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ORIGINAL COMMUNICATION

Assessment of habitual energy and macronutrient intake in adults: comparison of a seven day food record with a dietary history interview

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Objective: To examine the quantitative agreement between a 7 day food record and a diet history interview when these are conducted under the same conditions and to evaluate whether the two methods assess habitual diet intake differently among subgroups of age and body mass index (BMI).
Design: Cross-sectional study.
Setting: Population study, Denmark.
Subjects: A total of 175 men and 173 women aged 30–60 y, selected randomly from a larger population sample of Danish adults.
Interventions: All subjects had habitual diet intake assessed by a diet history interview and completed a 7 day food record within 3 weeks following the interview. The diet history interview and coding of records were performed by the same trained dietician.
Main outcome measure: Median between-method difference in assessment of total energy intake, absolute intake of macronutrients, and nutrient energy percentages. Difference between reported energy intake from both methods and estimated energy expenditure in different subgroups.
Results: Energy and macronutrient intake was assessed slightly higher by the 7 day food record than by the diet history interview, but in absolute terms the differences were negligible. The between-method difference in assessment of total energy intake appeared to be stable over the range of age and BMI in both sexes. As compared to estimated total energy expenditure, both diet assessment methods underestimated energy intake by approximately 20%. For both methods the under-reporting increased by BMI in both sexes and by age in men.
Conclusions: Energy and macronutrient intake data collected under even conditions by either a 7 day food record or a diet history interview may be collapsed and analysed independent of the underlying diet method. Both diet methods, however, appear to underestimate energy intake dependent on age and BMI.
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Background

Epidemiologic investigations addressing the relation between diet and disease require methods for the assessment of long-term dietary intakes that are valid on a group level, but optimally also at an individual level, especially regarding their ability to rank individuals correctly based on reported intakes. A commonly used method for habitual diet assessment in epidemiological studies is the diet history technique. This method aims at assessing the usual individual dietary intake by questioning individuals on the frequency and amount of their consumption of regularly eaten foods on a regular basis. Since the technique of the interviewer-administered diet history is time-consuming and relies heavily upon the skills of the interviewer, self-administered food frequency questionnaires are often used to assess habitual diet in large-scale epidemiological studies (Willett, 1998a). The food-record technique represents another method for assessing habitual diet intake in individuals. As a prospective method, this method does not rely on subject's long-term memory, but places a substantial burden on subjects with regard to motivation and maintenance of spontaneous diet habits. A daily record of ingested foods is considered to give reasonably accurate measurement of actual diet intake and a 7 day record seems to give a representative measure of the habitual dietary intake (Bingham, 1987).

It has been argued that 7 day food records should serve as the 'gold standard' in validation studies of different types of self-administered food frequency questionnaires (Willett, 1998b). However, in practice the diet history interview and 7 day food records have interchangeably served as 'gold standards' (Willett *et al*, 1985; Block & Woods 1990; Block *et al*, 1992; Jain *et al*, 1996). So far, relatively few studies have compared the results of dietary history interviews with those of a 7 day food record in the same individuals (Huenemann & Turner, 1942; Jain *et al*, 1980; Stuff *et al*, 1983; Mahalko *et al*, 1985; Hankin *et al*, 1991; Block *et al*, 1992; Jain *et al*, 1996). Since the purpose of the majority of these studies has been to evaluate the relative validity of the two diet assessment methods, the agreement between methods has typically been summarised by calculation of the correlation or regression coefficients or the degree of cross-classification. Indeed, only few studies have actually focused on the absolute agreement between the methods and the individual variation of the between-method differences (Huenemann & Turner, 1942; Stuff *et al*, 1983; Mahalko *et al*, 1985).

In the present study, we quantitatively tested the agreement between the two long-term diet assessment methods and the individual variation of the lack of agreement between methods among 348 individuals who underwent both a diet history interview and completed a 7 day record as a part of a population study. Since certain subgroups may tend to under-report food intake and certain foods when interviewed by a professional diet expert, we also examined whether the two methods assess habitual diet intake differently among subgroups of age and body mass index (BMI) among men and women. The present comparison of the two methods will be used to consider the questions: (1) do the two methods give different results? (2) Can diet data obtained by the two methods be collapsed and analysed independently of the underlying diet assessment method? (3) Do the two methods assess habitual diet intake differently among subgroups of age and BMI suggesting that one method may be superior to the other regarding capture of unbiased diet record in certain subgroups?

