Total energy expenditure, body fatness, and physical activity in children aged 6–9 y[1,2]

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ABSTRACT

Background: The recent worldwide increase in the prevalence of childhood obesity may be due in part to a decrease in children's physical activity levels.

Objective: The current study of children in the years just before puberty aimed to *1*) measure total energy expenditure (TEE) by use of the doubly labeled water (DLW) method, *2*) determine the proportion of TEE related to physical activity, *3*) investigate the relations between measures of physical activity and body fatness, and *4*) investigate possible sex differences in these relations.

Design: The DLW technique was used to measure TEE over 10 d in 106 healthy children (52 boys) aged 7.8 ± 0.9 y ($\bar{x}$ ± SD). Fat-free mass, and hence fat mass, was derived from the ^{18}O dilution space. Resting energy expenditure (REE) was calculated with use of the Schofield equations. Physical activity level was calculated as TEE/REE.

Results: Mean TEE in both boys (7871 ± 1135 kJ/d) and girls (7512 ± 1195 kJ/d) was significantly different ($P < 0.0001$) from FAO/WHO/UNU recommendations (13% and 9% lower, respectively). There was no significant difference in physical activity level between boys (1.69 ± 0.22) and girls (1.71 ± 0.23). In boys but not girls, physical activity level was inversely correlated with BMI ($r = -0.37$, $P < 0.01$), fat mass ($r = -0.46$, $P < 0.005$), and percentage of body fat ($r = -0.50$, $P < 0.0001$).

Conclusions: In boys but not girls, percentage of body fat is inversely associated with physical activity level. Physical activity is one factor contributing to body fatness in boys, but additional factors may influence the size of the fat stores in girls. *Am J Clin Nutr* 2001;74:524–8.

KEY WORDS Energy expenditure, doubly labeled water, children, body fat, body composition, physical activity, sex differences, childhood obesity

INTRODUCTION

The prevalence of overweight and obesity in children in Australia and other westernized countries has increased significantly over the past 2 or more decades (1–4). This increase in prevalence has arisen as a result of major environmental change, including changes in physical activity energy expenditure (AEE) and dietary energy and fat intakes (2).

The years just before puberty (ages 6–9 y) are an important time to target the management and prevention of obesity in children. This period overlaps with the time of adiposity rebound (between 4 and 7 y of age), the period when adiposity, as measured by body mass index or triceps skinfold thickness, begins to rise again (5). This period is recognized as a critical period for the development of obesity, with early adiposity rebound appearing to predict the development of later obesity (5–7). The ages of 6–9 y are also of interest because this is a time when activity and eating patterns may be changing as children become established in school and other routines of middle childhood. For these reasons, it was of particular interest to examine the relation between physical activity and body fatness in children of this age group.

AEE is one component of total energy expenditure (TEE), the other components of which are resting energy expenditure (REE), the thermic effect of food, and the energy cost of growth. The doubly labeled water (DLW) technique enables the noninvasive measurement of TEE in free-living subjects over a 10–14-d period and is a well-established reference method for measuring TEE and the energy expenditure due to physical activity (8–12).

In a meta-analysis of DLW studies conducted in adults, Westerterp and Goran (13) examined the relation between physical activity and body composition and found that there was a sex difference: in males but not females, a lower physical activity level (PAL) was associated with a higher percentage of body fat. In a study of preschool children, however, Davies et al (14) found that high percentages of body fat were associated with low PALs in both boys and girls. Most of the studies in which the DLW method was used to measure TEE and AEE in children were conducted in very young children, ie, those aged 1–5 y (15–18); few DLW studies have been performed in children aged 6–9 y (19–21). The aims of the current study of children in the years just before puberty were to *1*) measure TEE by DLW, *2*) determine the proportion of

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TEE related to physical activity, *3*) investigate the relations between measures of physical activity and body fatness, and *4)* investigate possible sex differences in these relations.

