (SE 29·63) kJ/kg (*n* 20). The mean metabolizable energy intake was equivalent to 338·4 (SE 28·4)kJ/kg per 24 h. Available values for the energy intake at individual meals (eight children), are illustrated in Fig. 1. The nutrient composition of their energy intake was estimated to be 16% from protein, 14% from fat and 70% from carbohydrate.

MR. The individual mean values for the resting and postprandial MR are illustrated in Table 2. The postprandial MR is significantly higher than the resting level ($P < 0{\cdot}05$, 15 df, Student's *t* test), the difference representing a 12 (SE 2·4)% enhancement of the postprandial over the resting level. The diurnal variation in the level of MR and its variation in relation to meals are illustrated in Table 3 and Figs. 1 and 2. The variation in the level of the RQ is similarly illustrated in Table 3 and Figs. 3 and 4. There was no significant difference in the level of the RQ between postprandial and resting metabolism. The trend for the RQ to rise with increasing postprandial interval (Fig. 4) was not statistically significant (Student's *t* test for paired values). An apparent increase in the prevalence of values for RQ indicative of net lipogenesis from carbohydrate (in 20, 41 and 50% of all mean observations in the $\leqslant 4$, $> 4 - \leqslant 8$ and > 8 h postprandial intervals respectively, the RQ was greater than 1·0), did not reach statistical significance (χ^2 analysis).

Variability of the MR. The degree of individual variability in the resting MR (RMR) was quantified by calculating the coefficients of variability for all children in whom there were at least two observations of the RMR (twenty-five observations on ten children). This gives

Table 1. *Age and body size of twenty-four black Kenyan children*

Subject no.	Age (months)	Wt (kg)	Length (m)	Wt-for-length SD score	Estimated subcutaneous body fat* (% body-wt)	Estimated lean body-wt† (kg)	Surface area‡ (m^2)	Metabolic body size (kg body-wt$^{0.75}$)
1♀	79	19·5	1·196	−1·14	ND	ND	0·81	9·3
2	16	11·95	0·772	+1·93	25·4	8·91	0·53	6·4
3	14·5	8·5	0·728	−1·22	13·9	7·3	0·43	5·0
4	14	9·05	0·740	−0·8	23·6	6·9	0·45	5·2
5	43·5	11·65	0·903	−1·57	20·9	9·1	0·56	6·3
6	18	9·8	0·782	−0·64	10·3	8·8	0·48	5·5
7	61	16·48	1·033	+0·01	17·6	13·6	0·71	8·2
8	19	13·67	0·859	+1·46	18·5	11·2	0·60	7·1
9	58	12·73	0·967	−1·93	11·5	11·3	0·60	6·7
10	24·5	12·76	0·860	+0·8	24·2	9·7	0·57	6·8
11	18	8·02	0·711	−1·05	17·2	6·7	0·44	4·8
12	17	8·03	0·724	−1·52	15·9	6·8	0·42	4·8
13	24	12·34	0·860	0·00	27·1	9·0	0·56	6·6
14	43	16·1	0·982	+0·41	17·1	13·3	0·69	8·0
15	49	14·46	0·954	−0·08	13·7	12·5	0·64	7·4
16	21	10·49	0·815	−1·16	20·2	8·4	0·51	5·8
17	31	12·74	0·858	+0·48	23·0	9·8	0·57	6·7
18	15·5	8·61	0·742	−1·22	10·2	7·7	0·44	5·0
19	16	6·06	0·676	−2·8	16·7	5·7	0·35	3·9
20	18	9·86	0·807	−1·33	10·2	8·9	0·49	5·6
21	7B	7·44	ND	ND	ND	ND	ND	4·5
22	30	9·66	0·806	−1·18	18·6	7·9	0·48	5·5
23	30	10·67	0·819	−0·36	17·0	8·4	0·51	5·9
24♀	5B	4·98	0·614	−1·56	17·0	4·1	0·31	3·3

B, Breast-fed; ND, not determined.

* Estimated by anthropometry (Dauncey *et al.* 1977).

