Validation of dietary history method in a group of elderly women using measurements of total energy expenditure

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(*Received 21 July 1994 – Revised 27 February 1995 – Accepted 1 May 1995*)

The objective of the present study was to validate energy intake data, obtained by dietary history, in twelve elderly women aged 69–82 years. Energy and protein intakes were obtained using the dietary history method with a reference period of 30 d. Reported energy intake was compared with total energy expenditure (TEE) measured on two consecutive days in a respiration chamber. Reported protein intake was compared with mean N excretion from four 24 h urine collections. Mean reported energy intake was 7·2 (SD 1·5) MJ/d which was lower than TEE ($P = 0·059$). Reported protein intake was 64 (SD 13) g/d and lower than estimated protein intake ($P = 0·053$). The percentage underestimation was not related to body weight or percentage body fat. Subjects with a relatively high TEE or a relatively high estimated protein intake underestimated their energy intake to a greater extent. The discrepancy between reported energy intake and TEE was positively associated with the discrepancy between reported and estimated protein intakes. The results of this present study show an underestimation of energy intake of about 12% when using the dietary history method. Physical activity diaries completed in the chamber and during 4 d at home, as well as pedometer counts, indicated a higher level of physical activity in the free-living situation compared with the chamber situation. This suggests that the actual underestimation of energy intake may be even higher in this group of elderly women. These results have implications for the use of the dietary history method in, for example, epidemiological studies carried out in elderly subjects.

Elderly: Energy intake: Dietary history: Energy expenditure

In many epidemiological surveys dietary intake data are collected to study the intakes of energy and nutrients and to investigate their relation with morbidity and mortality (Willett, 1990). Assessing dietary intake of elderly subjects reveals some specific problems (van Staveren *et al.* 1994). The 24 h recall might be unreliable in elderly people due to a decline in short-term memory with age (Caliendo, 1981) and a weighed record can be difficult to complete. The dietary history method seems a suitable method for elderly subjects since it requires limited effort by the subjects and does not depend on short-term memory (Haraldsdottir, 1989).

Many studies have validated the dietary history method in young subjects, however, few validation studies have been carried out in elderly subjects (Steen *et al.* 1977; Mahalko *et al.* 1985; Borelli *et al.* 1989; Pietinen *et al.* 1990; Nes *et al.* 1991). In most of these studies weighed records were used as a reference method. However, the weighed record is sensitive to systematic bias (Prentice *et al.* 1986). Only one study in elderly subjects used a more objective reference method, the urinary excretion of N (Steen *et al.* 1977).

Another approach for evaluating energy intake data is the measurement of energy expenditure (Poehlman, 1992). Under the assumption that the body is in energy balance,

* Reprints not available.

energy intake should equal energy expenditure. Measuring total, daily energy expenditure and comparing this with estimated energy intake data can therefore give information about the validity of energy intake data. In elderly subjects only the diet record method has been compared with total energy expenditure (TEE; Goran & Poehlman, 1992; Pannemans & Westerterp, 1993; Reilly *et al.* 1993) or with an estimation of TEE (Johnson *et al.* 1994). These studies showed an underestimation of the dietary intake data, ranging from 10–31 %. A validation of the dietary history method in elderly subjects using measurements of TEE has not been reported before.

The purpose of the present study was to evaluate the validity of energy intake data, obtained by dietary history, in healthy elderly women, aged 69–82 years. As a reference method 24 h energy expenditure was used. In addition, urinary N excretion was measured to validate the reported protein intake and thereby the energy intake.

SUBJECTS AND METHODS

Subjects

From a study population of 120 elderly men and women who had participated in an earlier study on body composition (Visser *et al.* 1994), twelve women were recruited. All subjects were apparently healthy, weight stable, and were living in the surroundings of Wageningen. One woman lived in a residential home, the other women were non-institutionalized. All subjects except one (smoking 3–4 cigarettes/d) were non-smokers, and did not use any medication known to influence energy expenditure. The physical activity score of the women, as determined by means of a questionnaire (Voorrips *et al.* 1991 *a*), suggested that the elderly women were not extremely physically active and suggested a large variation in free-living physical activity level between the subjects. Some characteristics of the women are described in Table 1. The study protocol was approved by the Ethical Committee of the Department of Human Nutrition, Wageningen Agricultural University and all subjects signed an informed consent form.

