Comparison of multiple-pass 24-hour recall estimates of energy intake with total energy expenditure determined by the doubly labeled water method in young children

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ABSTRACT

Objective This study determined the accuracy of the multiple-pass 24-hour recall method for estimating energy intake in young children by comparing it with measurements of total energy expenditure made using the doubly labeled water method.

Design Three multiple-pass 24-hour recalls were obtained over a 14-day period to estimate mean energy intake. Total energy expenditure was measured over the same 14-day period under free-living conditions using the doubly labeled water technique.

Subjects/setting Twenty-four children between the ages of 4 and 7 years were tested at the General Clinical Research Center/Sims Obesity Nutrition Research Center at the University of Vermont.

Statistical analysis *t* Tests, paired *t* tests, Pearson product-moment correlation coefficients, pairwise comparison to show relative bias and limits of agreement, and regression analysis were used to test the relationships among study variables.

Results No difference was found between 3-day mean energy intake and total energy expenditure for the group (t=2.07, P=.65). The correlation between individual measures of energy intake and total energy expenditure was not statistically significant (r=.25, P=.24).

Conclusions Data from 3 days of multiple-pass 24-hour recalls were sufficient to make valid group estimates of energy intake. The method was not precise for individual measurements of energy intake. *J Am Diet Assoc. 1996; 96:1140-1144.*

The application of the doubly labeled water methodology to measure total energy expenditure has provided investigators with a criterion method to assess the validity of tools designed to measure energy intake. This is based on the concept that in subjects who are in energy balance, energy intake must be equivalent to total energy expenditure as measured by doubly labeled water (1). The few studies that have been conducted in children using doubly labeled water suggest that diet histories and food frequency questionnaires overestimate energy intake (2,3). On the other hand, weighed-food records have been found to underestimate energy intake, particularly among obese adolescents (2,4). Because the manner in which systematic overreporting and underreporting occurs is not known, the validity of measuring dietary intake in children using these methods is questionable (5).

The 24-hour recall has been used widely in studies involving children (6-8). Nevertheless, the recall has not been compared previously with measurements of energy expenditure made using doubly labeled water. Thus, the aim of this study was to determine the accuracy of the multiple-pass 24-hour recall method for estimating energy intake in young children by comparison with measurements of total energy expenditure made using the doubly labeled water method.

METHODS

Sample

Data from 24 white children (12 boys, 12 girls) between the ages of 4 and 7 years who volunteered for our ongoing studies on energy requirements in young children were used for this study. The children were recruited by newspaper advertisement and word of mouth from Burlington, Vt, and the surrounding rural areas. The study procedures were approved by the Committee on Human Research for the Medical Sciences at the University of Vermont, and written informed consent was obtained from the parents of each child before participation.

General Outline of Study Protocol

The study was performed at the General Clinical Research Center (GCRC)/Sims Obesity Nutrition Research Center at the University of Vermont. On the evening before testing, the children came to the GCRC for collection of baseline urine samples and oral dosing with doubly labeled water. On the

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following morning, the children returned to the GCRC for assessment of body composition, collection of additional urine samples for the measurement of total energy expenditure by the doubly labeled water method, and recording of a multiple-pass 24-hour recall. Other tests completed at this time are beyond the scope of this article.

The children and their parents were unaware that total energy expenditure was being measured in the children over the subsequent 14-day period, as they were informed that the purpose of the oral dose of doubly labeled water and the urine collections was measurement of body composition. The children returned to the GCRC 14 days after the initial testing for repeat measurement of body composition, collection of two more urine samples, and recording of another multiple-pass 24-hour recall.

Table 1
Characteristics of the subjects[a]

Characteristic	Boys (n=12)	Girls (n=12)
Age (y)	5.5±0.7	6.4±1.0**
Height (cm)	115.2±9.2	120.8±8.7
Weight (kg)	24.2±7.2	26.4±6.4
Body mass index	18.0±3.1	17.9±2.7
Fat mass (kg)	5.2±3.3	7.3±4.0
Fat-free mass (kg)	19.0±4.7	18.8±3.6
Percent body fat	20.3±7.6	27.8±8.6*
Father overweight[b] (no.)	7	9
Mother overweight[c] (no.)	9	9

[a]Data are presented as means±1 standard deviation.
[b]Paternal overweight defined as body mass index >27.8.
[c]Maternal overweight defined as body mass index >27.3.
*$P<.05$ by independent *t* test.
**$P<.01$ by independent *t* test.