† Calculated by difference from body-weight and subcutaneous fat weight.

‡ Calculated using weight and length (Gehan & George, 1970).

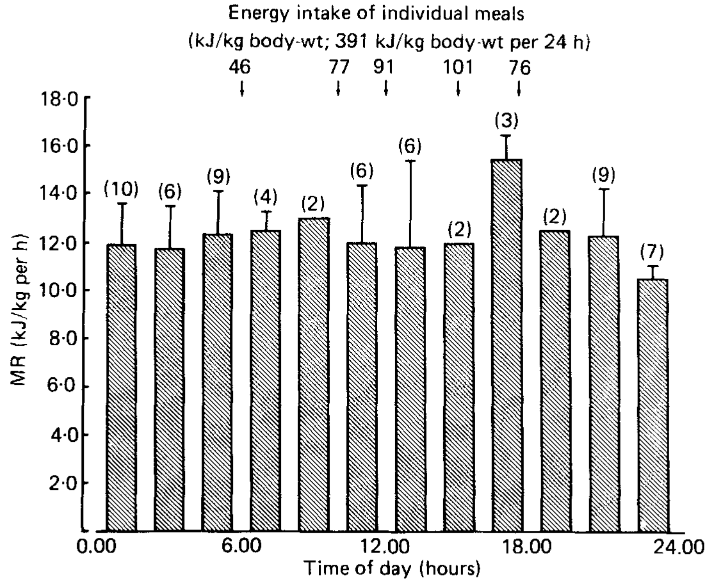

Fig. 1. Diurnal variation in metabolic rate (MR). Values are means, with their standard errors represented by vertical bars, for twenty-four children. Numbers of observations in parentheses. Values for energy contents of individual meals (↓) are based on eight children.

Table 2. *The metabolic rate (MR) and respiratory quotient (RQ) during postprandial (< 1 h after food) and resting metabolism*

(Mean values for sixty-nine measurements on twenty-four children)

	Mean postprandial			Mean resting		
Subject no.	MR (kJ/kg per h)	RQ	No. of observations	MR (kJ/kg per h)	RQ	No. of observations
1	11·1	1·01	2	9·8	0·88	1
2	8·6	0·78	2	ND	ND	0
3	11·6	0·82	1	12·4	0·8	1
4	12·1	0·82	3	ND	ND	0
5	ND	ND	0	13·3	0·96	2
6	ND	ND	0	9·8	0·89	2
7	12·2	0·98	1	11·3	0·85	2
8	10·2	0·89	1	11·7	0·84	1
9	14·9	1·09	1	12·4	1·01	4
10	16·8	0·88	2	8·0	0·86	1
11	14·0	0·95	1	12·9	1·0	3
12	14·1	0·94	1	10·9	1·08	3
13	ND	ND	0	11·5	0·94	1
14	12·7	0·84	1	11·2	0·95	1
15	11·0	1·12	4	14·1	1·07	2
16	16·5	0·83	1	12·9	1·05	1
17	10·6	0·99	4	10·1	0·96	2
18	ND	ND	0	12·8	1·21	1
19	15·2	0·95	2	11·8	1·03	2
20	2·8	0·99	1	8·7	1·22	1
21	14·9	0·88	1	ND	ND	0
22	12·2	1·11	1	13·4	1·08	3
23	11·5	1·0	2	8·9	0·9	1
24	14·0	0·9	2	ND	ND	0
Total no.			34			35
Mean	12·6*	0·94		11·4*	0·98	
SE	0·47	0·022		0·37	0·026	

ND, not determined.

Mean values for post prandial MR were statistically significantly different from those for resting MR (Student's *t* test for paired values): * $P < 0\cdot05$.

a value for the mean coefficient of variability of 9·2 (SD 6·23) %. The influence of sleep on the level of the MR was quantified by comparing values for the sleeping and awake children with available paired values. No significant difference in the level of the MR was demonstrated by Student's *t* test. The biological variability in the RMR, estimated by the coefficient of variability of the twenty mean values for the RMR (Table 2) was calculated to be 14·3%.

