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Total energy expenditure in small for gestational age infants

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Abstract

***Aim*—To measure total energy expenditure and body composition in small for gestational age (SGA) infants in order to investigate proposed hypermetabolism in such babies.**

***Methods*—A cross sectional study of 52 SGA infants measured at 5 weeks of age was made, using existing data from appropriate for gestational age (AGA) infants as controls. The double labelled water technique was used to assess both total energy expenditure and body composition.**

***Results*—Multiple regression analysis showed that expressing energy expenditure per kg fat free mass adjusts for body composition in infants of this age. The relation between total energy expenditure and fat free mass differed between the two groups.**

***Conclusion*—These data indicate that for a given fat free mass the total energy expenditure of SGA infants is greater than that of AGA infants. Such data should be taken into account when energy requirements for SGA infants are being considered.**

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Keywords: energy expenditure, small for gestational age, body composition, fat free mass.

It has long been suggested that infants born small for gestational age (SGA) have a higher metabolic rate than appropriate for gestational age (AGA) infants,[1–5] leading to the concept of relative hypermetabolism in SGA infants. Understanding the pathophysiology of energy metabolism in growth retarded and undernourished infants is of considerable importance in nutritional management and may have implications for long term outcome. However, it is also known that body composition is altered in SGA infants, with a reduction in fat stores.[6 7] Differences in body composition can produce artificial differences in metabolic rate when this is expressed as kJ/kg body weight or as oxygen consumption in ml/kg body weight.[8–10] Metabolic variables are better expressed relative to fat free mass (FFM), which at least partly negates the effect of body size and body composition.[11–13]

In the past it has been difficult to measure both total energy expenditure (TEE) and body composition in infants, but the double labelled water technique now makes such measurements possible.[14 15] Thus we assessed the correlation between total energy expenditure and fat free mass in a cohort of SGA infants and AGA infants at 5 weeks of age, in order to investigate potential differences in energy metabolism between the two groups.

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Methods

All infants were recruited from the Rosie Maternity Hospital, Cambridge. A total of 52 AGA infants and 54 SGA infants were recruited when the infants were less than 4 days old. Infants were classified as SGA if their birthweight was below the 10th centile for gestation using Gairdner and Pearson charts.[16]

The SGA infants were initially recruited for a randomised placebo controlled study to test the hypothesis that L-carnitine supplementation in term SGA infants would improve catchup growth. Infants were randomly allocated to receive daily carnitine or placebo for the first 12 weeks of life, and were stratified by diet and sex. The assessment of total energy expenditure in SGA infants, reported here, was an additional planned outcome of the study.

At about 5 weeks of age, TEE was measured using the double labelled water technique over seven days. The technique has been described elsewhere in detail[11 14]; it involves an oral administration of two stable isotopes (^{2}H and ^{18}O) and the subsequent collection of spot urine samples for seven days. Isotopic enrichment in the pre- and post-dose samples was analysed using isotope ratio mass spectrometry. The multipoint approach was used with an assumed respiratory quotient over the seven days of 0·855.

Fat free mass (FFM) was calculated from the measurement of total body water inherent in the double labelled water technique. Reference values[17] were used for the proportion of water in FFM in the calculation. Body weight, length, and head circumference were also recorded.

STATISTICAL ANALYSIS

The correlation between TEE and FFM in the AGA and SGA groups was modelled by multiple regression, with TEE as the dependent variable. Both TEE and FFM were analysed after logarithmic transformation to test for a power relation and to adjust for heteroscedasticity. The difference between groups was modelled by a dummy variable (1/0) identifying the SGA group, and an interaction between the SGA babies and FFM was also tested for.

Results

Measurements of total energy expenditure were obtained in 89 (49 AGA; 40 SGA)

Table 1 Some physical characteristics of the infants at birth and aged 5 weeks

	AGA (mean (SD))	*SGA (mean (SD))*
Gestation (weeks)	39·8 (1·4)	39·2 (1·3)
Birthweight (kg)	3·42 (0·45)	2·60 (0·24)
Weight (kg)	4·42 (0·48)	3·71 (0·35)
Length (cm)	54·7 (1·8)	52·2 (1·9)
Head circumference (cm)	38·0 (1·2)	36·6 (1·05)
Total energy expenditure (kJ)	1276 (380)	1301 (401)
Fat free mass (kg)	3·73 (0·33)	3·23 (0·36)
Fat mass (kg)	0·81 (0·32)	0·47 (0·26)
% Fat	17·5 (5·9)	12·5 (6·7)

infants. Of the other 17 initial recruits, one of the SGA infants died before the age of 5 weeks, and four families withdrew from the study before measurement. Reasons for other loss of data included poor parental compliance and the infant possetting or vomiting during or soon after dosing. There was no significant difference in TEE between those infants receiving carnitine or placebo and so the data have been combined.

