Predicting total energy expenditure from self-reported dietary records and physical characteristics in adult and elderly men and women[1,2]

James L Seale

ABSTRACT

Background: Energy requirements and nutrient intakes are commonly estimated from self-reported dietary records, but such estimation has proven to be unreliable. When energy intakes determined from dietary records are compared with energy expenditures measured with the use of doubly labeled water, the former consistently underestimate energy requirements and have a high degree of variability.

Objective: The objective of this study was to reduce the bias and variability of self-reported dietary records through the use of stepwise multiple regression analysis to develop models that relate energy expenditure measured with the use of doubly labeled water to energy intake from dietary records, sex, and fat-free mass (or weight and height).

Design: Data from 54 healthy adult men and women were used to develop these models.

Results: Fat-free mass, energy intake, and sex accounted for 86% of the variability in energy expenditure, whereas energy intake, sex, height, and weight accounted for 83%. When the model relating fat-free mass, energy intake, and sex to energy expenditure was tested on published data, it reduced the bias and variability of self-reported dietary records from −17 ± 27% to 3 ± 16%. When the model relating energy intake, sex, weight, and height to energy expenditure was tested on published data, it reduced the bias and variability of self-reported dietary records from −19 ± 25% to −0.3 ± 19%.

Conclusion: Results from this study indicate that a simple relation can be used to correct self-reported dietary records to estimated energy requirements. *Am J Clin Nutr* 2002;76:529–34.

KEY WORDS Energy requirement, food intake, energy expenditure, doubly labeled water, dietary records, self-reporting bias

INTRODUCTION

The energy needs of a weight-stable adult population are most appropriately defined from measurements of habitual energy expenditure (EE) (1). Because measurements of habitual EE are often difficult to obtain, energy requirements are frequently determined from estimates of energy intakes (EIs). When the body weight and composition of healthy individuals are stable and the individuals are not growing, pregnant, or lactating, EE and EI are equivalent (1).

Energy requirements can be directly assessed from total energy expenditure (TEE) measured with the use of doubly labeled water ($^{2}H_2{}^{18}O$) (2). Naturally occurring, nonradioactive stable isotopes of hydrogen (^{2}H) and oxygen (^{18}O) are used to label the total body water pool. ^{18}O is eliminated from the water pool as water and carbon dioxide, whereas ^{2}H is eliminated only as water. The difference in the elimination rates of ^{18}O (k_O) and ^{2}H (k_H) is related to the carbon dioxide production rate (rCO_2), from which EE can be determined (3).

When energy requirements are estimated from EI, all food consumed must be accounted for during a period when body weight and composition are in a steady state. EI determined from self-reported dietary intake records requires that subjects record the type and amount of all the food that they consume during the assessment period. The EI and nutrient intakes of the entire diet are computed as the sum of the energy and nutrients available from each food item consumed.

Self-reported dietary intake records have played a central role in assessing the nutrient and energy requirements of populations. When EIs estimated from self-reported dietary records are compared with TEE measured with the use of doubly labeled water, the former consistently underestimate energy requirements (4–19). Not only are self-reported dietary records biased; they also have a high degree of variation (18). Trends in the amount of underestimation and variability of self-reported dietary records have been associated with weight, obesity, sex, income, level of education, and living arrangements (16–19).

The purpose of this study was to develop mathematical expressions that relate an individual's EI and physical characteristics to TEE. The physical characteristics of age, sex, fat-free mass (FFM), and fat mass (FM) were considered in one expression. Because these measurements are not always or readily available, a second expression was developed that included the more easily obtained physical characteristics of sex, age, weight, and height.

SUBJECTS AND METHODS

Subjects

Data from healthy adult women ($n = 27$) and men ($n = 27$) aged 32–82 y who participated in studies at the Beltsville Human

[1] From the Diet and Human Performance Laboratory, Beltsville Human Nutrition Research Center, Agricultural Research Service, US Department of Agriculture, Beltsville, MD.

[2] Address reprint requests to JL Seale, Building 308, Room 212, BARC-East, 10300 Baltimore Avenue, Beltsville, MD 20705-2350. E-mail: seale@bhnrc.arsusda.gov.

Received November 17, 2000.

Accepted for publication October 31, 2001.

