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ORIGINAL CONTRIBUTION

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Obesity as a major determinant of underreporting in a self-administered food frequency questionnaire: Results from the EPIC-Potsdam study

Übergewicht als Prädikator für die Unterschätzung der Energieaufnahme in einem Verzehrshäufigkeits-Fragebogen: Ergebnisse der EPIC-Potsdam-Studie

Summary The phenomenon of underreporting of dietary intake has been observed previously in many epidemiologic studies. In this study it was investigated whether dependencies exist between energy intake obtained by a semi-quantitative, self-administered food frequency questionnaire and lifestyle or anthropometric factors, particularly obesity.

The study population consisted of 2 531 subjects, men aged 40 to 64 years and women aged 35 to 64 years from the general population of Potsdam and the surrounding areas. First, subjects were allocated into quintiles of the ratio 'reported energy intake (EI)' to 'calculated basal metabolic rate (BMR)' as a measure of age and weight adjusted energy intake. No apparent dependencies between socio-economic variables and the ratio EI/BMR were observed. Among anthropometric variables, BMI and related measures of obesity were inversely related to the ratio EI/BMR in men and women. While dietary intake was directly related to the ratio EI/BMR in absolute quantities, energy adjusted intake of fat, protein, carbohydrate, and alcohol was found to be independent of this ratio. Energy adjusted food group consumption was also found to be independent of the ratio EI/BMR, showing only slightly increasing trends across quintiles of EI/BMR for cereals and fats, and a slightly decreasing trend for sweet foods in women. When subjects were classified into three categories of BMI, reported energy intake decreased across categories. Estimated energy expenditure based on BMR was increasing with BMI categories. A close direct relationship was observed between BMI categories and the difference between reported energy intake and estimated energy expenditure.

It is concluded that obesity is a major determinant of underreporting. Energy adjusted dietary variables were found to be largely independent of such methodological influences.

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Zusammenfassung Die Angaben zur Energie- und Nährstoffaufnahme aus einem semi-quantitativen Verzehrshäufigkeits-Fragebogen wurden auf eine mögliche Unterschätzung in Abhängigkeit vom relativen Körpergewicht untersucht. Die Studienpopulation bildeten 2 531 Personen aus Potsdam und den umliegenden Gemeinden, Männer im Alter von 40 bis 64 Jahren und Frauen im Alter von 35 bis 64 Jahren.

Das Verhältnis von Energieaufnahme (EI) zu Grundumsatz (BMR) diente als Maß für die alters- und gewichtsunabhängige relative Energieaufnahme. Die Studienteilnehmer wurden auf Basis des Parameters EI/BMR in Quintile eingeteilt. Zwischen dem body mass index (BMI) und dem Parameter EI/BMR konnte, bei Männern und Frauen, ein inverses Verhältnis beobachtet werden. Zwischen verschiedenen sozio-ökonomischen Variablen und EI/BMR zeigte sich dagegen kein Zusammenhang. Während die absolute Nährstoffaufnahme mit steigendem EI/BMR zunahm, war der energieadjustierte Verzehr von Fett, Protein, Kohlenhydraten und Alkohol unabhängig von der relativen Energieaufnahme. Der Verzehr aus Lebensmittelgruppen, ebenfalls energieadjustiert, zeigte bei Frauen einen leicht ansteigenden Trend über die EI/BMR-Quintile für die Gruppen ‚Getreide' und 'Fette' sowie einen leicht abfallenden Trend für ‚Süßigkeiten'. Nach Zuordnung der Meßwerte in drei BMI-Kategorien, zeigte sich, daß die angegebene Energieaufnahme mit zunehmendem BMI abnahm. Der auf Basis des BMR geschätzte Energieverbrauch stieg dagegen über die BMI-Kategorien an. Es konnte ein direkter Zusammenhang zwischen der Differenz von angegebener Energieaufnahme und geschätztem Energieverbrauch und dem relativen Körpergewicht beobachtet werden.