Energy Intake Measurement by Multiple-Pass 24-Hour Recall

The multiple-pass 24-hour recall method was originally developed by the US Department of Agriculture (USDA)–Human Nutrition Information Service (HNIS) (8) to limit the extent of underreporting that occurs with self-reported food intake (1). The method differs from the traditional 24-hour recall because the interviewer uses three distinct passes to garner information about a subject's food intake during the preceding 24 hours. We adapted a version of the method for use in our studies, and it is described here in detail.

The first pass is termed the *quick list*. Here, the respondent is asked to recall everything the child ate the previous day using any recall strategy he or she chooses. The second pass is termed the *detailed description*. In this pass the respondent is asked to clarify any foods mentioned in the quick list. For example, if the respondent reports that the child ate breakfast cereal, the interviewer would then ask whether milk was consumed with the cereal and if so the type and amount. The respondent would also be asked whether anything else was consumed with the cereal (eg, sugar, fruit of any kind). The third pass is termed the *review*. The interviewer reviews the list of foods mentioned and probes for additional eating occasions (eg, did the child eat anything after dinner, before bedtime?) and clarifies food portion sizes. Food portion sizes are estimated using two-dimensional food models designed to be used with the Food Intake Analysis System developed at the University of Texas, Health Science Center at Houston, School of Public Health and the USDA-HNIS. The food models include common household measures and dishes such as cups, spoons, bowls and glasses; geometric shapes such as circles, rectangles and wedges; and food-specific gram weight descriptions. We also encouraged parents to consult school menus to improve the accuracy of the recalls (9).

The interviews were conducted by a registered dietitian, a research technician with a master's degree in nutrition, or a senior undergraduate dietetics student, all of whom were trained by one of the authors (R.K.J.). Interviews were performed with the child's mother (occasionally the father would contribute) in conjunction with the child, as this procedure is known to improve the completeness of the recall (10). A single administration of the 24-hour recall is of little use in classifying persons as to usual intake because of the substantial intraindividual, day-to-day variation in food intake that occurs (11). Thus, we conducted repeated administrations of the 24-hour recall on nonconsecutive days to estimate the habitual intakes of the children (11). Three recalls per child were completed over the 14-day measurement period for total energy expenditure. The first recall was conducted in person during the child's first visit to the GCRC, the second was conducted via telephone during the 14-day dosing period with doubly labeled water, and the third recall was conducted in person during the child's day-14 visit to the GCRC.

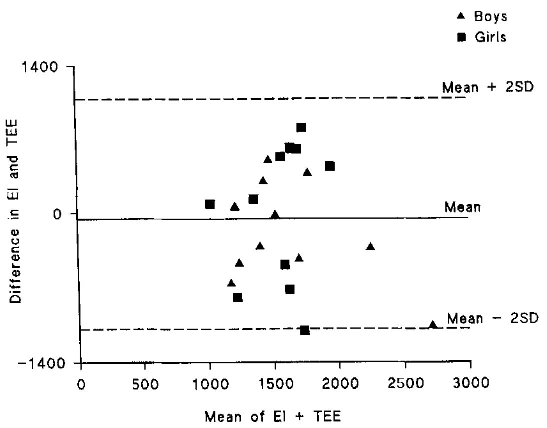
The recalls were coded and analyzed by the GCRC research dietitian who was trained in the use of the Food Intake Analysis System (version 2.1, 1992, Human Nutrition Center, University of Texas Health Science Center, School of Public Health) by a registered dietitian from the University of Texas. This system was selected because it is based on the same database used to analyze data from the USDA Nationwide Food Consumption Survey, Continuing Survey of Food Intakes by Individuals, which allows for comparisons of the nutrient intakes of our sample with the nationwide samples of children surveyed by USDA. In addition, the Food Intake Analysis System includes several desirable features such as the ability to add foods not included in the database, modify recipes, and default food codes that are generated from USDA surveys. For example, if a respondent reports that he or she ate breakfast cereal but cannot recall the kind or amount, the Food Intake Analysis System allows the coder to enter a default food that represents a mixture of the most commonly eaten cereals in the mean amount eaten by the US population.