Study protocol

During a home visit the methods of the study were thoroughly explained. During a second home visit a dietary history was obtained. In the following week 24 h TEE was measured on two consecutive days in a respiration chamber. On the days between the dietary history interview and TEE measurements two 24 h samples of urine were collected at home and two 24 h samples were collected during the calorimetric sessions to evaluate the validity of the protein intake data. To compare physical activity level in the chamber with physical activity level in the free-living situation, physical activity diaries were completed during the stay in the respiration chamber and during 4 d at home. As a more objective method, number of steps were counted by a pedometer on the same days as the activity diaries were completed. Body composition was determined after the TEE measurements.

Dietary history

Energy intake was determined using a modified dietary history (De Groot & van Staveren, 1988) with a reference period of 30 d. All interviews were carried out by the same trained investigator at the subject's home. Usual portion sizes were weighed to the nearest 1 g on a digital scale (Sartorius GMBH PT6, Göttingen, Germany) or standardized household measures were used. For the calculation of energy intake and macronutrient intake the Dutch food composition table was used (Stichting Nederlands Voedingsstoffenbestand, 1986).

Table 1. *Characteristics of the twelve women participating in the study*

	Mean	SD
Age (years)	74	3
Body weight (kg)	65·4	11·6
Height (m)	1·60	0·05
Body mass index (kg/m²)	25·6	4·7
Body fat (%)	37·9	9·6
Fat-free mass (kg)	39·6	3·5

Energy expenditure

TEE was measured over 24 h using whole-body indirect calorimetry (van Es, 1958; van Es *et al.* 1984). Recoveries of combusted alcohol were 100·2 (SD 0·8)% for O_2 and 98·7 (SD 0·8)% for CO_2. The equation of Weir (1949) was used to calculate TEE from the amounts of consumed O_2 and produced CO_2 over 24 h.

TEE was measured on two consecutive days. The subjects entered the calorimeter in the evening (23.00 hours), 8–9 h before the start of the measurements (07.30 hours the next morning). Immediately at the end of the first 24 h period the measurement of the following 24 h period started. The ambient temperature was set at 21–22° in daytime and at 18–19° during the night. Since the temperature was adjusted when the subjects felt uncomfortable it can be assumed that the subjects stayed in a thermoneutral room. Mean 24 h temperature was 20·7 (SD 1·0)°. Relative humidity was between 60 and 70%. The room was fully equipped with a small kitchen and water-tap, writing desk, television, radio and telephone, bed, toilet-chair, comfortable chair and cycle ergometer (type RH, Lode BV, Groningen, The Netherlands). Two airlocks served as an inlet for food and as an outlet for faeces and urine. The three meals, snacks and drinks consumed during the stay in the calorimeter were provided and the amount was based on the results of the preceding dietary history. Subjects kept their own meal pattern and consumed foodstuffs similar to those eaten in the free-living situation. The activity pattern in the room was partly standardized. The standardization consisted of 8 h lying down in bed and cycling five times for 15 min on a cycle ergometer (20 W, 40 rev./min). Two subjects cycled only two to three times a day. The remainder of the time was spent in sitting activities and standing activities (dressing, preparing meals, making tea or coffee, washing dishes), simulating light housekeeping. The performance of strenuous physical exercise was not allowed.

Urine collection and analysis

Urine collections were made over 24 h in plastic 2-litre jugs (containing 5 ml glacial acetic acid and 15 ml water) on 2 d at home and while the subjects were in the respiration chamber. Collections commenced after the first void in the morning. Subjects were instructed to report incomplete urine collections to the investigators. In that case an additional set of urine jugs was given to collect 24 h urine on another day. In the respiration chamber a toilet-chair was available, so the subjects had to collect all the urine. The investigators checked the times of the first and last void. The 24 h urine samples were stored at −20° before analysis. The urea concentration (mmol/l) was measured (Boehringer Mannheim BV 396346 kit, Almere, The Netherlands) and multiplied by urine weight to obtain the total urea production (g/d). The assumption was made that 85% of urinary N (U_N) is excreted as urea (Bonsnes, 1978; Bingham & Cummings, 1985). The protein intake

(g) was estimated as $6{\cdot}25 \times (U_N + 2)$ (Isaksson, 1980). A mean value of the four separate days was used to compare the estimated protein intake with the reported protein intake and thus to validate indirectly the energy intake.

