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ENERGY COSTS OF ACTIVITIES OF PRESCHOOL CHILDREN

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ABSTRACT

Energy expenditures were measured in 47 children, 17-45 months old, under basal metabolic conditions (mean ± SD: 38 ± 5 cal/kg/min) and while resting supine (44 ± 5), sitting (47 ± 6), walking leisurely on level ground (71 ± 8), walking rapidly at a grade (98 ± 11), climbing and descending ramps (87 ± 7), climbing stairs (94 ± 8) and riding on a tricycle (73 ± 5). These values are greater than those reported in adults per unit of body weight. Consequently, the energy costs of activities determined in adults should not be applied to preschool children. Our results support the following recommendations to calculate the energy expenditure of preschool children in time-and-motion studies: a)use the energy costs of activities that have been measured in children, whenever available; and b) use 1.2, 2 and 2.5 times the child's basal metabolism, respectively, for sedentary, light and moderately heavy activities, or use the values determined in adults per unit of body weight multiplied by 2 for sedentary activities, and by 1.2 for all other activities.

KEY WORDS: Energy expenditure, physical activity, exercise, basal metabolism, time and motion studies, preschool children.

INTRODUCTION

Measurements of total energy expenditure of free-ranging humans are important to determine dietary energy requirements, since energy expended in physical activity is the largest and most variable determinant of energy balance. This has been recognized by international committees of experts on energy requirements and the latest dietary recommendations that will soon be published (Report of the Joint FAO/WHO/UNU Expert Consultation on Energy and Protein Requirements, Rome, October, 1981; B. Torún was a participant) are based primarily on estimates of total energy expenditure.

One of the most widely accepted ways to estimate the total energy expenditure of free-ranging individuals are the so-called time-and-motion studies (1), which have two components: a) timed observations of the activities performed by an individual, and b) summation of the energy costs of the timed activities. Energy costs can be determined experimentally by direct or indirect calorimetry, or the values reported by other investigators can be used. There is, however, little information on the energy cost of the usual activities of young children. Consequently, the energy cost of similar activities performed by adults, calculated per unit of body weight, have been used to estimate children's energy expenditure. The validity of this approach may be questioned, as it assumes that there are no changes related to age in the energy required to perform a task.

This brief communication reports the energy costs of several activities commonly observed in children 2-4 years old, it compares them with the energy costs of equivalent activities measured in adults and it gives recommendations to calculate the energy expenditure of preschool children.

MATERIALS AND METHODS

Indirect calorimetry measurements were done on 40 boys and 7 girls, 17 to 45 months old (mean ± SD: 31 ± 8), who were healthy and adequately nourished at the time of the studies, although they had been previously malnourished. Their heights corresponded to those of average North American children 21 ± 4 months old (2). Mean body weight was 11.24 ± 1.44 kg and weight-for-height was 98 ± 5% of the NCHS 50th percentile standards (2).

The studies were done in Guatemala City, at an altitude of 1,500 m and room temperatures of 18-24°C. The experimental procedures were approved by an institutional Human Rights Committee, clearly explained to the children's parents and accepted by them.

Basal oxygen consumption was measured with a diaferometer (Kipp, Delft, Holland), 9-12 h postprandial and while still sleeping, for 7-9 hours. Chloral hydrate, 4 mg/kg, was administered orally when a child woke up prior to performing the test. Oxygen volumes were converted to standard conditions of temperature, pressure and humidity (STPD). Energy expenditure was calculated using the energy equivalence of oxygen for the measured respiratory quotients (RQ; range: 0.78-0.91) or assuming an RQ of 0.82.

The energy cost of activities was measured by inhaling room air through a small Hans-Rudolph valve (W. E. Collins, Braintree, Massachusetts) and a pediatric respiratory face mask partially filled with modelling clay to reduce the dead space. The system's inspiratory dead space was 35 ml. Measurements were done after a child had been performing the corresponding activity for at least 2 min. They were repeated 3-11 times in the same child, at different hours of the day and at different time intervals between meals. Exhaled air was collected for 2-4 min in a 30-liter latex rubber balloon. Within 10 min of collection, oxygen concentration was measured using room air as the standard, with an analyzer equipped with a microfuel cell (model 320-B, Teledyne, San Gabriel, California) that was calibrated with a certified gas mixture. Expired volume was measured with a dry gas meter (model 802, Singer, American Meter Division) calibrated with a 600-liter Tissot gas meter (W. E. Collins, Braintree, Massachusetts). Gas volumes were converted to standard conditions (STPD). Energy expenditure was calculated assuming an RQ of 0.82, which corresponds to an energy equivalence of oxygen of 4.825 kcal/l O_2 STPD.

