Improved reporting of habitual food intake after confrontation with earlier results on food reporting

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The aim of the present study was to improve the reporting of food intake by confronting subjects with their way of reporting food intake, e.g. under-recording and/or undereating. To minimize portion size errors, eighteen female dietitians were recruited as subjects. Energy- and water intake were measured for 1 week with a weighed dietary record. Resting metabolic rate was measured with an open-circuit ventilated-hood indirect calorimeter, and physical activity was measured with an accelerometer for movement registration. Water loss was estimated with ^{2}H-labelled water. Energy balance was checked for by measuring empty body-weight 1 week before the start, at the start and at the end of the recording week. In the first part of the study, the change in body weight in the non-recording week was 0·14 kg and in the recording week –0·45 kg (*P* 0·02), indicating 12 % undereating. Total water intake closely matched measured water loss, indicating a high recording precision. There was under-reporting of habitual food intake that could be fully explained by undereating. In the second part of the study, subjects were confronted with these results and the protocol was repeated. This time there was no significant change in body weight in the recording week, indicating no undereating. The reporting of habitual food intake had been improved. In conclusion, in the studied group of highly motivated lean women, under-reporting of habitual food intake (here due to undereating) could be eliminated by confrontation with the results of this phenomenon.

Energy balance: Water balance: Dietary assessment

Under-reporting of habitual food intake is seen in many studies and in different populations. The most accurate way to measure habitual food intake is still not established and a valid method is much needed for nutrition research. Discrepancies between reported food intake and measured energy expenditure (with the doubly-labelled water method) ranged from 20 to 50 % in obese subjects (Prentice *et al*. 1986; Bandini *et al*. 1990; Schoeller, 1990; Schoeller *et al*. 1990; Westerterp *et al*. 1991; Lichtman *et al*. 1992; Black *et al*. 1993; Buhl *et al*. 1995; Kempen *et al*. 1995; Velthuis-te Wierik *et al*. 1995) and from 0 to 30 % in lean subjects (Schulz *et al*. 1989; Bandini *et al*. 1990; Livingstone *et al*. 1990, 1992; Schoeller, 1990; Schoeller *et al*. 1990; Westerterp *et al*. 1991; Edwards *et al*. 1993; Davies *et al*. 1994; Sjödin *et al*. 1994; Martin *et al*. 1996; Pannemans & Westerterp 1996; Bandini *et al*. 1997; Black *et al*. 1997). Until recently it was not clear whether the discrepancy was due to under-recording (an energy intake below energy expenditure with no change in body mass), to undereating (an energy intake below energy expenditure accompanied by a decline in body mass) or to both. We were able to investigate both mentioned errors with simultaneous measurements of energy balance and water balance (Goris & Westerterp, 1999). Body mass decline over the reporting week, as a measure for energy balance, was an indication for undereating. Water loss in excess of reported water intake was an indication for under-recording. The recording precision of water intake was assumed to be representative for total food recording (Goris & Westerterp, 1999). This first study to enable the division of under-reporting into undereating and under-recording also gave information for providing comments to the subjects. Feedback on the reporting of food intake can be useful to make subjects aware of their way of reporting food intake e.g. under-recording and/or undereating. After the feedback, a second period of food reporting might improve the reporting of habitual food intake. The aim of this present study was to improve the reporting of habitual food intake, by confronting subjects with the results of an earlier reporting of food intake. Food and water intake were measured with a 7 d weighed food record, and energy expenditure was calculated from measurement of resting metabolic rate and physical activity. Water loss was measured with ^{2}H elimination. The study was split into two parts; the first part was to investigate the two errors

Abbreviations: PA, physical activity; RMR, resting metabolic rate.

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under-recording and undereating and the second part was to improve the reporting of habitual food intake. To be able to distinguish under-recording from undereating it was necessary to minimize portion size errors. Therefore, dietitians were chosen as subjects as they are familiar with weighing and reporting food items accurately.