Materials and methods

Study population

The present study was a part of the Danish MONICA project (an international study conducted under the auspices of the World Health Organization to monitor trends and determinants and mortality from cardiovascular disease) carried out between 1982 and 1984 as part of the Glostrup Population Studies at the Copenhagen County Center for Preventive Medicine. The study population comprises an age- and sex-stratified random sample of men and women born in 1922, 1932, 1942 and 1952 living in 11 municipalities in the western part of Copenhagen County. All subjects in the sample ($n=4807$) were invited to a general health examination by a standard letter containing information about the survey. A total of 3785 subjects (79%) attended the health examination. The study population and the general differences between participants and non-responders has been described in detail previously (Jørgensen, 1990).

Examination procedure

The health examination include: (1) a self-administered questionnaire that contained detailed questions regarding tobacco smoking, alcohol intake, physical activity at work and during leisure time, and other lifestyle factors plus socio-demography and other health-related items; (2) a general clinical health examination including a measurement of height and weight.

Diet history interview. On the day of the health examination every fifth participant was randomly selected to undergo a diet history interview by a trained dietician ($n=613$). Throughout the study period the interview was performed by the same dietician. The subjects were questioned about their habitual diet using non-leading, open-ended questions on diet intake during the previous month. The interviewer began the interview by asking the subject to describe eating times, meal patterns, dishes, foods and portion sizes for a typical day. Quantities were explored by means of food models, photo series, cups and measures. After the usual pattern of eating had been described, a checklist of the frequency of consumption of specific foods was administered.

Seven day food record. All study subjects, including subjects who underwent a diet history interview ($n=613$) and those who did not ($n=3172$), were given thorough verbal and written instructions in how to complete a 7 day food record within a 3 week period after the health examination. The food record form used at the Glostrup Population Studies comprises four pages. The front page contains instructions for correct completion of the record together with average household weights of 19 frequently consumed foods, eg the weight of an egg, a slice of bread etc. For butter and liver paste three examples are given of typical amounts put on a slide of bread. The next two pages have lines for 100 foods divided into nine groups: dairy products, bread and cereals, fats, cold cuts etc, vegetables, meat (including poultry and fish), drinks, fruit and miscellaneous. On the last page are blanks for foods that do not fit into any of the nine groups such as mixed dishes, home-made salads and cakes. The form is clearly divided into 7 days. The entries are in grams, estimated as accurately as possible or preferably weighed. The participants were instructed to complete the diet record during a 'average' 7 day period with as few pre-planned extraordinary social arrangements as possible and to return the record by mail within 3 weeks. All food records were manually checked and coded by the same the dietician who performed the diet history interview.

Estimated total energy expenditure (TEE). To compute an estimate of TEE the formula

$$\text{TEE (MJ/day)} = \text{BMR}^{*}\text{PAL}$$

was used. BMR (basal metabolic rate) was predicted from sex, age, weight and height using the equations proposed by WHO (World Health Organization, 1985). The PAL (physical activity level) value for each subject was estimated on basis of the matrix between answers to questions on leisure time activity and activity at work from the health questionnaire as previously described by Fogelholm *et al* (1998). In the questionnaire subjects were asked to place themselves into one of four categories of leisure time activity and five categories of activity at work. The four categories of leisure time activity were: (1) sedentary; (2) moderately physically active at least 4 h per week; (3) energetically physically active at least 3 h per week; and (4) participation in competitive sport activities several times per week. The five categories of activity at work were: (1) sedentary work; (2) standing and walking; (3) walking and lifting; (4) physically strenuous work; and (5) not working, ie sedentary. The matrix between self-reported activity levels at leisure time and at work resulted in combined individual PAL values that ranged between 1.3 and 2.3.

A total of 1863 subjects (49.2%) completed the 7 day food records. A comparison of the subjects who completed the 7 day records with those who did not, showed that women, never- and ex-smokers, and married subjects were more willing to fill in the record, while BMI, school education, vocational training, and social status only had minor influence (Jørgensen, 1992). Furthermore, no difference between the dietary values of the respondents' and non-respondents' food consumption according to a short food frequency questionnaire was observed (Jørgensen, 1992).