Physical activity diary

TEE of the elderly women was measured in a confined situation. To compare physical activity level in the respiration chamber with the free-living physical activity level, all subjects completed physical activity diaries during their stay in the respiration chamber and also during 4 d at home (two normal weekend days and two normal weekdays). All physical activities were recorded in intervals of 5 min. To facilitate recording, the physical activities were categorized into seven groups of different energy expenditure level, ranging from 'lying' to 'sports activities' (van Raaij *et al.* 1990). Subjects who had difficulty understanding the method were asked to complete a test-diary for 1 d. This diary was discussed afterwards to make the subjects familiar with the method. On the first page of each diary, examples of activities of each category were given to facilitate the classification of daily activities. Activities that were difficult to classify were noted by the subjects on a separate page in the diary and discussed afterwards with the investigators.

Pedometer

On the day the activity diaries were completed the subjects wore a pedometer (Kasper & Richter, Uttenreuth, Germany) to determine the number of steps taken per day. The pedometer was attached to a belt around the waist. Every subject used the same pedometer at home and during the stay in the respiration chamber. Step size was adjusted to 0·95 m for all subjects, as step size varies during different activities. The total recorded distance during 1 d was divided by the adjusted step size to calculate the number of steps per day.

Body composition and anthropometry

All anthropometric measurements were made after voiding with the subjects only wearing swimming suits or underwear. Body weight was measured to the nearest 0·05 kg using a digital scale (Berkel ED-60-T, Rotterdam, The Netherlands). Height was measured to the nearest 0·001 m using a wall-mounted stadiometer. BMI was calculated as weight (kg) divided by height squared (m^2).

Body composition was calculated from total body water measured by isotope dilution. An accurately weighed amount of D_2O (about 14–15 g) was given orally to the subjects. After a dilution time of 3 h, in which the subjects refrained from eating and drinking, a venous blood sample was drawn. After sublimation of the plasma, the deuterium concentration was determined in the sublimate by infrared analysis (Lukaski & Johnson, 1985). Total body water was estimated from the D_2O concentration in the plasma and corrected for a 5% overestimation of the dilution space (Schoeller *et al.* 1980). Fat-free mass was calculated as total body water divided by 0·732, assuming a hydration coefficient of the fat-free mass of 0·732 (Pace & Rathbun, 1945). Body fat was calculated as body weight minus the fat-free mass.

Statistical methods

The data were analysed using the statistical program SAS (Statistical Analysis Systems; SAS Institute Inc., Cary, USA). Differences between reported energy intake and TEE, as well as differences between reported and estimated protein intake, were tested with paired Student's *t* tests. Correlations between the variables are Pearson's product-moment correlations. All results are presented as means and standard deviations (SD). Two-sided *P* values $< 0{\cdot}05$ were considered significant.

RESULTS

Table 1 summarizes some general characteristics of the study population. Table 2 gives the results of the estimated energy intake and measured TEE. Mean energy intake of the women was 7166 (SD 1532) kJ/d. Reported energy intake was 11·6 (SD 7·4)% lower than energy expenditure. Only three out of twelve women had a higher energy intake than energy expenditure (Fig. 1). The percentage underestimation of energy was not associated with percentage body fat (r −0·31, P = 0·3), BMI (r −0·35, P = 0·3) or body weight (r −0·44, P = 0·2). However, the difference between energy intake and expenditure was associated with energy expenditure (r −0·58, P = 0·049; Fig. 2). That is, the dietary history method underestimated energy intake more in subjects with a relatively high TEE.

Protein intake was 64 (SD 13) g/d as estimated by the dietary history method (Table 2). Reported protein intake was on average 10·1 (SD 7·6)% lower than the estimated protein intake as calculated from the mean N excretion from four 24 h urine collections. The mean weight of the urines collected at home was 2·11 (SD 0·46) kg, and not significantly different from the weight of the urines collected in the chamber (1·92 (SD 0·85) kg, P = 0·25). The protein intake at home, as estimated from two 24 h urine collections, was similar to the estimated protein intake in the chamber, 74·4 (SD 15·0) g and 74·4 (SD 14·9) g respectively (P = 1·0). The discrepancy between the estimated and reported protein intake was not related to percentage body fat (r −0·27, P = 0·4), BMI (r −0·44, P = 0·2) or body weight (r −0·47, P = 0·1). The difference between the two methods was associated with the estimated protein intake (r −0·62, P = 0·03) (Fig. 3). This suggests that the dietary history method underestimated protein intake more in subjects with a relatively high estimated protein intake. The difference between reported energy intake and energy expenditure was positively related to the difference between reported and estimated protein intake (r 0·72, P = 0·009) (Fig. 4).

