Validity of reported energy expenditure and energy and protein intakes in Swedish adolescent vegans and omnivores[1–3]

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ABSTRACT

Background: It is difficult to obtain accurate reports of dietary intake; therefore, reported dietary intakes must be validated. Researchers need low-cost methods of estimating energy expenditure to validate reports of energy intake in groups with different lifestyles and eating habits.

Objective: We sought to validate the reported energy expenditure and energy and protein intakes of Swedish adolescent vegans and omnivores.

Design: We compared 16 vegans (7 females and 9 males; mean age: 17.4 ± 0.8 y) with 16 omnivores matched for sex, age, and height. Energy expenditure as reported in a physical activity interview and energy and protein intakes as reported by diet history were validated by using the doubly labeled water method and by measuring urinary nitrogen excretion.

Results: The validity of reported energy expenditure and energy and protein intakes was not significantly different between vegans and omnivores. The physical activity interview had a bias toward underestimating energy expenditure by 1.4 ± 2.6 MJ/d (95% CI: 2.4, 0.5 MJ/d). The diet-history interview had a bias toward underestimating energy intake by 1.9 ± 2.7 MJ/d (95% CI: 2.9, 1.0 MJ/d) but showed good agreement with the validation method for nitrogen (protein) intake (underestimate of 0.40 ± 1.90 g N/d; 95% CI: 1.10, 0.29 g N/d).

Conclusions: The physical activity and diet-history interviews underestimated energy expenditure and energy intake, respectively. Energy intake and expenditure were underestimated to the same extent, and the degree of underestimation was not significantly different between vegans and omnivores. Valid protein intakes were obtained with the diet-history method for both vegans and omnivores. *Am J Clin Nutr* 2002;75:268–74.

KEY WORDS Vegetarian, vegan, omnivore, adolescent, energy expenditure, energy intake, protein intake, physical activity, dietary assessment, doubly labeled water, biological markers

INTRODUCTION

Few validated dietary surveys have been done in adolescents. Published reports of these surveys showed that the diet-history (DH) method produced valid estimates of energy intakes (EIs), whereas the diet-record method underestimated intakes by ≤46% (1–3). Unvalidated dietary surveys of adolescents are also scarce, and often report EIs and energy expenditures (EEs) that are not consistent with long-term survival (4, 5). Such reports often give the EE and EI data in relation to basal metabolic rate (BMR), reporting the food intake level (FIL = EI/BMR) and physical activity level (PAL = EE/BMR), which are too low for long-term survival.

Assessment of dietary intakes in populations with various lifestyles and dietary habits may give rise to methodologic problems, producing different biases in different populations. In addition, food databases used for calculating nutrient intakes are usually designed for the most prevalent eating habits in the population, which are typically omnivorous diets. Consequently, many vegetarian food items are missing from the databases and, thus, information about them must be collected and entered manually if correct nutrient intake values are to be obtained.

Doubly labeled water (DLW) can be used as a biological marker to validate reported energy intake (EI_{rep}) and reported energy expenditure (EE_{rep}) (3, 5). The method is expensive to use in large populations, and only a limited number of dietary surveys have been validated by the DLW method. Therefore, there is a need for simplified, less expensive, but still valid methods of estimating EE_{rep}. With a simplified validation method, EI_{rep} could then be validated by comparison with EE_{rep} in large population studies; the ratio of EI_{rep} to EE_{rep} should equal 1.0 if the estimates of EI_{rep} and EE_{rep} are accurate (5).

Protein (nitrogen) intake can be validated by comparing it with nitrogen excretion in urine samples collected over 24 h (6, 7). Because the proportion of total energy derived from protein is often relatively constant, protein intake is also an indicator of total food (energy) intake. The Swedish food database contains information on the protein, but not the nitrogen, contents of foods. To convert nitrogen excretion to protein intake, an average nitrogen intake of 16% in dietary protein is usually assumed (7).

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However, for veganism and other unusual dietary habits, this assumption may give rise to biased estimates of protein intake.

