

Energy intake and energy expenditure: A controlled study comparing dietitians and non-dietitians

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ABSTRACT

Background Underreporting of food intake has been commonly observed. We hypothesized that experience with recording dietary information might increase the accuracy of the records. To test this hypothesis, we compared energy intake and energy expenditure in dietitians—who are experienced in recording food intake—with those of non-dietitians, whose only exposure to training to record food was in the context of this trial.

Subjects/setting Subjects for this study were 10 female registered dietitians and 10 women of comparable age and weight who were not dietitians.

Design This study compared the energy intake obtained from 7-day food records with energy expenditure measured over the corresponding 7-day period using doubly labeled water.

Statistical analysis Data were compared by an analysis of variance

Methods All subjects were trained to provide a 7-day weighed food intake record. Energy expenditure was measured with doubly labeled water over the 7 days when the weighed food intake record was obtained. A total of 10

dietitians and a control of group of 10 women of similar age and weight were recruited for this study. Participants were told that the goal was to record food intake as accurately as possible, because it would be compared with the simultaneous measurement of energy expenditure determined by doubly labeled water.

Results: The energy expenditure of the dietitians and controls were not different ($2,154 \pm 105$ [mean \pm standard error of the mean] kcal/day for dietitians and $2,315 \pm 90$ kcal/day for controls). The dietitians underreported their energy intake obtained from the food records by an average of 223 ± 116 kcal/day, which was not different from their energy expenditure. Participants in the control group, as hypothesized, significantly underreported their energy intake (429 ± 142 kcal/day, $P < .05$).

Conclusion Dietitians estimated their energy intake more accurately than non-dietitians, suggesting that familiarity with and interest in keeping food records may lead to more reliable estimates of energy intake. *J Am Diet Assoc.* 2002; 102:1428-1432.

The introduction of doubly labeled water as a technique for measuring energy expenditure in animals (1,2) and human beings (3,4) has profoundly changed the interpretation of energy intake estimated from food intake records. In essentially all studies (3-14), the estimate of energy intake using a food record is lower than the energy expenditure as measured using doubly labeled water; furthermore, the

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magnitude of this error increases in obese individuals compared with nonobese individuals (10).

Underreporting consists of two components (6,14). The first is the failure to report all of the food that is eaten, to misreport food portions, or to incorrectly describe the foods eaten. The second is the underrecording that may be associated with the task of recording food intake. Because dietary food records are widely used as a source of information about food intake of people in the United States, it is important to develop strategies to improve the estimation of energy intake (15). We hypothesized that professionals who are educated in dietetics and familiar with foods would have a smaller difference between energy expenditure measured with doubly labeled water and energy intake determined from weighed food records than people who were not dietitians or foodservice workers. This controlled trial was designed to test this hypothesis. Professional dietitians and age- and weight-matched women were recruited to participate in a study in which they would record their food intake using a weighed food record.

During the time of the weighed food intake, energy expenditure was measured using doubly labeled water.

METHODS AND MATERIALS

Subjects

Subjects for this study were dietitians and non-dietitians, whose characteristics are listed in the Table. Two groups of women participated in this protocol. The dietitians were aged 36.4 ± 3.8 years compared with 33.43 ± 2 years for the non-dietitian participants. The height (163.6 ± 2.1 cm for dietitians vs 165.6 ± 1.6 cm for non-dietitians), weight (61.3 ± 2.5 kg for dietitians vs 63.3 ± 3.5 kg for non-dietitians) and body mass index (23 ± 1.1 kg/m² for dietitians vs 23.1 ± 1.2 kg/m² for non-dietitians) were not significantly different. Only 2 or 3 of the dietitians were employed in research; the remaining dietitians were employed in clinical or management positions.

The dietitians were recruited at one of the meetings of the Baton Rouge (La) Dietetic Association, during which the study was described. It was presented as a challenge for dietitians to record their food intake with sufficient accuracy so as not to be different from the estimate of energy expenditure obtained from doubly labeled water. The non-dietitians were recruited from the institutional database by matching age, sex, and weight of healthy women to that of one of the dietitians. The nature of the study was described and subjects signed their "informed consent," which had been approved by the Pennington Institutional Review Board. During the time of the study, participants were encouraged to maintain their usual level of activity.