Of the 613 subjects who underwent a diet history interview, a total of 349 subjects also completed a 7 day food record. Coding of both sets of dietary data for computer calculation of nutrients was done by the same dietician who also performed diet history interview. The coding of the two diet assessment methods was done independently of each other and, thus, blinded. Nutrient calculations into daily averages was done using the DANKOST 1 program based on the Danish Food Composition Tables, 1985 (Fødevaredirektoratet, 1985).

Of the 349 subjects who had diet intake assessed by both methods, one person (a woman aged 60 y with a BMI of 19.8 kg/m^2) was excluded from the analysis due to an extremely high energy assessed by the 7 day food record method (23 MJ) in comparison with a energy intake of 6.8 MJ assessed by the diet history method. The present study, thus, included a total of 348 subjects (175 men and 173 women). Nutrients analysed by the DANKOST 1 program included total energy, protein, carbohydrates, fats, minerals and vitamins. Intake from vitamin and minerals was not included in the present analysis.

Statistical methods

The main purpose of the present study was to test the *degree* of agreement between two diet methods' ability to measure daily energy and macronutrient intake in the same individuals. For this purpose, calculation of correlation coefficients are inappropriate since they only measure the strength of a relation between the two measurements and not the quantitative agreement between them (Bland & Altman, 1986). To give quantitative estimates of the agreement between the two diet methods we used alternative statistical methods suggested by Bland and Altman (1986) including graphical techniques (Bland–Altman plots) and simple calculations. Furthermore, the similarity of the two methods in classifying energy and macronutrient intake was examined by the ability of the two methods to classify each person in the same intake quartiles.

Since the distribution of means and differences of total energy and most macronutrient energy percentages from the two methods were non-normally distributed before and after log-transformation of data, non-parametric statistical tests were used for the present analyses (Wilcoxon signed-rank test for differences, Kruskal–Wallis test for identical distribution of differences). Accordingly, the agreement between the two methods was summarised by estimating the median of the between-method difference and the corresponding limits of agreement for the differences as the 2.5 and 97.5 percentiles of the differences.

Results

The characteristics of the 348 study subjects including age, BMI, smoking, alcohol habits, physical activity and school education are shown in Table 1. Figure 1 shows total energy intake assessed by the two methods plotted against each other. In both men and women, the data points cluster around the line of equality. Similar plots of macronutrients and energy percentages assessed by the two methods gave identical results (data not shown). Figure 2 shows the between-method difference in assessment of total energy intake plotted against the average total energy intake from both methods with indication of the median difference and limits of agreement (Bland–Altman plot). As noted from Figure 2, the difference between the two methods showed no serious systematic variation over the range of average energy intake in men and women ($r=0.17$, $P=0.02$ and $r=0.01$, $P=0.90$, respectively). Similarly, no systematic variation over the range of the averages was present for fat, protein and carbohydrate intake as well as for the macronutrient energy percentages in men and women (data not shown). The absence of the variation over the averages made it possible to summarise the lack of agreement between methods (bias) by estimating the median difference and the limits of agreements as the 2.5–97.5 percentiles for the median difference. A highly significant systematic variation for alcohol energy percentage, however, was present in men ($r=-0.20$, $P=0.008$). Accordingly, analyses on alcohol energy percentage in men were divided into two categories–under and above 7.5 alcohol energy percentage—within which categories no systematic variation of the differences was observed ($r=-0.13$, $P=0.17$ and $r=-0.21$, $P=0.10$, respectively).

The medians for total energy, macronutrients, and nutrient energy percentages for the two dietary methods in men and women are shown in Table 2 together with the medians of the between-method difference. With few exceptions, total energy and macronutrient intake was assessed higher by the 7 day food records than by the diet history interview (Table 2). In men and women, total energy intake was measured approximately 0.2 MJ higher by the 7 day food records than by the diet history interview. In men, no significant difference in assessment of nutrient energy percentages between the two methods was observed. In women, fat energy percentage was assessed significantly higher by the diet interview than by diet records (0.4%) while diet records captured carbohydrate energy percentage higher than the interview (0.5%). In absolute terms, the report differences in energy and macronutrient intake by the two methods (significant or non-significant), however, were negligible. Limits of agreement for nutrient energy percentages, thus, varied within $\pm 6\%$ and limits of agreement for energy intake within -0.9 to $+1.8$ MJ (Table 2).