Total Energy Expenditure Measurement

Total energy expenditure was measured over a 14-day period under free-living conditions using the doubly labeled water technique as described previously (12). Briefly, four timed urine samples were collected after an oral loading dose of doubly labeled water of 0.15 g $H2^{18}O$ and 0.12 g $_2H20$ per kilogram body mass: two the morning after dosing and two in the morning 14 days later. Samples were analyzed in triplicate for $H2^{18}O$ and $_2H2O$ by isotope ratio mass spectrometry at the Energy Metabolism Research Unit in the Department of Nutrition Sciences at the University of Alabama at Birmingham. Turnover rates and dilution spaces of $H2^{18}O$ and $_2H2O$, carbon dioxide production rates, and total energy expenditure were calculated as described previously (12).

Body Composition Measurement

Body composition was measured in the children by means of bioelectrical resistance. Whole-body resistance was measured twice, 14 days apart, using an RJL bioelectric analyzer (Mt Clemens, Mich) with electrodes placed at sites recommended by the manufacturer. The instrument was calibrated before each test. Body weight and height were measured before each



Level of agreement between EI (3-day mean energy intake as measured by the multiple-pass 24-hour recall) and TEE (total energy expenditure as measured by doubly labeled water). SD=standard deviation.

measurement of bioelectrical resistance. Total body water was calculated from height^2/resistance using the equation of Kushner et al (13), an equation that has been cross validated in previous studies against the measurement of total body water (14). Fat-free mass was estimated from total body water using age-specific hydration factors in children as described previously (12). Fat mass was derived from the difference between body weight and fat-free mass. The parents' height and weight were recorded and body mass index (BMI) was calculated (kg/m^2). Parents were categorized as overweight as follows: fathers, BMI>27.8 and mothers, BMI>27.3 (15).

Statistics

Data are presented as means ± standard deviations. We used t tests to determine differences between boys and girls. A paired t test was used to test the difference between total energy intake estimated by the mean of three multiple-pass 24-hour recalls and total energy expenditure determined by the doubly labeled water method. The correlation between energy intake and total energy expenditure was examined using the Pearson product-moment correlation coefficient. Agreement between the measures of energy intake and total energy expenditure was assessed according to the method of Bland and Altman (16) as recommended by Livingstone et al (2). With this method, a pairwise comparison was used to show the relative bias (mean difference) and the limits of agreement (mean difference ± two standard deviations of the difference) between the estimate of energy intake and the reference measure (total energy expenditure) by plotting the mean difference between the two methods against the mean of the two estimates. Regression analysis was conducted to examine the relationships among various independent variables (sex, age, body composition, parental obesity) and misreporting of energy intake (the difference between energy intake and total energy expenditure). Data were analyzed using Quattro Pro for Windows (version 6.2, 1995, Borland International, Scotts Valley, Calif) and BMDP (BMDP Statistical Software,1990, Berkeley, Calif) software packages. Statistical significance was set at $P<.05$.

RESULTS

Table 1 presents a summary of the physical characteristics of the subjects and their parents. The girls were significantly older ($P=.01$) and had a higher percent body fat ($P=.03$) than the boys. There were no significant differences between the boys and girls in any of the other variables listed in Table 1. The children's mean BMI was slightly higher than the norm for their age group (average BMI for 5-year-old girls=15; average BMI for 5-year-old boys=16) (17).

Mean 3-day energy intake as determined by the multiple-pass 24-hour recall, total energy expenditure, and the misreporting of energy intake is presented in Table 2. The misreporting of energy intake was not statistically different between the boys and girls as determined by a t test ($P=.33$). Thus, data for the boys and girls were combined as one group for all further analyses.

The difference between the 3-day mean energy intake (1,553 kcal/day) and total energy expenditure (1,607 kcal/day) was not statistically significant ($t=2.07$, $P=.65$) by paired t test (see Table 2). Thus, on a group basis the multiple-pass 24-hour recall accurately estimated the children's energy expenditure. The correlation between energy intake and total energy expenditure was not statistically significant ($r=.25$, $P=.24$), which indicates that on an individual basis the ability to predict energy expenditure from energy intake was poor.