The results of the physical activity diaries are shown in Table 3. Time spent per activity category in the chamber *v.* the free-living situation is reported. The diaries suggested that relatively more time was spent on more strenuous physical activities in the free-living situation than in the respiration chamber. Thus, TEE in the respiration chamber might be lower than the normal TEE of the elderly women. To compare physical activity level in the chamber with the free-living situation more objectively, pedometers were used to count the number of steps taken on the same days as the diaries were completed (Table 3). This method also indicated a much higher physical activity level in the free-living situation.

DISCUSSION

In the present study energy intake values for elderly women, estimated by means of a dietary history, were validated. Both reference methods, 24 h energy expenditure and 24 h urinary N excretion, indicated a considerable and comparable underestimation of reported energy and protein intake in this group of elderly women.

The study population consisted of twelve healthy elderly women, most of them living independently. Body weight, height and body composition were comparable with values for elderly women in earlier studies at the department (Visser *et al.* 1994). Body weight was also comparable with body weight of elderly women of the same age living in the Netherlands: 69·8 kg for women aged 60–69 years and 67·1 kg for women aged 70 years and older (Centraal Bureau voor de Statistiek, 1992). Underestimation of energy intake is reported to be more pronounced in obese than in lean subjects (Prentice *et al.* 1986). Since the women in the present study had a normal body composition for their age, and since they were all highly motivated, it seems unlikely that body fatness influenced their report of energy intake to a great extent.

Table 2. *Energy and protein intakes, obtained by dietary history,* v. *total energy expenditure and estimated protein intake from 24 h urine collections in elderly women*

(Mean values and standard deviations for twelve subjects)

	Mean	SD	*P* value*
Energy (kJ/d)			
Intake	7166	1532	—
Expenditure	8299	1294	—
Difference	−1132	537	0·059
Protein (g/d)			
Intake	64·4	13·2	—
Intake estimated from urine	74·4	14·1	—
Difference	−10·0	4·6	0·053

* Dietary history method *v*. reference method; difference = dietary history minus reference method.

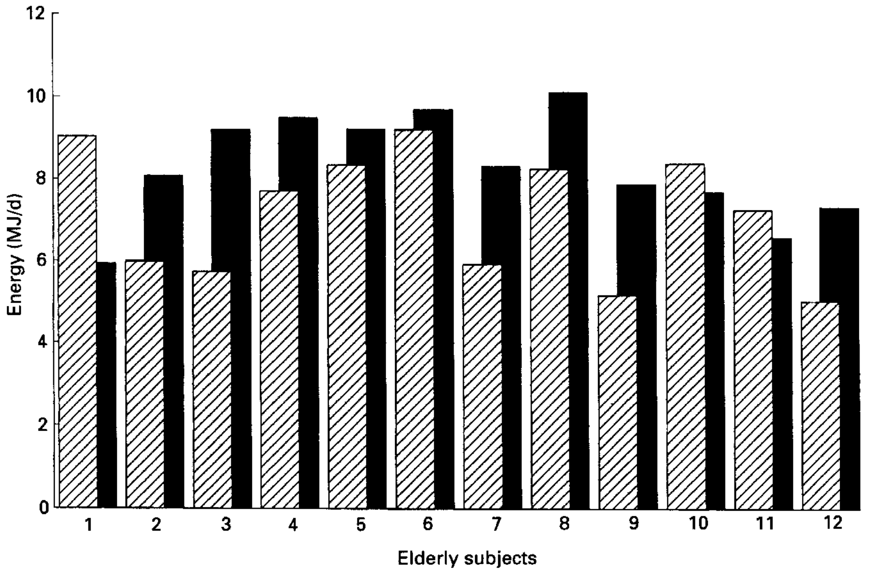

Fig. 1. Energy intake (▨), obtained by dietary history, and total energy expenditure (■) of twelve elderly women.

