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Accuracy of food intake reporting in obese subjects with metabolic risk factors

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The aim of the present study was to determine the accuracy of reported energy intake according to a food-frequency questionnaire (FFQ) and dietary records (DR) in obese subjects with metabolic syndrome risk factors. Subjects were twenty-three men and twenty-seven women with mean BMI of 35·7 (range 30·5–43·8) kg/m^2 who participated in a dietary interview based on a FFQ and completed weighed DR. Total energy expenditure was measured with the doubly labelled water method. Total energy expenditure, measured RMR and physical activity level did not differ between under-reporters (50 % of the sample) and non-under-reporters. Under-reporters had lower median intake of sweets, desserts and snacks than non-under-reporters (100 *v.* 161 g/d (P=0·0008) and 61 *v.* 128 g/d (P=0·0002) according to the FFQ and DR, respectively). The DR also showed lower energy density (6·7 (SD 1·3) *v.* 7·9 (SD 1·6) kJ/g; P=0·0064), lower intake of sugary drinks (0 *v.* 167 g/d; P=0·0063) and higher scores for dietary restraint (9·0 (SD 5·0) *v.* 6·1 (SD 3·5); P=0·0285) in under-reporters. Energy density was associated with accuracy according to the FFQ (Spearman's rank correlation coefficient (R_S) 0·406; P=0·0034) and the DR (R_S 0·537; P<0·0001). In multivariate analysis, consumption of bread and sweets, desserts and snacks measured by the FFQ was positively associated with accuracy ($R^2_{adjusted}$ 0·46 (95 % CI 0·32, 0·70)). According to the DR, consumption of sweets, desserts and snacks was also associated with accuracy, as was dietary restraint (inversely) ($R^2_{adjusted}$ 0·67 (95 % CI 0·54, 0·83)). In obese subjects with metabolic risk factors, intake of sweets, desserts and snacks, bread and dietary restraint were determinants of reporting accuracy.

Energy intake: Under-reporting: Eating behaviour: Doubly labelled water

In 2001, the National Cholesterol Education Program defined the metabolic syndrome as a constellation of at least three of five risk factors (increased waist circumference, hypertriacylglycerolaemia, low HDL-cholesterol, high blood pressure, and high fasting glucose) that increase the risk of CHD and recommended that the metabolic syndrome should be a target of risk-reduction therapy after the primary target, level of LDL-cholesterol, is met (Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults, 2001). One of the primary methods of risk reduction is weight loss. Studies have shown that even a modest degree of weight loss induced by dietary and lifestyle change in individuals with characteristics of the metabolic syndrome is associated with clinical benefits (Tuomilehto *et al.* 2001). However, counselling for weight loss is hampered by the difficulty in obtaining accurate dietary data (Lissner, 2002). The development of the doubly labelled water (DLW) method to estimate total energy expenditure (TEE) has led to general acceptance of the notion that dietary self-reporting substantially underestimates energy intake (EI), and data have accumulated for nearly two decades showing that obese individuals are more likely to under-report than others (Prentice *et al.* 1986, 1996; Braam *et al.* 1998; Hill & Davies, 2001).

Studies on the accuracy of dietary self-reporting have considered a number of factors in addition to a high BMI that may influence the likelihood of under-reporting. These include sex, age, socio-economic status, eating behaviour and dieting, physical activity, non-smoking, psychological factors and the cultural context as reviewed recently (Livingstone & Black, 2003). Under-reporting is accentuated when repeated assessment of dietary intake is conducted (Caan *et al.* 2004). Furthermore, certain foods and nutrients are more likely to be under-reported than others, primarily carbohydrates, fats, snacks, and foods or drinks that are considered to be unhealthy (Bingham *et al.* 1995; Heitmann & Lissner, 1995; Poppitt *et al.* 1998; Tonstad *et al.* 1999; Goris *et al.* 2000; Hill & Davies, 2001). Such selective under-reporting may lead to spurious associations between dietary components and biological markers or risk factors (Lissner *et al.* 1998). Poor accuracy of dietary data may be more pronounced and may mislead public policy, in particular when subjects at high risk for disease are considered, for example, individuals with the metabolic syndrome, as indeed has been demonstrated recently (Rosell *et al.* 2003). In this study, under-reporters had a higher prevalence of the metabolic syndrome than other subjects and associations between the diet and the components of the metabolic syndrome differed between under-reporters and the remaining subjects (Rosell *et al.* 2003).

The aim of the present investigation was to examine the determinants of self-reporting of energy in a sample of obese men and women with the metabolic syndrome or at least two of its risk factors and to explore the specific foods, eating patterns and behaviour that are associated with under-reporting using the DLW method to estimate TEE. The overall goal was to inform

Abbreviations: CL, confidence limit; DLW, doubly labelled water; DR, dietary record; EI, energy intake; FQ, food quotient; FFQ, food-frequency questionnaire; IQR, interquartile range; OPEN, Observing Protein and Energy Nutrition; TEE, total energy expenditure.

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the dietary advice that is appropriate for this group of individuals. Because cigarette smoking may confound the relationship between nutrient intakes and under-reporting (Dallongeville *et al.* 1998), we chose to include only non-smokers in the study.