Isotope (¹⁸O) Dilution

After an overnight fast, urine and saliva samples were obtained for measurement of baseline isotopic enrichment. The subjects then drank a dose of heavy water containing 0.132 g H₂¹⁸O and total 0.108 g ²H₂O/kg body weight. The container was washed with an additional 50 mL tap water; this was also given to the subject. For total body water measurements, 3- and 4-hour saliva samples were taken. Subjects provided morning urine samples on days 1, 2, 7, and 8 following administration of the heavy water for determination of isotope elimination and energy expenditure. A 7-day period was chosen to coincide with the duration of the weighed food intake record and is within the 5- to 25-day metabolic period for women (5). Analysis required 4 mL saliva or urine for duplicate measurement of deuterium and 3.0 mL urine or saliva for duplication measurement of ¹⁸O. Total body water was calculated using ¹⁸O isotopic enrichments measured in saliva samples obtained before the dose and 3 to 4 hours (averaged) after the dose (3). The mean daily CO₂ production was calculated according to Schoeller (5) with revised dilution space constants (16). Energy expenditure was calculated by multiplying rCO₂ by the energy equivalent of CO₂ for an estimated RQ of 0.86. The ¹⁸O isotope abundances were measured on a Finnigan MAT 252 gas-inlet Isotope Ratio Mass Spectrometer (Bremen, Germany) with a CO₂-water equilibration device (17). Salivary enrichment was measured by comparing a baseline sample using the average of the 2- and 3-hour postdose samples. The coefficient of variation for repeat measurement of deuterium is 0.53% and for ¹⁸O the coefficient of variation is 0.26% with either saliva or urinary samples. In a comparison of measurements between 18 laboratories, our laboratory was within 2% of the mean (11).

Table

Demographic variables, energy expenditure, and reported nutrient intakes from weighed food records of dietitians and non-dietitians

	Dietitians ^a	Non-dietitians ^a
Age (y)	36.4 (27.9, 44.9)	33.4 (26.2, 40.6)
Height (cm)	163.6 (158.9, 168.4)	165.6 (161.9, 169.2)
Weight (kg)	61.3 (55.7, 66.9)	63.3 (55.4, 71.2)
Body mass index	23.0 (20.4, 25.6)	23.1 (20.3, 25.9)
Energy expenditure (kcal)	2,154 (1,917, 2,392)	2,315 (2,112, 2,519)
Energy intake (kcal)	1,931 (1,754, 2,108)	1,886 (1,605, 2,167)
Protein (g)	76 (67.3, 84.4)	66 (57.0, 74.4)
Carbohydrate (g)	266 (232, 300)	238 (200, 277)
Fat (g)	59 (47.9, 70.0)	72 (56.9, 87.4)

^aMean and 95% confidence interval; mean values are rounded.

Food Intake

Food intake was measured using a 7-day weighed food record that was completed during the time when energy expenditure was determined by doubly labeled water. For this technique, each subject received a scale (EKCO Household Diet Scales, EKCO Housewares, Inc., Franklin Park, Ill) and was instructed to use the scale to weigh all solid foods consumed as frequently as was possible. All participants viewed a video and were given the same written materials (food record forms, instructions for keeping the food records, guides for determining portion size, food description guidelines, tips for recording food intake, pictures of common serving sizes, an example of a completed food record, and a form for recipe information). Data from the food records were entered into Moore's Extended Menu (MENu) Database by trained dietetic students and verified and corrected by one of two senior dietitians (CMC and AAK), who reviewed the record with each subject. In comparison tests with analytically measured food intake, the MENu database was closer than other commercial databases and was selected as the nutrient database for the Dietary Effects on Lipoproteins and Thrombogenic Activity and Dietary Approaches to Stop Hypertension multicenter trials, which were funded by the National Institutes of Health (18,19). On average, when we have records double entered for quality control, the variability is approximately 15% to 18%. However, our standard operating procedure requires 100% verification of all entered records by the dietitian who reviewed the record with the subject (AAK) and for this study a final check by the lead dietitian (CMC).