The aim of this study was to validate a physical activity (PA) interview and a DH interview for estimating EE, EI, and protein intake in Swedish adolescent vegans and omnivores by comparison with biological markers of EE and protein intake. This validation study is part of a larger study comparing young vegans and omnivores in terms of their dietary intakes and nutritional status.

SUBJECTS AND METHODS

Subjects

Thirty-two adolescents living in Umeå, Sweden, were recruited by using advertisements and visits to schools: the subjects were 16 vegans and 16 omnivores matched to the vegans by sex, age (±6 mo), and height (±3.5 cm). The subjects had to be in good health, have no chronic diseases, and be aged 16–20 y. Vegans were defined as people eating foods of plant origin only and were included if they had been consuming such a diet for ≥6 mo and were planning to continue this diet. Omnivores were defined as people eating foods of both plant and animal origin and were included if they had been consuming such a diet for their entire life and were planning to continue this diet. In total, 65 vegetarians and 272 omnivores were interviewed before the 32 subjects were enrolled. All participants gave their written, informed consent. The study was approved by the Research Ethics Committee of the Medical Faculty, Umeå University.

Dietary assessment

DH interviews were conducted (by CLL) with all the subjects between January and June 1998. Each subject was questioned about his or her usual food intake during two 1–2-h interviews separated by 1–2 wk. The aim was to describe the subjects' typical eating patterns over the preceding 3 mo. During the first interview, meal patterns, food choices, and food frequencies were discussed. Subjects were asked to bring recipes and information about dietary supplements to the second interview. Subjects described average portion sizes of food items in terms of household measures, standard weights of food items, 3-dimensional food models, or validated food-portion photographs representing known weights (8). The food, beverage, and supplement intakes from the DH interview were entered into the dietary analysis program STOR MATS 4_03e, which uses the Swedish food composition database (version 2_97; Rudans Lattdata, Vasteras, Sweden). When composite foods not present in the database were reported, the subjects' own recipes were entered. Months of vegetarianism reported in the interview were defined as months of eating either lactoovovegetarian or lactovegetarian diets, which include dairy products and eggs or just dairy products, respectively, but no meat, poultry, or fish. Months of veganism were defined as months of eating foods of plant origin only. Body weight in light underwear was measured to the nearest 0.1 kg and height was measured to the last completed 0.5 cm.

Urine collections

After the first DH interview, each subject started the first of four 24-h urine collections. Because many factors can affect nitrogen balance, both before and during the urine collection, subjects were asked to provide information about any problems during the collection. To this end, subjects were asked if they had lost any urine, used any medication, had any problems with diarrhea, had atypical dietary intake or PA, or perspired a lot. However, it is difficult to estimate the influence of these factors on the results.

The completeness of the urine collections was verified by giving the subjects para-aminobenzoic acid (PABA) and measuring the amount excreted in the urine (9). Each subject took 3 tablets containing 80 mg PABA each: one tablet on awakening (after first emptying the bladder), one within 6 h (at the midday meal), and one within 12 h (at the evening meal). The 24-h urine collections began after the subjects awoke in the morning and emptied their bladders and continued until the next morning. Each 24-h urine collection was weighed and 2 samples from each collection were analyzed for PABA and nitrogen contents.

PABA in the urine was measured colorimetrically (9). Urine collections containing 85–110% of the PABA consumed were classified as complete. Urine collections containing <85% of the PABA consumed were classified as incomplete. Those urine collections containing <50% or >110% of the PABA consumed were rejected. For the collections containing 50–85% of the PABA consumed, the nitrogen content was adjusted by using a linear regression method (10) and the following equation.

$$\text{Compensated N} = \text{excreted N} + [0.088 \times (93 - \text{PABA})] \quad (1)$$

where compensated N is the estimated nitrogen content (in g) after compensating for incomplete urine collections, excreted N is the excreted nitrogen (in g) in incomplete urine collections, 0.088 is the slope from a linear regression between PABA and nitrogen excretion (10), 93 is the mean PABA recovery (93%) in complete urine collections (9), and PABA is the recovery of PABA in incomplete urine collections, which is a value of 50–85%.

