Validity of reported energy intake in preadolescent girls¹–³

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ABSTRACT Energy intake and energy expenditure were assessed in 109 girls aged 8–12 y. Intake was estimated from a 7-d dietary record based on household measures. Expenditure was measured with the doubly labeled water technique during a 2-wk period. Overall, the mean (± SD) energy intake was 7.0 ± 1.67 MJ/d and the mean energy expenditure was 8.03 ± 1.28 MJ/d. The mean difference between intake and expenditure was 1.03 ± 1.77 MJ/d (P < 0.0001). The mean proportion of actual intake reported was 88.3 ± 21.0%. Multivariate-regression analysis showed that age and total daily energy expenditure were significantly and independently related to the reporting error. Coefficients for age and total daily energy expenditure were both positive, indicating that as age and daily energy expenditure increased, the magnitude of the error of reporting increased. Income, ethnicity, parental obesity, and body fat were not significantly related to accuracy of reporting. The use of food records to determine energy intake appears to provide more accurate results in younger than in older girls, and the accuracy of the method apparently decreases as energy expenditure increases. Am J Clin Nutr 1997;65(suppl):1138S–41S.

KEY WORDS Energy intake, energy expenditure, doubly labeled water, preadolescents, children, girls

INTRODUCTION

Measurement of energy intake in individuals and populations is essential in determining energy requirements. Food records are commonly used to estimate daily energy intake, but the validity of such records was difficult to determine without direct observations until the development several years ago of the doubly labeled water method to assess energy expenditure in free-living humans.

In studies in which the doubly labeled water method is used, subjects are given stable isotopes of both hydrogen and oxygen. Because the oxygen of water and that of carbon dioxide are in equilibrium through the action of carbonic anhydrase (1), whereas hydrogen is lost only as water, the difference in the loss of the two isotopes reflects carbon dioxide production. Knowledge of the food quotient (FQ), which is based on the proportions of carbohydrates, protein, and fat in the diet, allows daily energy expenditure to be determined. The respiratory quotient (RQ) can be estimated from the FQ by means of the following relation:

\[ FQ = RQ = \frac{\dot{V}CO_2}{\dot{V}O_2} \]  

(1)

where \( \dot{V}CO_2 \) is the rate of carbon dioxide production measured with the doubly labeled water technique and \( \dot{V}O_2 \) is the rate of oxygen consumption. Thus, daily energy expenditure can be calculated.

The doubly labeled water method is noninvasive and easy to perform and requires minimal effort by the subjects. Urine samples for the evaluation are collected before administration of the isotope and at least twice afterward. Subjects are free to engage in their daily activities. Isotopic enrichments before and after administration of the isotope are used to calculate daily carbon dioxide production.

Under conditions of weight maintenance, energy intake equals energy expenditure. Therefore, if energy expenditure is measured, the validity of reports of energy intake can be assessed. Under conditions of weight change, however, energy intake and energy expenditure are different. When subjects gain weight, energy intake exceeds energy expenditure and body fat stores increase. When subjects lose weight, energy intake is lower than energy expenditure and body fat stores decrease. Thus, in subjects undergoing weight change, validating reports of energy intake requires measures of change in body composition as well as of energy expenditure.

We previously studied how well dietary records predicted energy expenditure in obese and nonobese adolescents (2). Energy intake was determined from dietary records that made use of household measures and were collected during a 2-wk period. In the nonobese group, the mean (± SD) reported energy intake was 9.17 ± 2.59 MJ/d and the mean measured energy expenditure was 11.53 ± 2.49 MJ/d. In the obese group, these values were 8.10 ± 3.02 MJ/d and 14.18 ± 2.56 MJ/d, respectively. The reported intake was 80.6 ± 18.7% of the expenditure in the nonobese group and 58.7 ± 23.6% of the expenditure in the obese group (2). This paper describes a study of the relation between energy expenditure and energy intake in preadolescent girls aged 8–12 y.

METHODS

The study was approved by both the Committee on the Use of Humans as Experimental Subjects, Massachusetts Institute of Technology, Cambridge; and the Department of Community Health, Tufts University School of Medicine, Boston.

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² Supported by the National Institutes of Health (grants MO1 RR00088, DK/HD 50537, and P30-DK46200) and the Weight Watchers Foundation.

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of Technology (MIT), and the Human Investigations Review Committee, New England Medical Center. The subjects were participants in a study of growth and development. Premenarcheal girls aged 8–12 y were recruited from schools in Cambridge, MA; from the MIT summer day camp; and by contacting the subjects’ friends. The criterion for admission was a triceps skinfold thickness value below the 85th percentile for age and sex (3).