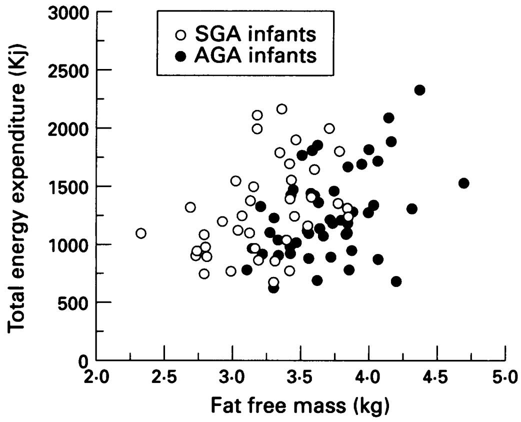
Some physical characteristics of the two groups at 5 weeks of age of infants are shown in table 1. The SGA infants differed significantly from the AGA infants having a lower body weight ($t=8·9$; $P<0·001$), being shorter ($t=6·35$; $P<0·001$) and with less body fat ($t=3·72$; $P<0·001$). Total energy expenditure did not differ significantly ($t=0·34$). Data on the AGA infants have been reported before.[11] The correlation between TEE and FFM in both the AGA and SGA infants are shown in fig 1.

The results of the multiple regression analysis shown in table 2 revealed that the appropriate power for FFM in the model – that is, 1·21 – was not significantly different from 1, showing that the ratio TEE:FFM adjusts for FFM in this age group of infants. Regression analysis also revealed that the correlation between FFM and TEE differed between the two groups of infants with the intercept of the regression lines differing significantly ($t=2·65$; $P<0·1$), but the slopes were not significantly different ($t=0·25$; $P=0·803$). This indicates that for a given fat free mass, the total energy expenditure of the SGA infant is greater than that of AGA infants.

Discussion

As would be expected at 5 weeks of age, the SGA infants were lighter, shorter, and had a smaller head circumference than AGA infants. Moreover, body composition differed, with the SGA infants having a significantly lower percentage body fat. The definition of SGA being below the 10th centile will clearly produce a heterogenous group of infants and the reasons for their relative smallness may be varied. Nevertheless, the definition is a standard one and the differences we have found in the correlation between fat free mass and total energy expenditure might not have been so profound if the smallness of the babies was produced by a vast array of causes.

Total energy expenditure has been shown to differ in SGA in comparison with AGA infants



Correlation between TEE and FFM in both sets of infants. Closed circles represent AGA infants; open circles SGA infants.

when the fat free mass of the infants is taken into account. Further measures of energy metabolism such as sleeping metabolic rate, the energy cost of growth, and thermogenesis would be required to evaluate which components of total energy expenditure are raised in SGA infants. Nevertheless, existing data in slightly older infants suggest that the largest components of TEE are basal metabolic rate and the energy cost of activity.[18 19] It should be remembered that while the energy cost of growth is very high at 5 weeks of age, this cost is primarily energy stored and this will not be measured by the double labelled water technique as energy expended.

There is little evidence to suggest that the energy cost of activity is greater in SGA infants, and in fact several studies have reported similar levels of activity when compared with AGA infants.[3 5] Therefore, it is more likely that basal metabolic rate is greater per kilogram of fat free mass in SGA infants. The two compartment body composition model – that is, dividing the body into fat and fat free masses – is the simplest of a number of multicompartmental models that now exist. It would be naive to consider that the composition of the fat free mass is consistent between individuals in terms of either tissue types or organ sizes. Abdulrazzaq and Brooke[5] suggested that the increased energy expenditure in SGA infants is explained, at least in part, by the relatively large brain in comparison with AGA infants. In this study the SGA infants had a significantly smaller mean head circumference than the AGA infants. Nevertheless head size, and by inference brain size, should be related to fat free mass in order to test the hypothesis proposed by Abdulrazzaq and Brooke. However, head circumference was not a significant factor in determining the TEE of the SGA infants, after adjusting for fat free mass.