The level of agreement between energy intake estimated by the multiple-pass 24-hour recall method and total energy expenditure was analyzed by plotting individual differences between the two values against the mean of both values (see Figure). The mean difference between the two measurements was −53.8 kcal/day. The limits of agreement (mean difference between energy intake and total energy expenditure) ranged from −1,102 to 807 kcal/day, which indicates poor agreement between the two measurements on an individual basis.

Energy intake misreporting (energy intake − total energy expenditure) was not correlated bivariately with any of the subject characteristics listed in Table 1. Thus, none of the children's measured physiologic variables or their parents' obesity status was predictive of energy intake overreporting or underreporting. This suggests that there was no bias toward overreporting or underreporting of energy intake that was dependent on these measured variables.

DISCUSSION

The use of the doubly labeled water methodology as a reference technique for the validation of energy intake measurement methods depends on the premise of energy balance; that is, energy intake equals energy expenditure when subjects are in energy balance (5). During normal growth and development young children increase their total body mass; thus, they are not in energy balance over extended periods. The average 5-year-old child gains 2.7 kg/year (17). If we assume that 75% of this gain in body weight is fat-free mass and 25% is fat mass, energy deposition will account for approximately 25 kcal/day in a growing child. We measured total energy expenditure over a 14-day period; hence, the amount of energy attributed to increased body mass was minimal. According to Schoeller (1), the only exceptions to this assumption are young infants and pregnant women, who increase body energy stores at high enough rates to introduce meaningful differences between energy intake and energy expenditure.

The multiple-pass 24-hour recalls generated a measure of mean energy intake that was 97% of measured total energy expenditure in this group of children. Basiotis et al (18) defined a "precise" estimate of intake as being within 10% of the true intake for a group 95% of the time. According to this definition, our multiple-pass 24-hour recall produced a valid estimate of the group energy intake. Black et al (19) contend that during an investigation some subjects will be examined during a period of low food intake and others during a period of high food intake, but random selection should ensure that the mean provides a valid measure of the habitual intake of that population. Hence, at the group level, if a satisfactory tool is used to measure dietary intake, the measurement of total energy expenditure should validate the measurement of habitual energy intake.

Black et al (19) state that absolute agreement between intake and expenditure is not expected from a single measurement. This is due to the daily variability that occurs in food intake, which adversely affects the accuracy of estimates of intakes. We used the mean of 3 days of energy intake as estimated from three, nonconsecutive, multiple-pass 24-hour recalls collected over a 14-day period. Basiotis et al (18) established that in a group of 29 adults (13 men and 16 women), 3 days of intake measurements were required to estimate the true average energy intake for the group. However, 27 days were required for the men and 35 days for the women to accurately estimate the true average energy intake for an individual. In our studies, we limited the collection of dietary intake information to 3 days of recalls within the 14-day dosing period because it was not realistic to place any additional burden on the children and their parents.

Estimates of energy intake were not biased by any of the children's measured physiologic variables or their parents' obesity status. Others have found that age, gender, and body fatness bias energy intake estimates (2,4,20,21). It has been well established that obese persons underestimate their energy intake to a greater degree than normal-weight subjects (20,22,23). In spite of a wide range of body fatness in our sample, it was not related to the misreporting of energy intake. Our findings that energy intake measurements in young children are unbiased have been corroborated by others (2,19) and may be explained partially by parental input. Food intake was largely reported by the children's mothers, with some assistance from the child and other caregivers. All of the children and their mothers were self-selected, highly motivated, compliant volunteers. Thus, it is possible that energy intake bias is greater among randomly selected, less-motivated samples such as those drawn for large nationwide surveys of diet and health.

Mertz (5) suggested that because we do not know exactly how misreporting of energy intake occurs, (ie, do subjects underreport all foods equally or do they underreport those foods with a "bad" connotation to a greater degree?), investigators cannot assume that concurrent estimates of macronutrient and micronutrient intakes are valid. On the other hand, when group estimates of energy intake are validated against a well-accepted criterion method, the coinciding estimates of macronutrient and micronutrient intakes should also be valid. Thus, when used appropriately with groups of young children, the multiple-pass 24-hour recall should provide valid estimates of the adequacy of their diets and the relationships between various dietary components and physiologic parameters.