Comparisons of the two methods were also made by categorising total energy intake, absolute and relative nutrient intake into quartiles (Table 3). In women, the percentage for exact agreement among quartiles was lowest for fat

Table 1 Characteristics of study subjects. The Monica I Study, Copenhagen County Center for Preventive Medicine, Research Unit for Dietary Studies, Copenhagen, Denmark 1982–1984

Variable		*Women (n=173)*	*Men (n=175)*
Age	(mean (s.d.), y)	46.1 (11)	47.2 (11)
Body mass index	(mean (s.d.), kg/m^2)	23.5 (3.3)	25.2 (3.2)
Smoking	(percentage current smokers)	49.1	59.4
Alcohol intake	(percentage abstainers)	18.5	6.3
Physical activity	(percentage sedentary)	27.8	18.3
School education	(percentage less than 8 y)	36.6	38.3

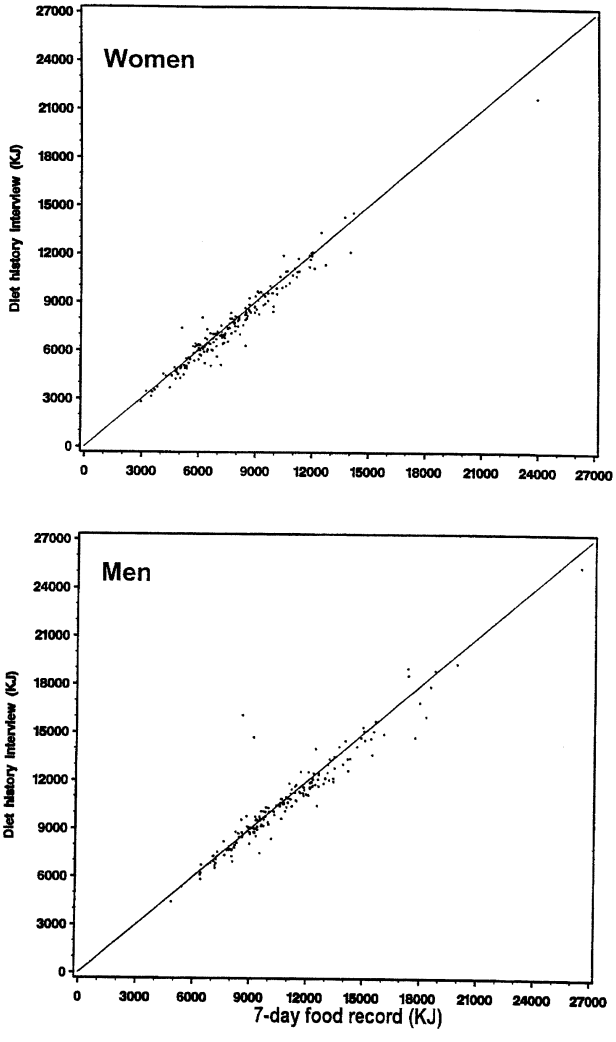

Figure 1 Total daily energy intake (kJ) assessed by a diet history interview and 7 day food records plotted against each other with line of equality marked.

