Correlates of over- and underreporting of energy intake in healthy older men and women

Rachel K Johnson, Michael I Goran, and Eric T Poehlman

ABSTRACT

The aim of this study was to determine whether variations in physiological characteristics were predictive of over- or underreporting of energy intake in older men and women. Total energy expenditure was predicted in 81 older men (66 ± 6 y) and 56 older women (66 ± 6 y) from a previously developed equation that uses the doubly labeled water method. The degree of over- or underreporting of energy intake was derived by subtracting predicted total daily energy expenditure from self-reported energy intake obtained from a 3-d diet record. Older women underreported energy intake (-2206 kJ/d ± 1841) to a greater degree than did older men (-1301 kJ/d ± 1908) (P = 0.01). In men, none of the physiological variables were significantly correlated with over- or underreporting of energy intake. Among the women, percent body fat was negatively correlated with underreporting of energy intake (r = -0.42, P = 0.001). Thus, the underreporting of energy intake increased with the amount of adiposity in women.

KEY WORDS

Elderly people, energy intake underreporting, adiposity

Introduction

One of the major obstacles in nutritional epidemiology research has been uncertainty about the validity of existing dietary assessment methodologies (1). The doubly labeled water method for measuring total daily energy expenditure can serve as a reference for assessing the accuracy of conventional dietary intake methodologies (2). This concept is based on the premise that the measurement of total energy expenditure in free-living individuals can serve as a proxy measure of energy intake when subjects are in energy balance (3). Studies using the doubly labeled water method, conducted among diverse age groups with a variety of health and/or disease states, confirm that self-reports of energy intake tend to be lower than measured total energy expenditure (2, 4-9). Taken collectively, these studies found that self-reported food intakes underestimated habitual energy intakes.

It is generally accepted that the arduous task of recording food intake may contribute to the unintentional underreporting of energy intake. However, it is also possible that certain physiological characteristics may be predictors of the discrepancy between reported energy intake and total energy expenditure. Elucidating these characteristics could be a meaningful step toward the application of correction factors to national dietary survey data to arrive at more accurate determinations of habitual energy intake in elderly people. This is particularly important in older men and women in whom energy requirements are unknown, and who experience extremes of thinness and fatness. Low body weight in elderly people increases the risks for systemic infection and mortality (10, 11), whereas on the other end of the energy spectrum, it is estimated that 10% of men and women between 65 and 75 y of age are severely obese (12).

Although the doubly labeled water method can accurately measure free-living energy expenditure, the technique does not lend itself to large epidemiologic studies. Major disadvantages of this technique include its high cost, the scarcity of stable isotopes, and the need for an isotope ratio mass spectrometry, leaving the doubly labeled water method available in only a few sophisticated research settings. Given these limitations, we recently developed a prediction equation for estimating total energy expenditure in healthy older men and women using independent variables, which are easily measured in a clinical setting (6). In the present study we applied this prediction equation to a large sample of well-characterized, healthy older men and women and thereafter examined factors that were predictive of the discrepancy between self-reported energy intake and predicted total energy expenditure.

Subjects and methods

Subjects

Data from 81 older white males (aged 56-78 y) and 56 older white females (aged 56-81 y) who volunteered for our ongoing

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2 Supported by United States Department of Agriculture HATCH Act Project #H489 (RKJ), the American Diabetes Association (MIG), the United States Department of Agriculture (MIG), a Shannon Award from the National Institute of Child Health and Human Development (MIG), the National Institute on Aging AG-07857 (ETP), the American Association of Retired Persons (ETP), the Andrus Foundation (ETP), a Research Career and Development Award from the National Institute of Aging (ETP), and in part by the General Clinical Research Center (National Institutes of Health grant no. RR-109) and the Sins Obesity Nutrition Research Center.