We measured urinary nitrogen (N_{meas}) by using the Kjeldahl technique with a Tecator 1002 (Perstorp Analytical, Bristol, United Kingdom). The N_{meas} value was divided by the excretion factor 0.81 and was used as a biological marker for nitrogen intake as reported in the DH interview (9). The reported nitrogen intake (N_{rep}) was obtained by entering the protein factors from The National Food Table of Sweden 1996 for each food item in the food database of the STOR MATS 4_03e program. The protein factors are those that were used in the food table to convert the analyzed nitrogen content of each food item to protein content, on the basis of the nitrogen content of proteins. The digestibility of vegetable proteins differs from that of animal proteins, and when dietary fiber intakes increase, fecal nitrogen excretion also increases (11). Thus, in comparison with an individual who consumes less fiber and consumes animal protein, a vegan would be expected to excrete less nitrogen in the urine and more in the feces for a given amount of consumed protein. However, we did not take this issue into account because it would have required several days of fecal collections; we thought that this would increase the dropout rate dramatically.

Doubly labeled water method

After the subject had completed the DH interviews and the four 24-h urine collections, total EE was measured (EE_{meas}) during a 14-d period with use of the DLW method (12). This method involves enriching the body water with isotopes of hydrogen (^{2}H) and oxygen (^{18}O) and then determining the washout kinetics of the isotopes as the concentrations decline exponentially toward the natural abundance concentrations. Each subject collected 3 baseline urine samples before ingesting an oral dose of 0.12 g ^{2}H and 0.25 g ^{18}O per kg estimated body water (13, 14).

TABLE 1
Background data for the Swedish vegans and omnivores in 1997–1998[1]

	Females		Males	
	Vegans (n = 7)	Omnivores (n = 7)	Vegans (n = 9)	Omnivores (n = 9)
Age (y)	17.2 ± 0.6	17.2 ± 0.8	17.7 ± 0.8	17.7 ± 1.0
Height (cm)[2]	167 ± 5	168 ± 4	180 ± 7	180 ± 6
Weight (kg)[2,3]	70.7 ± 8.8[4]	58.7 ± 7.7	66.1 ± 6.2	70.2 ± 4.7
BMI (kg/m^2)[3]	25.4 ± 3.8[4]	20.9 ± 2.5	20.5 ± 1.7[4]	21.6 ± 1.0
Body water by doubly labeled water (kg)[2,3]	33.4 ± 3.8	31.2 ± 2.7	39.8 ± 3.7[4]	43.3 ± 1.4
Duration of vegetarianism (mo)[5]	38 ± 7	0	32 ± 14	0
Duration of veganism (mo)[5]	23 ± 10	0	22 ± 14	0

[1] $\bar{x}$ ± SD. Analyses were performed with a two-factor ANOVA with diet and sex as the 2 factors.
[2] Significant main effect of sex, $P < 0.05$.
[3] Significant interaction effect of diet and sex, $P < 0.05$.
[4] Significantly different from omnivores of the same sex, $P < 0.05$.
[5] Significant main effect of diet, $P < 0.05$.

The bottle was washed out and the subject also ingested the rinse water to ensure that all the DLW was consumed. Single urine samples were taken 24 h after the dose was administered and then on days 4, 8, and 14. Body weight was measured to the nearest 0.1 kg while the subject wore only light underwear and after the subject emptied the bladder, both before the dose and 14 d later. Height was measured to the last completed 0.5 cm. The subjects were in good health, consumed their normal diets, and lived in the same communities during the 14-d study period.

Urine samples were stored at −18°C until analyzed. Isotope concentrations were measured in the urine by using isotope ratio mass spectrometry (Aquasira R; VG Isogas Ltd, Middlewhich, United Kingdom). The analytic precision was 0.00002 atom percent (AP) (0.2 ppm) for ^{2}H and 0.00004 AP (0.4 ppm) for ^{18}O. Carbon dioxide production rate was calculated by using a multipoint method (13).