Materials and methods

Protocol

Food intake was measured with a 7 d food record. Energy balance was monitored by measurement of body mass. Subjects were weighed 1 week before the start of the food recording week, and at the start and end of the recording week. Thus, possible weight fluctuations because of food recording could be compared with normal weight fluctuations. During the first week, the non-recording week, there were no further measurements. In the second week energy and water intake were measured with a weighed food record. Energy expenditure was estimated by two measurements of resting energy expenditure (at the start and end of the recording week) and by the assessment of physical activity during the whole recording week. Water loss was measured with ^2H elimination.

When all subjects had followed the protocol once, they came together 1 to 6 months later and were confronted with the qualitative and quantitative results on under-recording and/or undereating of the whole group and of themselves. They were given a detailed personal copy to take home as well. All subjects were asked to follow the same protocol again, independent of personal results of the reporting of food intake, and to do it better. The confrontation with the results should help the subjects to improve the reporting of food intake.

Subjects

Dietitians (*n* 27) were recruited, via letters and meetings, from Maastricht University, Maastricht University Hospital, home-nursing association and dietitians' practices in Maastricht and surrounding area. Subjects were informed about the goal of the study to stimulate them to record their food intake accurately. All subjects were healthy women with a mean age of 34 (SD 9) years (range 22–60) and a mean BMI of 22·1 (SD 2·3) kg/m^2 (range 17·4–26·0). Subjects who were pregnant, lactating or slimming were not included in the study. Two subjects were post-menopausal. The protocol was approved by the university ethics committee.

Body mass

Body mass was measured three times (with 7 d intervals). Thus, possible weight fluctuations because of food recording can be compared with normal weight fluctuations. As weight fluctuations can be influenced by phase of menstrual cycle, the phase of the cycle was noted. Subjects were weighed (in underwear) in the morning, before any drink or beverage consumption and after voiding, on a digital balance accurate to ±0·01 kg (Sauter, type E1200; Ebingen, Germany).

Food and water intake

A 7 d weighed food record was chosen because it does not rely on the memory of a subject and is commonly used for measuring habitual food intake of individuals and groups. Subjects were instructed to weigh everything they ate and drank on an electronic scale (EKS; Sélestat, Sweden; maximum 2000 g, accurate to ±1 g) and record it in a structured food diary. The food records were converted into intake of total energy and water with a computer program based on food tables (Becel Nutrition Program, Nederlandse Unilever Bedrijven B.V., Rotterdam, The Netherlands).

The amount of metabolic water was estimated from protein, fat and carbohydrate intake derived from the 7 d food record and from the change in body mass. Oxidation of protein yields 0·41 ml water/g, fat 1·07 ml/g and carbohydrate 0·6 ml/g (Fjeld *et al*. 1988). A change in body mass of 1 kg was assumed to be a change of 0·75 kg fat mass and 0·25 kg fat free mass (fat mass being pure fat and fat free mass being 73 % water and 27 % protein; Westerterp *et al*. 1995).

Energy expenditure

Energy expenditure was estimated from measured resting metabolic rate (RMR) and physical activity (PA). RMR was measured by means of an open-circuit ventilated-hood system, in the morning in a fasting state while lying for 30 min in a supine position. Gas analyses were performed by a paramagnetic O_2 analyser and an i.r. CO_2 analyser (Servomex type 500A; Crowborough, Sussex, UK), similar to the analysis system described by Schoffelen *et al*. (1997). Weir's formulas (1949) were used for calculating RMR.

Physical activity was registered with a triaxial accelerometer for movement registration (Tracmor; Philips Research, Eindhoven, The Netherlands). The Tracmor was an improved version (same principle, but smaller; 70×20×8 mm) of the Tracmor used in previous studies (Bouten *et al*. 1996). In short, the Tracmor measures accelerations in the antero-posterior, medio-lateral and vertical directions. The Tracmor has been validated against doubly-labelled water (Westerterp & Bouten, 1997). The Tracmor output explained 64 % of the variation in the average daily metabolic rate adjusted for sleeping metabolic rate with a standard error of estimate of 0·9 MJ/d (Westerterp & Bouten, 1997). Subjects wore the Tracmor in a waist belt at the low back during waking hours and recorded the times when they got up, took the Tracmor on and off, and when they went to bed. The registered accelerations in counts/min were used as an objective measure for the PA level of each subject.