For the doubly labeled water assessment of energy expenditure, subjects were admitted to the Clinical Research Center at MIT for one night. Medical histories were obtained and physical examinations performed to ensure that the girls were healthy. On the evening of admission, the subjects consumed no food or beverages after 1800. At 2000 a baseline urine sample was obtained and an oral dose of doubly labeled water [0.25 g H$_2$18O and 0.12 g $^2$H$_2$O/kg estimated total body water (TBW)] was given. After administration of the isotopes, all urine voided until 0600 the next morning was collected for determination of urinary isotope losses. The second urinary voiding of the morning, obtained at ≈0800, was collected for measurement of $^{18}$O and $^2$H enrichment above baseline values. The sample was used for determination of TBW and the beginning of the energy-expenditure period. Subjects were instructed to collect a sample of the second voiding of the day on day 7 of the study, while they were at home. Subjects returned to the research center 2 wk after admission. At that time, the second voiding of the day was again collected, to end the energy-expenditure period.

The method used for the analyses of $^{18}$O and $^2$H is described elsewhere (4). Oxygen dilution space was calculated according to the method of Halliday and Miller (5). The $^{18}$O dilution space was assumed to be 1% higher than TBW (6) and the $^2$H space was assumed to be 3% higher than the $^{18}$O dilution space. The mean daily rate of carbon dioxide production (mol CO$_2$/d) was calculated with use of a modification of Lifson’s equation (7), as follows:

$$r_{CO_2} = \frac{N}{2.078}(1.01k_0 - 1.04k_h) - 0.0246r_{Cr}$$  \hspace{1cm} (2)

where $N$ is TBW in mol, $k_0$ is the $^{18}$O elimination rate, $k_h$ is the $^2$H elimination rate, and $r_{Cr}$ is the estimated rate for isotopically fractionated water loss and equal to 1.05$N$ (1.01$k_0 - 1.04k_h$) (7, 8). The elimination rates of the $^2$H and $^{18}$O isotopes were calculated according to the two-point method, with use of isotopic enrichment relative to predose and the time difference between collection of the initial and final urine samples, as follows:

$$k = \frac{(lnAPE_i - lnAPE_f)}{\Delta t}$$  \hspace{1cm} (3)

Energy expenditure was calculated from Weir’s equation (9) with use of the amount of carbon dioxide production calculated from the doubly labeled water method and VO$_2$ calculated from the food quotient. The food quotient was calculated from the proportion of fat, carbohydrate, and protein in the diet (10). The theoretical precision of the doubly labeled water method for measuring carbon dioxide production is 3% (11). Validation studies done in four laboratories using respiratory-exchange measurements found the precision of the doubly labeled water method to be 5% (12). Reproducibility in the measurement of energy expenditure in both long- and short-term studies was 6% (13, 14).

On enrollment in the study, the subjects were taught by a registered dietitian how to keep a food diary. Food models and measuring cups and spoons were used to instruct the participants about portion sizes. The girls were asked to estimate the size of items that could not be measured.

After the training, the subjects kept a food diary for 7 d, during the second week of the measurement of energy expenditure. To help maximize compliance, the dietitian telephoned each subject twice during the week of record keeping. During the telephone conversations, the dietitian and participant reviewed the past 2 d of dietary recording. When the subject returned to the research center at the end of the 2-wk period, the dietitian reviewed the entire report with each girl. Computerized dietary analysis (FOOD PROCESSOR II, Version 3.06; ESHA Research, Salem, OR) was used to calculate energy intake. Food quotients were determined from the diaries under the assumption that underestimates of portion size would not alter the percentage of macronutrients consumed.

In our previous study of adolescents aged 12–16 y, we found that as age increased, the difference between intake and expenditure also increased and the percentage of actual intake reported decreased (2). These results were consistent with those of Livingstone et al (15), who examined energy intake and energy expenditure in 7-, 9-, 12-, and 15-y-old children with use of a weighed-food record to estimate energy intake. Energy intake in the 7- and 9-y-old children did not differ from expenditure. Among the 12- and 15-y-old children, however, energy intake was significantly lower than expenditure.

To determine whether age or other factors influenced the accuracy of dietary reporting in the preadolescents in this study, we examined reporting accuracy (defined as the difference between energy expenditure and energy intake) in each year of age in the cohort by using a multivariate-regression analysis that included age, weight, total daily energy expenditure, percentage body fat, parental obesity, family income, and ethnicity.

**RESULTS**

A total of 113 girls were originally recruited for the study. Four were subsequently excluded from the analyses because of incomplete record keeping. The mean (± SD) overall energy intake for the remaining 109 subjects was 7.0 ± 1.67 MJ/d, whereas the mean energy expenditure was 8.03 ± 1.28 MJ/d. The mean difference between intake and expenditure was 1.03 ± 1.77 MJ/d (paired t = 6.07; P < 0.0001). The mean percentage of the intake reported was 88.3 ± 21.0%. The relation between energy intake and expenditure is shown in Figure 1 and Table 1.

The multivariate-regression analyses found that only total daily energy expenditure and age were significantly and independently related to reporting accuracy (model $R^2 = 0.25$; Table 2). Both coefficients were positive, indicating that as age and total daily energy expenditure increased, the difference between energy expenditure and energy intake increased. Income, parental obesity, weight, and percentage body fat were not significantly related to accuracy. Ethnicity was significant only for the “other” group (n = 8), in which six different ethnic groups were represented. The heterogeneity of this group makes the findings difficult to interpret.
FIGURE 1. Relation between reported daily energy intake and daily energy expenditure assessed with the doubly labeled water method in 109 preadolescent girls.