SUBJECTS AND METHODS

Subjects

One hundred six children (52 boys and 54 girls) aged 6.0–9.6 y were involved in this study. Sixty-two children were recruited from 28 state primary schools in western Sydney, 39 were recruited from one state school in Brisbane, and 5 were recruited through university staff at the Queensland University of Technology. In Sydney, all state schools within a 10-km radius of the study center, an area that encompasses a population with wide-ranging socioeconomic status, were contacted by letter. With the approval of the school principals, the information was then distributed to the parents, inviting their children to participate in the study. In Brisbane, children were recruited from one state school and through staff at the Queensland University of Technology. In both Sydney and Brisbane, children with a chronic illness other than asthma or with acute illness at the time of the study were not recruited. At the time of the study, no children were taking medications that would have affected the results, such as β_2 agonists or methylphenidate.

The study protocol was explained to the parents and the children, and informed, written consent was obtained from a parent. In Sydney the study was approved by the Human Ethics Committee of The Children's Hospital at Westmead, and the NSW Department of Education and Training gave approval for the children to be recruited through state schools. In Brisbane the study was approved by the Queensland University of Technology Human Research Ethics Committee and approval was also given from the relevant state school in conjunction with Education Queensland.

Protocol

In Sydney, children attended the study center (James Fairfax Institute of Paediatric Nutrition at The Children's Hospital at Westmead) after school or during school holidays. The subjects were studied from June 1998 to February 1999. At this visit, the study protocol was explained, anthropometric measurements were obtained, and the DLW dose was given as detailed below. In Brisbane, children were visited at home initially, where they were given the dose of doubly labeled water. The children then attended the Human Movement Clinic at the Queensland University of Technology for their anthropometric measurements.

Anthropometry

Anthropometric measurements were made by using standardized techniques. In both study centers, standing stretched height (±0.1 cm) was measured with a Harpenden stadiometer (Holtain Ltd, Crymych, United Kingdom). Body weight (±0.01 kg) in light clothing was measured by using digital scales. Body mass index (BMI) was calculated as weight/height^2 (in kg/m^2).

The heights, weights, BMIs, and ages of the boys and girls in our study were compared with those of a recently well-sampled population of Australian schoolchildren [Health of Young Victorians Study (1)]. Weight, height, and BMI were also compared with the National Center for Health Statistics (NCHS) reference population (22, 23). These measurements were normalized by being expressed as SD (*z*) scores (23, 24).

Total energy expenditure

TEE was measured over a period of 10 d by using the DLW method. A baseline urine sample was collected before the subjects were given an oral DLW dose (0.05 g/kg ^2H_2O and 0.125 g/kg $H_2{}^{18}O$) from a flask with use of a drinking straw. The flask was weighed before and after dosing to calculate the actual dose given. Isotopes were from CK Gas Products Ltd ($H_2{}^{18}O$; Berkshire, United Kingdom) and the Australian Nuclear Science and Technology Organisation (^2H_2O; Lucas Heights, Australia). At home, subjects collected a urine sample 3–6 h postdose and then once daily for the next 10 d. Samples were frozen until collected by the research assistant at the end of this period. Samples were analyzed for ^2H_2O and $H_2{}^{18}O$ by isotope ratio mass spectrometry in the energy metabolism laboratory at the Queensland University of Technology. The technique is described in detail elsewhere (25, 26). In brief, the multipoint approach was used with an assumed respiratory quotient over the 10-d period of 0.85. In individuals in energy balance and with zero or minimal growth over a period of days, TEE will also be equal to total energy intake. In the age range of the children in this study, the energy stored in new tissue, ie, growth, will be a very small proportion (≈2%) of total energy intake.

Measurement of body composition

Fat-free mass was calculated from the ^{18}O dilution space by assuming that this is 1% larger than total body water and by using the appropriate value for the hydration of fat-free mass in children of different ages (27). Fat mass was calculated as the difference between body weight and fat-free mass. Percentage of body fat was calculated by using fat mass and body weight.