Subjects and methods

Subjects

Fifty non-smoking, obese men and women with a mean age of 43·2 (SD 10·3; range 24–64) years and a mean BMI of 35·7 (SD 3·3; range 30·5–43·8) kg/m^2 and two or more risk factors for the metabolic syndrome according to the National Cholesterol Education Program (glucose $\geq$6·1 mmol/l or HDL-cholesterol $\leq$1·03 mmol/l for males or $\leq$1·29 mmol/l for females or serum triacylglycerols $\geq$1·69 mmol/l or waist circumference $>$102 cm for males or $>$88 cm for females or systolic blood pressure $\geq$130 mmHg and diastolic blood pressure $\geq$85 mmHg) were recruited by newspaper advertisement and referral to the Department of Preventive Cardiology at Ullevål University Hospital (Oslo, Norway). Subjects were screened via blood chemistry and a medical examination done by a physician to assess risk factors and eligibility to the study. Fifteen subjects had two risk factors, twenty-seven subjects had three risk factors and eight subjects had four risk factors; thus 60 % had the full metabolic syndrome. Exclusion criteria were body weight $>$135 kg, current dieting, cigarette smoking, history of eating disorder or chronic disease, suspected non-compliance due to abuse of drugs or alcohol, drug- or insulin-treated diabetes mellitus, migraine requiring intermittent medication, use of thyroxin, diuretics or weight-reducing agents and use of inhaled or oral β-agonists or corticosteroids. The educational level of each subject was determined according to the number of years of education and categorised as completed primary school, high school or a university degree. The Ethical Committee (region 1 in Norway) approved the protocol and all participants gave their written informed consent. The study was conducted between October 2001 and October 2003.

Measurements

Height was measured with a standardised wall measuring stick scale to the nearest 0·5 cm. Subjects were weighed (in underwear) with a digital weight (SECA, Hamburg, Germany) to the nearest 0·1 kg. Weight was measured at the screening and baseline visits and on day 1 and day 15 of the DLW measurement period. Weight changes during the DLW period were calculated as the difference between day 15 and day 1 and weight changes during the 3-month study as the difference between day 15 of the DLW period and baseline. Waist was measured in the standing position at the level of umbilicus (unclothed) and hip circumference was measured at the level of the greater trochanter. Body composition was determined by dual-energy X-ray absorptiometry (Lunar Expert 1116; Lunar Corp., Madison, WI, USA). The measurement was done in 15 min. The CV for the dual-energy X-ray absorptiometry measurements was 3–4 %. RMR was measured with a standard portable ventilated hood system (Deltatrac® Metabolic Monitor; Datex Instrumentarium Corp., Helsinki, Finland). The Deltatrac® was calibrated by automatic standard gas calibration at the start of each measurement. The subjects slept at home the night before the measurement. On the day of the measurement the subjects took a taxi to the site. The subjects fasted during the last 12 h before the measurement and were instructed not to eat or drink anything but water on the day of the measurement. After changing clothes and mounting the equipment, the subjects relaxed for 30 min in the recumbent position before the head was covered with the canopy. Measurements were done at 1 min intervals for 20–25 min. A mean value of at least a 10 min period at a stable level of energy expenditure was defined to be the RMR.

Doubly labelled water method

Energy expenditure by the DLW method was measured over a period of 14 d and used as a measure of habitual energy expenditure. Sample analyses and calculation procedures have been described in detail elsewhere (Slinde *et al.* 2003). First a baseline urine sample was collected for the determination of the background isotope enrichment (day 1). Then a weighed mixture of ^{2}H-labelled and oxygenated water, corresponding to 0·05 g ^{2}H-labelled water and 0·10 g ^{18}O-labelled water/kg body weight, was ingested. The percentage enrichment of the waters was 99·9 % for ^{2}H and 10·0 % for ^{18}O. The dose was planned to enrich body water with approximately 350 parts per thousand (δ per mil) for ^{2}H and 60 parts per thousand (δ per mil) for ^{18}O. Urine samples were collected from the second voiding during day 2, day 3, day 4, day 8, day 13, day 14 and day 15. The mean time interval between drinking dose and the first post-dose urine sample was 22 (SD 3; range 12–30) h. The participants were instructed to collect the urine spot, register exact voiding time and freeze the samples at home. Participants were called every voiding day to ensure compliance with the procedure. When the samplings were completed, the urine samples were stored at −75°C until transportation to the laboratory on dry ice.

Analysis of the isotopic enrichment was determined in triplicates with a Thermoquest Finnigan MAT Delta plus isotope-ratio mass spectrometer with a water/H_2-CO_2 equilibrating device (Thermoquest Finnigan MAT, Bremen, Germany). The precision defined as standard error in triplicate samples is 0·26 for ^{3}H and 0·10 for ^{18}O. Tap water was collected and analysed for background measurements and all TEE calculations were corrected for the content of isotopes in the drinking water. TEE was calculated by the multi-point method using linear regression as suggested by the International Dietary Energy Consultancy Group (1990). All elimination curves were checked for major or diverging residuals. The CV for the elimination constants was on average 3·2 % for hydrogen and 2·7 % for oxygen. The mean N_o:N_d ratio was 1·033 (SD 0·008; range 1·007–1·049). We used the relationship between pool size of ^{2}H (N_d) and pool size of ^{18}O (N_o) as a quality measurement for the DLW. The mean food quotient (FQ) determined from the food-frequency questionnaire (FFQ) was 0·85 (SD 0·016; range 0·81–0·89). The individual N_o:N_d ratio and FQ of the participants were used in the calculation of the energy equivalence of the produced CO_2 as suggested by the International Dietary Energy Consultancy Group (1990).