TABLE 1
Physical characteristics, energy intake (EI) from self-reported dietary records, and total energy expenditure (TEE) measured with the use of doubly labeled water of the subjects[1]

	Women (n = 27)	Men (n = 27)
Age (y)	62.1 ± 11.9 (41–80)	61.2 ± 15.3 (32–82)
Height (m)	1.63 ± 0.06 (1.54–1.73)	1.76 ± 0.08[2] (1.60–1.97)
Weight (kg)	68.1 ± 10.0 (52.9–92.7)	83.9 ± 9.3[2] (63.3–104.9)
BMI (kg/m^2)	25.8 ± 3.8 (17.9–31.7)	27.2 ± 2.4 (23.1–33.2)
FM (kg)[3]	26.2 ± 8.4 (13.9–44.3)	23.1 ± 5.6 (8.9–39.1)
FFM (kg)[3]	41.9 ± 2.8 (37.2–48.6)	60.7 ± 7.4[2] (48.1–76.4)
EI (MJ/d)[4]	7.49 ± 1.52 (4.77–12.13)	9.22 ± 2.15[2] (4.80–13.16)
TEE (MJ/d)[5]	9.55 ± 0.70 (8.20–10.90)	12.85 ± 1.47[2] (9.66–15.90)
TEE − EI (MJ/d)	2.07 ± 1.51[6]	3.64 ± 1.62[2,6]

[1] $\bar{x}$ ± SD; range in parentheses. FM, fat mass; FFM, fat-free mass.
[2] Significantly different from women, $P < 0.05$.
[3] Determined by isotope dilution ($H_2{}^{18}O$).
[4] Determined from self-reported dietary records.
[5] Determined by using the doubly labeled water method.
[6] Significantly greater than zero.

Nutrition Research Center were used to develop mathematical expressions relating TEE measured with the use of doubly labeled water to EI determined from self-reported dietary records. The studies were approved by the Agricultural Research Service Human Studies Review Committee of the US Department of Agriculture and by the institutional review board of Georgetown University, the Penn State Geisinger Institutional Research Review Board, or the Johns Hopkins Committee on Human Research. All subjects were medically screened and found to be free of metabolic disease. All subjects gave informed consent to participate in this study after the procedures were explained to them. All subjects were financially compensated for their participation.

Dietary intake records

EI was estimated from self-reported dietary intake records collected during 3–7 d. Subjects were required to record the type and amount of all food consumed during a weight-stable period. Subjects were trained by registered dietitians to use scales, measuring spoons, and cups and to estimate portion sizes when they were unable to actually measure the food consumed. The dietary records were periodically reviewed in the presence of the subjects to resolve any uncertainty in the entries and to assess the completeness of the record. Subjects were instructed not to change their behavior, including physical activities and eating habits, during the recording period. The completed dietary records were evaluated for energy and nutrient content. The energy content of the entire diet was computed as the sum of the energy available in each food item consumed.

Doubly labeled water

Average daily rCO_2 and EE were determined by using doubly labeled water for 10–14 d. Volunteers were given an oral dose of doubly labeled water (0.14 g $H_2{}^{18}O$/kg body wt and 0.70 g ^2H_2O/kg body wt) after a baseline urine sample was collected. Subjects were given labeled containers and instructions for collecting urine specimens. Second-void urine samples were collected on the first 3 d and last 3 d of the sampling period. Baseline urine samples collected before the dose and second-void urine samples collected on the first 3 d and the last 3 d were analyzed for ^2H and ^{18}O concentrations.

The ^2H concentration was determined by using an infrared spectrophotometer (MIRAN 1A-FF; Foxboro/Wilks Inc, South Norwalk, CT) on duplicate vacuum sublimations of urine (20). The CV for repeated values from multiple deuterium analysis of body water samples is 1.57% (PROC GLM; SAS Institute Inc, Cary, NC). The ^2H dose was calculated to provide the best accuracy for the given instrument sensitivity for determining ^2H_2O clearance for 10–14 d (21). The ^{18}O concentration was determined in a commercial laboratory with the use of the carbon dioxide equilibrium method and an isotope-ratio mass spectrometer. Blind standards derived from a serial dilution of the $H_2{}^{18}O$ dose were included with the samples to validate the laboratory results. Linear regression on the standard concentration versus analyzed values (r^2 = 0.99999; slope = 0.995 ± 0.001; intercept = 0.000 ± 0.000) indicated accurate ^{18}O analysis.

The ^2H and ^{18}O zero-time intercepts and elimination rates (k_H and k_O) were calculated by using least-squares linear regression on the natural logarithm of isotope concentration as a function of elapsed time from dose administration (Corel Quatro Pro 8; Corel Corporation, Ottawa, Canada). The zero-time intercepts were used to determine the isotope pool sizes at the time of dose (21). The ^{18}O pool size was used to estimate total body water, N (^{18}O pool size/1.01). rCO_2 was calculated from k_H, k_O, and N according to equation 1 (22)

$$rCO_2\ (L/d) = (N/2f_3)(1.01k_O - 1.04k_H)[1 - 1.05(f_2 - f_1)] \quad (1)$$

where the constant isotope fractionation factors (f) are 0.941 (f_1), 0.992 (f_2), and 1.039 (f_3). The respiratory quotients determined from the self-reported dietary records were used to estimate EE from rCO_2. These analytic techniques and computational methods were validated in 9 subjects as having an accuracy of 1.6 ± 2.6% (23).