Resting energy expenditure

Children were measured after school and it was therefore not possible to determine the REE of each subject in the fasted state. It was shown in our facility and in others, however, that there is good agreement between the REE of children measured by indirect calorimetry and the REE predicted by the Schofield equations (28–30). For example, Firouzbakhsh et al (29) measured REE directly in 199 healthy children aged 5–16 y and found good agreement between measured REE and REE predicted by the Schofield equations. The Schofield equations have been widely used to predict REE in several studies in children (31–33). We therefore calculated predicted REE for each subject by using the Schofield equations based on body weight, age, and sex (30).

Statistical analysis

The data were analyzed by using SPSS for WINDOWS (version 9.0; SPSS Inc, Chicago), and all data are presented as means ± SDs. A one-sample Student's *t* test was used to test for differences between *1*) children's height, weight, and BMI *z* scores and the NCHS reference population median and *2*) World Health Organization recommendations for energy intake and the TEE of the children in the study. One-way analysis of variance was used to examine differences in physical characteristics, total energy expenditure, and PALs between boys and girls. Pearson's correlation coefficient was used to derive the level of association between variables. Stepwise multiple regression analysis was used to examine relations between sex, measures of energy expenditure, and body composition. A nonparametric test (Mann-Whitney *U* test) was used to compare the age, height, weight, and BMI of the children in our study with those of

TABLE 1
Physical characteristics, total energy expenditure, and measures of physical activity of subjects[1]

	Total group (n = 106)	Boys (n = 52)	Girls (n = 54)
Age (y)	7.8 ± 0.9	7.8 ± 0.9	7.8 ± 0.9
Height (cm)	127.5 ± 7.8	127.9 ± 8.4	127.1 ± 7.2
Height z score	0.34 ± 0.93[2]	0.37 ± 1.06[2]	0.30 ± 0.80[2]
Weight (kg)	27.8 ± 6.2	27.6 ± 6.3	28.1 ± 6.1
Weight z score	0.60 ± 1.11[2]	0.55 ± 1.24[2]	0.64 ± 0.98[2]
BMI (kg/m^2)	17.0 ± 2.4	16.7 ± 2.3	17.2 ± 2.4
BMI z score	0.20 ± 0.97[2]	0.08 ± 1.00	0.31 ± 0.93[2]
Fat mass (kg)	8.0 ± 3.9	7.1 ± 3.8	8.8 ± 4.0[3]
Fat-free mass (kg)	20.0 ± 3.4	20.5 ± 3.8	19.2 ± 2.8[3]
Percentage of body fat (%)	27.5 ± 8.1	24.6 ± 8.4	30.3 ± 6.8[4]
TEE			
(kJ)	7688 ± 1174[5]	7871 ± 1135[5]	7512 ± 1195[5]
(% of WHO recommendation)[6]	89 ± 16	87 ± 15	91 ± 16
PAL (TEE/REE)	1.70 ± 0.23	1.69 ± 0.22	1.71 ± 0.23
AEE			
(kJ)	3139 ± 989	3178 ± 969	3101 ± 1016
(% of TEE)	40.0 ± 8.0	39.7 ± 8.0	40.3 ± 8.1

[1] x ± SD. TEE, total energy expenditure measured by doubly labeled water; PAL, physical activity level; REE, resting energy expenditure; AEE, activity energy expenditure (TEE − REE).
[2] Significantly different from the National Center for Health Statistics (20, 21) reference population median of zero, $P < 0.05$.
[3,4] Significantly different from boys (one-way ANOVA): [3] $P < 0.05$, [4] $P < 0.0001$.
[5] Significantly different from FAO/WHO/UNU (34) recommendations, $P < 0.0001$.
[6] FAO/WHO/UNU recommendation for energy intake based on weight, age, and sex (34).

children in the Health of Young Victorians Study (1) because of the unequal numbers in the 2 studies.