DISCUSSION

One of the advantages of using a dietary record to measure energy intake is that it represents the subjects' current diet. However, an accurate dietary record requires that subjects report all food consumed. The significant positive correlation between accuracy and total daily energy expenditure observed in this study indicates that subjects who ate more reported their energy intake less accurately.

The increase in underreporting with greater age has several potential sources. First, as children get older, they spend more time outside the home and consume a greater proportion of their diet in places other than home. When not at home, children may forget or ignore food intake. On some occasions, such as meal consumption in restaurants or schools, the lack of an available method to measure or weigh the food before eating may produce errors in estimating portion size. Furthermore, the food composition of prepared foods often cannot be determined.

In addition, parents may be more likely to help younger children with food records, whereas older children and adolescents may be more independent, or their parents may expect them to take more responsibility for the record keeping. Adolescents, however, may not be conscientious about keeping dietary records and may fail to record all food items eaten. In some cases, they may not want their parents to know what they have eaten, and if they are concerned about their parents' having access to the food record, they may not record certain items. Moreover, a preoccupation with weight or denial may increase the inaccuracy of food records, especially among adolescent girls. Finally, the process of keeping a food record may alter eating habits. Subjects who want to be perceived as eating the correct foods may change their eating habits during the recording period.

In summary, we found that the use of food records to determine energy intake was more accurate in younger than in older girls. Our results are consistent with those of Livingstone et al (15). Surprisingly, reporting accuracy in our nonobese subjects was not affected by parental obesity or percentage body fat. In addition, our multivariate-regression analysis found that neither income nor ethnicity was significantly related to accuracy. Only total energy expenditure and age were significantly related to the completeness of reporting. More research is needed to understand how age and level of daily energy expenditure contribute to the accuracy of dietary reporting.

We thank the girls who were the subjects of this study and Pamela Ching, Dung Vu, and staff members at the Clinical Research Center, Massachusetts Institute of Technology.

REFERENCES

3. Must A, Dallal GE, Dietz WH. Reference data for obesity: 85th and 95th percentiles of body mass index (wt/hf)2 and triceps skinfold

TABLE 1
Energy expenditure and percentage of actual energy intake reported in girls stratified by age

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>Reporting error</th>
<th>Percentage of energy intake reported</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MJ/d</td>
<td>%</td>
</tr>
<tr>
<td>8 (n = 14)</td>
<td>0.30 ± 1.47</td>
<td>97.1 ± 22.6</td>
</tr>
<tr>
<td>9 (n = 40)</td>
<td>0.45 ± 1.41</td>
<td>94.8 ± 18.4</td>
</tr>
<tr>
<td>10 (n = 33)</td>
<td>1.43 ± 1.97*</td>
<td>83.7 ± 22.6</td>
</tr>
<tr>
<td>11 (n = 19)</td>
<td>1.69 ± 1.51*</td>
<td>80.7 ± 16.1*</td>
</tr>
<tr>
<td>12–16 (n = 14)*</td>
<td>2.34 ± 1.99*</td>
<td>78.1 ± 16.7*</td>
</tr>
</tbody>
</table>

* ± SD.
# Reporting error = measured energy expenditure minus reported energy intake.

1,4 Significantly different from zero: \( P = 0.05 \), \( P < 0.001 \).

3,6 Significantly different from 100%: \( P < 0.01 \), \( P < 0.001 \).

Because there were too few girls \( z 12 \) y in this study \( n = 3 \), the data for this age group are from a previous study (2).

TABLE 2
Regression coefficients for the prediction of the difference between energy expenditure and energy intake in 95 preadolescent girls

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Coefficient</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>0.502</td>
<td>0.012</td>
</tr>
<tr>
<td>Parental obesity (≥1 obese parent)</td>
<td>0.036</td>
<td>NS</td>
</tr>
<tr>
<td>Ethnicity (compared with white)</td>
<td>Black</td>
<td>0.597</td>
</tr>
<tr>
<td>Hispanic</td>
<td>1.174</td>
<td>0.087</td>
</tr>
<tr>
<td>Other</td>
<td>1.511</td>
<td>0.017</td>
</tr>
<tr>
<td>Percentage of body fat (%)</td>
<td>0.024</td>
<td>NS</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>-0.020</td>
<td>NS</td>
</tr>
<tr>
<td>Family income (&gt; $20,000)</td>
<td>-0.384</td>
<td>NS</td>
</tr>
<tr>
<td>Daily energy expenditure (MJ)</td>
<td>0.561</td>
<td>0.014</td>
</tr>
</tbody>
</table>

Data are presented on only 95 subjects because of missing information on parental obesity.
VALIDITY OF REPORTED ENERGY INTAKE IN GIRLS