Statistical Analysis

The list of primary response variables analyzed in this study is total daily energy intake (in kilocalories); protein, carbohydrate and fat intake (in grams); and total energy expenditure (in kilocalories) as measured by doubly labeled water. A mixed model approach was used to test for differences in response with respect to the two groups of subjects (trained and untrained) in energy intake, macronutrients, and total energy expenditure. In the model, the characterization of a subject (trained vs untrained) presented a fixed effect. The random subject effect was expressed by repeated measure design approach with a compound symmetry type covariance structure. Separate analysis was carried out to investigate under-reporting with the weighed method. The difference between total energy expenditure and energy intake from the weighed food record was calculated and then analyzed using a mixed

model. With a random subject we allowed for different within- and between-subject variances for the two (trained and untrained) groups using a group statement. All analyses were performed using PROC MIXED and PROC IML in SAS (version 8.1, 2000, SAS, Cary, NC).

RESULTS

Energy and Macronutrient Intake

The estimates of energy, fat, protein, and carbohydrate intake obtained from the weighed dietary record is presented in the Table as the mean and 95% confidence interval. The energy intake estimated for the professional dietitians using the weighed food intake method was (1,931±78). In the nonprofessional subjects, energy intake was (1,886±124). The weighed food intake record also showed a small, although not significant, difference in intake of protein ($P=.09$) and carbohydrate ($P=.22$) between dietitians and controls. Fat intake was not significantly lower for the dietitians than non-dietitians ($P=.15$). Average alcohol consumption for the 20 subjects was 8.6±1.7g/d or approximately 60 kcal/day (about 3% of average daily intake).

Energy Expenditure

The Table also contains the energy expenditure determined during the weighed food intake record period using the doubly labeled water method. The values of energy expenditure were not significantly different between the dietitians and the non-dietitians. The mean energy intake for the 7 days of the weighed food record and the corresponding 7-day energy expenditure for each subject are shown in the Figure. The Figure illustrates the variability in intake relative to energy expenditure and the difference in variability of intake between subjects. The average energy intake relative to energy expenditure was lower for the control group than for the professional dietitians.

The mean energy expenditure of the dietitians calculated from doubly labeled water was 223±116 kcal/day more than energy intake estimated from the weighed food record. For the nonprofessional control group, energy intake was underreported by 429±142 kcal/day, relative to energy intake determined from the weighed food record. The comparison of energy expenditure with reported energy intake for the participants in both groups is shown in the Figure. The control group participants significantly underestimated their energy intake relative to the dietitians whose energy intake was not significantly lower than the energy expenditure estimated from doubly labeled water.

DISCUSSION

The major finding of this study is that the energy intake calculated from a weighed food intake record was not significantly different from the energy expenditure measured by doubly labeled water during the same 7-day interval. In contrast, participants in the control group of nonprofessionals significantly underreported their energy intake calculated from a weighed food intake record as compared with the energy intake measured from doubly labeled water.

The use of doubly labeled water to measure energy expenditure was first used in animals more than 40 years ago (1) and in human beings slightly more than 20 years ago (3). The principal assumptions are that the background isotope enrichment does not change during the course of the study and that

the respiratory quotient used to convert from CO₂ production to oxygen uptake is close to that of the subjects under study. A number of studies have been done to validate this procedure (5). When compared with respiratory gas analysis or intake balance techniques, the mean difference in 33 subjects was 0.6±6.3 % (5). In another review (6), the repeatability of the method over short and long intervals was reported to be 6%. In 11 separate studies from 3 institutions, the accuracy of the method was found to be 1% and the precision (1 standard deviation) of 6% (6). In a comparison study between 18 laboratories that measured doubly labeled water, our laboratory was within 2% of the theoretical value (11). Based on these validation studies, doubly labeled water has become the gold standard for measuring energy expenditure in ambulatory outpatients. Using this method, the energy expenditure for the 2 groups of women included in this study was similar and in the range expected for young to middle-aged women (17).