RESULTS

Characteristics of children

The physical characteristics of the total group and of boys and girls separately are shown in **Table 1**. Boys were not significantly different from girls with respect to weight, weight z score, height, height z score, BMI, and BMI z score. However, as expected, fat mass and percentage of body fat were significantly higher in girls and fat-free mass was significantly higher in boys.

The mean height, weight, and BMI z scores of both the total group and of the girls were significantly different from zero, indicating that these groups were taller, heavier, and had a higher BMI than did the NCHS reference population. The mean height and weight z scores of the boys were also significantly different from zero. By contrast, the heights, weights, and BMIs of our study group were not significantly different from those of the Australian reference population (1).

Comparison of energy expenditure variables between boys and girls

Also shown in Table 1 are data on TEE, measures of physical activity, and TEE as a percentage of published reference values for energy intake (32). The FAO/WHO/UNU recommendations used were those based on body weight as the major predictor of energy requirements, classified according to age and sex. In both boys and girls, TEE was significantly lower than published recommendations for energy intake (13% and 9% lower, respectively).

Three indexes of physical activity are shown in the table: PAL, which is the ratio of TEE to REE; AEE, which is the difference between TEE and predicted REE; and AEE as a percentage of TEE. The mean values for PAL and AEE as a percentage of TEE were not significantly different between boys and girls.

Relations between energy expenditure variables and anthropometric variables

Summarized in **Table 2** are the significant correlations between energy expenditure variables and anthropometric variables for boys and girls. Sex was a significant predictor of percentage of body fat ($R^2 = 0.123$, $P < 0.0001$), fat mass ($R^2 = 0.049$, $P = 0.022$), and fat-free mass ($R^2 = 0.037$, $P = 0.048$). Therefore, separate analyses were performed for boys and girls to investigate the relations between measures of body composition and measures of physical activity.

In boys, PAL and AEE as a percentage of TEE were inversely related to weight, weight z score, BMI, BMI z score, fat mass, and percentage of body fat. The relation between PAL and percentage of body fat is shown in **Figure 1**. There was a significant relation between these 2 variables for boys but not for girls. The regression line for boys is shown in the figure and is represented by the equation

$$PAL = -0.013 \times \text{percentage of body fat} + 2.00 \qquad (1)$$

for which R^2 is 0.25, $P < 0.0001$, and SEE = 0.003.

DISCUSSION

In this study of 106 children, TEE measured by DLW was ≈11% lower than current recommendations for energy intake (34). The recommendations for the energy requirements of children of the FAO/WHO/UNU report were based on measured energy intake increased by 5% to allow for a desirable PAL (34). When this report was published, no accurate data on the direct assessment of average daily energy expenditure were available because the DLW method was not widely in use. Our

TABLE 2
Correlations between energy expenditure components and anthropometric variables[1]

	Boys (n = 52)			Girls (n = 54)		
	TEE	AEE (% of TEE)	PAL	TEE	AEE (% of TEE)	PAL
Height	0.52[2]	−0.13	−0.17	0.54[2]	0.04	0.002
Height z score	0.40[3]	−0.21	−0.22	0.34[4]	0.03	−0.01
Weight	0.52[2]	−0.32[4]	−0.32[4]	0.54[2]	−0.10	−0.12
Weight z score	0.28[4]	−0.42[3]	−0.40[3]	0.38[5]	−0.21	−0.14
BMI	0.30[4]	−0.40[3]	−0.37[5]	0.39[3]	−0.16	−0.17
BMI z score	0.16	−0.41[3]	−0.37[5]	0.26	−0.14	−0.14
Fat mass	0.23	−0.51[2]	−0.46[3]	0.46[2]	0.13	−0.16
Fat-free mass	0.64[2]	−0.02	−0.07	0.53[2]	−0.03	−0.04
Percentage of body fat (%)	−0.05	−0.56[2]	−0.50[2]	0.35[4]	−0.13	−0.16