Die Ergebnisse zeigen, daß Übergewicht als ein wesentlicher Prädiktor für die Unterschätzung der Energieaufnahme gelten kann. Energieadjustierte Werte der Nährstoffaufnahme erscheinen unabhängig von dem methodischen Einfluß der Unterschätzung.

Key words obesity – underreporting – energy intake – nutrient intake – dietary questionnaire

Schlüsselwörter Übergewicht – underreporting – Energieaufnahme – Nährstoffaufnahme – Verzehrshäufigkeits-Fragebogen

Introduction

Epidemiological studies are often said to have a problem of obtaining adequate data of individual exposure. This is in particular true for nutritional epidemiological studies in which dietary habits are evaluated in respect to relative risk. Large-scale studies, comprising several 10,000 participants, often apply semi-quantitative questionnaires to assess habitual dietary intake because these are considered to be cost-efficient and impose only modest demand on subjects. Most of the large-scale cohort studies decided to use self-administered food frequency questionnaires, comprising 100 to 150 food items, that can be completed and processed for analyses in a comparatively short time. The validity and reliability of such questionnaires are usually tested in substudies (8, 14, 22, 23, 34). These studies indicated that semi-quantitative food frequency questionnaires are able to reflect the distribution of habitual energy and macronutrient intake of a population and to rank subjects according to their dietary intake even if with some degree of misclassification. In analysis of relative risks it is usually assumed that misclassification due to errors in exposure assessment, if present, affect subjects at random and, therefore, within-study comparisons remain valid. It is unlikely that dietary instruments will be improved significantly by increasing accuracy, for instance by modifiying questionnaire design or mode of inquiry (36). Subsequently, attention has to be focused on a better understanding of the sources of measurement error related to dietary questionnaires in order to avoid false conclusions based on insufficient understanding of the measurement instrument. A major problem of dietary assessment seems to be the phenomenon of reporting lower energy intake than physiologically required, the so called underreporting. Recently, underreporting of true dietary intake was discussed and evaluated in many studies (2, 16, 19, 20, 21, 32). The consistent findings of these studies employing different methods and investigating different populations lead to the conclusion that underreporting seems to be a common problem of many questionnaires or recording based measurement instruments of dietary intake. Underestimation of food intake might be due to an inadequate methodology, failure of memory, or the tendency of subjects to conceal their true dietary intake conciously or subconciously. As the underlying reasons appear to be very complex and difficult to assess, there is a strong interest in identifying certain characteristics of individuals that are associated with underreporting. The most consistent findings refer to obesity. Obesity was found to be positively related to reporting low energy intake (2, 16, 21). However, this relation was not observed in all studies (19, 32). Other determinants for underreporting under discussion are age, sex, level of physical activity, social status, dieting behavior, and psychosocial determinants (19, 20, 32).

Within the framework of the East German contribution to EPIC (European Prospective Investigation into Cancer and Nutrition) (27) dietary information is obtained by a self-administered food frequency questionnaire. The purpose of the present study was to evaluate dietary intake data obtained by this questionnaire with respect to dependencies between reported low relative energy intake and other factors, in particular obesity. It was also investigated in which way underestimation of energy intake relates to macronutrient intake and consumption from food groups. Sufficient knowledge about the pattern of underreporting is a prerequisite for unbiased analyses of diet-disease relationships in the investigated cohort. Differentially biased dietary information questions the assumption that all subjects are affected by methodological errors and will result in false estimates of relative risks.

Subjects and methods

Subjects

The recruitment of the East German cohort of the EPIC-Study (27) is based on addresses from population registration offices in Potsdam and the surrounding areas and contacted men aged 40 to 64 years and women aged 35 to 64 years.

The current analysis was restricted to those study participants who were recruited from January to June 1995. During this period 10 791 people were invited to participate in the cohort study. Out of them 3 494 completed all the basic examinations and the questionnaires, and gave written informed consent. The 963 subjects who reported weight changes of more than five kilograms during the past two years before examination were excluded from the analysis. The remaining 2 531 subjects were considered to be in energy balance and formed the current study population.