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Received June 24, 1993

Accepted for publication Nov 18, 1993

studies on aging and energy metabolism were used for this study. The volunteers for our studies were recruited by advertisement from Burlington, VT, and the surrounding rural areas. All participants were in excellent general health, as defined by 1) no clinical evidence of coronary heart disease as assessed by normal resting and exercise stress test electrocardiograms, 2) a resting blood pressure < 140/90 mm Hg, 3) absence of any prescription or over-the-counter medication that could affect cardiovascular function, 4) no medical history of diabetes, and 5) weight stability (±2 kg by medical history within the past year). The procedures used in this study were approved by the Committee on Human Research for the Medical Sciences at the University of Vermont. Written informed consent was obtained from each subject before the investigation.

Measurements of physical characteristics

Subjects were admitted to the Clinical Research Center the evening before all metabolic measurements. All volunteers were fed a standard meal at 1800 h (4186 kJ, 55% of energy as carbohydrate, 15% of energy as protein, and 30% of energy as fat). The next morning the following were determined: 1) resting metabolic rate (RMR), 2) body composition from underwater weighing, 3) maximal aerobic power (VO\textsubscript{2}max), 4) anthropometrics, and 5) leisure time activity 6). Instructions for reporting of dietary intake were also given at this time. The reproducibility of these tests was reported previously (13).

RMR was measured for 45 min in the early morning after an overnight fast by respiratory gas analysis using a ventilated-hood system, as previously described (13). Energy expenditure was calculated by using the Weir equation (14). It is important to note that RMR was measured on an inpatient basis, which yields RMR measurements that are lower than RMR measurements done on an outpatient basis in our laboratory (15).

Height was recorded to the nearest 0.5 cm by using a stationary inflexible measuring tape and head board. Body weight was measured to the nearest 0.5 kg by using a calibrated scale. Body mass index (BMI) was calculated as weight (in kg) divided by height\textsuperscript{2} (in m). Total body density was measured by underwater weighing with simultaneous measurement of residual lung volume by the helium-dilution method (16), and the Siri equation (17) was used to estimate the percentage of body fat. Fat mass was calculated by multiplying body weight times percent fat, and fat-free mass was calculated by subtracting fat mass from body weight. To estimate upper and lower body fat distribution, a measuring tape was used to determine the waist-to-hip circumference ratio while subjects stood upright. Waist measurements were taken at the minimal circumference of the abdomen, and the hip circumference was measured at the maximal gluteal protuberance of the buttocks. Skinfold-thickness measurements were taken from nine sites on the right side of the body with Lange calipers (Cambridge, MA). Each skinfold value was taken by the same investigator (ETP) and represents the mean of three consecutive measurements.

VO\textsubscript{2}max was measured by a progressive and continuous test to exhaustion on the treadmill, as previously described (13). Subjects self-selected their running speed, and the incline was increased by 2.5% every 2 min from an initial level of 0% until volitional fatigue. The attainment of VO\textsubscript{2}max required meeting at least two of the following criteria: 1) attainment of age-predicted maximal heart rate, 2) a maximal respiratory exchange ratio > 1.0, or 3) no further increase in oxygen consumption, despite an increase in workload.

The energy cost of leisure time activities (LTAs) during the previous 12-mo period was estimated by using The Minnesota Leisure Time Physical Activity Questionnaire (18, 19), as previously described (13). This evaluation is a structured interview that assesses the frequency and duration of participation in recreational activities over the previous 12-mo period. Each activity is assigned an intensity code (eg, walking for pleasure, 3.5; cross-country skiing, 8.0) that is multiplied by the total estimated minutes in the year spent performing this activity. The cumulative cost for LTA over the previous year was averaged and expressed as kJ/d. We previously showed that in elderly subjects LTA is highly correlated (r = 0.83, P < 0.001) with the energy expenditure of physical activity as estimated from the difference between total energy expenditure (by the doubly labeled water method) and RMR (by indirect calorimetry) (6).