Respiratory quotient and food quotient

We estimated the respiratory quotient to be 0.85 on the basis of previous studies in omnivores (15). The food quotient (FQ) was calculated by using the following equation:

$$FQ = (p \times 0.81) + (f \times 0.71) + (c \times 1.00) + (a \times 0.67) \quad (2)$$

where p, f, c, and a represent the percentage of energy from protein, fat, carbohydrate, and alcohol consumed, respectively, as reported in the DH interview.

Physical activity assessment

PA interviews were conducted (by CLL) 14 d after each subject ingested the oral dose of DLW. Subjects were questioned about their PA during the past 2 wk in a 30- to 60-min interview at the university; they were asked to bring a school schedule, diary, and training schedule to help them recall different activities. Information about the type and duration of each activity was collected. The activities were categorized into 6 activity grades that had different definitions and PA ratios (16): sleep (1.0), very light activity (1.4), light activity (1.7), moderate activity (3.0), heavy activity (4.0), and very heavy activity (6.0). A mean reported PAL (PAL_{rep}) was then calculated.

Validity of reported estimates

The validity of the EI_{rep} was estimated by calculating the FIL (4), which was then compared with the PAL (17). BMR was calculated on the basis of age, sex, and weight in equations presented by Schofield in 1985 (18). FIL/PAL_{meas}, PAL_{rep}/PAL_{meas}, and (N_{rep} × 0.81)/N_{meas} should all equal 1.0 if we obtained true estimates of EE by using PA interviews and true estimates of energy and nitrogen intakes by using DH interviews.

Statistical analysis

The results are expressed as means ±SDs and means with 95% CIs; the values obtained with 2 different methods were plotted according to Bland and Altman (19) to assess their agreement. Differences between measurements and groups were analyzed by using two-factor analysis of variance (ANOVA) with diet and sex as the 2 factors and by using Wilcoxon's signed-rank test. A two-tailed P value <0.05 was considered statistically significant. All statistical analyses were performed with SPSS, version 10.0 (SPSS Inc, Chicago).

RESULTS

Subjects

Some characteristics of the subjects are shown in **Table 1**. The mean age of the 32 subjects was 17.4 ± 0.8 y. The vegans had been practicing their dietary regimen for a mean of 1.9 y (range: 0.5–3.5 y). Female vegans had a higher body weight and body mass index (BMI; in kg/m^2) than did female omnivores, but male vegans had a lower BMI and body water content than did male omnivores. Group averages for weight and BMI were not significantly different between vegans and omnivores.

Validity of reported energy expenditure

Female vegans had significantly lower PAL_{rep} and PAL_{meas} than did female omnivores, but the validity of EE_{rep} (PAL_{rep}/PAL_{meas}) was not significantly different between the 2 dietary groups (**Table 2**). However, the PA interview method underestimated EE by 1.44 ± 2.55 MJ/d (95% CI: 2.37, 0.52 MJ/d) (**Figure 1**).

Validity of reported energy intake

Female vegans had a significantly lower FIL than did female omnivores, but the validity of EI_{rep} (FIL/PAL_{meas}) was not significantly different between the 2 dietary groups (Table 2); vegans underreported EI by 14%, whereas omnivores underreported EI

TABLE 2
Validation of reported energy expenditure and energy and protein intakes in Swedish vegans and omnivores by using the doubly labeled water method and 24-h urine collections in 1997–1998[1]

	Females		Males	
	Vegans (n = 7)	Omnivores (n = 7)	Vegans (n = 9)	Omnivores (n = 9)
BMR (MJ)[2,3]	6.78 ± 0.63	6.11 ± 0.50	7.43 ± 0.44	7.68 ± 0.48
FIL[2]	1.16 ± 0.34[4]	1.69 ± 0.48	1.58 ± 0.24	1.71 ± 0.29
$PAL_{reported}$[2]	1.48 ± 0.11[4]	1.66 ± 0.09	1.61 ± 0.17	1.68 ± 0.16
$PAL_{measured}$[2,5]	1.41 ± 0.22[4]	1.84 ± 0.44	1.87 ± 0.39	2.05 ± 0.33
$FIL/PAL_{measured}$	0.84 ± 0.25	0.92 ± 0.19	0.87 ± 0.19	0.85 ± 0.16
$PAL_{reported}/PAL_{measured}$[2]	1.08 ± 0.21	0.93 ± 0.15	0.89 ± 0.17	0.83 ± 0.10
$(N_{reported} \times 0.81)/N_{measured}$[2,6]	0.78 ± 0.15[4]	1.02 ± 0.11	1.01 ± 0.22	0.99 ± 0.14[7]