If it is assumed that the energy intake data in the present study are correct, and that measured TEE in the respiration chamber is a good estimate of daily, free-living energy expenditure of the elderly women, nine of the twelve women would be in a negative energy balance. Since body weight of the women was measured in an earlier study, the value was compared with their present body weight. During the last 11 (SD 3) months the mean change in body weight of the group was +0·50 (SD 1·34) kg ($P = 0·22$). This indicates that the women were on average in energy balance in the last year and that the energy intake data may not reflect actual energy intake.

The mean reported energy intake of 7·2 MJ/d in the present study was comparable with other studies on energy intakes of apparently healthy elderly women carried out in The Netherlands. In these studies energy intakes of elderly women were 7·9 MJ/d (Wat eet

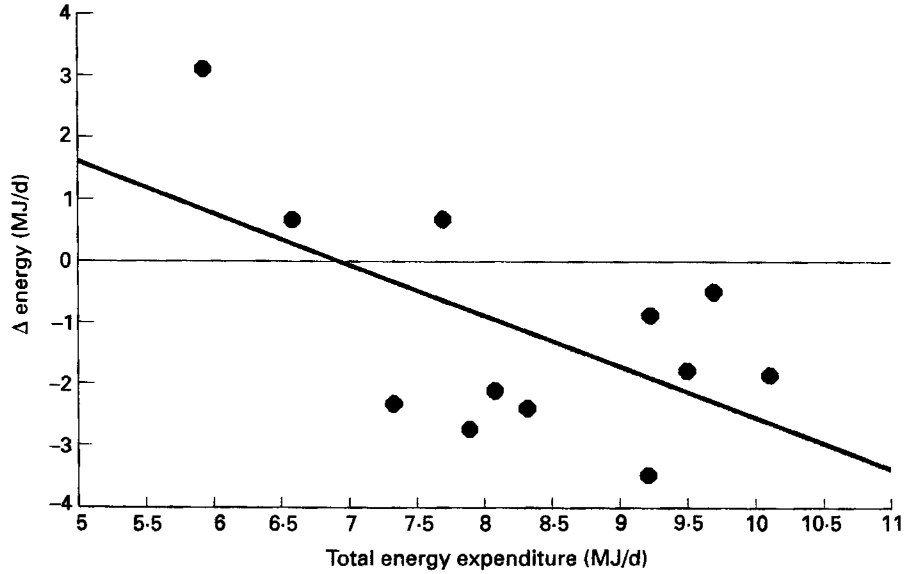

Fig. 2. Total energy expenditure *v.* the difference between reported energy intake and energy expenditure of twelve elderly women (r −0·58, $P = 0·049$).

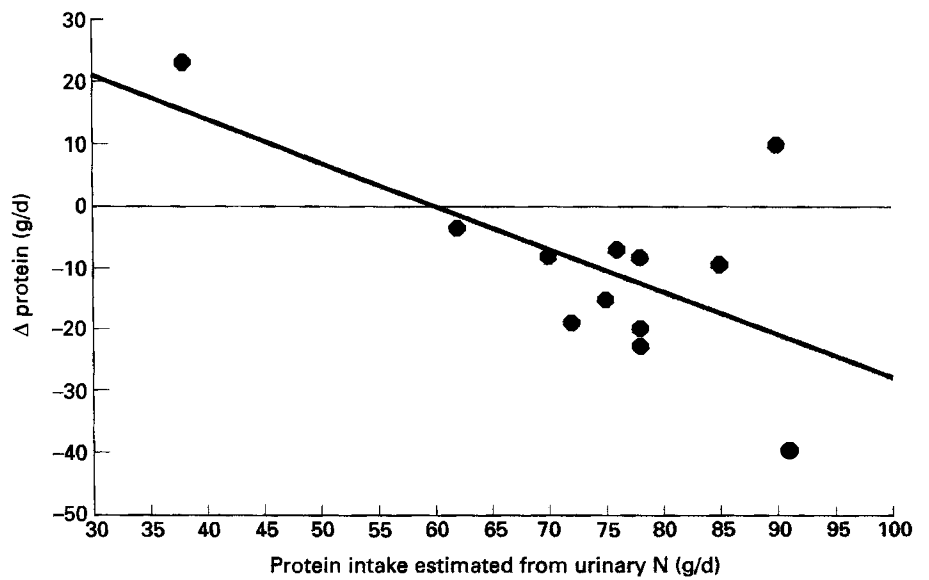

Fig. 3. Protein intake estimated from urinary nitrogen *v.* the difference between reported protein intake and estimated protein intake of twelve elderly women (r −0·62, $P = 0·03$).