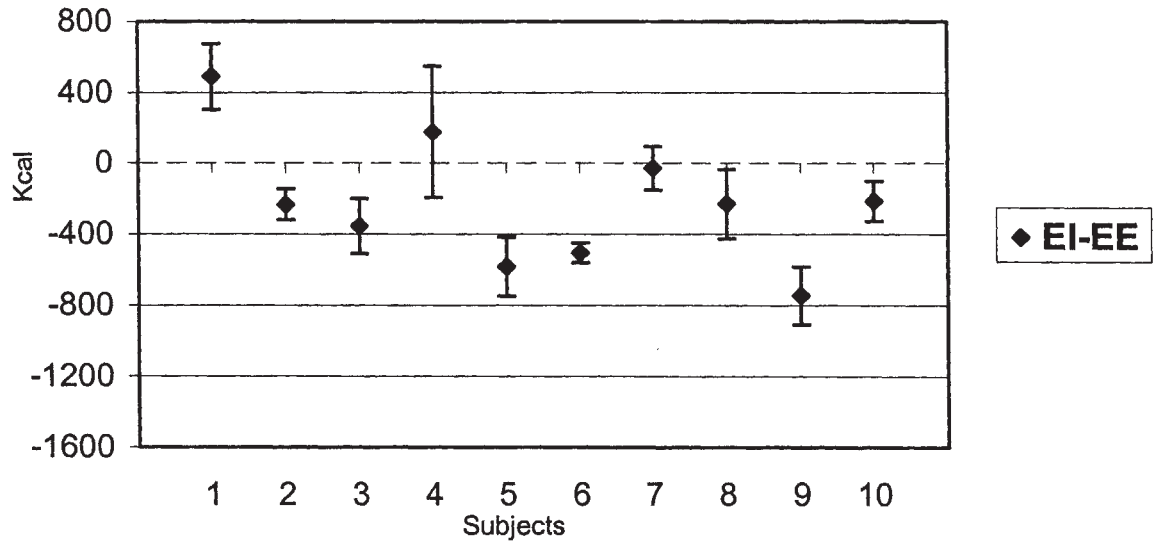
The estimate of energy intake from dietary records is usually lower than the estimate of energy expenditure determined from doubly labeled water (7,9,10,14,20-23). The degree of underestimation for normal-weight subjects ranges from 10% to 30%. In obese individuals, the degree of underreporting is higher, ranging from 20% to 50% and occurs in both adults and children (7,8-10,22,23). Our study also demonstrates underreporting.

Underreporting of food intake has two parts. The first is undereating, which occurs when subjects eat less than they normally would (14,24). The second is the failure to report foods that are actually eaten or to identify foods incorrectly or portion sizes as smaller than what was consumed. In a 2000 study of overweight individuals, Goris et al (14) estimated that underreporting represented about one-third and underreporting accounted for two-thirds of the discrepancy between the intake of food energy and energy expenditure.

To determine whether professional experience with food and dietetics was important in recording food intake accurately, we invited professional dietitians to compete individually with the measurement of energy expenditure determined by doubly labeled water. If professional experience in recording food intake in detail can reduce the discrepancy between energy intake and expenditure, we predicted that dietitians would be closer to estimating their intake of food energy than people with no training in foods. This prediction proved to be correct. The energy intake of dietitians was not significantly lower than the energy expenditure. In contrast, participants in the nonprofessional control group underreported by about 400 kcal/day, or 20%, less than energy expenditure, a difference that was significantly below their energy expenditure. We would thus conclude that experience with food could reduce some of the discrepancy between reporting of energy intake and actual energy expenditure.