Methods

Dietary questionnaire

A self-administered, semi-quantitative food frequency questionnaire (SFFQ) was the basic instrument for assessment of habitual dietary intake in the Potsdam cohort. The questionnaire consisted of 148 food items and included questions regarding the consumption of sauces and fat content of certain food items. First, the participant selected his typical portion size from colored photos or from specified units (glass, slice, etc.). Subsequently, one out of nine consumption frequencies (from 'once a month' to 'five times a day') had to be selected. Some items of the group 'fresh fruit and vegetables' were asked and calculated by season. Additionally, there were questions on general consumption patterns that were used to adjust the consumption frequencies given in the questionnaire. The SFFQ was mailed to the study participants 10 days before the basic examinations at a study center, with the note to return it to the study center at the time when the basic examinations were performed. In the study center the SFFQ was read by an optical scanner and subsequently checked for missing information and plausibility by a computer program. Missing information was requested during the participants' stay at the study center. This procedure lead to complete and consistent dietary information of each participant.

Nutrient and energy intake was calculated from food intake derived by the SFFQ using data from the German Federal Food Code (24). The consumed quantity was obtained by multiplying portion size with the corresponding consumption frequency.

The reliability and validity of the SFFQ was checked in a pilot study. This study revealed that the SFFQ is able to measure dietary intake in similar quality to other intruments of this type (5, 6, 7).

Other lifestyle information

Other lifestyle questions were inquired by a second self-administered questionnaire, and a computerized interview conducted by trained interviewers. These instruments included questions about socio-demographic characteristics, physical activity, and occupation. Physical activities comprised gardening, housework, and manual work at home, measured as hours per day during winter and summer season. The activities were quantitatively summed and combined to the variable 'domestic work'. A second variable 'sports' represents hours per week spent with sporting activities only.

Anthropometry

Anthropometric measurements included weight, height, waist and hip circumferences, skinfold measurements (biceps, triceps, subscapular, suprailiac), and chest width and depth.

Body weight was measured without shoes and with participants only wearing light underwear to the nearest 0.1 kg. Percentage of body fat was calculated according to Womersly and Durnin (37). Fat free mass was calculated as body weight minus fat mass, body mass index (BMI) as body weight divided by height squared. The coefficient of variation for inter- and intra-observer effect for most anthropometric measures, except skinfolds and for the composite parameters, was shown to be below 5 % (17).

Energy expenditure

First, basal metabolic rate (BMR) was calculated for each subject by the equations of Schofield et al. (30) from weight and age. Then, the reported energy intake (EI) by SFFQ was related to calculated BMR and expressed as EI/BMR. As the variability of BMR is determined by age and body composition to a large extent, this ratio was considered as a measure of relative energy intake, adjusted for these physical characteristics (9).

As suggested by FAO/WHO/UNU (10) energy requirements can be estimated by multiplying BMR with a factor representing physical activity for population groups, indicated as PAL (physical activity level). The PAL-value is calculated as total energy expenditure (TEE) divided by BMR. In the absence of weight loss or weight gain, the ratio EI/BMR must equal TEE/BMR or the PAL-value, respectively. To be able to compare energy requirements with reported energy intake, an estimate of energy requirements was obtained for each subject by multiplying calculated BMR with a factor of 1.51 for men and 1.53 for women. These factors were the mean ratio of EI/BMR of the population under study. The difference between energy intake and energy requirements gives an estimate of the reporting error, valid on group level. On individual level they may be associated with misclassification since energy requirements are not only determined by weight and age, but also by physical activity, metabolic efficiency, and eating habits.