Nederland, 1988), 7·9 MJ/d (Löwik *et al.* 1989), 7·8 MJ/d (Moreiras *et al.* 1991), and 6·9 and 7·4 MJ/d for active and sedentary elderly women respectively (Voorrips *et al.* 1991 *b*). These studies used either a 2 d 24 h diet record (Wat eet Nederland, 1988) or a dietary history method (Löwik *et al.* 1989; Moreiras *et al.* 1991; Voorrips *et al.* 1991*b*) to collect energy intake values.

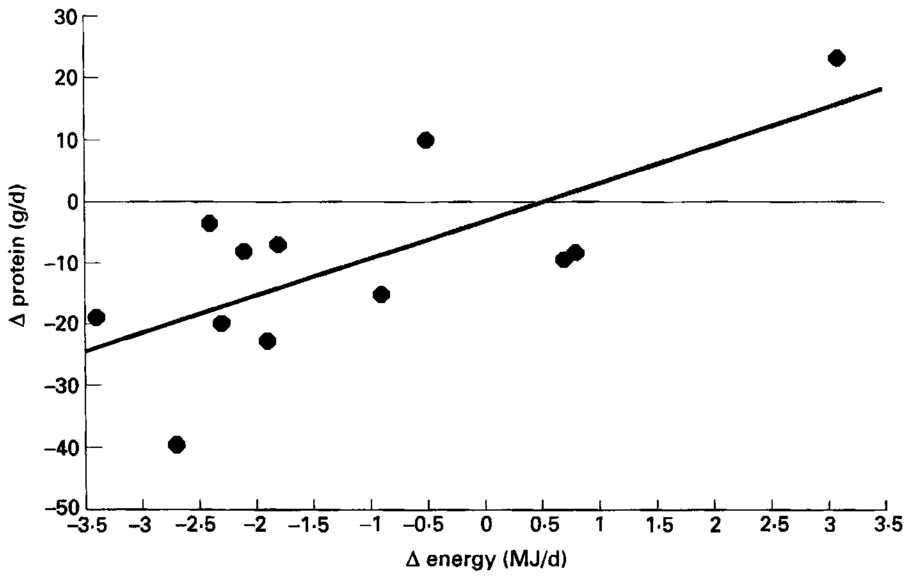

Fig. 4. The over- or underestimation of protein *v.* the over- or underestimation of energy intake of twelve elderly women (r 0·72, $P = 0·009$).

Table 3. *Activity pattern and pedometer counts of elderly women in a respiration chamber and in the free-living situation*

	Respiration chamber		Free-living		
	Mean	SD	Mean	SD	*P* value*
Activity category (min/d)					
Lying	525	36	539	89	0·6
Sitting quietly or very light sitting activity	694	84	488	98	0·0001
Light-to-moderate sitting activity	0	0	21	24	0·01
Standing or light standing activity	127	92	186	100	0·06
Standing activity or walking around	19	26	110	96	0·002
Walking activity or cycling	66	21	87	58	0·2
Recreational activity	2	5	9	9	0·03
Pedometer					
Steps/d	1749	1276	7757	3350	0·0001

* Respiration chamber *v.* free-living situation.

In the present study estimated energy intake was only 88 (SD 26) % of TEE in the respiration chamber. Several studies report an underestimation of energy intake compared with TEE in elderly women (Goran & Poehlman, 1992; Pannemans & Westerterp, 1993; Reilly *et al.* 1993). The energy intake values in these studies were respectively 69, 73 and 90% of the TEE, which was determined using the doubly-labelled water method. These studies used 3 d diet records (Goran & Poehlman, 1992; Reilly *et al.* 1993) or 4 d diet records (Pannemans & Westerterp, 1993) to obtain the energy intake values. Recently, Johnson *et al.* (1994) showed a 24% underestimation of energy intake by a 3 d diet record in elderly women. However, these authors did not actually measure TEE but used an estimated TEE based on leisure-time activities and resting metabolic rate. This suggests not only that the diet record seems to underestimate energy intake in elderly women, but that the dietary history method, which in general reports higher intakes than the record method (Nes *et al.* 1991), might also underestimate energy intake.