Food-frequency questionnaire

A FFQ was used as the basis of an interview with a registered dietitian (M. S.), lasting between 1 and 2 h. The FFQ was designed to assess the food intake during the last 3 months and based on two previously developed FFQ (Lindroos *et al.* 1993; Andersen *et al.* 1999). The questionnaire elicited frequencies and consumption of 174 individual food items or constellations of items grouped together according to the typical Norwegian meal pattern. Specifically the consumption of soft drinks and alcoholic beverages, sweet baked goods, cookies, cakes, ice cream, desserts, sweets, chocolate and snacks as nuts, potato crisp and popcorn were asked for. The FFQ also included twenty-one summary questions and seven dietary supplement questions. An atlas of food portions as well as photographs, household measurements and ordinary models of sweets and snacks was used to estimate portion sizes. Particular attention was given to extra layers of bread spread, food eaten during cooking, fat used in frying and extra portions of dinner and dinner leftovers. The FFQ interview was done immediately following the DLW measurement period.

Weighed dietary records

Participants were provided with food scales and instructed to weigh each individual food item using a digital scaled weight and provide notes on ingredients of composite dishes with approximate quantities. When weighing was not appropriate, the subject used household measurements and pictures to record portion sizes. Forty-nine subjects completed dietary records (DR) for three non-consecutive days. One male subject was not able to complete the DR due to personal problems. The records were done with 3–4 d between each recording and all days of the week were about equally represented. On average the DR were completed a mean of 34 (SD 25) d before the DLW measurements.

We assessed eating frequency by counting the number of eating occasions recorded in the DR. An eating occasion was defined as a food or snack (solid or liquid) containing energy with an interval of >1 h separating the occasions (Farshchi *et al.* 2005).

Assessment of eating behaviour

Forty-nine subjects completed the Norwegian version of the Three Factor Eating Questionnaire. One male refused to fill in the questionnaire. The Three Factor Eating Questionnaire was developed to measure cognitive and behavioural components of eating (Stunkard & Messick, 1985). The scale contains subscales for restraint (possible scores 0–21), disinhibition (0–16) and hunger (0–14). The restraint subscale assesses the intent to control food intake to achieve and maintain a desired body weight. The disinhibition scale assesses overeating in response to a variety of situations associated with loss of control of food intake, while the hunger subscale assesses subjective feeling of hunger and food cravings.

Definition of under-reporters and non-under-reporters of energy

Subjects were identified as under-reporters, accurate reporters and over-reporters of energy based on the 95 % confidence limits (CL) of the expected EI:TEE ratio of 1·00. The 95 % CL between the two measurements were calculated from the published equation (Black & Cole, 2000):

$$95\,\%\text{CL} = \pm 2 \times \sqrt{((\text{CV}_{\text{TEE}})^2 + (\text{CV}_{\text{EI}}^2/\text{d}))}.$$

CV_{TEE} for repeated measurements for energy measurements by the DLW method was 8 % (Black & Cole, 2000). CV_{EI} is the within-subject CV for daily intake of energy and 23 % was used (Bingham, 1987). The number of days was 90 for the FFQ and 3 for the DR.

According to this calculation, subjects were classified as under-reporters, accurate reporters and over-reporters, depending on how much EI:TEE deviated from the expected ratio of 1·00. Subjects defined as accurate-reporters$_{\text{FFQ}}$ had an EI_{FFQ}:TEE ratio within the 95 % CL (0·83, 1·17), under-reporters$_{\text{FFQ}}$ had an EI_{FFQ}:TEE ratio below the lower CL ($<0{\cdot}83$) and over-reporters$_{\text{FFQ}}$ had an EI_{FFQ}:TEE ratio above the upper CL ($>1{\cdot}17$). Accurate-reporters$_{\text{DR}}$ had an EI_{DR}:TEE ratio within the 95 % CL (0·69, 1·31), under-reporters$_{\text{DR}}$ had an EI_{DR}:TEE ratio below the lower CL ($<0{\cdot}69$) and over-reporters$_{\text{DR}}$ had an EI_{DR}:TEE ratio above the upper CL ($>1{\cdot}31$). According to the FFQ, two males and two females were classified as over-reporters; while, according to the DR, one female was an over-reporter. Because the number of over-reporters was minor, accurate reporters and over-reporters were grouped as non-under-reporters.

Calculations and statistics

The FFQ and the DR were coded manually for calculations of total energy, energy density, energy-yielding nutrients and food items with a computer program based on the Norwegian food composition table (Rimestad *et al.* 1995; National Association for Nutrition and Health, 1996). Because of the low median intake of specific foods, we grouped food items into the following categories: fruit, berries, juice and jam; milk; bread; vegetables; boiled potatoes, rice and pasta; fatty meats, minced meat and sausages; chicken and meat with less fat; fish and fish products; oil, butter and margarine; fatty cheese; sweets, desserts and snacks; sugary drinks. The calculated dietary intake of energy assessed by FFQ and DR was compared directly to the estimated TEE from the DLW measurement. Energy density was calculated for the whole diet minus all drinks (coffee, tea, milk, juice, soft drinks and alcoholic beverages).

The results are presented as means and standard deviations, or medians with interquartile ranges (IQR) for non-normally distributed data. Mean and median differences were tested with the unpaired Student's *t* test and the Mann–Whitney signed rank test, respectively.

Anthropometrics, daily intake of nutrients and food and eating scores for restraint, disinhibition and hunger were correlated with the EI:TEE ratio calculated by the FFQ and the DR. Pearson's correlation coefficients were calculated for normally distributed variables and Spearman's rank correlation coefficients (R_S) were calculated for skewed variables. Simple regression analyses were conducted to assess the relation of reporting accuracy to percentages of energy from protein, fat, and carbohydrate and food intakes to determine whether there was selective under-reporting. Factors that were statistically significant in the univariate analysis were entered into a multiple regression analysis to identify the most important factors correlated to reported accuracy of EI. Because the intake of food is reflected in the calculated diet composition, we chose to enter the reported intake of food instead of diet composition in the multivariate regression analyses.