Body composition

FFM was determined by the isotope dilution of ^{18}O (FFM = ^{18}O pool size · 1.01^{-1} · 0.723^{-1}). FM was determined as the difference between total body weight and FFM.

Statistical analysis

An analysis of variance was used to determine significant differences in physical characteristics, EI, and TEE between the women and the men (PROC GLM; SAS Institute Inc). Multiple regression analysis and stepwise regression analysis were used to develop empirical models that related TEE measured with the use of doubly labeled water to sex, age, FFM, FM, and EI from self-reported dietary records (model 1) and to sex, age, weight, height, and EI from self-reported dietary records (model 2) (PROC GLM, SAS INSIGHT, and PROC REG; SAS Institute Inc). Pitman's test was used to compare the EE predicted by using model 1 (PEE1) with that predicted by using model 2 (PEE2) (24). The correlation between the sum of the residuals [(PEE1 − TEE) + (PEE2 − TEE)] and the difference in the residuals [(PEE1 − TEE) − (PEE2 − TEE)] was tested (PROC CORR, SAS Institute Inc). Residuals were also tested by using analysis of variance to determine significant differences by sex and age and between normal-weight (BMI < 25; n = 17), overweight (25 < BMI < 30; n = 28), and obese (BMI > 30; n = 9) groups (PROC GLM; SAS Institute Inc).

RESULTS

The physical characteristics, EI, and TEE of the subjects are shown in **Table 1**. Values in the table represent the mean (± SD)

TABLE 2
Stepwise multiple regression analysis relating total energy expenditure (TEE) measured with the use of doubly labeled water to fat-free mass (FFM), energy intake (EI) estimated from self-reported dietary records, and sex (women = 0 and men = 1)[1]

Dependent variable	Step	Independent variable	R^2	P
TEE	1	FFM	0.8210	<0.0001
TEE	2	EI	0.8445	<0.0076
TEE	3	Sex	0.8553	<0.0595

[1] R^2 is the fraction of explained variance. The last step provides the cumulative R^2.

and the range for age, height, weight, BMI, FM, FFM, EI, TEE, and TEE − EI. The women had significantly lower values for height, weight, FFM, EI, and TEE than did the men. EI was significantly lower (25 ± 15%) than TEE. The mean value for TEE − EI was significantly lower in the women than in the men. However, the difference in TEE − EE between the women (21 ± 15%) and men (29 ± 13%) was not significant when expressed as a percentage. Furthermore, when subjects were grouped as normal-weight, overweight, or obese, the difference between TEE and EI was significantly less in the normal-weight subjects than in the overweight and obese subjects.

Results from a stepwise regression analysis of TEE measured with the use of doubly labeled water with FFM (in kg), EI (in MJ/d) from self-reported dietary records, and sex (women = 0, men = 1) are shown in **Table 2**. The mathematical relation resulting from the stepwise regression that predicts TEE is shown in equation 2

$$\text{PEE1 (MJ/d)} = 3.332 + 0.114 \cdot \text{FFM} + 0.195 \cdot \text{EI} + 0.827 \cdot S \quad (2)$$

where S is sex. The regression analysis indicates that FFM, EI, and sex contribute 86% of the variability in TEE.

Results from a second stepwise regression analysis of TEE measured with the use of doubly labeled water with the more commonly reported variables of sex (women = 0, men = 1), height (H; in m), EI (in MJ/d) from self-reported dietary records, and weight (W; in kg) are shown in **Table 3**. The mathematical relation resulting from the stepwise regression that predicts TEE is shown in equation 3.

$$\text{PEE2 (MJ/d)} = -2.158 + 1.839 \cdot S + 5.076 \cdot H + 0.249 \cdot \text{EI} + 0.0234 \cdot W \quad (3)$$

TABLE 3
Stepwise multiple regression analysis relating total energy expenditure (TEE) measured with the use of doubly labeled water to sex (women = 0 and men = 1), height, energy intake (EI) estimated from self-reported dietary records, and weight[1]

Dependent variable	Step	Independent variable	R^2	P
TEE	1	Sex	0.6808	<0.0001
TEE	2	Height	0.7776	<0.0001
TEE	3	EI	0.8148	<0.0026
TEE	4	Weight	0.8251	<0.0969

[1] R^2 is the fraction of explained variance. The last step provides the cumulative R^2.