Energy intake and predicted total energy expenditure

Total energy expenditure was predicted by using a published equation developed in our laboratory from the measurement of total energy expenditure by using the doubly labeled water method in 13 healthy, free-living older men and women (seven men and six women, aged 56–78 y) (6). In this previously performed analysis, stepwise-regression analysis was used to determine the strongest independent predictors of total energy expenditure by using sex, age, height, fat mass, fat-free mass, LTA, VO\textsubscript{2}max, RMR, fasting respiratory exchange ratio, 3-d reported food intake, and the food quotient value of the diet as potential independent variables. VO\textsubscript{2}max and LTA explained 86% of the variation (R\textsuperscript{2}) in total energy expenditure and RMR and LTA explained 83% of the variation (R\textsuperscript{2}) in total energy expenditure in this sample. We predicted total energy expenditure in our larger sample using the following equation:

\[\text{PTEE (kJ/d)} = (1.29 \times \text{LTA}) + (0.98 \times \text{RMR}) + 1620\]

where PTEE is the predicted total energy expenditure and LTA and RMR are expressed in kJ/d; the adjusted R\textsuperscript{2} = 0.83. We selected this equation in favor of the one using VO\textsubscript{2}max and RMR because 1) we wanted to include a measure of maximal aerobic power (VO\textsubscript{2}max) as a potential predictor of energy intake misreporting; 2) we did not want common variables in both the prediction equation and as a possible independent predictor variable, because this would produce spuriously high correlations; and 3) the two published prediction equations had comparable R\textsuperscript{2} values.

Self-reported energy intake was obtained from a 3-d, self-administered food diary, which included two weekdays and one weekend day. Subjects were strongly encouraged not to change their normal dietary habits and were trained by research assistants familiar with the procedure on how to measure and report food intakes. Subjects were taught how to describe the quantity of food ingested with the aid of a dietary scale, measuring cups, and spoons. Food records were checked for completeness by a research assistant at the time of their return by the subject. The records were analyzed for energy content by using the Nutritionist III software package (version 4.0; N-Squared Computing, Salem, OR).

An estimate of the discrepancy between self-reported energy intake and predicted total energy expenditure was obtained by
higher and reported energy intake was 38% higher in the men
presented in Table 2. Predicted total energy expenditure was 19%
tween the two groups.

was generated. There were no significant differences in age,
derreported energy intake when compared with the men

was significantly lower compared with the men. The volunteers

significantly higher in the women whereas VO2 max and RMR

were significantly different from males, \( P = 0.001 \) (independent t test).

\( ^1 \) In kg/m².

subtracting predicted total energy expenditure from the self-re-
ported energy intake. When this method is used, a negative value
would indicate a reported energy intake less than the predicted
total energy expenditure (underreporting) and a positive value
would denote a reported energy intake greater than the predicted
total energy expenditure (overreporting).

Statistics

Mean (±SD) values are presented for all measures. Differences
between men and women were assessed by using independent t tests. The Pearson product-moment correlation coefficient
was used to derive the level of association between pairs of variables. Multiple-correlation regression analysis was used to
determine the relative contribution of selected independent variables to the variation in the dependent variable (energy intake
over- or underreporting). All statistics were performed by using
either Clinfo (BBN Software Products Corporation, Cambridge,
MA) or BMDP (BMDP Statistical Software, Berkeley, CA) soft-
ware packages.

Results

Table 1 presents a summary of the physical characteristics of
the subjects. The men and women were similar with respect to
age, BMI, and LTA. The men were significantly taller, had a
greater waist-hip ratio, and weighed more than the women be-
cause of a greater quantity of fat-free mass. Percent body fat was
significantly higher in the women whereas VO2 max and RMR
were significantly lower compared with the men. The volunteers
in the present study were compared with the original 13 subjects
from which the prediction equation for total energy expenditure
was generated. There were no significant differences in age, body
weight, fat mass, fat-free mass, VO2 max, LTA, and RMR be-
tween the two groups.