RMR and body size. A highly significant relation was seen between RMR and the conventional units of body size, i.e. body-weight, surface area, (estimated) lean body-weight, and body-weight$^{0\cdot75}$ (Klieber, 1964) (Fig. 5). Inspection of the coefficients of determination of the four regression equations indicates that the relation between RMR and body size was not substantially altered by substitution of the body-weight by derived units such as surface area.

Apparent energy balance, defined here as the difference between the intake of metabolizable energy and the resting expenditure, i.e. the RMR over a 24 h period, was calculated from available values for eighteen children. Twelve of these children were apparently in

Table 3. *Variation in the level of the metabolic rate (MR) and the respiratory quotient (RQ)*

(Mean values with their standard errors)

Diurnal variation						Postprandial variation					
Time of day (hours)	MR (kJ/kg per h)		RQ		No. of observations	Period postprandial (h)	MR (kJ/kg per h)		RQ		No. of obervations
	Mean	SE	Mean	SE			Mean	SE	Mean	SE	
00.00–02.00	11·85	0·75	0·95	0·03	10	> 0–2	13·5	0·79	0·91	0·04	15
> 02.00–04.00	11·75	0·72	0·98	0·05	6	> 0–4	12·1	0·64	0·98	0·03	19
> 04.00–06.00	12·33	0·59	0·99	0·05	9	> 4–6	10·9	0·45	0·99	0·04	9
> 06.00–08.00	12·45	0·39	0·99	0·03	5	> 6–8	11·4	0·58	0·99	0·58	9
> 08.00–10.00	12·95	ND	1·02	ND	2	> 8–10	11·5	0·7	0·99	0·06	6
> 10.00–12.00	11·97	0·98	1·0	0·05	6	> 10–12	12·04	0·52	1·02	0·05	9
> 12.00–14.00	11·75	1·50	0·92	0·06	6	> 12	13·9	ND	0·93	ND	2
> 14.00–16.00	11·95	ND	0·94	ND	2						
> 16.00–18.00	15·42	0·59	0·80	0·07	4						
> 18.00–20.00	12·5	ND	1·10	ND	2						
> 20.00–22.00	12·23	0·66	0·95	0·03	9						
> 22.00–24.00	10·44	0·23	0·98	0·05	8						

ND, not determined.

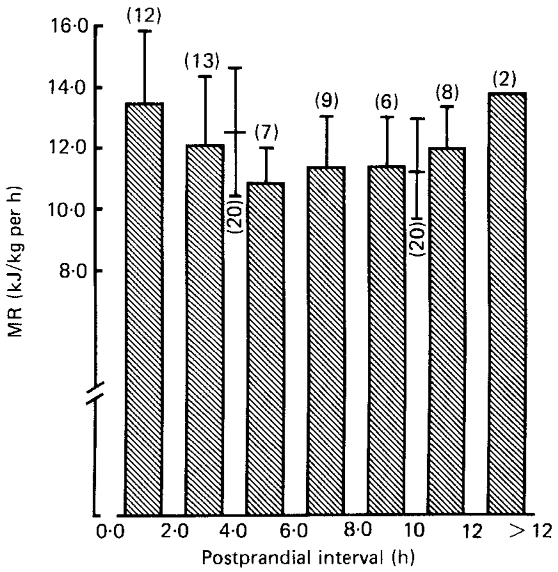

Fig. 2. Variations in metabolic rate (MR) in relation to meals. Values are means, with their standard errors represented by vertical bars. Numbers of observations in parentheses. Values for all meals are combined, leading to fewer numbers for longer postprandial intervals (usually nocturnal observations). Mean values of all postprandial and resting observations (*n* 20) are also presented.