[1] $\bar{x}$ ± SD. Analyses were performed with a two-factor ANOVA with diet and sex as the 2 factors. BMR, estimated basal metabolic rate; FIL, food intake level (reported energy intake/BMR); PAL, physical activity level (energy expenditure/BMR); N, nitrogen.
[2] Significant interaction effect of diet and sex, $P < 0.05$.
[3] Significant main effect of diet, $P < 0.05$.
[4] Significantly different from omnivores of the same sex, $P < 0.05$.
[5] Significant main effect of sex, $P < 0.05$.
[6] 81% of reported nitrogen intake divided by measured nitrogen excretion in urine.
[7] n = 8.

by 12%. However, the DH interview method underestimated EI by 1.93 ± 2.65 MJ/d (95% CI: 2.89, 0.97 MJ/d) (**Figure 2**); the bias of the method was consistent in the 2 dietary groups.

Validity of reported protein intake

The mean recovery of PABA from the 24-h urine collections was 74% for vegans and 72% for omnivores (n = 15). A total of 23 urine collections were excluded. However, 3 or 4 collections were acceptable for 26 of the subjects: 24 urine collections were classified as complete and 81 were incomplete but the nitrogen content was adjusted as described in Methods.

Four collections were usable for each of 17 subjects, yielding 68 collections; 18 of these 68 collections were classified as complete and the nitrogen content of the remaining 50 collections was adjusted. Three collections were usable for each of 9 subjects, yielding 27 collections; 5 of these 27 collections were classified as complete and the nitrogen content of the remaining 22 collections was adjusted. Two collections were usable for each of 5 subjects, yielding 10 collections; 1 of these 10 collections was classified as complete and the nitrogen content of the remaining 9 collections was adjusted. One subject had a PABA recovery >130% in all 4 urine collections and was therefore excluded.

The calculated protein factor was 6.00 for vegans and 6.22 for omnivores. Female vegans reported a significantly lower $(N_{rep} \times 0.81)/N_{meas}$ than did their omnivorous counterparts, but the validity of N_{rep} was not significantly different between the 2 dietary groups (Table 2). The reported nitrogen intake from the DH interview showed good agreement with the N_{meas} in that the mean difference between $(N_{rep} \times 0.81)$ and N_{meas} was −0.40 ± 1.90 g/d (95% CI: −1.10, 0.29 g/d) (**Figure 3**).

Comparison of the validity of the energy and protein intakes

A comparison of FIL/PAL_{meas} with $(N_{rep} \times 0.81)/N_{meas}$ by Wilcoxon's signed-rank test showed no significant difference between EI_{rep} and reported protein intakes among the vegans, but a significant difference was found among the omnivores ($P < 0.05$; data not shown). There was no significant difference between males and females within either dietary group with regard to the validity of energy and protein intakes.

Urinary isotope concentrations

The mean (±SD) enrichments in the 96 background samples were 0.0146 ± 0.0001 AP (146 ± 1 ppm) for ^2H and 0.1994 ± 0.0002 AP (1994 ± 2 ppm) for ^{18}O. The SD between subjects was 0.0001088 AP (1.088 ppm) for ^2H and 0.0001655 AP (1.655 ppm) for ^{18}O, and the SD within subjects ranged from 0.0000026 AP (0.026 ppm) to 0.0000275 AP (0.275 ppm) for ^2H and from 0.0000024 AP (0.024 ppm) to 0.0000853 AP (0.853 ppm) for ^{18}O. The ratio of ^2H to ^{18}O in terms of space occupied by the isotopes was 1.0125 ± 0.0177.