It is unlikely that the lower energy intake compared with the measured TEE could have been caused by an overestimation of TEE in the respiration chamber. First, the respiration equipment was calibrated regularly by alcohol burned during 24 h, showing recoveries of 100·2% and 98·7% for O_2 and CO_2 respectively. Second, no significant day-effect ($P =$ 0·93) was found between the two measurement days. All subjects reported feeling at ease after the first 9 h, after which the actual measurements started. The within-person day-to-day variation coefficient of total energy expenditure was 3·3%, which is comparable with the values from other studies (4·6%, Warwick *et al.* 1988 and 2·6%, De Boer *et al.* 1987). Thus, it may be assumed that the TEE data are correct and that TEE may be used as a reference method.

The urinary N excretion method was used to validate reported protein intake and thus indirectly validate energy intake. In the present study a positive association was observed between reported protein and energy intakes (r 0·58, $P = 0·049$). A close association between energy and protein intakes in elderly people has been reported before. The data of the SENECA study show narrow ranges for the percentage of energy from protein in elderly people from eighteen towns in twelve countries of Europe (12·4–16·6% in men and 12·9–17·4% in women; Moreiras *et al.* 1991). The reported protein intake tended to be lower than the protein output as calculated from the excretion of U_N. The U_N:dietary N ratio (dietary N calculated as protein intake/6·25) was 118 (SD 28)%, and much higher than the value of 81% reported by Bingham & Cummings (1985). These results indicate an underestimation of the protein intake by the dietary history method. Incomplete urine collections may have contributed to the error in the difference between reported protein intake and estimated protein intake. However, incomplete urine collections would lead to a lower estimated protein intake. If some incomplete urine collections had been used the underestimation of the dietary history method would in fact be larger than the observed 10–12%. Only one study compared the protein intakes of elderly people with the urinary N output (Steen *et al.* 1977). In that study the protein intake of elderly females was 63 g and their output (24 h urinary N output × 6·25) 66 g, which was not significantly different. However, in that study the dietary N was estimated from a single 24 h urine collection which can be substantially in error (Bingham & Cummings, 1985).

From the physical activity diaries it was concluded that free-living physical activity level was considerably higher than the physical activity level in the respiration chamber. In the respiration chamber more time was spent on light activities (A–C, Table 3) than in the free-living situation (1219 (SD 100) min and 1048 (SD 94) min respectively, $P = 0·0001$). Furthermore, in the respiration chamber less time was spent on more strenuous activities (D–G, Table 3) than in the free-living situation (214 (SD 102) min and 392 (SD 94) min respectively, $P = 0·0001$). Also, the number of steps as measured by a pedometer was much higher in the free-living situation than in the respiration chamber. This is probably due to the fact that in the free-living situation significantly more time was spent standing and walking around (110 (SD 96) min) than in the chamber situation (19 (SD 26) min, $P = 0·002$). The difference between reported energy intake and energy expenditure was almost significant. However, since the physical activity level of the elderly women was higher in the free-living situation than in the respiration chamber, the deviation between reported energy intake and TEE might be even larger than shown in the present study.

The results of this study may have implications for the use of the dietary history method in, for example, epidemiological studies investigating the relationship between energy intake and morbidity. Since subjects with a high energy expenditure level or with a high estimated protein intake appear to underestimate their energy intake to a greater extent, differential misclassification may occur. More studies investigating the problem of underestimation of energy intake in elderly subjects are necessary.

In summary: the results of the present study suggest that energy intake, obtained by a dietary history, may be underestimated by 10–12% in healthy, elderly women compared with TEE as measured in a respiration chamber. Physical activity level of the elderly women participating in this study was higher in the free-living situation than in the respiration chamber. Therefore, underestimation of energy intake may be even higher in the free-living situation. The results of the present study point to the need for validation studies of dietary assessment methods in elderly people.

The authors thank the twelve participants for their enthusiastic and invaluable cooperation. We thank Annemiek van der Horst for her help in conducting the study. We are indebted to Frans Schouten and Martin Los for their indispensable technical assistance in the energy expenditure measurements. We thank the Department of Human and Animal Physiology for the use of the respiration chambers. M.V. is supported by the Nutricia Research Foundation.

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Printed in Great Britain