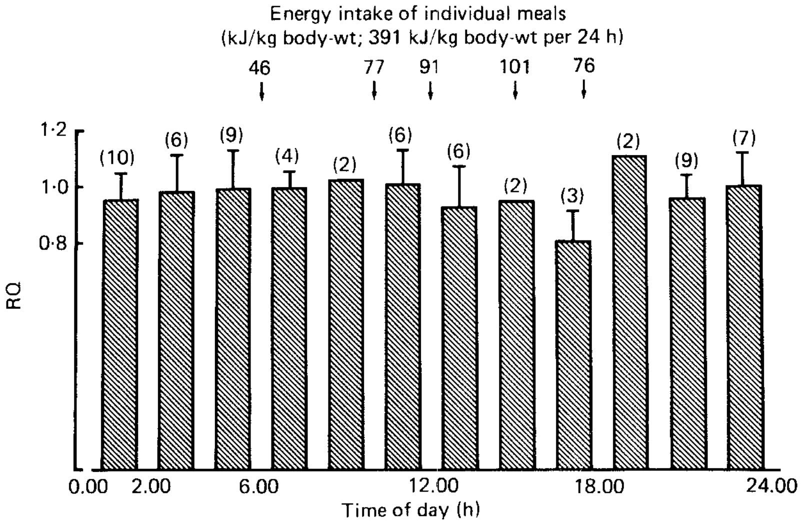

Fig. 3. Diurnal variation in the respiratory quotient (RQ). Values are means, with their standard errors represented by vertical bars, for twenty-four children. Numbers of observations in parentheses. Values for energy contents of individual meals (↓) are based on eight children.

positive balance, and the mean level of balance was equivalent to 67·3 (SE 30·04) kJ/kg per 24 h (*n* 18) (Duggan *et al.* 1985).

DISCUSSION

The mean level of energy intake by the twenty children was close to the World Health Organization (1973) recommendations and did not represent overfeeding. The nutrient composition of the energy intake (values for eight children) was typical of Third World diets

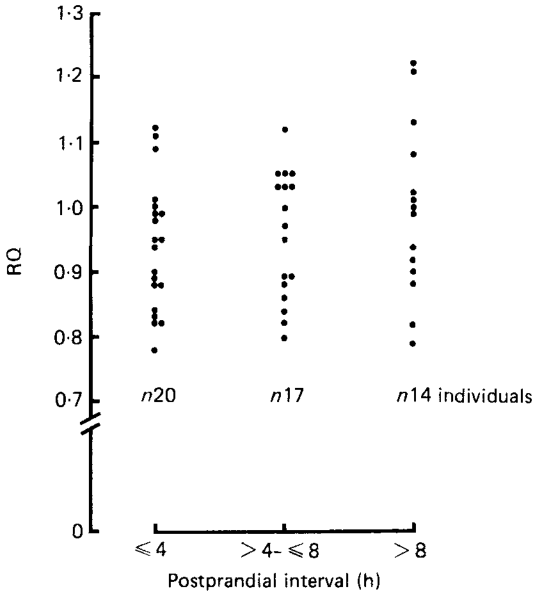

Fig. 4. Variation in the respiratory quotient (RQ) in relation to postprandial interval. Observations recorded are mean values for an individual in the stated time-period.