The components of energy intake over- and underreporting are
presented in Table 2. Predicted total energy expenditure was 19%
higer and reported energy intake was 38% higher in the men
when compared with the women. The women significantly un-
derreported energy intake when compared with the men (\( t = 2.77, P < 0.01 \)). On average, the men underreported their intake
by 12% and the women by 24%. Because of this difference, we
examined possible physiological predictors of the discrepancy
between reported energy intake and predicted total energy ex-
penditure separately by sex.

A summary of the bivariate associations between the depend-
ent variable, energy intake over- and underreporting, and the
independent physiological variables under consideration are
shown in Table 3. The over-and underreporting of energy intake
were not significantly correlated with any of the measured phys-
iological variables in the men. Among the women, underreport-
ing of energy intake increased as fat mass and percent body fat
increased.

The two variables that were predictive of energy intake un-
derreporting in the women (percent body fat and fat mass) were
highly intercorrelated (\( r = 0.83, P = 0.001 \)) as both represented
measures of adiposity. Because of the multicollinearity of these
two variables, the use of multiple regression did not add to the
amount of variation explained in the dependent variable. Thus,
among the women, percent body fat explained the most variation
in energy intake underreporting (\( r = -0.42, P = 0.001, \) Fig 1).

<table>
<thead>
<tr>
<th>Physiological variable</th>
<th>Males (n = 81)</th>
<th>Females (n = 56)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.01</td>
<td>0.06</td>
</tr>
<tr>
<td>Height</td>
<td>0.11</td>
<td>0.03</td>
</tr>
<tr>
<td>Weight</td>
<td>0.07</td>
<td>-0.03</td>
</tr>
<tr>
<td>BMI</td>
<td>0.02</td>
<td>-0.01</td>
</tr>
<tr>
<td>Waist-hip ratio</td>
<td>-0.01</td>
<td>0.03</td>
</tr>
<tr>
<td>Fat mass</td>
<td>0.02</td>
<td>-0.28</td>
</tr>
<tr>
<td>Fat-free mass</td>
<td>0.09</td>
<td>0.24</td>
</tr>
<tr>
<td>Percent body fat (%)(^1)</td>
<td>0.01</td>
<td>-0.42(^2)</td>
</tr>
<tr>
<td>VO2 max (L/min)(^3)</td>
<td>0.05</td>
<td>-0.16(^2)</td>
</tr>
</tbody>
</table>

\(^1\) A negative value denotes that for a given increase in a variable (eg, percent body fat), the greater the underreporting of energy intake.
\(^2\) \( P > 0.05. \)
\(^3\) Measured by hydrostatic weighing.
\(^4\) \( P = 0.001. \)
The objective of this study was to determine the physiological characteristics that were correlated with the discrepancy between self-reported energy intake and predicted total daily expenditure in healthy older men and women. The major findings are 1) older women underreport energy intake to a greater degree than do older men, and 2) increasing adiposity is an independent predictor of underreporting in older women.

The doubly labeled water method is too expensive and technically demanding to be used as a validator of energy intake measurements in large samples. Thus, we predicted total daily energy expenditure from an equation generated from a smaller sample of older men and women (6) to provide a preliminary understanding of the biases that may exist in self-reported energy intake data collected from older individuals. Although the original prediction equation was generated from a small sample size (n = 13), the $R^2$ for the equation was high ($R^2 = 0.83$, SEE = $\pm 1013$ kJ) and it was applied in the present study to an independent sample of similar race, geographic location, selection criteria, and physiologic characteristics.