The tests were considered significant at $P<0{\cdot}05$. Statistical analyses were performed using the StatView 5.0.1 software (SAS Institute Inc., Cary, NC, USA).

Results

Characteristics of participants according to sex are shown in Table 1. Subjects had high concentrations of triacylglycerols, diastolic blood pressure and waist circumference in accordance with the inclusion criteria. Restraint and hunger scores were similar for men and women, but women scored higher than men on the disinhibition factor.

Eating characteristics of under-reporters and non-under-reporters

Relative to TEE, both men and women under-reported EI in both dietary assessment methods. EI among male subjects was under-reported by 14·1 (SD 18·9; range −36·0 to 41·6) % according to the FFQ and by 27·9 (SD 14·4; range −3·1 to 51·7) % according to the DR compared with the measured TEE. Female subjects under-reported EI by 20·6 (SD 24·1; range −35·2 to 62·9) and 31·0 (SD 22·0; range −44·6 to 69·0) % according to the FFQ and the DR, respectively. No significant difference by sex was seen in the reported EI relative to TEE. More than 50 % of the subjects were classified as under-reporters of EI according to both methods (Table 2).

Anthropometrics, energy expenditure, energy density, daily intakes of energy-yielding nutrients and foods and scores for eating behaviour in under-reporters and non-under-reporters according to the FFQ and DR are shown in Tables 3 and 4, and Tables 5 and 6, respectively. Eating frequency assessed by the DR is also shown in Table 6. According to the DR, under-reporters had a lower energy density of the diet and reported a lower intake of ‘sweets, desserts and snacks’ and sugary drinks, as was reflected in a higher percentage of energy from protein and a lower percentage of energy from sugar among under-reporters compared with non-under-reporters. However, the reported absolute amount of protein was lower in under-reporters compared with non-under-reporters according to both dietary assessment methods (92·2 (SD 23·0) *v*. 117·2 (SD 30·9) g; $P=0·0018$ according to the FFQ and 80·7 (SD 23·7) *v*. 97·5 (SD 20·0) g; $P=0·0116$ according to the DR). Energy-adjusted intake of sweets, desserts and snacks (median) was lower among under-reporters than non-under-reporters, respectively (7·7 (interquartile range (IQR) 4·9–10·9) *v*. 11·0 (IQR 7·6–14·7) g/MJ; $P=0·0275$) according to the DR. According to the FFQ the same trend was seen, although not statistically significant (11·1 (IQR 7·0–13·7) *v*. 12·2 (IQR 9·9–14·8) g/MJ; $P=0·2256$). Sweets, desserts and snacks intake was inversely related to percentage energy from protein according to the FFQ (R_S −0·51; $P=0·0004$) and the DR (R_S −0·48; $P=0·0008$). According to the DR, the energy density of the diet was associated with sweets, desserts and snacks (R_S 0·553; $P=0·0001$) and according to the FFQ the association was not significant (R_S 0·272; $P=0·573$).

No significant differences were seen in eating behaviour scores in under-reporters compared with non-under-reporters, with the exception of restraint scores, which were higher in under-reporters than non-under-reporters according to the DR (Table 5).

During the DLW period, the mean weight change in all participants was 0·1 (SD 1·0; range −3·6 to 1·8) kg. No significant weight difference was seen between under-reporters and non-under-reporters (0·01 (SD 0·97) *v*. 0·22 (SD 1·11) kg; $P=0·4768$ according to the FFQ and 0·01 (SD 1·12) *v*. 0·29 (SD 0·82) kg; $P=0·3299$ according to the DR). There was no significant difference in the weight change between under-reporters and non-under-reporters in the entire 3-month period of the study (1·24 (SD 1·56) *v*. 1·49 (SD 1·57) kg; $P=0·5769$ according to the FFQ and 1·50 (SD 1·50) *v*. 1·21 (SD 1·65) kg according to the DR).

Reporting accuracy

The relationship of reporting accuracy to anthropometrics, energy density, diet composition, intakes of food and eating behaviour scores is shown in Table 7. According to the FFQ, reporting accuracy was inversely correlated to the percentage energy from protein and positively to the percentage energy from sugar and the energy density of the diet. Accuracy was positively associated with the intake of the following: sweets, desserts and snacks; fatty cheese; bread; milk; oil, butter and margarine. Scores for restraint were inversely and scores for hunger were positively

Table 1. Characteristics of participants*
(Mean values and standard deviations)

	Men (*n* 23)		Women (*n* 27)		
	Mean	SD	Mean	SD	*P*
Age (years)	44	10	42	11	0·5543
Height (m)	1·82	0·07	1·69	0·06	<0·0001
Weight (kg)	115·1	13·8	104·5	12·1	0·0058
BMI (kg/m^2)	34·6	2·9	36·6	3·4	0·0290
Tissue fat (%)	41·5	7·5	53·3	5·6	<0·0001
Waist (cm)	118·4	10·0	106·4	9·4	<0·0001
Hips (cm)	110·0	7·6	117·6	9·6	0·0036
Waist:hip ratio	1·1	0·1	0·9	0·1	<0·0001
Systolic blood pressure (mmHg)	128	11	123	15	0·1824
Diastolic blood pressure (mmHg)	85	8	85	10	0·9143
Total cholesterol (mmol/l)	6·2	1·1	6·2	1·3	0·9217
LDL-cholesterol (mmol/l)	3·8	0·7	4·1	1·1	0·4256
HDL-cholesterol (mmol/l)	1·1	0·2	1·3	0·3	0·0044
Triacylglycerols (mmol/l)	2·7	1·6	1·9	0·8	0·0184
Glucose (mmol/l)	5·4	0·6	5·3	0·5	0·8167

* Differences between sexes were tested with unpaired *t* tests.