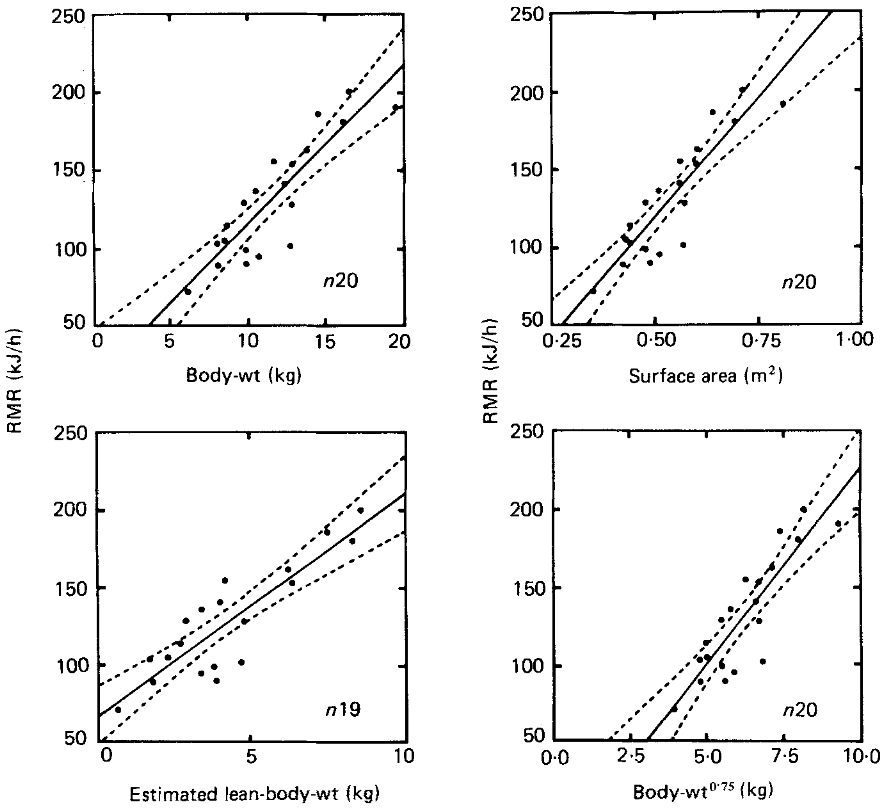

Fig. 5. The relation between resting metabolic rate (RMR) and body size estimated by body-weight, surface area, lean body-weight and body-weight$^{0\cdot75}$. r^2 is 0·78, 0·77, 0·77 and 0·78 respectively. Regression (——) and 95% confidence limits (- - -) illustrated. $P < 0\cdot001$ in each case.

(Perissé *et al.* 1969). That is to say, the percentage contribution by protein to total energy was similar to that in Western adult and toddler diets (McKillop & Durnin, 1981), but there was a lower contribution from fat and a correspondingly higher contribution from carbohydrate.

The level of the RMR in these children accords with that observed in healthy white infants and children (Table 4). The unusual findings include a postprandial elevation of the MR in the absence of overfeeding, and levels of RQ higher than have been reported in both adults (Brobeck & Dubois, 1980) and children fed on Western diets (Table 4). The postprandial enhancement of the MR was less dramatic than has been described during catch-up weight gain on high-energy, high-fat diets (Ashworth, 1969; Brooke & Ashworth, 1972). Its presence at modest levels of intake of a high-carbohydrate diet may reflect the higher biosynthetic cost when lipogenesis is from carbohydrate rather than fat (Flatt, 1978).

Lipogenesis is an important feature of normal growth in childhood. It may be calculated that about 50% of the energy gained between 9 and 12 months by the reference infant (Fomon, 1967) is deposited as fat. Lipogenesis evidently occurred during both postprandial and resting metabolism (Fig. 5), evidenced by the fact that 20% of the values for the postprandial and 33% for the resting RQ were greater than unity. Nevertheless, net fat gain, at these levels of apparent energy balance, was likely to have been small.

Our findings support the hypothesis that short-term fat storage is a feature of energy metabolism in these children, and that the cost of lipogenesis is likely to contribute, together with the cost of protein turnover, to total energy expenditure. The implications for long-term energy balance of these additional energy costs are uncertain. It may be argued that levels of RQ close to unity actually represent the oxidation of carbohydrate. We are, however, confident of our experimental estimate of the RQ, which was determined using reliable analysers, known to be unaffected by hydrogen contamination (Whyte *et al.* 1983), which were meticulously calibrated over a narrow range of gas concentrations. A similar pattern of RQ has been observed in adults after a glucose load (Acheson *et al.* 1984), and in rats in positive energy balance on a high-carbohydrate diet (G. R. Hervey and G. Tobin, unpublished results).