TABLE 4
Energy expenditure predicted by using FFM, energy intake (EI), and sex (PEE1) and by using sex, height, EI, and weight (PEE2) for the women and the men[1]

	Women	Men
PEE1 (MJ/d)	9.55 ± 0.47	12.85 ± 1.11[2]
PEE1 − TEE (MJ/d)	0.00 ± 0.63	0.00 ± 0.89
PEE2 (MJ/d)	9.55 ± 0.55	12.85 ± 0.94[2]
PEE2 − TEE (MJ/d)	0.00 ± 0.70	0.00 ± 0.97

[1] $\bar{x}$ ± SD. TEE, total energy expenditure.
[2] Significantly different from women, $P < 0.05$.

The regression analysis indicates that sex, height, EI, and weight contribute 83% of the variability in TEE.

The mean values for PEE1, PEE2, PEE1 − TEE (0.0 ± 6.6% and 0.0 ± 6.9% for the women and the men, respectively), and PEE2 − TEE (0.0 ± 7.3% and 0.0 ± 7.5% for the women and the men, respectively) are shown in **Table 4**. Individual differences between predicted and measured EE are shown in **Figures 1** (PEE1 − TEE) and **2** (PEE2 − TEE). Because sex was a factor in the predictive equations, there was no significant difference between the 2 residuals in the women or the men. There was also no significant difference in residuals between the normal-weight, overweight, and obese groups. Correlation analysis of [(PEE1 − TEE) + (PEE2 − TEE)] with [(PEE1 − TEE) − (PEE2 − TEE)] indicated that the sum of the residuals and the difference between the residuals were not correlated and that the SDs of the residuals were not significantly different.

The mathematical relation for PEE1 (equation 2) was validated with published data for TEE, FFM, EI, and sex (5–8). A summary of the results is shown in **Table 5**. A comparison of TEE with PEE1 indicated that the mean difference between TEE and PEE1 was 1.4 ± 17% and −6.4 ± 14% in the 39 women and the 11 men, respectively. When TEE was compared with EI directly in the same subjects, the difference was 20.1 ± 29.9% and 6.5 ± 15.1% in the women and the men, respectively. Individual differences between PEE1 and TEE are shown in **Figure 3**. When the residuals (PEE1 − TEE) were compared by sex and age (≥ or < 40 y)

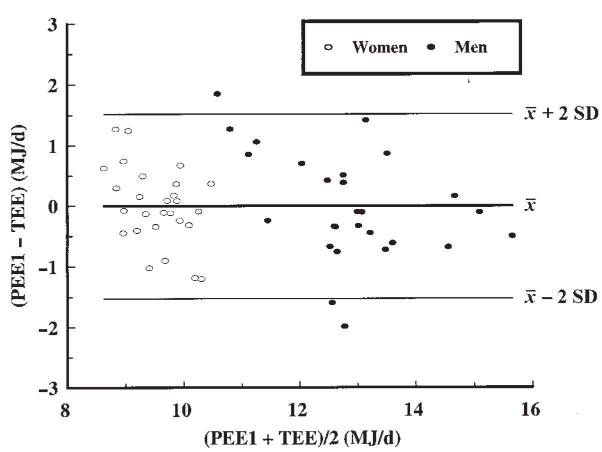

FIGURE 1. Differences between energy expenditure predicted by using model 1 (PEE1) and total energy expenditure (TEE) measured with the use of doubly labeled water plotted against mean values for 27 women and 27 men.

The American Journal of Clinical Nutrition

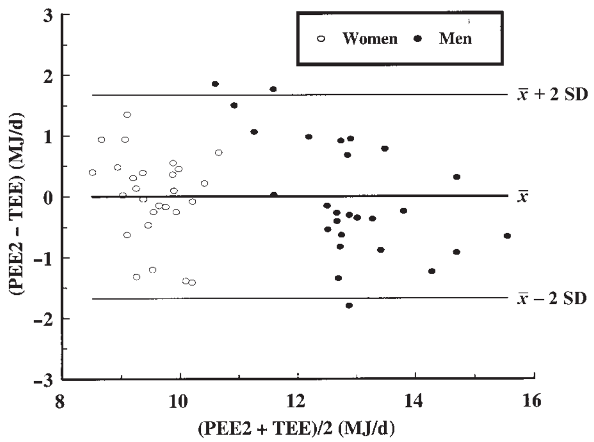

FIGURE 2. Differences between energy expenditure predicted by using model 2 (PEE2) and total energy expenditure (TEE) measured with the use of doubly labeled water plotted against mean values for 27 women and 27 men.

and between the normal-weight, overweight, and obese groups, no significant differences in the residuals were found.