Statistics

Study participants were allocated to quintiles of EI/BMR. The respective cut points were 1.18, 1.36, 1.57, and 1.84 for men and 1.17, 1.36, 1.55, and 1.81 for women. Dependencies between the parameter EI/BMR and anthropometric and dietary variables were evaluated by calculating the means of these variables for each quintile of EI/BMR. Test for linear trend, controlled for age, BMI, physical activity, and smoking status, was applied to the distribution of these variables within quintiles. BMI was ranked into three categories (BMI < 25, 25 ≤ BMI < 30, and BMI ≥ 30). The group means of three BMI categories were evaluated for differences by the Kruskal-Wallis test in case of non-normally distributed, and the Scheffé test in case of normally distributed variables, respectively. Energy adjustment was performed according to the residual method (33). The statistical calculations were done separately for men and women utilizing the SAS statistical software (29).

Results

Basic characteristics of the study population are given in Table 1. There was no apparent difference in mean BMI between men and women. More men than women reported a high school education. Among men the percentage of persons working full time and percentage of smokers was higher compared to women.

A significantly declining trend by quintiles of EI/BMR was seen for BMI, percentage of body fat, and weight in men and women (Tables 2 and 3). Mean calculated BMR was slightly decreasing from the bottom to the top quintile, corresponding to body weight. Socio-economic variables of Table 1 were also tested with respect to differences between quintiles. There were no apparent dependencies between these variables and the EI/BMR ratio.

As expected, reported energy intake by SFFQ increased with increasing EI/BMR-quintiles. However, energy adjusted fat, protein, carbohydrate, and alcohol intake values revealed no significant differences and trends across quintiles of EI/BMR.

Table 1 Subjects' characteristics (mean (SD))

	Men (n=1104)	Women (n=1427)
age (y)	54.1 (7.7)	51.1 (8.9)
weight (kg)	80.2 (10.9)	65.9 (10.9)
body mass index (kg/m²)	26.4 (3.2)	25.1 (4.0)
percentage of persons		
full time occupation (%)	61	52
married (%)	86	72
education: 8 years or less (%)	29	34
education: 10 years (%)	27	31
education: high school (%)	44	35
current smokers (%)	20	14

Table 2 Mean (SD) values for anthropometric and absolute and energy adjusted dietary variables by quintiles of the ratio energy intake to estimated basal metabolic rate (EI/BMR), men (n=1104)

	EI/BMR < 1.18	EI/BMR 1.18-1.36	EI/BMR 1.37-1.57	EI/BMR 1.58-1.84	EI/BMR >1.84	P of linear trend[1]
EI/BMR	1.00 (0.15)	1.28 (0.05)	1.45 (0.06)	1.69 (0.08)	2.18 (0.33)	-
BMI (kg/m²)	27.8 (3.6)	26.8 (2.9)	26.2 (2.8)	26.0 (3.0)	25.2 (3.1)	*
body fat (%)	25.6 (7.0)	23.9 (5.0)	23.1 (4.4)	22.5 (4.9)	21.8 (5.3)	**
weight (kg)	84.3 (12.6)	81.1 (9.3)	79.9 (10.0)	79.5 (10.5)	76.2 (10.3)	*
calculated BMR (MJ)	7.5 (0.7)	7.4 (0.5)	7.3 (0.6)	7.3 (0.6)	7.1 (0.6)	n.s.
reported energy intake (MJ)	7.6 (1.2)	9.4 (0.7)	10.7 (0.9)	12.2 (1.2)	15.5 (2.5)	*
absolute dietary intake						
fat (g)	66.5 (16.3)	83.9 (13.8)	98.9 (17.6)	116.1 (21.4)	152.0 (37.1)	*
protein (g)	65.0 (13.5)	80.5 (12.7)	87.9 (13.8)	100.8 (17.5)	125.7 (29.7)	*
carbohydrates (g)	187.6 (38.2)	233.6 (34.7)	260.5 (36.7)	297.7 (46.5)	367.6 (79.0)	*
alcohol (g)	16.2 (15.6)	18.9 (16.3)	21.6 (16.4)	22.1 (19.7)	25.5 (27.0)	*
energy adjusted dietary intake						
fat (g)	99.8 (11.2)	96.6 (12.0)	97.4 (13.9)	97.9 (15.3)	98.4 (22.9)	n.s.
protein (g)	88.6 (8.3)	88.2 (11.1)	87.5 (11.6)	88.1 (12.2)	87.6 (21.3)	n.s.
carbohydrates (g)	254.1 (26.4)	259.1 (31.8)	257.5 (36.9)	260.3 (41.5)	259.0 (59.7)	n.s.
alcohol (g)	15.5 (15.0)	17.3 (16.9)	17.0 (17.4)	15.2 (18.6)	15.0 (27.0)	n.s.