Water loss

Water loss over the recording week was measured with the ^2H elimination method (Fjeld *et al*. 1988). Subjects drank a deuterium (^2H_2O) dilution (70 g water with an enrichment of 5 atom percent excess ^2H) after voiding (baseline urine sample) the evening before the start of the recording week. Elimination was calculated from two urine samples directly after dosing (at day 1 in the morning and evening) and two at the end of the observation period (day 7 in the evening, day 8 in the morning). ^{2}H content was measured in urine samples with an isotope ratio mass spectrometer (Westerterp *et al*. 1996). Water loss was calculated from ^{2}H elimination with the equation of Fjeld *et al*. (1988) as described previously (Westerterp *et al*. 1992).

Questionnaire

At the end of the recording week subjects filled in a questionnaire about their experiences with food recording to determine if they always weighed and recorded their food intake and if they changed habitual food intake.

Statistics

Twenty-seven subjects participated in the first part of the study, of whom eighteen also participated in the second part of the study. Of the other nine subjects, one was pregnant during the second period of measurements, three subjects went abroad and five subjects found it too much of a burden to follow the protocol twice. There were no significant differences in body mass changes, BMI, age, energy intake and RMR, and percentage discrepancy between water intake and loss in the first part of the study, among the five subjects who did not want to participate twice and the other twenty-two subjects (ANOVA, $P > 0{\cdot}05$; data not shown). Also, no differences were found between the nine subjects who participated only once and the eighteen subjects who participated twice (ANOVA, $P > 0{\cdot}05$). The results presented here, therefore, are from the eighteen subjects who followed the protocol twice. Mean values and standard deviations were calculated from the results of both parts of the study. A one way repeated-measures ANOVA and a Scheffé test (*post hoc*) were used to compare the three measurements of body mass on a within subject basis. The changes in body mass were compared with a paired *t* test (two-sided). A factorial ANOVA test was used to measure the influence of the phase of the menstrual cycle on the body mass changes.

Measurements of RMR at the start and end of the recording week were compared with a paired *t* test (two-sided) and means were calculated if both measurements did not differ significantly from each other.

RMR, PA and body mass changes are all independent measures for energy metabolism. Multiple and simple regression analyses were used to assess the contribution of these independent variables to reported energy intake.

Results of both reporting weeks were compared with each other with a paired *t* test (two-sided). Significance was reached when $P < 0{\cdot}05$. The StatView™SE+ (1988, Abacus Concepts, Inc., Berkeley, CA, USA) was used for statistical analysis.

Results

Part one of the study

The mean results of the three body mass measurements were, in sequence of time, 59·5 (SD 7·1), 59·7 (SD 7·1) and 59·2 (SD 6·9) kg. The last mean body mass differed significantly from the first two measurements ($P = 0{\cdot}03$). Mean body mass changes over the non-recording and recording week (Table 1) differed significantly ($P = 0{\cdot}04$). Subjects in the pre-ovulation period (*n* 13) had a body mass change over the recording week of –0·67 (SD 0·78) kg and subjects in the post-ovulation period (*n* 5) had a body mass change of 0·14 (SD 0·55) kg ($P = 0{\cdot}02$).

The mean body mass loss of 0·45 (SD 0·69) kg over the recording week, which implied undereating, represented 13·4 (SD 20·7) MJ (1 kg body mass was assumed to be equivalent to 30 MJ (Westerterp *et al*. 1995)) or 1·9 (3·0) MJ/d. The undereating amounted to 12 (SD 30) % of the energy requirement calculated as energy intake plus the energy equivalent of the body mass loss. Reported water intake plus metabolic water was closely correlated with measured water loss (r 0·98, $P = 0{\cdot}0001$), indicating a high recording precision. The difference between water loss and total water intake was not related to the average of water loss and intake (r^2 0·08, $P = 0{\cdot}27$) (Altman & Bland, 1983). The relative bias (the average of the difference between water loss and intake) was 0·32 litre/d and the estimate of error (SD of the difference) was 0·16 litre/d. The relative bias of 0·32 litre/d was significantly different from zero (see p. 367). The answers on the questionnaire subjects filled in at the end of the recording week indicated that subjects did not change their food pattern during the recording week. However,