Table 2. Percentage of participants classified as under-reporters, accurate reporters and over reporters of energy intake by the food-frequency questionnaire and the dietary records

	Food-frequency questionnaire (*n* 50)			Dietary records (*n* 49)		
	Percentage	Male (*n*)	Female (*n*)	Percentage	Male (*n*)	Female (*n*)
Under-reporters of energy	56	12	16	53	11	15
Accurate reporters of energy	36	9	9	45	11	11
Over-reporters of energy	8	2	2	2	0	1

associated with accuracy. According to the DR, the percentage energy from protein and scores for restraint were inversely correlated to accuracy, while the percentage energy from fat, energy density, eating frequencies, intakes of 'sweets, desserts and snacks', sugary drinks, 'fatty meat, minced meat and sausages', and fatty cheese and hunger were positively associated with accuracy. Reporting accuracy was not significantly correlated to educational level (R 0·156; P=0·2781).

The multiple regression analysis of the reporting accuracy of energy according to the FFQ is shown in Table 8. 'Sweets, desserts and snacks', energy density, fatty cheese, bread, 'oil, butter and margarine', and restraint were entered into the model. 'Sweets, desserts and snacks' and bread (R^2_{adj} 0·46 (95 % CI 0·32, 0·70)) were significant predictors. The multiple regression analysis of the reporting accuracy of energy according to the DR is shown in Table 9. 'Sweets, desserts and snacks', energy density, sugary drinks, restraint, eating frequency and hunger were entered into the multivariate model and 'sweets, desserts and snacks' and restraint were significant predictors of the variation in the reporting accuracy of energy (R^2_{adj} 0·67 (95 % CI 0·54, 0·83)). Eating frequency was positively correlated to sweets, desserts and snacks (R_S 0·54; P=0·0002) and sugary drinks (R_S 0·30; P=0·0360). Individual items in the category of sweets, desserts and snacks showed the same trends as the entire category (data not shown).

Discussion

The present study focused on subjects with the metabolic syndrome or two risk factors for the metabolic syndrome. The reported consumption of sweets, desserts and snacks was lower among under-reporters than non-under-reporters and showed a significant association with reporting accuracy according to both methods of dietary assessment (FFQ and DR) in the multiple regression analyses. In addition, bread consumption assessed by the FFQ was a significant contributor to reporting accuracy. Dietary restraint was an additional significant contributor to accuracy assessed by DR.

About half of this obese population with metabolic risk factors under-reported EI. This finding is in accordance with the Observing Protein and Energy Nutrition (OPEN) study that included 484 subjects of whom 142 had BMI ≥30 kg/m^2, and 57 % of the

Table 3. Anthropometry, energy expenditure, energy intake, energy density, macronutrient composition and eating scores in under-reporters (UR) and non-under-reporters (non-UR) according to the food-frequency questionnaire*

(Mean values and standard deviations)

	UR (*n* 28)		Non-UR (*n* 22)		
	Mean	SD	Mean	SD	*P*
Tissue fat (%)	49·1	8·7	46·2	9·0	0·2489
Waist:hip ratio	1·0	0·1	1·0	0·1	0·8777
BMI (kg/m^2)	36·3	3·6	35·0	2·7	0·1522
Total energy expenditure (kJ/d)	14 038	2464	13 819	2524	0·7594
RMR (kJ/d)	7606	898	7452	1178	0·6016
Physical activity level†	1·84	0·17	1·86	0·21	0·7401
Energy intake (kJ/d)	9573	2571	13 938	3723	<0·0001
Energy intake:total energy expenditure	0·68	0·12	1·01	0·18	<0·0001
Energy density (kJ/g)	6·49	1·06	7·35	2·13	0·0699
Diet composition (% energy)					
Fat	34·5	3·9	35·5	5·9	0·4793
Protein	16·3	2·4	14·8	2·4	0·0287
Carbohydrate	45·2	5·5	46·6	7·0	0·4349
Sucrose	5·4	2·9	8·6	8·3	0·0698
Alcohol	2·7	2·9	2·3	4·5	0·7038
Eating scores‡					
Restraint	8·5	4·8	6·3	3·9	0·0929
Disinhibition	8·1	3·2	8·2	3·2	0·9180
Hunger	5·3	2·9	6·0	3·4	0·4625

* Differences between UR and non-UR were tested with unpaired *t* tests.
† Physical activity level is calculated by dividing total energy expenditure by RMR.
‡ The results of one male were missing.

Table 4. Intake of food in under-reporters (UR) and non-under-reporters (non-UR) according to the food-frequency questionnaire*

(Medians and interquartile ranges)

	UR (*n* 28)		Non-UR (*n* 22)		
Food (g/d)	Median	IQR	Median	IQR	*P*
Fruit, berries, juice and jam	246	140–387	305	78–614	0·6182
Milk	202	55–338	302	154–604	0·0451
Bread	152	114–180	213	125–286	0·0837
Vegetables	190	116–269	197	123–332	0·8298
Boiled potatoes, rice and pasta	153	119–210	190	119–208	0·4117
Fatty meat, minced meat and sausages	71	47–82	66	32–161	0·9820
Chicken and meat with less fat	69	43–103	68	28–93	0·5909
Fish and fish products	58	36–92	82	28–105	0·8298
Oil, butter and margarine	50	28–67	67	29–91	0·1112
Fatty cheese	24	9–48	35	18–72	0·1594
Sweets, desserts and snacks	100	64–135	161	121–196	0·0008
Sugary drinks	63	0–211	150	18–378	0·2146

IQR, interquartile range.
* Differences in reported intake of food in UR and non-UR were tested with the Mann–Whitney signed rank test.