[1] controlled for age, BMI, physical activity, smoking; * P < 0.001, ** P < 0.01

Table 3 Mean (SD) values for anthropometric and absolute and energy adjusted dietary variables by quintiles of the ratio energy intake to estimated basal metabolic rate (EI/BMR), women (n=1427)

	EI/BMR < 1.17	EI/BMR 1.18-1.36	EI/BMR 1.37-1.55	EI/BMR 1.56-1.81	EI/BMR >1.81	P of linear trend[1]
EI/BMR	0.99 (0.13)	1.26 (0.06)	1.45 (0.05)	1.67 (0.07)	2.20 (0.40)	-
BMI (kg/m²)	26.4 (4.6)	25.7 (4.0)	25.0 (3.7)	24.7 (3.9)	23.5 (3.2)	*
body fat (%)	34.9 (5.4)	34.4 (5.0)	33.9 (5.2)	33.3 (5.4)	31.7 (5.4)	*
weight (kg)	69.3 (12.8)	67.1 (10.8)	65.8 (9.5)	64.9 (10.5)	62.3 (9.2)	*
calculated BMR (MJ)	6.6 (1.0)	6.5 (0.9)	6.4 (0.9)	6.4 (0.9)	6.3 (0.9)	n.s.
reported energy intake (MJ)	6.6 (1.4)	8.2 (1.2)	9.3 (1.4)	10.7 (1.7)	13.7 (2.8)	*
absolute dietary intake						
fat (g)	51.5 (11.8)	67.1 (11.5)	76.4 (11.6)	88.5 (14.5)	118.9 (29.1)	*
protein (g)	52.4 (10.9)	63.4 (10.2)	70.5 (10.3)	79.0 (14.4)	99.7 (21.6)	*
carbohydrates (g)	151.6 (28.5)	187.3 (25.7)	211.1 (27.8)	242.4 (34.4)	304.5 (67.2)	*
alcohol (g)	5.8 (7.7)	6.6 (7.3)	7.1 (7.3)	8.3 (9.4)	11.5 (14.3)	*
energy adjusted dietary intake						
fat (g)	75.6 (8.3)	75.1 (9.6)	74.8 (10.5)	74.8 (11.7)	75.5 (18.5)	n.s.
protein (g)	69.4 (7.1)	69.2 (8.0)	69.3 (9.2)	69.0 (11.0)	68.2 (17.8)	n.s.
carbohydrates (g)	206.4 (19.6)	207.8 (22.8)	208.1 (26.6)	208.9 (31.4)	208.8 (43.5)	n.s.
alcohol (g)	5.5 (7.8)	5.0 (7.6)	4.8 (8.6)	4.9 (10.2)	4.9 (13.8)	n.s.

[1] controlled for age, BMI, physical activity, smoking; * P < 0.001, ** P < 0.01

Table 4 Food group consumption by quintiles of the ratio of energy intake to estimated basal metabolic rate (EI/BMR) absolute and energy adjusted means (SD) for men (n=1104)