Table 1. Reported intake of energy, resting metabolic rate, physical activity counts and body mass changes of the first recording week (part one) and of the second recording week‡ (part two)

(Values are means and standard deviations for eighteen subjects)

	Part one of the study			Part two of the study		
	Mean	SD	Range	Mean	SD	Range
Energy intake (MJ/d)§	8·5	1·2	6·8–11·9	9·4*	1·4	7·1–12·1
Resting metabolic rate (MJ/d)	5·9	0·4	5·3–6·4	6·0	0·5	4·9–6·7
Physical activity (counts/min)	158	69	90–315	114	42	61–198
Body mass change over non-recording week (kg)	0·14	0·67	–0·96–1·73	–0·23	0·49	–1·0–0·90
Body mass change over recording week (kg)	–0·45†	0·69	–1·42–0·93	–0·15	0·59	–1·15–0·95
Total water intake (litre/d)	2·8	0·8	1·7–5·4	2·9	0·8	1·9–5·7
Total water loss (litre/d)	3·1	0·8	2·0–5·7	3·0	0·9	2·1–5·9

Mean value was significantly different from that in part one of the study: *$P < 0{\cdot}04$.
Mean value was significantly different from that in the non-recording week: †$P < 0{\cdot}04$.
‡ The second recording week was after subjects were confronted with the results of the first food recording week.
§ Values are means based on 7 d food diaries of eighteen female subjects and ranges refer to differences among subjects.

weighing and recording food intake for 7 d was experienced as quite a burden.

Part two of the study

In the second part of the study, the mean results of the three body mass measurements were, in sequence of time, 60·0 (SD 6·8), 59·8 (SD 6·6) and 59·6 (SD 6·5) kg. The last mean body mass differed significantly from the first measurement ($P=0·02$). Body mass changes over the non-recording week and recording week (both independent of the phase of the menstrual cycle) did not differ significantly from each other and did not differ from zero ($P=0·7$, Table 1).

Mean daily energy intake was 9·4 (SD 1·4) MJ (Table 1) and was 0·8 (SD 1·2) MJ higher than the reported energy intake in part one of the study ($P=0·04$). The higher energy intake of 11 (SD 17) % of reported energy intake of the first part, was not due to a higher PA in part two of the study. PA was lower in part two compared with part one of the study ($P=0·01$). The higher energy intake in part two was related to the change in body mass of the first part (Fig. 1). This was a negative relationship; from the subjects who lost body mass in the first part of the study, those who lost most body mass showed the largest increase in energy intake. This relation remained significant when data from the five subjects who gained body mass in the first part of the study were excluded. All except one subject increased their energy intake (relative to part one). Subjects who gained weight in the first part of the study showed a small increase in energy intake (n 4) or decrease in energy intake (n 1) in part two. The subject who had an increase of about 75 % in energy intake in the second part of the study relative to the first part of the study over-recorded her food intake (see later). Excluding these data did not change the correlation between the percentage extra energy intake and change in body mass over the first recording week.

Measured water loss was fully explained by reported water intake and the amount of metabolic water (r 0·98; $P=0·0001$). There was no difference ($P=0·09$) between water loss (3·0 (SD 0·9) litre/d) and water intake (2·9 (SD 0·8) litre/d), so the reporting of water intake was done very accurately. However, two subjects had a discrepancy between water intake (reported intake + metabolic water) and water loss of more than 10 % of water loss. One subject over- and one subject under-recorded the water intake (and thus the food intake). These two subjects have been excluded from the regression analysis on energy intake, because of the over/under-recording, as their energy intake could not be explained by measures of energy. Energy intake was explained by RMR (P 0·01), PA (P 0·03) and the change in body mass over the recording week (P 0·05, Table 2). RMR and PA were independently related to energy intake. In a simple regression analysis the change in body mass was not related to energy intake.