Table 2 Result of multiple regression analysis, with TEE the dependent variable

Predictor	*Coefficient*	*Standard deviation*	*t ratio*	*P value*
Constant	5·52	0·39	14·07	<0·001
FFM	1·21	0·30	4·07	<0·001
Dummy variable (SGA *vs* AGA)	0·19	0·07	2·65	<0·01

While head circumference is, of course, only a proxy to brain size, this finding casts doubt on the often quoted correlation between a high TEE in SGA infants and relatively large brain size. The sizes of other organs which contribute significantly to metabolic rate in neonates (liver, heart, kidney, etc) could not be evaluated in this study and thus the combined effect of organ size relative to the remainder of the fat free mass cannot be evaluated. A reduction in cell mass may mainly only affect muscle mass, a relatively low energy expending tissue, with other more metabolically active organs such as the liver being spared from a similar reduction in cell mass.

This study shows that total energy expenditure is significantly higher in SGA infants when FFM has been adjusted for. If energy requirements of SGA babies are based, therefore, on body weight alone, using national or international recommendations, the energy requirement will be underestimated. Such data should be taken into account when energy requirements for SGA infants are being considered.

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1 Hill JR, Robinson DC. Oxygen consumption in normally grown, small-for-dates and large-for-dates new born infants. *J Physiol* 1968; **199:** 685–703.
2 Bhakoo NN, Scopes JW. Minimal rates of oxygen consumption in small-for-dates babies during the first week of life. *Arch Dis Child* 1974; **49:** 583–5.
3 Chesse P, Reichman B, Verellen G, Putet G, Smith JM, Heim T, *et al.* Metabolic consequences of intrauterine growth retardation in very low birth-weight infants. *Ped Res* 1984; **18:** 709–13.
4 Couderay M, Schutz Y, Micheli JL, Calome A, Jequier E. Energy-nitrogen balances and protein turnover in small and appropriate for gestational age low birth-weight infants. *Eur J Clin Nutr* 1988; **42:** 125–36.
5 Abdulrazzaq YM, Brooke OG. Is the raised metabolic rate of the small-for-gestation infant due to his relatively large brain size? *Early Hum Dev* 1988; **16:** 253–61.
6 Brooke OG, Wood C, Butters F. The body proportion for small-for-dates infants. *Early Hum Dev.* 1984; **10:** 85–94.
7 Picaud J-C, Putet G, Rigo J, Salle L, Senterre J. Metabolic and energy balance in small and appropriate for gestational age very low birth-weight infants. *Acta Paediatr (Suppl)* 1994; **405:** 54–9.
8 Davies PSW, Cole TJ, Lucas A. Adjusting energy expenditure for body weight in early infancy. *Eur J Clin Nutr* 1989; **43:** 641–5.
9 Wells JCK, Davies PSW. Sleeping metabolic rate and body size in 12 week old infants. *Eur J Clin Nutr* 1995; **49:** 323–8.
10 Davies PSW. Energy metabolism and obesity in childhood. *Hormone Res* 1993; **39:** 77–80.
11 Davies PSW, Ewing G, Lucas A. Energy expenditure in early infancy. *Br J Nutr* 1989; **62:** 621–9.
12 Owen OE, Holup JL, D'Alessio DA, Craig ES, Polansky M, Smalley KJ, *et al.* A reappraisal of the calorific requirements of man. *J Clin Nutr* 1987; **46:** 875–85.
13 Ravussin E, Borgardus C. Relationship of genetics, age and physical fitness to daily energy expenditure and fuel utilization. *Am J Clin Nutr* 1989; **49:** 968–75.
14 Coward WA. The doubly-labelled water ($^2H_2{}^{18}O$) method: principles and practice. *Proc Nutr Soc* 1988; **47:** 209–18.
15 Coward WA, Roberts SB, Cole TJ. Theoretical and practical considerations on the doubly-labelled water ($^2H_2{}^{18}O$) method for the measurement of carbon dioxide production rate in man. *Eur J Clin Nutr* 1988; **42:** 207–12.
16 Gairdner D, Pearson J. Revised Gairdner-Pearson growth charts. *Arch Dis Child* 1985; **60:** 1202–6.
17 Fomon SJ, Haschke F, Ziegler EE, Nelson SE. Body composition of reference children from birth to age 10 years. *Am J Clin Nutr* 1982; **35:** 1169–75.
18 Wells JCK, Davies PSW. The components of energy metabolism in 12 week old infants. *Ann Hum Biol* 1995; **22:** 175.
19 Wells JCK, Davies PSW. The energy cost of physical activity in 12 week old infants. *Am J Hum Biol* 1995; 7 85–92.