Table 5. Anthropometry, energy expenditure, energy intake, energy density, macronutrient composition and eating scores in under-reporters (UR) and non-under-reporters (non-UR) according to the dietary records*

(Mean values and standard deviations)

	UR (*n* 28)		Non-UR (*n* 22)		
	Mean	SD	Mean	SD	*P*
Tissue fat (%)	49·2	8·2	45·9	8·7	0·2613
Waist:hip ratio	1·0	0·1	1·0	0·1	0·7869
BMI (kg/m^2)	36·4	3·2	35·0	3·4	0·1531
Total energy expenditure (kJ/d)	14 107	2791	13 613	2021	0·4866
RMR (kJ/d)	7598	990	7394	1022	0·4836
Physical activity level†	1·85	0·22	1·84	0·15	0·9143
Energy intake (kJ/d)	8071	1999	12 756	4112	< 0·0001
Energy intake: total energy expenditure	0·57	0·09	0·85	0·16	< 0·0001
Energy density (kJ/g)	6·70	1·34	7·90	1·59	0·0064
Diet composition (% energy)					
Fat	34·8	6·5	36·2	5·5	0·4396
Protein	16·8	3·3	14·7	2·3	0·0151
Carbohydrate	46·3	7·5	46·6	6·2	0·9789
Sucrose	4·9	3·3	9·3	7·0	0·0063
Alcohol	1·3	2·8	2·1	4·5	0·4819
Eating scores‡					
Restraint	9·0	5·0	6·1	3·5	0·0285
Disinhibition	7·7	3·2	8·9	3·0	0·2184
Hunger	4·8	2·9	6·4	3·2	0·0769

* Differences between UR and non-UR were tested with unpaired *t* tests.
† Physical activity level is calculated by dividing total energy expenditure by RMR.
‡ The results of one male were missing.

obese participants were classified as under-reporters of energy according to the FFQ (Subar *et al.* 2003). In the present study, men under-reported EI by 14 % and women by 21 % according to the FFQ. According to the DR, men and women under-reported EI by 28 and 31 %, respectively. In comparison, Goris *et al.* (2000) found a 37 % under-reporting of energy by male subjects with a BMI similar to that of subjects in the present study.

A novel finding in the present study was that consumption of bread according to the FFQ was a significant contributor to accuracy. This finding may be partly explained by the association between bread consumption and an irregular or frequent meal pattern. In Norway bread-based meals are typically consumed two to three times per d. In addition, bread is often consumed as a between-meal snack. The extra bread eaten at irregular meals and snacks may be forgotten or not reported. In contrast, consumption of bread was not associated with accuracy measured by DR. However, under eating may be a major problem with DR as discussed below.

Consumption of sweets, desserts and snacks was robustly associated with reporting accuracy, and was the only multivariate determinant of accuracy in addition to bread consumption according to the FFQ. These two variables explained almost half of the multivariate variance in accuracy. Likewise, reported intake of sweets, desserts and snacks was associated with accuracy

Table 6. Daily intake of food and eating frequency in under-reporters (UR) and non-under-reporters (non-UR) according to the dietary records*

(Medians and interquartile ranges)

	UR (*n* 28)		Non-UR (*n* 22)		
Food (g/d)	Median	IQR	Median	IQR	*P*
Fruit, berries, juice and jam	253	110–354	195	75–388	0·9680
Milk	126	0–292	127	54–370	0·5090
Bread	154	121–213	198	121–235	0·3890
Vegetables	115	75–149	103	57–158	0·8100
Boiled potatoes, rice and pasta	118	85–168	100	58–202	0·6025
Fatty meat, minced meat and sausages	52	8–121	119	38–164	0·1158
Chicken and meat with less fat	71	20–100	34	9–63	0·2033
Fish and fish products	44	0–137	47	4–122	0·7800
Oil, butter and margarine	31	17–56	40	21–79	0·2662
Fatty cheese	23	13–34	28	8–47	0·3781
Sweets, deserts and snacks	61	38–93	128	108–185	0·0002
Sugary drinks	0	0–110	167	0–335	0·0057
Eating frequency (times/d)	4·7	3·3–5·0	5·0	4·3–6·0	0·2333

IQR, interquartile range.
* Differences in reported intake of food in UR and non-UR were tested with the Mann–Whitney signed rank test.

according to the DR. The finding of low reports of sweets, desserts and snacks is in accordance with a number of previous studies. In a study by Livingstone *et al.* (1990), snacks were named as the most onerous and irritating aspect of the recording procedure and subjects admitted having omitted or simplified some measurements. In a Norwegian survey, Johansson *et al.* (1998) reported that under-reporters had a lower intake of cakes, potato chips, chocolate, sweets and sugar-containing soft drinks. Likewise, among non-obese women, Bingham *et al.* (1995) found a lower intake of breakfast cereals, cakes and sugars and confectionery in under-reporters compared with accurate reporters and consumption of sugar and sweet foods was also lower in under-reporters in two other large surveys (Rothenberg *et al.* 1997; Cook *et al.* 2000). Based on data from a number of studies Heitmann & Lissner (1995) concluded that snack-type foods might preferably be forgotten or suppressed when obese subjects omit food items in dietary reporting. This notion has been directly substantiated in an elegant study. Poppitt *et al.* (1998) covertly measured the food intake of obese and non-obese women confined to a metabolic facility and allowed *ad libitum* food intake. Food consumed during a meal was reported accurately, but the between-meal snack food was under-reported by over one-third. With the exception of the study by Livingstone *et al.* (1990), under-reporters were identified according to calculated EI:RMR ratios, N excretion or directly measured in a metabolic facility. One strength of the present study is that we quantified the contribution of under-reporting of sweets, desserts and snacks to accuracy in free-living, obese subjects with the DLW method according to both the DR and the FFQ.