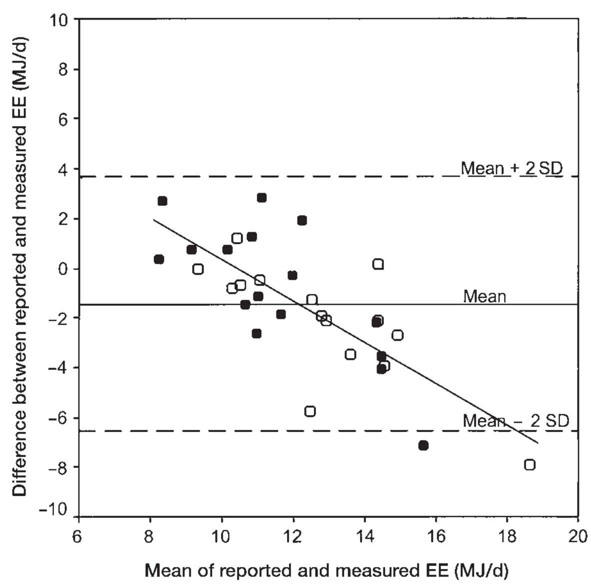

FIGURE 1. Difference between reported (during physical activity interview) energy expenditure (EE) and measured (by the doubly labeled water method) EE plotted against the mean of the reported EE and measured EE in 16 omnivores (□) and 16 vegans (■). The solid horizontal line represents all subjects (r^2 = 0.5808). Negative values for the difference indicate that reported EE was lower than measured EE. r = −0.762, $P < 0.05$. Linear regression equation: $y = 8.661 - 0.833x$.

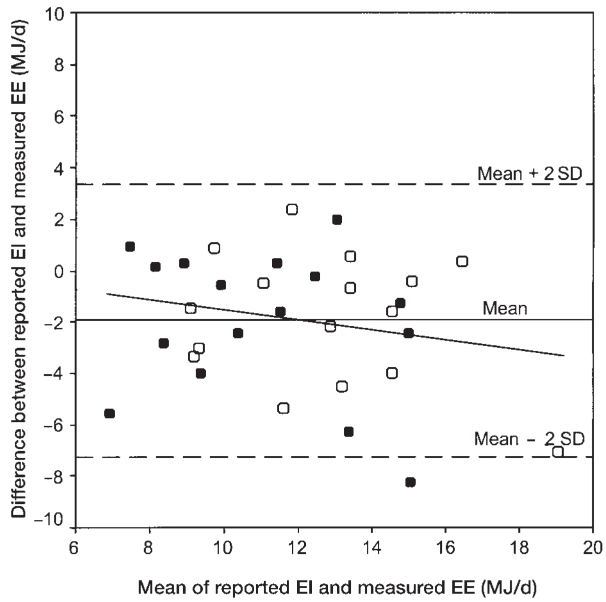

FIGURE 2. Difference between reported (during diet-history interview) energy intake (EI) and measured (by the doubly labeled water method) energy expenditure (EE) plotted against the mean of reported EI and measured EE in 16 omnivores (□) and 16 vegans (■). The solid horizontal line represents all subjects (r^2 = 0.0450). Negative values for the difference indicate that reported EI was lower than measured EE. r = −0.212 (NS). Linear regression equation: $y = 0.396 - 0.196x$.