[1] TEE, total energy expenditure measured by doubly labeled water; AEE, activity energy expenditure (TEE – REE); PAL, physical activity level (TEE/REE).
[2] $P < 0.0001$.
[3] $P < 0.005$.
[4] $P < 0.05$.
[5] $P < 0.01$.

findings agree with the results of several studies, mostly in younger children, which also found that TEE measured by the DLW method yields lower values than current recommendations for energy intake (13–15). Because our findings are based on a selected sample of Australian children, however, we must exercise some caution when extrapolating our results to the wider pediatric population.

The mean PAL values for both boys (1.69) and girls (1.71) in the present study are similar to or a little lower than the values reported in other studies of children of the same age (17, 19, 35). In the current study, the mean values for AEE as a percentage of TEE (39.7% in boys and 40.3% in girls) were lower than those reported in a UK study of 7-y-old children (45.1% in boys and 47.9% in girls) (17). An important question to be considered when comparing PAL between studies is how representative are those studies of the populations from which they were sampled? The anthropometric characteristics (height, weight, and BMI) of our sample of children were not significantly different from those reported in a recent population study of healthy Australian children (1). This suggests that, in terms of growth and body fatness, our sample is representative of the Australian pediatric population and that our results can be generalized to this population.

The development of the DLW method has enabled the relation between physical activity and body composition to be investigated more reliably. Studies have shown that low PALs in children aged 1–5 y are associated with increased percentages of body fat (12, 14). The results of our study show that for the total group of 106 children there was an inverse association between PAL and measures of body fatness. However, there was a notable sex difference: in boys but not in girls, a higher percentage of body fat, fat mass, weight, weight z score, BMI, and BMI z score were each associated with lower PALs and lower AEEs as a percentage of TEE. These results agree with those of Ku et al (36), who found that moderate and strenuous activity scores (calculated by use of activity diaries) in 8-y-old boys had significant inverse correlations with percentage of body fat, whereas there was no significant correlation of activity with body fatness in 8-y-old girls. Sex differences between physical-activity-related energy expenditure and body composition were also previously reported in adults (11). In a meta-analysis of 22 studies in which the TEE of 290 subjects aged 18–49 y was measured by DLW, a significant relation between AEE and percentage of body fat was observed in men but not in women (13). The current study is the first to find a similar sex difference in children in the years just before puberty.

Our study protocol did not allow us to investigate the reasons for the sex difference we found in the relation between measures of physical activity and body fatness. A possible explanation is that in boys aged 6–9 y, either the PAL has a primary influence on body fat or body fatness significantly affects the PAL. In contrast, the PAL may play a less significant role in determining body fatness in girls. In girls, other factors, such as a greater effect of dietary energy or dietary fat intake on body fatness or differences in nutrient partitioning between the sexes, may be more important. A study in adults examined the effect of an increase in physical activity on energy balance and body composition without limiting energy intake (37). A more pronounced loss of body fat mass in men than in women was observed; women tended to compensate for increased energy expenditure by increasing their energy intake. In light of these findings in adults, the sex differences found in the current study of children in the years just before puberty warrant further investigation.

Our results suggest that lower PALs may contribute to the rise in prevalence of childhood obesity, particularly in boys. Further