Although only one child was significantly wasted on the day of study, there was considerable variation in body composition, evidenced by the wide range both in the SD scores of weight-for-length, and in the estimated contribution of subcutaneous fat to total body-weight (6·7–21%) (Table 1). Nevertheless, the relation between RMR and body size was not improved when the latter was estimated by indicators which are highly influenced by body composition and conventionally expected to give a better prediction of metabolic body size than that given by body-weight. This observation contrasts with findings in adults (Miller & Blyth, 1953; Banerjee & Sen, 1958) in whom basal MR (BMR) is shown to correlate more closely with lean body mass than with body-weight or surface area.

It must, however, be remembered that the RMR, which includes some energy expenditure on growth, is an imperfect estimator of the BMR. Nevertheless, regression analysis of our previous findings for children with infection-associated underfeeding (Duggan *et al.* 1985), when the RMR is likely to be closer to the BMR, gave similar results. Alternatively, the estimate of the lean body mass may be imprecise because the geometric model of subcutaneous fat takes no account of visceral fat. The prediction of the lean body-weight by technically more sophisticated methods such as body density or total body potassium is likely to be less reliable in children than in adults, since the calculation depends on the chemical composition of the lean body. This cannot be assumed to be constant in the immature or malnourished child (Moulton, 1923; Standard *et al.* 1959; Brock & Friis Hansen, 1965; Friis Hansen, 1971). Another important consideration is the changing contribution to the total MR made by visceral organs such as the heart and the kidneys

Table 4. *Comparison of values for resting metabolic rate (RMR) and respiratory quotient (RQ) obtained in studies in infants and children*

RMR (kJ/kg per h)		RQ							
Mean	SE	Mean or range	SE	Method of indirect calorimetry	No. of observations	Age or wt range	Comment	Country	Source
11·43	0·16	1·16	0·01	Closed circuit	38	2–17 months	In hospital	USA	Benedict & Talbot (1914)
9·9	ND	ND		Closed circuit	ND	12–18 kg	Healthy children	USA	Lewis *et al.* (1943)
9·05	0·02	ND		Closed circuit	72	1–11 months	Healthy infants	Sweden	Karlberg (1952)
10·2	ND	ND		Closed circuit	15	25–43 months	Recovered malnourished	Jamaica	Montgomery (1962)
7·8–9·3	ND	ND		Ventilated hood	81 (four children)	12–18 months	Recovering malnourished	Jamaica	Ashworth (1969)
11·5	ND	0·81–0·88		Ventilated hood	34 (twelve children)	3–20 months	Recovering malnourished	Jamaica	Brooke & Ashworth (1972)
10·8	ND	ND		Ventilated hood	20	4–5 years	Children of obese parents	England	Griffiths & Payne (1976)
11·7	ND	ND		Ventilated hood	8 (seven children)	9–18 years	Healthy children	USA	Kien *et al.* (1978)
10·2	ND	ND		Ventilated incubator	15	10–29 d	Low birth weight	England	Brooke *et al.* (1979)
10·4–11·7	ND	ND		Ventilated incubator	34 (six children)	1–7 d	Low birth weight	The Netherlands	Sauer *et al.* (1979)
7·4	0·2	0·94	0·01	Ventilated incubator	28 (thirteen children)	0–1 month	Low birth weight	Canada	Chessex *et al.* (1981)
11·38	0·37	0·94	0·02	Ventilated hood	35 (twenty children)	5–79 months	Healthy children	Kenya	Present study

ND, not determined.

during the course of childhood growth (Holliday, 1971). It is also evident that the burden of lean weight loss during malnutrition is largely borne by muscle, with relative sparing of vital structures.

As a result of complex changes associated with the chemical maturation of the lean body, and the unequal rates of weight gain (and loss) by various organs in the growing body, the lean body mass may be a less reliable index of metabolic body size in the child than it is in the adult. In practical terms there appears to be no advantage in standardizing RMR with reference to body size indicators other than simple body-weight.

In summary these findings suggest that ethnic variation in the RMR is unlikely in children and that body-weight is an acceptable metabolic standard. The level of RQ and the enhancement of the postprandial MR observed in the present study is likely to represent the normal pattern of energy metabolism in healthy children eating a high-carbohydrate diet.

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