The mathematical relation for PEE2 (equation 3) was validated with a somewhat larger set of published data for TEE, sex, height, EI, and weight (5, 7–10). A summary of these results is shown in **Table 6**. A comparison of TEE with PEE1 indicated that the mean difference between TEE and PEE2 was 1.0 ± 17% and −0.6 ± 20% in the 61 women and the 26 men, respectively. When TEE was compared with EI directly in the same subjects, the difference was 20.0 ± 27.1% and 17.6 ± 22.0% in the women and the men, respectively. Individual differences between PEE2 and TEE are shown in **Figure 4**. When the residuals (PEE2 − TEE) were compared by sex and age (≥ or < 40 y) and between the normal-weight, overweight, and obese groups, no significant differences in the residuals were found.

DISCUSSION

Obesity and the health complications it causes are increasing concerns of the adult population in the United States. Obesity commonly occurs when EI is greater than EE. An accurate estimation of energy requirements is necessary to combat or avoid obesity and its complications. TEE measured with the use of doubly labeled water is an ideal method for estimating energy requirements in a weight-stable adult population. Unfortunately, the practical limitations of cost, the availability of stable isotopes, and the complexity of this method prohibit its use in determining habitual EE outside of a research environment. To a great extent, nutrition researchers and health professionals rely on self-reported food intake, including dietary records, to estimate usual dietary intakes and energy requirements. However, self-reported dietary records consistently underestimate energy requirements (4–16). In the 13 studies cited, EI from self-reported dietary records underestimated TEE measured with the use of doubly labeled water by a combined average of 23% in 253 adults (183 women and 70 men). The degree of underestimation varied from 13% (7) to 50% (13). Because of this bias and variability, the validity of using self-reported dietary records to estimate nutrient and energy intakes is questionable.

The bias and variability associated with the use of self-reported dietary records to estimate EI were shown to be related to several variables, including sex, age, and obesity (15–17). In an attempt to develop a mathematical relation between TEE measured with the use of doubly labeled water and EI from self-reported dietary records, we used stepwise regression with EI, sex, age, FFM, and FM as independent variables. The results of this analysis indicated that FFM, EI, and sex were significant predictors of TEE and contributed 86% of the variability in energy requirements. Because FFM values are not as commonly reported as are height and weight, a mathematical relation was also developed between TEE and EI, sex, age, weight, and height. The results of this analysis indicated that sex, height, EI, and weight were significant predictors of TEE and contributed 83% of the variability in energy requirements. Correlation analysis on the sum of the residuals and on the difference between the residuals showed that both expressions predict EE equally well. Both of these mathematical expressions eliminated any significant bias associated with sex or obesity. Age was not a significant factor in either expression. However, because the subject population used to develop these expressions was predominately older ($\bar{x}$ age: 61 y) and the age range was somewhat restricted, the application of these results may be limited.

To test the validity of the mathematical expressions developed, both equations were used to predict TEE from published studies in which individual results of TEE, EI, and corresponding physical characteristics were reported. The equation relating TEE to FFM, EI, and sex reduced the bias and variability in reported EI from −17 ± 27% to 3 ± 16% when applied to published data (5–8). Furthermore, the bias in the predicted EE compared with measured EE was not significantly related to sex, age, or obesity. The equation

TABLE 5
Results from published data including subjects' fat-free mass (FFM), energy intake (EI) from self-reported dietary records, total energy expenditure (TEE) measured with the use of doubly labeled water, and energy expenditure predicted from FFM, EI, and sex (women = 0 and men = 1) (PEE1)

Study	*n*	Sex	Age	FFM	EI	TEE	PEE1	PEE1 − TEE
			y	*kg*	*MJ/d*	*MJ/d*	*MJ/d*	*MJ/d*
Prentice et al (5)	19	F	32	44.9 ± 5.7[1]	7.54 ± 1.56	9.12 ± 1.69	9.90 ± 0.73	0.78 ± 1.23
Schulz et al (6)	2	F	25	49.0 ± 2.0	10.50 ± 1.40	11.05 ± 0.15	10.94 ± 0.50	−0.11 ± 0.35
	4	M	25	62.6 ± 6.3	14.73 ± 1.93	14.38 ± 1.77	14.14 ± 1.09	−0.24 ± 1.68
Goran and Poehlman (7)	6	F	64	41.5 ± 2.7	6.00 ± 1.57	8.76 ± 0.88	9.21 ± 0.33	0.46 ± 0.75
	7	M	68	58.3 ± 4.2	9.73 ± 0.97	11.20 ± 1.53	12.68 ± 0.57	1.49 ± 1.42
Clark et al (8)	12	F	39	40.5 ± 6.6	8.19 ± 2.74	10.50 ± 2.10	9.48 ± 0.77	−1.02 ± 1.90
Combined	39	F	39	43.1 ± 6.1	7.65 ± 2.22	9.58 ± 1.86	9.72 ± 0.79	0.13 ± 1.60
	11	M	57	59.9 ± 5.5	11.55 ± 2.78	12.35 ± 2.23	13.21 ± 1.06	1.06 ± 1.73