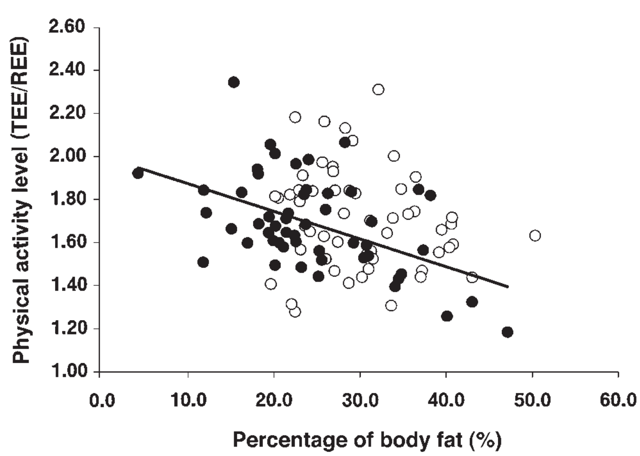

FIGURE 1. Relation between physical activity level [total energy expenditure (TEE)/resting energy expenditure (REE)] and percentage of body fat for 106 girls (○; $r = -0.16$, NS) and boys (●; $r = -0.50$, $P < 0.0001$). The regression line for boys is shown.

studies are required to investigate the contribution of physical activity, sex differences, dietary intake, and related factors to body fatness so that appropriate interventions can be targeted to the important public health problem of obesity.