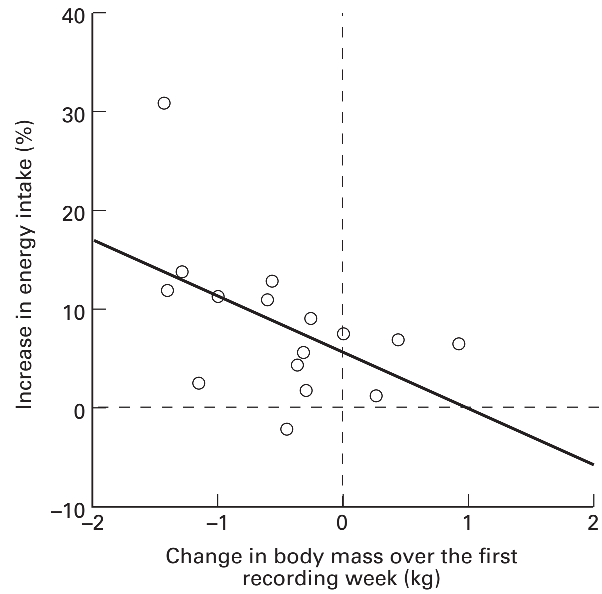

Fig. 1. Improved reporting of food intake after confrontation with earlier results on food reporting: the relationship between the change in body mass during the first food recording week (part one) and the percentage increase in energy intake in the second food recording week (part two) compared with the first (part one) (r 0·51, $P<0·04$).

Subjects did not change their food pattern during the recording week, according to their answers on the questionnaire. Subjects (50 %) answered that the confrontation with the results of the first recording week made them more careful to maintain their habitual food pattern. The higher energy intake in the second part of the study was due to a higher carbohydrate (part one 250 g *v.* part two 275 g, $P=0·03$) and fat intake (part one 73 g *v.* part two 83 g, $P=0·02$). Subjects ate less carbohydrate- and fat-containing foodstuffs during the first recording week than during the second recording week.

Discussion

This present study is, to our knowledge, the first attempt to

Table 2. The attribution of resting metabolic rate (RMR), physical activity (PA) and the change in body mass over the recording week to energy intake in a simple and in a multiple regression analysis on energy intake (part 2 of the study, n 16)

	Explained variation (%)	Statistical significance: $P=$
RMR	37	0·01
PA	24	0·05
Δ Body mass	17	0·1
RMR + PA + Δ body mass*	66	0·004

* Multiple regression equation: energy intake (kJ/d) = −738 + 1·46 × RMR (kJ/d) + 12·8 × PA (counts/min) + 720 × Δ body mass (kg/week).

improve the reporting of habitual food intake. Subjects showed 12 % under-reporting of food intake at the first time of food recording, which could be fully explained by undereating. Individual confrontation with this phenomenon improved the reporting of habitual food intake the second time. Information about the sort of errors made (e.g. under-eating and/or under-recording) helped subjects to improve the reporting of habitual food intake. In most studies subjects receive instructions on weighing and recording food intake. A few studies (de Vries *et al*. 1994; Seale, 1995; Sawaya *et al*. 1996; Seale & Rumpler, 1997) also mentioned explicitly that subjects were instructed not to lose or gain weight during the recording period. The instructions provided to the subjects in the first part of this study were not very different from other studies. Subjects were informed about the aim of the study, and were asked not to change their activity-, eating- and behaviour patterns during the food recording interval. The instructions were obviously not sufficient to avoid under-reporting of food intake in the present study and in earlier studies. Subjects changed their food intake in the first part of the study, probably unconsciously, according to the answers on the questionnaire. Confronting subjects with their own behaviour on food reporting seems to be a way to get reliable data on habitual food intake. There was a direct relationship between the change in body mass over the recording week in part one of the study and the increase in energy intake in part two compared with part one of the study. The more subjects lost weight in the first part of the study, the more they ate in the second part of the study. The answers subjects gave to the questionnaire after the second recording period revealed that 50 % of all the subjects did notice that they ate more during the second recording period. They answered that they improved the reporting of habitual food intake this time.