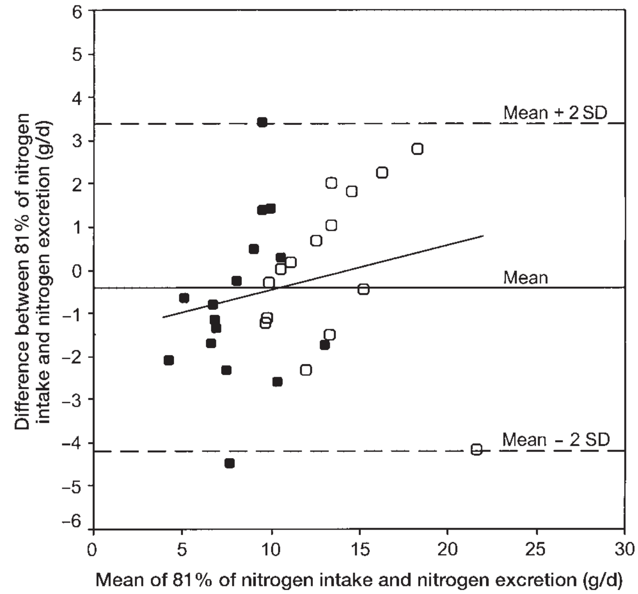

FIGURE 3. Difference between 81% of reported (during diet-history interview) nitrogen intake and mean nitrogen excretion in 2, 3, or 4 different 24-h urine collections per subject (5 subjects with 2 collections, 9 subjects with 3 collections, and 17 subjects with 4 collections) plotted against the mean of 81% of nitrogen intake and nitrogen excretion in 15 omnivores (□) and 16 vegans (■). The solid horizontal line represents all subjects (r^2 = 0.0453). Negative values for the difference indicate that 81% of reported nitrogen intake was lower than nitrogen excretion. r = 0.213 (NS). Linear regression equation: $y = -1.523 + 0.105x$.

Respiratory quotient and food quotient

The estimated respiratory quotient was 0.85. The observed FQ averaged 0.90 for all subjects.

DISCUSSION

Subjects

The subjects in the present study, except for the female vegans, were similar in height, weight, and BMI to a sample of 251 females and 342 males living in Umeå (mean age: 16.8 y; range: 15.9–18.2 y) (20). The female vegans weighed more and had a higher mean BMI than both the larger sample and the matched female omnivores in the present study, which is the opposite of what was observed in female vegans in England aged 20–89 y (21). Because we enrolled a small, nonrandom sample of female vegans, it is difficult to draw any firm conclusions about these differences between female vegans and omnivores. However, the findings might indicate that some of the female vegans chose to be vegans to reduce their weight and BMI, instead of indicating that their weight and BMI were consequences of their dietary habits.

Validity of reported energy expenditure

The DLW method measures EE accurately under normal conditions with a precision of 2–8% (13). When the DLW method was compared with room calorimetry, the difference between the methods was not significant (1.6 ± 2.6%) (22). In another study, the CV was ≈9% for repeated DLW measurements (23). In the present study, we used the multipoint method of Schoeller (13) to calculate EE_{meas} from DLW and we also used the method of Coward (24) to calculate EE_{meas} (data not shown). No significant difference between the 2 calculation methods was found.

The PA interviews showed a bias toward underestimation of the EE_{rep} of the subject groups. One explanation may be that the values used for the PA ratio were too low for the reported activities. Also, some of the subjects' activities might not have been reported in the interviews. However, the degree of underestimation was only 3% for vegans but was 12% for omnivores (Table 2). Subjects with a high EE_{meas} tended to report amounts of PA that led to underestimates of PA and subjects with a low EE_{meas} tended to report amounts of PA that led to overestimates of PA with the method used in this study (Figure 1). Because the omnivores had a higher PAL, they also had a greater degree of underestimation with this method than did the vegans. This suggests that the PA interview had a bias in measuring the extreme values of EE.

Validity of reported energy intake

The use of DLW as an independent validation method for EI involves the assumption that the subjects are in energy balance, which was confirmed by comparing body weights at the start and end of the DLW interval. Because the amount of energy stored as new tissue is <5% during the pubertal growth spurt, it is reasonable to assume that EI and EE are equivalent in adolescents during a limited period of time (2). The finding that EI_{rep} was underestimated in the present study is in agreement with the findings of other studies. Dietary surveys in adolescents showed that EI was underestimated by 20–46% with 2-wk diet records, by 20–28% with 7-d diet records, and by 3% with the DH method (1–3).