For both the dietitians and non-dietitians, there was considerable day-to-day variability in reporting of energy intake (Figure). The range of variation was from 100 kcal over a 7-day period in one participant to more than 2,500 kcal/day in another. This wide range of variability occurred for both study groups and was not related to the day of the week. Drougas et al (25) reported that the lowest difference in energy intake and expenditure also occurred in dietitians compared with non-dietitians; but subjects trained in record keeping did no better than untrained subjects in self-reports of energy intake compared with energy expenditure determined by whole room calorimetry. Harrison et al (26) compared data from Egyptian

Difference in EI and EE for 10 dietitians



Difference in EI and EE for 10 non-dietitians

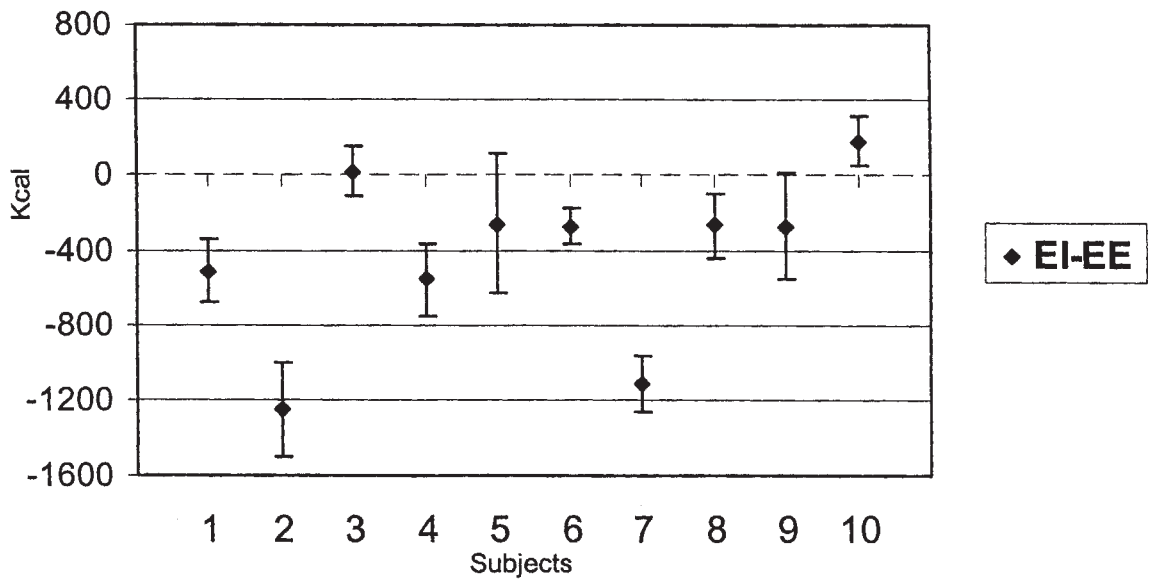
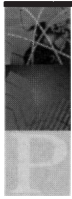


FIG. Comparison of energy expenditure (EE) determined for each individual from doubly labeled water and reported energy intake (EI) from weighed food record presented as mean of the difference (EI-EE) with standard error of the mean difference for reported energy intake.

women and US women and noted that food intake by dietary recall suggested that Egyptian women underreported energy intakes by only 10%, compared with US women who underreported at a level of approximately 30% of predicted energy expenditure. Clearly more work is needed to assess the amount of training needed to reduce the discrepancies to a minimum.



APPLICATIONS

The day-to-day variability and the difficulty of reaching actual levels of energy expenditure by dietary records (dietitians were 10% below and controls were 20% below the actual levels) limit the usefulness of dietary records in national surveys. In addition to total energy intake being underreported, Goris et al (14) have suggested that, at least for overweight individuals, the intake of dietary fat may be selectively underreported. Selective underreporting has been frequently observed (29, 30). The day-to-day variability also poses problems in deciding which data to accept and which to not accept. There is clearly a need for more precise and reproducible methods for estimating human energy intake in field settings. We may benefit by investigating international datasets with a lower percentage of underreporting to determine techniques that may improve the data collected in surveys of people in the United States. What is obvious from this study is that a more extensive training of subjects in recording of food intake may be beneficial. Perhaps stressing accuracy and completeness by motivating the subject to be very precise can be undertaken, along with more frequent reviews of records—perhaps allowing only a couple of days to elapse during a 1-week record-keeping period, as we chose to use in this study.

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