The degree of underreporting that occurred was outside the range of the expected error resulting from the application of the prediction equation. That is, the SEE of the prediction equation was $\pm 1013$ kJ, whereas on average the males underreported by $-1301$ kJ/d and the females underreported by $-2206$ kJ/d. In addition, the magnitude of underreporting (12% among men, 24% among women) is comparable with other published reports in normal-weight, younger subjects. Mertz et al (20) reported that participants in the Beltsville Nutrition Study reported food intakes that were 18% below maintenance values. Hallfrisch et al (21) reported that the energy intake needed to maintain body weight during 18 wk of metabolic studies was 19% greater in men and 37% greater in women than that estimated by self-recorded 7-d weighed food records. Livingstone et al (22) compared energy intake as measured by 7-d weighed dietary records and total energy expenditure measured concurrently with the doubly labeled water method and found that on average the men ($n = 16$) underreported their intake by 19% and the women ($n = 15$) by 18%. To date there is a paucity of work done in elderly people. This study provides new information on the degree of underreporting of energy intake that occurs in healthy, nonobese older persons.

In our sample, the older men were less likely to underreport their energy intake than were the older women. These sex differences have been noted in younger individuals. Black et al (23) reviewed 37 published studies and found that younger men were less apt to underestimate their intake than were younger women. Although the basis for these differences is not known, it could be speculated that the societal pressure placed on women to be slim induced alterations in their recording of food, which made them appear to be "small eaters." In addition, we found no physiological predictors of energy misreporting in the men. Although the reason for this finding is unclear, it is possible that many of the older men in this cohort had female spouses who were the primary food preparers in the household. If the female spouse took on the task of recording food intake, this could partially explain the lack of physiological predictor variables in the men.

In our sample of normal-weight older women, adiposity was a strong predictor of underreporting of energy intake. In the literature, underreporting has been found to occur to a greater degree among obese than among normal-weight subjects. Lichtman et al (9) reported that young, obese subjects underreported their actual food intake by 47% and Lansky and Brownell (24) found reporting errors that averaged 53%. It is possible that some of the women within the higher range of percent body fat were reducing their body weight at the time of the study and thus were not in energy balance for the 3-d period they were recording their energy intake. We feel this is unlikely however, because subjects reported weight stability before participating in the study. Thus, our data suggest that this bias towards increased underreporting by obese people occurs even within the range of body fatness observed among normal-weight, older women.

To our knowledge, only three studies have been performed using the doubly labeled water method to examine energy requirements in older individuals (6, 25, 26), but attempts to examine physiological predictors of the discrepancy between reported energy intake and total energy expenditure were limited...
by the smaller sample sizes. We found that among well-characterized, older men and women there were a limited number of physiological variables that predicted the underreporting of energy intake. Thus, research is needed that examines other non-physiological characteristics (income, marital, and educational status) and their relationship with energy intake underreporting.

All of our subjects were self-selected, highly motivated, compliant, elderly volunteers. Thus, the bias toward energy intake underreporting is unlikely to be an overestimate of either the frequency or amount of underreporting that would exist among randomly selected, less-motivated samples such as those drawn for large nationwide diet and health surveys like the National Health and Nutrition Examination Survey (NHANES) and the US Department of Agriculture Nationwide Food Consumption Survey (NFCS).

To date, when nutritionists interpret group nutrient intake data they base their conclusions on the assumption that although normal random variation occurs within the sample, the mean intake reflects the usual intake of that group. However, every published study to date has reported the presence of a systematic bias resulting from reported energy intakes that were lower than either measured energy expenditure, predicted energy expenditure, or observed energy intake. This bias can lead to false conclusions if it is associated with a physiological variable of interest. For example, studies comparing obese and normal-weight subjects have concluded that the energy intakes of the obese subjects are no higher than those of normal-weight subjects (27, 28). If the obese subjects in these studies were underreporting their food intake to a greater degree than were the lean subjects, these conclusions could be misleading.

We have defined two physiological variables that were associated with energy intake underreporting in older men and women: sex and adiposity in women. Hence, nutrient intake data collected from comparable samples of older individuals need to be examined keeping these biases in mind. As we compare energy intake derived from estimated diet records and intake determined to maintain body weight. Am J Clin Nutr 1991;54:291-5.

We thank Michael Toth and Stephen Pintauro for their assistance with the graphic presentation of the data, the staff of the Clinical Research Center, and the volunteers who participated in our study.

References