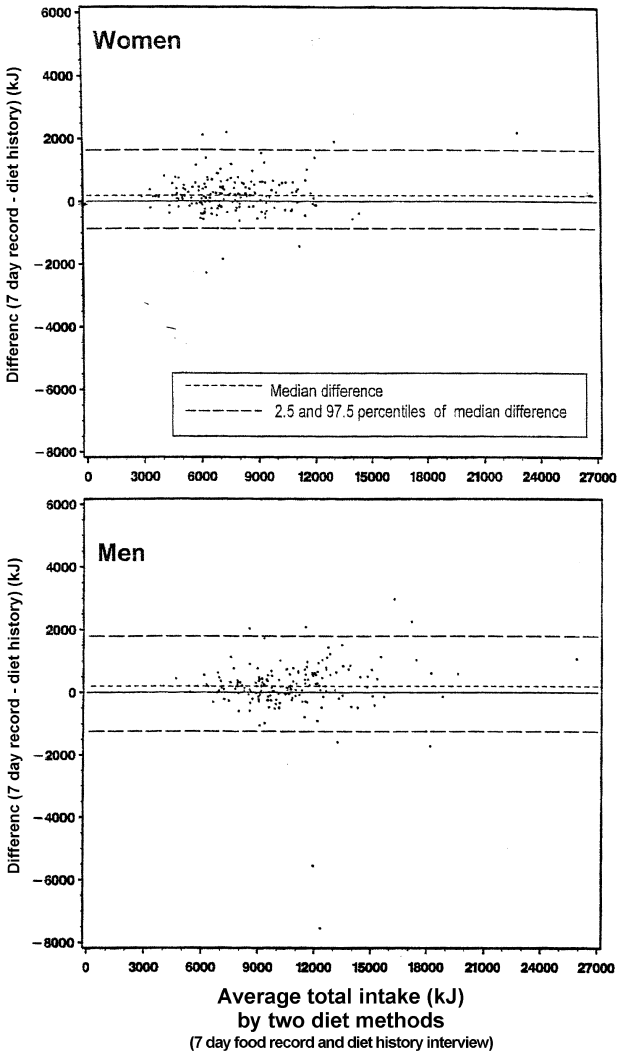

Figure 2 The between-method difference (diet history interview and 7 day food records) in assessment of total daily energy intake plotted against the average energy intake estimated from both methods with indication of the median difference and limits of agreement (Bland–Altman plot).

energy percentage (66%) and highest for alcohol energy percentage (86%). In men, exact quartile agreement was lowest for protein energy percentage (69%) and highest for absolute alcohol intake (90%). At least 97% of subjects were classified within the similar or the adjacent quartiles for most intake estimates.

As compared to estimated TEE both diet assessment methods appeared to underestimate total energy intake in the present study. Overall, the 7 day food records estimated energy intake approximately 16 and 19% lower in men and women, respectively, while the corresponding percentages for the diet history interview was 18 and 22%.

Figure 3 shows TEE and reported energy intake from both methods as a function of age in men and women. The between-method difference in assessment of energy intake appeared to be stable over the range of age in both sexes (*P*-value of Kruskal–Wallis test for identical distribution of differences over age groups = 0.93 and 0.67 for men and women, respectively). In men, the under-reporting of energy intake by both methods increased by age ($r = 0.18$, $P = 0.01$ for 7 day food records and $r = 0.21$, $P = 0.005$ for diet history interview). In women, no significant correlation between under-reporting of energy intake from the two methods and age was present.

Figure 4 shows TEE and reported energy intake from both methods as a function of four BMI categories in men and women. The between-method difference in assessment of total energy intake was stable over all categories of BMI (*P*-value of Kruskal–Wallis test for identical distribution of differences over BMI groups = 0.52 and 0.66 for men and women, respectively). As noted from Figure 4, the under-reporting of energy intake from both methods clearly increased by BMI in both sexes (correlation coefficients around 0.31–0.38 for both sexes, all *P*-values < 0.0001).

Discussion

The present study demonstrates a close quantitative agreement between a 7 day food record and a diet history interview in measuring habitual total daily energy intake and macronutrient intake at the individual level when the interview and coding of diet information from both diet assessment methods are performed by the same dietician. Futhermore, the agreement between methods appears to be stable over age and BMI in both sexes. As compared to the estimated energy expenditure, the present study demonstrates that both diet assessment methods underestimate energy intake by approximately 20% and that the under-reporting of energy intake increases by BMI in both sexes and by age in men.

In contrast with most (Jain *et al*, 1980; Hankin *et al*, 1991; Block *et al*, 1992; Jain *et al*, 1996; Black *et al*, 2000), but similar to other previous studies (Huenemann & Turner, 1942; Mahalko *et al*, 1985) we observed that the 7 day food record gave slightly higher nutrient estimates than the diet history interview. As compared to the more widely used structured interviews with specific questions on a large number of frequently consumed food, the traditional interview technique with non-leading and open-ended questions used in our study may tend to underestimate daily intake. However, as observed by others (Black *et al*, 2000), we found a close quantitatively agreement between the two methods and a small individual variation of the lack of agreement suggesting that for practical purposes the difference between methods in assessing energy and macronutrient intake is negligible.