[1] $\bar{x}$ ± SD.

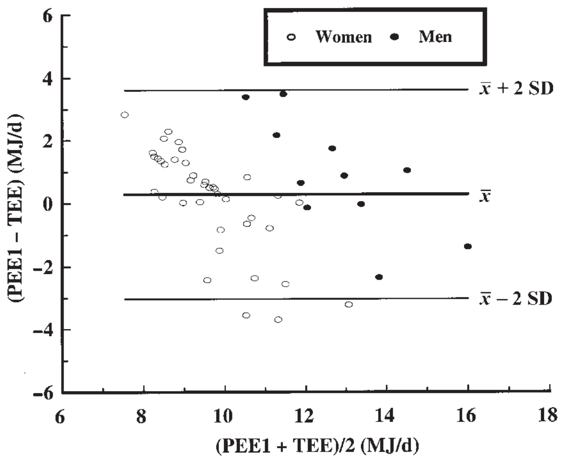

FIGURE 3. Differences between energy expenditure predicted by using model 1 (PEE1) and total energy expenditure (TEE) measured with the use of doubly labeled water plotted against mean values for 39 women and 11 men who participated in previously published studies (5–8).

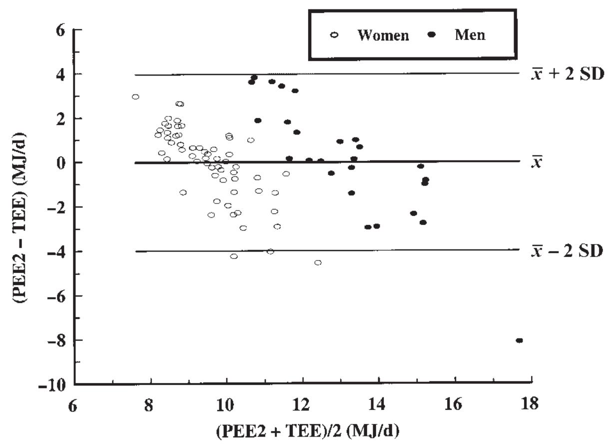

FIGURE 4. Differences between energy expenditure predicted by using model 2 (PEE2) and total energy expenditure (TEE) measured with the use of doubly labeled water plotted against mean values for 61 women and 26 men who participated in previously published studies (5, 7–10).

relating TEE to sex, height, EI, and weight reduced the bias and variability in reported EI from −19 ± 25% to −0.3 ± 19% when applied to published data (5, 7–10). Again, the bias in the predicted EE compared with measured EE was not significantly related to sex, age, or obesity. Although the variability between the subjects in these published studies was higher than that in the population used to develop the equations, the difference between predicted and measured EE in the subjects in the published studies was not significantly different from zero. Both equations appear to reasonably predict average daily EE from EI and measures of physical characteristics.

Physical characteristics such as FFM, sex, age, height, and weight have been related to daily EE measured with the use of doubly labeled water by using regression analysis (25, 26). FFM and age were found to account for 65% of the variability in TEE in 299 adults (25). Weight, height, age, and sex were found to explain 77% of the variability in TEE in 574 individuals (26). EI estimated from self-reported dietary records was added to the variables used to predict daily EE in an attempt to reduce individual variation. While EI contributed modestly in reducing variability in both equations (PEE1, 2.5% and PEE2, 3.7%), it was a significant factor and overall results were improved. However, the level of improved variability in TEE may not warrant the collection of EI data, which are often costly and difficult to obtain, for the sole purpose of estimating EE.