The improvement in the reporting of habitual food intake could have been a learning effect rather than a confrontation effect. However, in another study with subjects before and after a training intervention they found no under-reporting of food intake before the intervention and a 19 % under-reporting after the intervention. The reporting of food intake several times was perceived as quite a burden by the subjects and this probably caused the under-reporting the second time (Westerterp *et al*. 1991). In the case of a learning effect, the reporting of the food intake should have been improved and this was not the case. The dietitians in this study were familiar with reporting of food intake and a learning effect would not be very likely.

In the first part of the study, three out of the five women in the post-ovulation phase showed an increase in body mass over the recording week (for women in the pre-ovulation phase this was two out of the thirteen women). In the post-ovulation period, progesterone, a general metabolic stimulant, is increased. However, the consequent increase in energy intake and expenditure is at the same magnitude and subjects remain in energy balance (Buffenstein *et al*. 1995). The higher body mass during the post-ovulation period is probably due to water retention. Body mass declines again before the onset of the menses and is stable during the pre-ovulation period (Webb, 1986; Gong *et al*. 1989; Tarasuk & Beaton, 1991; Meijer *et al*. 1992; Buffenstein *et al*. 1995). Thus, the body mass loss of the women in the pre-ovulation period and of the two post-menopausal women seen in this study can only be explained by undereating.

The recording of food intake was done accurately in both parts of the study. The small shortage in water intake compared with water loss in part one was also seen in other studies that measured the water balance (Westerterp *et al*. 1992, 1996; Goris *et al*. 1999). This small shortage might be due to underestimation of the amount of calculated metabolic water. The amount of metabolic water was calculated from the carbohydrate, fat and protein intakes derived from the 7 d food record and from the change in body mass (part one of the study). In part two of the study there was no significant difference between water loss and intake. Subjects had no change in body mass over the recording week this time and probably weighed and recorded their food intake even more accurately than the first time. However, there were two subjects who had a difference of more than 10 % between water intake and loss. Their food intake could not be explained by measures of energy metabolism (e.g. RMR, PA, change in body mass), because of under- or over-recording of the food intake. Water loss, as an indicator of recording precision, could discriminate the under- or over-recorders of food intake from the accurate recorders of food intake.

A good recording of water intake does not necessarily imply that the same holds for the recording of food intake. However, most foodstuffs contain a certain amount of water; therefore, it was concluded that the food recording was also done accurately. In a recent study by Poppitt *et al*. (1998) selective under-reporting of snacks was found by obese and non-obese women in a metabolic facility. The women stayed for 24 h in a metabolic facility and had *ad libitum* food intake (which was covertly measured). The next day subjects had to write down what they ate and drank the previous 24 h. Food items eaten during a meal were reported well, but the between-meal snack foods were under-reported. The snacks provided were mostly carbohydrate-rich and they found selective under-reporting of carbohydrate. Measurements of 24 h food intake in a metabolic facility are difficult to compare with a 7 d weighed food record. This latter method does not rely on the memory of subjects. It is less likely to cause omission of recording of the various snacks consumed between the meals, unless recording is delayed. Still, selective under-recording of foods might introduce a small error in the measurement of total water intake and thus in the measurement of under-recording.

In conclusion, the significant body mass loss over the recording week indicated undereating. The measured water balance showed no sign of under-recording. In the first part of the study the under-reporting of food intake was fully explained by undereating. After confrontation with these results the subjects were able to improve the reporting of food intake. There was no significant body mass loss over the second recording week and water balance was stable. PA was decreased, but energy intake was significantly higher than found in the first recording. Measurements of energy- and water balance to detect under-reporting, undereating and under-recording can be used as key information to inform subjects about their way of food reporting. The lean, motivated women in this study were, with this information, able to improve the reporting of habitual food intake.

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