Table 7. Relation of accuracy according to the food-frequency questionnaire (FFQ) and dietary records (DR) to energy density, macronutrient composition, food, eating frequency and eating scores

(Correlation coefficients)

	FFQ		DR	
	EI:TEE	*P*	EI:TEE	*P*
Energy density*	0·406	0·0034	0·537	<0·0001
Diet composition (% energy)*				
Fat	0·224	0·118	0·292	0·0414
Protein	−0·438	0·0015	−0·403	0·0041
Carbohydrate	0·051	0·7273	0·191	0·1882
Sucrose	0·283	0·0462	0·251	0·0824
Alcohol	0·049	0·7342	0·220	0·1283
Food (g/d)†				
Fruit, berries, juice and jam	0·135	0·3445	0·040	0·7826
Milk	0·333	0·0197	0·007	0·9630
Bread	0·387	0·0067	0·262	0·0694
Vegetables	0·024	0·8690	−0·005	0·9735
Boiled potatoes, rice and pasta	0·201	0·1584	−0·013	0·9286
Fatty meat, minced meat and sausages	0·218	0·1270	0·300	0·0380
Chicken and meat with less fat	−0·093	0·5166	−0·237	0·1009
Fish and fish products	0·114	0·4250	0·002	0·9917
Oil, butter and margarine	0·379	0·0080	0·256	0·0758
Fatty cheese	0·398	0·0053	0·295	0·0407
Sweets, desserts and snacks	0·513	0·0003	0·698	<0·0001
Sugary drinks	0·214	0·1336	0·490	0·0007
Eating frequency (times/d)†	NA	NA	0·360	0·0125
Eating scores*				
Restraint	−0·373	0·0098	−0·388	0·0140
Disinhibition	0·038	0·7913	0·118	0·4203
Hunger	0·301	0·0369	0·318	0·0304

EI, energy intake; TEE, total energy expenditure, NA, not analysed.
* Correlation coefficients were calculated with Pearson's correlations.
† Correlation coefficients were calculated with Spearman rank correlations.

Table 8. Multiple regression analyses of reporting accuracy of energy according to the food-frequency questionnaire*

(Standardised regression coefficients with their standard errors)

	β	SE	*P*
Sweets, desserts and snacks	0·354	0·0002	0·0043
Energy density	0·031	0·0170	0·8113
Bread	0·380	0·0003	0·0163
Fatty cheese	0·093	0·0010	0·4434
Oil, butter and margarine	0·139	0·0010	0·3022
Restraint	−0·079	0·0060	0·5159

* Reporting accuracy is indicated by the energy intake:total energy expenditure ratio.

Table 9. Multiple regression analyses of reporting accuracy of energy according to the dietary records*

(Standardised regression coefficients and their standard errors)

	β	SE	P
Sweets, desserts and snacks	0·612	0·0002	< 0·0001
Energy density	0·053	0·0130	0·6298
Sugary drinks	0·104	0·0001	0·1508
Restraint	− 0·212	0·0040	0·0444
Eating frequency	0·154	0·0170	0·1450
Hunger	0·005	0·0060	0·9610

* Reporting accuracy is indicated by the energy intake:total energy expenditure ratio.

Despite a strong statistical association between reporting accuracy and sweets, desserts and snacks in the multivariate analyses, the difference in reported intake of sweets, desserts and snacks was only 60 g/d representing about 1 MJ/d. The energy difference between under-reporters and non-under-reporters was 4·5 MJ/d, thus less than one-quarter was accounted for. It appears that the underestimation is more general as seen in the energy density of the diet, at least according to the DR, and in the macronutrient composition. The percentage energy from protein was higher but the actual intake of protein was lower among under-reporters than non-under-reporters. Excretion of urinary N also indicated that protein intake was lower among under-reporters of energy (data not shown).

The percentage of energy from protein in the diet was strongly inversely related to the reported intake of sweets, desserts and snacks (data not shown). This and other studies (Heitmann & Lissner, 1995; Pryer *et al.* 1997; Livingstone & Black, 2003) suggest that when sweet and fatty foods are under-reported, the percentage of energy from protein increases. In the largest study using urinary N and DLW methodologies, protein density was similar for men, but slightly overestimated for women (Subar *et al.* 2003). Heitmann & Lissner (1995) found a positive association between under-reporting of protein (and total energy) and the degree of obesity among 323 lean and obese men and women. Compared with total energy, protein was over-reported by the obese subjects. Other studies have reported preferential under-reporting of fat (Bingham *et al.* 1995; Macdiarmid *et al.* 1998; Goris *et al.* 2000). Discrepancies between the studies may be explained by differences between populations due to different cultural attitudes or habits, temporal trends, chance or other factors. What foods are considered not healthy, and thus are under-reported, may be affected by societal expectations and messages from the media (Blundell, 2000). In the present study involving obese individuals with characteristics of the metabolic syndrome we speculate that under-reporters may be prone to under-report carbohydrate and fatty food used as sweets, desserts and snacks because of the influence of ongoing debates about low-glycaemic-index diets.