The degree of underrecording of EE and the variability in EI from self-reported intake records have been related to TEE measured with the use of doubly labeled water by examining the ratio of TEE to the basal metabolic rate and the ratio of EI to the basal metabolic rate, respectively (18, 27, 28). Among the principles used to determine this relation are that long-term EI is equivalent to TEE and that for most people the minimum survivable ratio of TEE to the basal metabolic rate is 1.27. Other factors used were the within-subject variations in EI and in the basal metabolic rate. Relations based on the number of subjects, the number of days that dietary records were collected, confidence limits of 95% or 99%, and measured or calculated basal metabolic rates were used to develop cutoff limits for minimum plausible ratios of EI to basal metabolic rates (27). The cutoff limits can be used to evaluate the bias in self-reported dietary records of populations but have limited ability to identify individual underrecorders (28). Furthermore, unlike the expressions proposed in this study, the cutoff limits are of limited utility in estimating EE from EI data.

TABLE 6
Results from published data including subjects' sex, weight, BMI, energy intake (EI) from self-reported dietary records, total energy expenditure (TEE) measured with the use of doubly labeled water, and energy expenditure predicted from sex, weight, BMI, and EI (PEE2)

Study	*n*	Sex	Age	Weight	BMI	EI	TEE	PEE2	PEE2 − TEE
			y	*kg*	*kg/m²*	*MJ/d*	*MJ/d*	*MJ/d*	*MJ/d*
Prentice et al (5)	19	F	32	70.5 ± 18.1[1]	26.5 ± 6.3	7.54 ± 1.56	9.12 ± 1.69	9.64 ± 0.68	0.53 ± 1.38
Livingstone et al (9)	15	F	35	62.4 ± 7.9	24.1 ± 2.9	8.00 ± 1.82	9.93 ± 1.48	9.46 ± 0.61	−0.47 ± 1.25
	16	M	32	79.7 ± 11.5	25.7 ± 3.2	11.21 ± 2.40	14.23 ± 2.86	13.31 ± 0.96	−0.91 ± 2.55
Goran and Poehlman (7)	6	F	64	65.2 ± 7.1	23.8 ± 2.7	6.00 ± 1.57	8.76 ± 0.88	9.27 ± 0.40	0.51 ± 0.85
	7	M	68	77.1 ± 6.9	25.3 ± 2.3	9.73 ± 0.97	11.20 ± 1.53	12.82 ± 0.61	1.62 ± 1.62
Clark et al (8)	12	F	39	55.4 ± 7.8	20.7 ± 2.8	8.19 ± 2.74	10.50 ± 2.10	9.48 ± 0.80	−1.02 ± 2.47
Rothenberg et al (10)	9	F	73	65.7 ± 5.5	24.9 ± 2.9	8.01 ± 1.76	9.60 ± 1.09	9.63 ± 0.39	0.03 ± 1.07
	3	M	73	74.0 ± 10.7	23.5 ± 2.3	10.45 ± 1.35	10.79 ± 1.67	13.04 ± 0.63	2.25 ± 1.19
Combined	61	F	43	64.3 ± 13.0	24.3 ± 4.7	7.70 ± 2.03	9.62 ± 1.70	9.53 ± 0.64	−0.09 ± 1.67
	26	M	46	78.3 ± 10.5	25.3 ± 3.0	10.73 ± 2.10	13.02 ± 2.89	13.15 ± 0.87	0.13 ± 2.58

[1] $\bar{x}$ ± SD.

While self-reported dietary records have shown a bias to underreport normal daily EE, they remain an important tool for nutrition researchers and health professionals in determining dietary intake. The bias toward underreporting EE does suggest that many other nutrients contained within the diet may also be underreported and that the degree of underreporting may be related to the bias in EI. Nutrition researchers and health professionals need to consider this error when using these dietary records. The models developed in this study may add some insight into the bias and errors encountered with intake data determined from self-reported dietary records.

Multiple regression analysis relating TEE measured with the use of doubly labeled water to EI from self-reported dietary records, sex, and FFM or height and body weight indicates that most of the variation between subjects was accounted for by using these variables. These results suggest that corrective measures relating EI and variables describing physical characteristics are possible. Although the variability in TEE predicted from the equations developed by using multiple regression analysis may limit the application of these equations to individual energy requirements, application to groups is promising. This possibility deserves further investigation.