Table 2 Median daily nutrient intakes and median nutrient energy percentages assessed by 7 day food records and diet history interviews in 175 men and 173 women and the median between-method difference (7 day records — diet history interview). The Monica I Study, Copenhagen County Center for Preventive Medicine, Research Unit for Dietary Studies Copenhagen, Denmark 1982–1984

	Women				*Men*			
	7 day food record	*Diet history interview*	*Median difference*	P-value[a]	*7-day food record*	*Diet history interview*	*Median difference*	P-value[a]
Energy (MJ)	7.4 (3.7–12.7)[b]	7.1 (3.5–12.1)	0.19 (−0.86–1.63)	<0.001	10.5 (6.4–18.3)	10.4 (6.2–18.6)	0.20 (−0.12–1.80)	<0.001
Protein (g)	65.6 (38.5–113.4)	63.9 (34.9–110.9)	1.0 (−9.7–14.9)	<0.001	85.1 (54.4–149.2)	84.5 (51.5–140.1)	1.5 (−8.1–16.7)	<0.001
Fat (g)	83.7 (34.2–187.1)	85.0 (31.5–182.8)	0.8 (−16.5–19.5)	0.04	116.2 (67.8–226.1)	111.8 (64.0–216.8)	2.3 (−14.4–32.1)	<0.001
Carbohydrate (g)	156.3 (77.6–300.0)	148.6 (74.1–289.1)	4.7 (−15.8–49.7)	<0.001	210.7 (114.0–414.0)	211.9 (111.9–428.8)	2.3 (−48.8–49.7)	0.001
Alcohol (g)	7.2 (0.0–45.9)	6.8 (0.0–44.5)	0.00 (−2.9–11.9)	0.88	19.0 (0.0–79.2)	18.6 (0.0–90.5)	0.00 (−11.3–11.4)	0.99
Protein energy percentage	15.2 (10.2–22.8)	15.3 (10.4–23.9)	−0.1 (−2.3–2.0)	0.14	13.6 (10.3–19.6)	13.7 (9.7–19.1)	−0.01 (−1.8–2.1)	0.37
Fat energy percentage	44.2 (30.8–59.4)	44.9 (32.2–61.6)	−0.4 (−6.1–4.8)	0.006	43.1 (30.4–57.8)	43.0 (29.1–57.0)	0.2 (−4.5–5.2)	0.07
Carbohydrate energy percentage	36.4 (24.7–48.0)	35.8 (22.9–48.4)	0.5 (−4.4–6.1)	<0.001	35.3 (22.9–51.4)	35.0 (23.0–54.1)	−0.01 (−6.4–4.7)	0.51
Alcohol energy percentage	2.8 (0.0–15.9)	2.7 (0.0–16.6)	0.00 (−1.9–3.8)	0.26				
Alcohol energy percentage <7.5					3.1 (0.0–7.6)	3.2 (0.0–7.2)	−0.01 (−1.5–2.6)	0.16
Alcohol energy percentage ⩾7.5					13.0 (7.4–26.1)	13.2 (7.2–26.0)	−0.3 (−4.3–3.4)	0.08

[a]*P*-values from Wilcoxon signed-rank test of differences between the two dietary assessment methods.
[b]Numbers in parentheses, 2.5 and 97.5 percentiles.

Table 3 Percentage of agreement within quartiles between the 7 day food records and the diet history interview in men and women. The Monica I Study, Copenhagen County Center for Preventive Medicine, Research Unit for Dietary Studies Copenhagen, Denmark 1982–1984

	Women			*Men*		
	Similar quartile classification	*Adjacent quartile classification*	*Gross misclassification*	*Silmilar quartile classification*	*Adjacent quartile classification*	*Gross misclassification*
Total energy	79.2	20.2	0	81.7	17.2	0.6
Protein (g/day)	75.2	22.5	0	82.9	16.6	0
Fat (g/day)	78.0	21.4	0	81.1	18.3	0
Carbohydrate (g/day)	80.3	18.5	0	83.4	16.0	0
Alcohol	83.8	14.5	0.6	90.3	9.1	0
Protein energy percentage	78.6	20.8	0	69.1	29.1	0.6
Fat energy percentage	65.9	31.2	0	75.4	24.0	0
Carbohydrate energy percentage	77.5	13.0	0	74.3	24.6	0
Alcohol energy percentage	85.6	12.1	0.6	88.6	11.4	0