In addition to basal conditions, energy expenditure was measured while the child was: a) lying down, awake, on a bed or on the floor, playing or resting; b) sitting on the floor or on a bed, playing with a toy or resting; c) walking leisurely in- or outdoors, on level ground, at his own pace, sometimes stopping for a few seconds; d) alternating the ascent and descent of ramps 10 m long with an inclination of 24%; the descent was faster, sometimes running; e) walking on a treadmill on a horizontal plane at a slow speed (25 m/min), or faster (37-48 m/min) and with an inclination of 4-10%; f) climbing a stairway, sometimes erect and sometimes on hands and feet; g) riding a tricycle indoors, on level ground, at his own speed, which usually was slow.

The residual variation of the repeated measurements was calculated after ascertaining the homogeneity of variances using Bartlett's and Box's tests (3).

RESULTS AND DISCUSSION

Table 1 shows the results expressed per unit of body weight. As an example, the energy expended by a 12-kg child was calculated. The pooled coefficients of variation for the activities measured ranged between 6 and 12%. There were no differences between boys and girls. The data for tricycle riding must be regarded with caution as they were obtained on only one child.

TABLE 1

Energy Expenditure of Preschool Children under Basal Conditions and While Performing Various Activities

Activity*	No. of Children	No. of Measurements	Energy Expenditure cal/kg/min	Energy Expended by a 12-kg Child kcal/min
Basal conditions	34	81	38 ± 5†	0.46
Lying down, awake	23	131	44 ± 5	0.53
Sitting quietly or playing	11	65	47 ± 6	0.56
Walking				
slowly on a horizontal treadmill	23	134	64 ± 8	0.77
leisurely on level ground	8	52	78 ± 6	0.94
up and down a ramp	7	44	87 ± 7	1.04
rapidly upwards on a treadmill	23	134	98 ± 11	1.18
Climbing stairways	6	34	94 ± 8	1.13
Riding a tricycle	1	11	73 ± 5	0.88

*See text for detailed description.

†Mean ± pooled standard deviation.

Table 2 compares the energy measurements in children with the values reported for adults performing similar activities. The energy costs of the leisure and slow treadmill walks on a horizontal plane were combined.

TABLE 2

Comparison of Energy Expenditures of Preschool Children with Those of Adult Men and Women, Expressed in Absolute Terms and as Multiples of Basal Metabolic Rate

	Children		Adult Men			Adult Women			Child/Adult Ratio*	
	cal/kg/min	**	cal/kg/min	**	Source†	cal/kg/min	**	Source†	cal/kg/min	**
Basal metabolism	38	-	18	-	(4-6)	17	-	(4-6)	2.1	-
Lying down, awake	44	1.2	20	1.1	(‡)	21	1.2	(7)	2.2	1.0
Sitting quietly, playing or in sedentary work	47	1.2	22	1.2	(4,5,8,9)	22	1.3	(7,10)	2.1	1.0
Walking leisurely on level ground	71	1.9	64	3.6	(4,5,9-11)	53	3.1	(7,10,12)	1.2	0.6
Walking up- and downhill	87	2.3	83	4.6	(5,9)	77	4.5	(7)	1.1	0.5
Walking rapidly at a grade	98	2.6	85	4.7	(9)				1.2	0.6
Leisure ride on tricycle or bicycle	75	1.9	58	3.2	(4)	58	3.4	(4,12)	1.3	0.6
Climbing stairs	94	2.5								

* Combining data of men and women.
**Ratio of energy cost of the activity/basal energy expenditure.
† Bibliographic sources from which the data were calculated.
‡ Viteri, F. E. and Torún B., unpublished results.

A clear distinction in the child/adult ratios could be made between sedentary and more energetic activities, and the ratios thus differentiated were very consistent (last two columns in Table 2). Under basal conditions and during sedentary activities (i.e., lying down, sitting), energy expenditures per unit of body weight were 2.1-2.2 times greater in children than in adults. Other more energy-demanding activities were only 10-30% costlier in children. The ratio of an activity's energy cost to the individual's basal metabolism was similar for children and adults performing sedentary activities, but it was 40-50% lower in children during the performance of other activities. This distinction could be due to the fact that basal metabolic energy expenditure per unit of body weight, which greatly influences the total energy cost of sedentary activities, is twice as large in preschool children than in adults. In contrast, the additional energy required for body displacement and heavier work is proportionately greater in adults, therefore producing a fall in the child/adult ratios during the performance of such activities.

In conclusion, the energy cost of all activities measured was greater in children than in adults, when expressed per unit of body weight. The differences were greater in sedentary activities, but they persisted during the performance of more energy-demanding tasks. Therefore, it is not adequate to apply the energy costs of activities measured in adults to tasks performed by young children. Consequently, we recommend the following in order to calculate the energy expenditure of preschool children based on time-and-motion studies:

1. Whenever available, use the energy costs of activities determined experimentally in children, such as those shown in Table 1.

2. For other sedentary activities use 1.2 times the basal metabolism of children of the same age, or use the energy costs determined in adults per unit of body weight multiplied by 2.

3. For other more energy-demanding activities use the child basal metabolism multiplied by 2 for light activities and multiplied by 2.5 for moderately heavy activities, or use the energy costs for adults per unit of body weight multiplied by 1.2.

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