The optimal number of eating occasions to facilitate weight reduction has been debated and it has long been believed that a ‘nibbling meal pattern’ could be beneficial for the purpose of weight reduction. However, a recent review concluded that weight loss was not facilitated by a high meal frequency (Bellisle, 2004). An association between frequent snacking and EI was also seen in a Swedish study among 4259 obese subjects (Bertéus Forslund *et al.* 2005). Our findings tend to support these findings since reported energy was, not surprisingly, related to the frequency of eating occasions. However, we did not find a statistically significant difference between the frequency of eating between under-reporters and non-under-reporters. The same was also seen in a study by Livingstone *et al.* (1990), and may be due to small sample size, which is also a limitation of the present study.

Dietary restraint, the self-imposed practice of consciously attempting to restrict EI with the purpose of preventing weight gain or promoting weight loss, is a common determinant of accuracy (Bathalon *et al.* 2000), though some conflicting data have been reported. For example, Taren *et al.* (1999) found no association between restraint and reporting accuracy in overweight individuals using 3 d DR to assess reported EI. Lindroos *et al.* (1997) found strong associations between EI, disinhibition and hunger, but a weaker association between EI and restraint in obese women. However, reporting accuracy was not considered in that study. In the OPEN study, restrained eating predicted reporting accuracy only when EI was assessed by the 24 h recall and only among men (Tooze *et al.* 2004). Furthermore, Bingham *et al.* (1995) could not differentiate restrained eating from the known effects of obesity on reporting accuracy. In a simple comparison of under-reporters and non-under-reporters, the present study clearly showed that under-reporters in this population had higher dietary restraint scores and restraint was a significant predictor of accuracy according to the DR. Dietary restraint did not contribute significantly to accuracy according to the FFQ. Hunger scores were associated with accuracy in the univariate but not in the final multiple analyses. Intercollinearity between several of the measured variables may explain these observations. Scores for restraint were inversely associated with the consumption of bread, milk and ‘oil, butter and margarine’ according to the FFQ (data not shown). Of these variables, bread consumption significantly contributed to accuracy in the multivariate analyses.

Methodological issues

When using DLW as an objective measure of EI, we assume that the subjects were in energy balance over the period of the measurement. The weight change during the DLW period was minor and in accordance with the weight change seen in the Dutch men (Goris *et al.* 2000). We could have adjusted for the weight change in the calculations, but according to the International Dietary Energy Consultancy Group (1990) the difficulty of accurately estimating change in body composition over the short period of DLW measurement is such that little advantage is gained. We could have adjusted for the increase in weight during the 3-month period resulting in a greater degree of underestimation. However, the 3-month study period that included holidays may not adequately represent long-term weight change. The DLW measurement was done during 14 d and may not measure the actual long-term energy expenditure (Livingstone & Black, 2003).

In the calculations of the TEE, we used the individually calculated FQ from the reported intakes according to the FFQ. The under-reporting of carbohydrate could be a concern. However, this probably does not affect the energy calculations because of the high homogeneity of FQ. Fat and carbohydrate intake may vary over a fairly wide range and still the variation in FQ is small (Black *et al.* 1986). The mean FQ was 0·85 in the present study, in agreement with a typically Western diet (Black *et al.* 1986).

While the FFQ method is prone to under-reporting due to difficulties in remembering eating occasions and estimating portions sizes, under-reporting according to weighed DR may be due both to under-eating and under-recording. We are not able to differentiate between under-eating and under-reporting because a 3 d food record has too short a time period to follow weight changes. It may be that subjects with high scores for dietary restraint actually under-eat when they record food intake to achieve weight reduction, but it has also been shown that restrained eaters as a group do not report all food they consume (Bathalon *et al.* 2000).

Dietary restraint became less obvious in the FFQ that covers a much longer time period including holiday seasons for almost all the participants, and most individuals do not restrict eating during holidays. Limitations of the present study were that we did not collect data on the temporal distribution of eating. Furthermore, the DR was collected for only 3 d and was done a mean of 34 d before the DLW measurement period. We chose the 3 d DR to minimise the burden on the participants in accordance with the suggestion by Trabulsi & Schoeller (2001), that in subjects defined as dietary resistant and obese, any precision gained through a long dietary recording period is outweighed by a larger magnitude of under-reporting. To minimise the burden of the participants was also the reason for obtaining the DR before the DLW measurement period. However, the results of the DR were largely in accordance with the results of the FFQ that covered the DLW measurement period.

In contrast to others (Johansson *et al.* 1998; Cook *et al.* 2000), we did not find any relationship between sex or education level and reporting accuracy. This may be due to the limited size of our sample or to differences between populations. Furthermore, in our sample of obese individuals, BMI, percentage of body fat and fat distribution did not predict reporting accuracy. This may be due to the small variation of BMI or that BMI levels out as a predictor for reporting accuracy of energy at BMI levels above 35 kg/m^2 as was observed in the OPEN study (Tooze *et al.* 2004). The study included only non-smokers and may not be applicable to obese smokers.

Implications

An understanding of the foods and meal patterns that are associated with errors in self-reported data is critical. Individuals often report their usual dietary intake and forget to report extra meals and snacks or more frequent eating patterns. These items must be particularly emphasised in dietary interviews. It was not our objective to determine which of the dietary assessment methods showed superior accuracy in this obese sample. However, it seems that the FFQ is less influenced by the restraint eating behaviour, while the DR may be an important tool to achieve change in eating behaviour because of increased attention. Because of their high risk, obese subjects with the metabolic syndrome or risk factors for the metabolic syndrome are prime targets for dietary advice to achieve weight reduction. While weight-stable, individuals that report high dietary restraint, low consumption of bread, sweets, desserts and snacks and a low frequency of eating may require particular attention when a dietary assessment is conducted.

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