REFERENCES

1. FAO/WHO/UMU Expert Consultation. Energy and protein requirements. Geneva: World Health Organization, 1985.
2. Lifson N. Theory of use of the turnover rates of body water for measuring energy and material balance. J Theor Biol 1966;12:46–74.
3. Weir JB. New methods for calculating metabolic rate with special reference to protein metabolism. J Physiol (Lond) 1949;109:1–9.
4. Seale JL, Rumpler WV. Comparison of energy expenditure measurements by diet records, energy intake balance, doubly labeled water and room calorimetry. Eur J Clin Nutr 1997;51:856–63.
5. Prentice AM, Black AE, Coward WA, et al. High levels of energy expenditure in obese women. Br Med J (Clin Res Ed) 1986;292:983–7.
6. Schulz S, Westerterp KR, Bruck K. Comparison of energy expenditure by the doubly labeled water technique with energy intake, heart rate, and activity recording in man. Am J Clin Nutr 1989;49:1146–54.
7. Goran MI, Poehlman ET. Total energy expenditure and energy requirements in healthy elderly persons. Metabolism 1992;41:744–53.
8. Clark D, Tomas F, Withers RT, et al. Energy metabolism in ‘large eating’ and ‘small eating’ women: studies using $^2H_2{}^{18}O$. Br J Nutr 1994;72:21–31.
9. Livingstone MBE, Prentice AM, Coward WA, et al. Accuracy of weighed dietary records in studies of diet and health. BMJ 1990:300:708–12.
10. Rothenberg E, Bosaeus I, Lernfelt B, Landahl S, Steen B. Energy intake and expenditure: validation of a diet history by heart rate monitoring, activity diary and doubly labeled water. Eur J Clin Nutr 1998;52:832–8.
11. Martin LJ, Wanfang S, Jones PJ, Lackwod GA, Tritcher DL, Boyd NF. Comparison of energy intakes determined by food records and doubly labeled water in women participating in a dietary-intervention trial. Am J Clin Nutr 1996;63:483–90.
12. Sawaya AL, Tucker K, Tsay R, et al. Evaluation of four methods for determining energy intake in young and older women: comparison with doubly labeled water measurements of total energy expenditure. Am J Clin Nutr 1996;63:491–9.
13. Singh J, Prentice AM, Diaz E, et al. Energy expenditure of Gambian women during peak agricultural activity measured by doubly-labeled water method. Br J Nutr 1989;62:315–29.
14. Withers RT, Smith DA, Tucker RC, Brinkman M, Clark DG. Energy metabolism in sedentary and active 49- to 70-yr-old women. J Appl Physiol 1998;84:1333–40.
15. Tomoyasu NJ, Toth MJ, Poehlman ET. Misreporting of total energy intake in older men and women. J Am Geriatr Soc 1999;47:710–5.
16. Black AE, Prentice AM, Goldberg GR, et al. Measurements of total energy expenditure provide insights into the validity of dietary measurements of energy intake. J Am Diet Assoc 1993;93:572–9.
17. Schoeller DA. Limitations in the assessment of dietary energy intake by self-report. Metabolism 1995;44(suppl):18–22.
18. Goldberg GR. From individual variation in energy intakes. . . to variations in energy requirements and adaptations to them. Br J Nutr 1997;78(suppl):S81–94.
19. Black AE, Goldberg GR, Jebb SA, Livingston MBE, Cole TJ, Pentice AM. Critical evaluation of energy intake data using fundamental principles of energy physiology: 2. evaluating the results of published surveys. Eur J Clin Nutr 1991;45:583–99.
20. Stansell MJ, Mojica L Jr. Determination of body water content using trace levels of deuterium oxide and infrared spectrophotometry. Clin Chem 1968;14:1112–24.
21. Seale JL, Miles CW, Bodwell CE. Sensitivity of methods for calculating energy expenditure by use of doubly labeled water. J Appl Physiol 1989;66:644–53.
22. Schoeller DA, Ravussin E, Schultz Y, Acheson KJ, Baertschi P, Jaquier E. Energy expenditure by doubly labeled water: validation in humans and proposed calculation. Am J Physiol 1986;250:R823–30.
23. Seale JL, Conway JM, Canary JJ. Seven-day validation of doubly labeled water method using indirect calorimetry. J Appl Physiol 1993;74:402–9.
24. Snedecor GW, Cochran WG. Statistical methods. 7th ed. Ames, IA: Iowa State University Press, 1980.
25. Schulz LO, Schoeller DA. A compilation of total daily energy expenditures and body weight in healthy adults. Am J Clin Nutr 1994;60:676–81.
26. Black AE, Coward WA, Cole TJ, Prentice AM. Human energy expenditure in affluent societies: an analysis of 574 doubly-labelled water measurements. Eur J Clin Nutr 1996;50:72–92.
27. Goldberg GR, Black AE, Jebb SA, et al. Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. derivation of cut-off limits to identify under-recording. Eur J Clin Nutr 1991;45:569–81.
28. Black AE. Critical evaluation of energy intake using the Goldberg cut-off for energy intake:basal metabolic rate. A practical guide to its calculation, use and limitations. Int J Obes Relat Metab Disord 2000;24:1119–30.