The observed FQ of vegans in the United Kingdom was reported to be 0.86–0.88 (15). The higher FQ of vegans compared with that of omnivores results from the higher proportion of carbohydrates in the vegans' diet. A higher FQ would yield a lower calculated EE and better agreement with the reported EI in this study. However, we did not use the observed FQ because it might not be the true FQ as a result of underreporting or overreporting of carbohydrate, fat, or protein intakes. Further, because one of the aims of this study was to validate the DH method, it would be incorrect to introduce an error in the validation method.

Validity of reported protein intake

The findings that the mean recovery of PABA from all urine collections was 73% and that 75% of the samples had a PABA recovery <85% indicate that it is difficult to obtain complete 24-h urine collections. Unfortunately, this is a fairly typical result (10, 25). Incomplete urine collections cannot be used to validate dietary data. To limit the consequences of this problem, a linear regression method was developed. This method allows for inclusion of urine collections with low PABA recovery (10). The fundamental principle of the linear regression method is described by Bingham and Cummings (9), who validated it in subjects confined to calorimeters. They concluded that an oral dose of PABA and urinary excretion of PABA are directly related, and that PABA is quantitatively excreted in the urine. The correlation coefficient was 0.99 for the relation between nitrogen and PABA recovery with the linear regression method (10), which indicates that any error in the adjustment method would probably be minor. There is no reason to believe that the relation between PABA excretion and nitrogen excretion would be physiologically different in the subjects in the present study than in other subjects. Also, there is no reason to believe that various amounts of protein intake would affect PABA excretion, and in turn affect the validity of the equation. In the present study, the nitrogen content of urine collections with PABA recovery between 50% and 85% was adjusted by using the linear regression method (10); this approach salvaged 81 of the 128 collections. For subject groups, the DH interview method showed good agreement with N_{meas}.

The DH interview method seemed to overestimate nitrogen intake at high intakes and underestimate it at low intakes, especially in omnivores (Figure 3). One possible explanation for this finding is that if the diet has a high proportion of protein-rich foods, such as meat, fish, and milk products, then these food items may be part of the main meals and may be easier to remember than foods eaten between meals (26). These foods are considered to be socially desirable and tend to be overestimated in contrast with socially undesirable foods, such as sugary snacks. The latter tend to be underestimated, thereby lowering the total reported EI (27).

Comparison of the validity of energy and protein intakes

Selective underreporting of food and nutrient intakes by high-FIL compared with low-FIL reporters has been described (12, 25). For example, in a small observational study, 101% of the protein intake but only 88% of the EI was reported (26). Similar selective underreporting was found in omnivores in the present study: 4 subjects (27%) had lower $(N_{rep} \times 0.81)/N_{meas}$ values and 11 subjects (73%) had higher $(N_{rep} \times 0.81)/N_{meas}$ values relative to their FIL/PAL_{meas} values. However, no significant difference was seen among vegans or by sex in either dietary group. A possible explanation for the difference observed in omnivores is that nitrogen intake was overestimated at higher intakes and underestimated at lower intakes with the DH interview method, as discussed above and as shown in Figure 3. Another possible explanation for the difference in omnivores is that the dietary intake data, urine data, and EE measurements represented different periods of time. However, because the DH method covered 3 mo, the DLW method spanned 2 wk, and the urine samples were collected on 4 random days between the DH and the DLW period, the effect of day-to-day variation should have been small.

One of the aims of the present study was to validate methods for estimating EI and EE that would avoid the high cost of the DLW method. Therefore, a cost comparison of the methods is of interest. The cost of DLW and related laboratory materials and analyses in this study was $500 per subject, compared with $1 per subject for the PA interview form. However, the cost of the actual DLW can vary substantially over time, depending on supply and demand and the dollar exchange rate. The labor cost of collecting the DLW samples compared with the labor cost of performing the interviews is approximately the same. However, the labor cost of conducting the DH interviews plus performing the nutritional calculations is much higher because ≈7 h of labor is needed per subject.

Conclusion

This study showed that there were no significant differences between vegans and omnivores in the validity of EE_{rep} as estimated by a PA interview or the validity of reported energy and protein intakes as estimated by a DH interview. However, EI and EE were underestimated to the same extent, whereas valid estimates of protein intake were obtained.

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