The multiple-pass 24-hour recall has many strengths that make it practical for use with large groups of children. The method is relatively quick (approximately 20 to 25 minutes per interview). The respondent burden is low compared with other methods such as weighed dietary records, so generally the method is well accepted by parents and children. The method is inexpensive: the two-dimensional food models can be reproduced easily and sent home with parents for use with telephone recalls. Lastly, when the recall is taken unannounced, there is little risk that food patterns are changed in an effort to "please" the interviewer.

Ideally, all dietary surveys should validate their methods against well-accepted criterion methods. As pointed out by Black et al (19), unfortunately no criterion methods are currently available for widespread use. The doubly labeled water method is too expensive and technically demanding. Other methods such as urinary nitrogen excretion are also unacceptable for routine use. However, smaller samples representing the age, gender, and physiologic characteristics of the larger group being surveyed could be used for validation studies with the doubly labeled water method. At the very least, investigators should evaluate their energy intake measurements against predicted energy requirements using techniques well described by Goldberg et al (24) and Black et al (25).

Table 2
Energy intake, total energy expenditure, and energy intake misreporting in young children[a]

Variable	Boys (n=12)	Girls (n=12)	Boys and girls (n=24)
Energy intake (kcal/d)[b]	1,508±422	1,597±461	1,553±435
Total energy intake (kcal/d)[c]	1,678±603	1,536±363	1,607±492
Misreporting (kcal/d)[d]	−169±460	+62±661	−54±570

[a]Data are presented as means±1 standard deviation.
[b]Mean energy intake as estimated by three multiple-pass 24-hour recalls.
[c]Total energy expenditure as measured by doubly labeled water over 14-day period.
[d]Energy intake misreporting=energy intake−total energy expenditure.

APPLICATIONS

Basiotis et al (18) state that to achieve the desired statistical precision in intake estimates for groups, investigators can either increase the number of days of food intake records for a set number of subjects or increase the number of subjects with a set number of food intake records. In this cohort of 24 children aged 4 to 7 years old, collecting 3 days of multiple-pass 24-hour recalls was sufficient to make a valid group estimate. The multiple-pass 24-hour recall method was more accurate, more practical, and less burdensome than other methods such as the food frequency questionnaire (3) and weighed 7-day dietary records (2), which have been tested previously against total energy expenditure determined by the doubly labeled water method in children. Thus, the multiple-pass 24-hour recall could be used, as we describe, to estimate the dietary intake of groups of young boys and girls with wide ranges of body fatness. The method was not precise, however, for individual measurements of energy intake, making it ineffectual for individual monitoring or nutrition counseling purposes.

In our sample, the multiple-pass 24-hour recall emerged as a useful, easily applied, practical measure of the "usual" and "typical" energy intake of a group of young children. ■

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OF INTEREST TO YOU

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- Pick your boss carefully. The right boss is interested in your personal and professional development, is a good mentor, is headed to the top, and is committed to taking you to the top.
- Keep your resume floating. Even if you have a great job and a great boss, keep scouting for new, challenging positions.
- Invest in yourself. To succeed in today's knowledge economy you must be infinitely curious and a voracious lifelong learner. Force yourself out of your "box" by reading outside your professional specialty for a half hour every day.
- Think projects. Today, most work is done via projects. To advance in this arena, go beyond developing your expertise and master the management and leadership skills needed to perform equally well as project manager or resource provider.
- Become an effective team player and leader. Successful teamwork requires learning to empower others and to be equally comfortable and effective as a team leader and in a supportive role as team member.
- Focus on delivering exceptional quality service. As a litmus test of your customer focus, check your calendar to determine how much time you spend with customers.
- Become a problem solver. In today's competitive job market you can no longer simply expect to be compensated for time, only for results and for problems solved.
- Become an effective networker. Build strong networks with other health care providers by eating lunch with different people, sitting with people you do not know at meetings, and attending conferences sponsored by other nutrition groups.

The final skill to develop is action. Action will liberate and empower you. Action will get you to grow, change, and adapt. Action will enable you to achieve the competitive edge, and will ensure that you thrive in this brave new world. —*Excerpted from Winning Management: 6 Fail-Safe Strategies for Building High-Performance Organizations by WOLF J. RINKE, PhD, RD, president of Wolf Rinke Associates, Clarksville, Md.*