The 7 day food record was completed by subjects within 3 weeks after the diet history interview. This sequence was chosen because it was felt that a dietary history was less likely to influence a subsequent 7 day food record than vice versa. Still the close agreement between the two diet assessment methods may theoretically have been caused by a 'training effect' so that the subjects deliberately or unconsciously may have filled in the 7 day food records according to their recent reported habitual diet history. With the lack of a cross-over design in the present study, we examined this hypothesis by comparing total energy intake and relative nutrient intake assessed by 7 day food records in subjects who initially underwent a diet history interview with those who did not participate in a interview. We found no age- or sex-specific significant differences in the medians of energy intake and relative and absolute nutrient intake between the two groups (data not shown), suggesting that our results are unlikely to be influenced by a training effect.

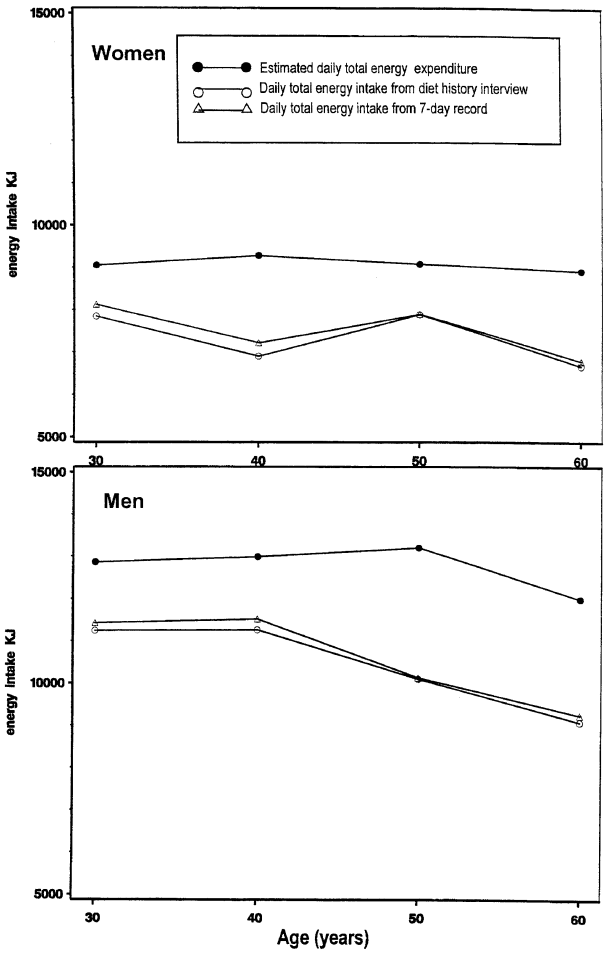

Figure 3 Estimated total energy expenditure and total daily energy intake assessed from a diet history interview and 7 day food records by age.