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REFERENCES

1. Lazarus R, Wake M, Hesketh K, Waters E. Change in body mass index in Australian primary school children, 1985–1997. Int J Obes Relat Metab Disord 2000;24:679–84.
2. World Health Organization. Obesity: preventing and managing the global epidemic. Report of a WHO consultation. Geneva 3–5 June 1997. Geneva: WHO, 1998. (WHO/NUT/98.1.)
3. Trioano RP, Flegal KM, Kuczmarski RJ, Campbell SM, Johnson CL. Overweight prevalence and trends for children and adolescents. The National Health and Nutrition Surveys, 1963 to 1991. Arch Pediatr Adolesc Med 1995;149:1085–91.
4. Freedman DS, Srinivasan SR, Valedz RA, Williamson DF, Berenson GS. Secular increases in relative weight and adiposity among children over two decades: the Bogalusa Heart Study. Pediatrics 1997;99:420–6.
5. Rolland-Cachera MF, Deheeger M, Bellisle F, Sempe M, Guilloud-Bataille M, Patois E. Adiposity rebound in children: a simple indicator for predicting obesity. Am J Clin Nutr 1984;39:129–35.
6. Whittaker RC, Pepe MS, Wright JA, Seidel KD, Dietz WH. Early adiposity rebound and the risk of adult obesity. Pediatrics [serial online] 1998;101:E5. Internet: http://www.pediatrics.org/cgi/content/full/101/3/e5 (accessed 30 July 2001).
7. Dietz WH. Periods of risk in childhood for the development of adult obesity—what do we need to learn? J Nutr 1997;127:1884S–6S.
8. Schoeller DA, van Santen E. Measurement of energy expenditure in humans by doubly labeled water method. J Appl Physiol 1982;53:955–9.
9. Schoeller DA, Ravussin E, Schutz Y, Acheson KJ, Baertschi P, Jequier E. Energy expenditure by doubly labeled water: validation in humans and proposed calculation. Am J Physiol 1986;250:R823–30.
10. Seale JL, Conway JM, Canary JJ. Seven-day validation of doubly labeled water method using indirect room calorimetry. J Appl Physiol 1993;74:402–9.
11. Schoeller DA. Measurement of energy expenditure in free-living humans using doubly labeled water. J Nutr 1988;118:1278–89.
12. Goran MI. Application of the doubly labeled water technique for studying total energy expenditure in young children: a review. Pediatr Exerc Sci 1994;6:11–30.
13. Westerterp KR, Goran MI. Relationship between physical activity related energy expenditure and body composition: a gender difference. Int J Obes Relat Metab Disord 1997;21:184–8.
14. Davies PSW, Gregory J, White A. Physical activity and body fatness in pre-school children. Int J Obes Relat Metab Disord 1995;19:6–10.
15. Goran MI, Carpenter WH, Poehlman ET. Total energy expenditure in 4- to 6-yr-old children. Am J Physiol 1993;264:E706–11.
16. Fontvieille AM, Harper IT, Ferraro RT, Spraul M, Ravussin E. Daily energy expenditure by five-year-old children, measured by doubly labeled water. J Pediatr 1993;123:200–7.
17. Davies PSW, Gregory J, White A. Energy expenditure in children aged 1.5 to 4.5 years: a comparison with current recommendations for energy intake. Eur J Clin Nutr 1995;49:360–4.
18. Salbe AD, Fontvieille AM, Harper IT, Ravussin E. Low levels of physical activity in 5-year-old children. J Pediatr 1997;131:423–9.
19. Davies PSW, Livingstone MBE, Prentice AM, et al. Total energy expenditure during childhood and adolescence. Proc Nutr Soc 1991;50:14A (abstr).
20. Grund A, Volbrecht H, Frandsen W, et al. No effect of gender on different components of daily energy expenditure in free living prepubertal children. Int J Obes Relat Metab Disord 2000;24:299–305.
21. McGloin AF, Livingstone MBE, Greene LC, et al. Energy expenditure and its components in relation to body fatness and risk of obesity in primary school children. Proc Nutr Soc 2000;59:71A (abstr).
22. World Health Organization. Measuring change in nutritional status. Geneva: WHO, 1983:61–101.
23. Hammer LD, Kraemer HC, Wilson DM, Ritter PL, Dornbusch SM. Standardized percentile curves of body-mass index for children and adolescents. Arch Dis Child 1991;145:259–62.
24. Dibley MJ, Staehling NW, Nieburg P, Trowbridge FL Interpretation of Z-score anthropometric indicators derived from the international growth reference. Am J Clin Nutr 1987;46:749–62.
25. Coward WA. The doubly labeled water ($^2H_2{}^{18}O$) method: principles and practice. Proc Nutr Soc 1988;47:209–18.
26. Davies PSW, Coward WA, Gregory J, White A, Mills A. Total energy expenditure and energy intake in the pre-school child: a comparison. Br J Nutr 1994;72:13–20.
27. 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.
28. Allen JR, McCauley JC, Waters DL, O'Connor J, Roberts DCK, Gaskin KJ. Resting energy expenditure in children with phenylketonuria. Am J Clin Nutr 1995;62:797–801.
29. Firouzbakhsh S, Mathis RK, Dorchester WL, et al. Measured resting energy expenditure in children. J Pediatr Gastroenterol Nutr 1993;16:136–42.
30. Schofield WN. Predicting basal metabolic rate, new standards and review of previous work. Hum Nutr Clin Nutr 1985;39C(suppl):5–41.
31. Amarri S, Coward WA, Harding M, Weaver LT. Importance of measuring CO_2-production rate when using ^{13}C-breath tests to measure fat digestion. Br J Nutr 1998;79:541–5.
32. Ksiazyk J, Lyszkowska M, Kierkus J. Energy metabolism in portal hypertension in children. Nutr 1996;12:469–74.
33. Spurr GB, Reina JC, Hoffmann RG. Basal metabolic rate of Colombian children 2–16 y of age: ethnicity and nutritional status. Am J Clin Nutr 1992;56:623–9.
34. FAO/WHO/UNU. Energy and protein requirements. World Health Organ Tech Rep Ser 1985;724.
35. Saris WHM, Emons HJG, Groenenboom DC, Westerterp KR. Discrepancy between FAO/WHO energy requirements and actual energy expenditure in healthy 7–11 year old children. In: Beunen G, Ghesquiere J, Reybrouck T, Claessens AL, eds. Children and exercise: 14th International Seminar on Pediatric Work Physiology. Stuttgart, Germany: Ferdinand Enke Verlag Press, 1990:119.
36. Ku LC, Shapiro LR, Crawford PB, Huenemann RL. Body composition and physical activity in 8-year-old children. Am J Clin Nutr 1981;34:2770–5.
37. Westerterp KR, Meijer GA, Janssen EM, Saris WH, Ten Hoor F. Long-term effect of physical activity on energy balance and body composition. Br J Nutr 1992;68:21–30.