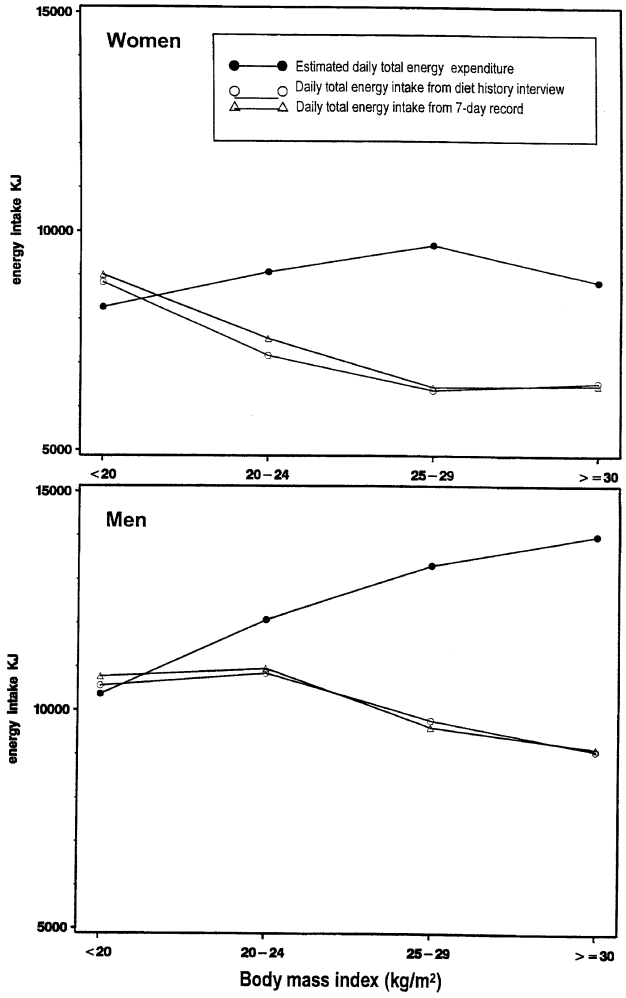

Figure 4 Estimated total energy expenditure and total daily energy intake assessed from a diet history interview and 7 day food records by body mass index.

The finding of a close quantitative agreement between 7 day food records and diet history in our study may have several explanations. Firstly, the close timing of 3 weeks between the measurements excludes an influence of seasonal variation on the results. Secondly, a similar coding of food intakes from both methods was ensured by using the same trained dietician throughout the study period. The coding and the calculation of nutrient intake from the two methods were performed independently of each other and left no possibility for the dietician to let the coding of data from one assessment method be influenced by the data coding from the other method.

The absolute and relative agreement between two dietary assessment methods does not necessarily indicate that the methods are valid measurements of habitual diet intake, but may merely reflect similar errors in both methods. Certainly, we observed that energy intakes from both methods were approximately 20% below TEE estimated from the WHO formulae for BMR and values for PAL. The reliability of the BMR prediction from the WHO formulae could be questioned. These formulae, however, have shown to be superior to alternative BMR formulae in other studies (De Lorenze *et al*, 1999; Bandini *et al*, 1995). Furthermore, the study material on which the WHO formulae were developed is similar to the present study population regarding age structure and ethnicity. To estimate the individual level of physical activity as accurately as possible we calculated PAL from self-reported information on physical activity level at leisure time and at work. The accuracy of self-reported physical activity may be questioned. The four-point leisure time physical activity scale used in the present study has been shown to discriminate sedentary and physically active subjects with respect to maximum oxygen uptake (Saltin & Grimby, 1968). We

therefore believe that the observed under-reporting by the two diet assessment methods in the present study is real. In support of this, recent evidence from studies involving biomarkers, such as doubly labelled water for measuring energy intake and urinary nitrogen for measuring protein intake (Schoeller, 1990; Heitmann, 1993; Visser *et al*, 1995; Sawaya *et al*, 1996; Rothenberg *et al*, 1998) suggest that self-reporting of diet intake by food records and diet history are biased towards under-reporting. A recent review of the studies that compared energy intake from diet records with energy expenditure measured by the doubly labelled water method reported a mean underestimation of energy intake of 16% (Black, 1999), which is close to the observed under-reporting of 20% in the present study.

Similar to other studies (Heitmann, 1993; Heitmann and Lissner, 1995) we observed that diet under-reporting increased with increasing body weight. Contrary to some studies (Livingstone *et al*, 1990; Mertz *et al*, 1991; Heitmann, 1993) but in agreement with others (Baecke *et al*, 1983) we observed that diet under-reporting also was dependent on age. The finding of a similar under-reporting by both methods among obese subject suggests that the more 'anonymous' food record method is hardly superior to the more confrontational diet history interview with respect to avoiding diet under-reporting among obese people.

We conclude that a diet history interview and a 7 day food record yield equal data on habitual diet intake when conducted under the same conditions, suggesting that data obtained under such circumstances may be collapsed and analysed independently of the underlying diet assessment method. The between-method difference in assessment of total energy intake is stable over the range of age and BMI in both sexes, but both diet methods underestimate energy intake dependent on BMI in both sexes and on age in men.

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