food group		EI/BMR < 1.18	EI/BMR 1.18-1.36	EI/BMR 1.37-1.57	EI/BMR 1.58-1.84	EI/BMR >1.84	p of linear trend[1]
bread and cereals (g)	adjusted	216 (9)	217 (64)	223 (61)	230 (75)	220 (108)	n.s.
	absolute	178 (62)	205 (65)	227 (63)	257 (77)	291 (108)	*
cakes, candy, desserts (g)	adjusted	113 (47)	110 (63)	112 (74)	103 (86)	122 (146)	n.s.
	absolute	71 (50)	105 (64)	131 (72)	155 (86)	237 (155)	*
fruit and vegetables (g)	adjusted	352 (102)	399 (137)	369 (122)	374 (148)	367 (199)	n.s.
	absolute	312 (106)	391 (137)	383 (121)	417 (147)	465 (204)	*
soft drinks, juices, water (ml)	adjusted	432 (370)	429 (389)	400 (390)	403 (403)	381 (466)	n.s.
	absolute	508 (371)	541 (390)	536 (391)	570 (405)	609 (476)	*
dairy products, cheeses (g)	adjusted	148 (121)	164 (157)	141 (149)	167 (191)	150 (268)	n.s.
	absolute	139 (124)	188 (158)	188 (148)	242 (192)	282 (272)	*
meat and fish (g)	adjusted	180 (45)	171 (60)	173 (60)	167 (70)	169 (136)	n.s.
	absolute	129 (53)	156 (62)	182 (64)	207 (77)	270 (147)	*
fat, mayonnaises, creams (g)	adjusted	47 (15)	48 (18)	46 (18)	48 (23)	47 (34)	n.s.
	absolute	45 (19)	45 (19)	49 (18)	58 (24)	71 (36)	*

[1] controlled for age, BMI, physical activity, smoking; * P < 0.001, ** P < 0.01, *** P < 0.05

Table 5 Food group consumption by quintiles of the ratio of energy intake to estimated basal metabolic rate (EI/BMR) absolute and energy adjusted means (SD) for women (n=1427)

food group		EI/BMR < 1.17	EI/BMR 1.18-1.36	EI/BMR 1.37-1.55	EI/BMR 1.56-1.81	EI/BMR >1.81	p of linear trend[1]
bread and cereals (g)	adjusted	169 (46)	174 (45)	177 (49)	180 (57)	180 (80)	***
	absolute	143 (49)	162 (46)	176 (49)	192 (58)	221 (76)	*
cakes, candy, desserts (g)	adjusted	105 (52)	95 (49)	93 (54)	92 (75)	95 (133)	***
	absolute	60 (53)	86 (49)	107 (55)	136 (76)	208 (152)	*
fruit and vegetables (g)	adjusted	360 (135)	379 (137)	371 (123)	351 (132)	354 (207)	n.s.
	absolute	328 (138)	377 (139)	391 (124)	395 (130)	458 (217)	*
soft drinks, juices, water (ml)	adjusted	530 (398)	497 (349)	470 (368)	526 (428)	517 (414)	n.s.
	absolute	593 (398)	574 (349)	558 (368)	626 (429)	646 (413)	*
dairy products, cheeses (g)	adjusted	192 (101)	192 (138)	196 (155)	183 (171)	201 (319)	n.s.
	absolute	146 (102)	194 (138)	230 (157)	254 (174)	363 (325)	*
meat and fish (g)	adjusted	111 (34)	114 (39)	110 (46)	111 (49)	110 (96)	n.s.
	absolute	83 (38)	107 (41)	117 (48)	135 (52)	173 (99)	*
fat, mayonnaises, creams (g)	adjusted	34 (13)	36 (14)	37 (16)	37 (16)	36 (26)	***
	absolute	27 (13)	34 (15)	40 (16)	45 (16)	56 (26)	*

[1] controlled for age, BMI, physical activity, smoking; * P < 0.001, ** P < 0.01, *** P < 0.05

If fat consumption was differentiated into intake of saturated, monounsaturated, and polyunsaturated fatty acids and carbohydrate consumption into monosaccharide, disaccharide, and polysaccharide intake, the energy adjusted values also did not vary significantly across quintiles. The same picture was seen for other nutrients such as ascorbic acid and calcium. All unadjusted values of dietary variables were increasing in conjunction with total energy intake from the lowest to the top quintile (data not shown).

Intake of food items were combined into seven food groups and analysed for dependencies with the parameter EI/BMR. Crude and energy adjusted intake of food groups by quintiles are presented in Tables 4 and 5. Crude food intake was increasing from the first to the fifth quintile for all food groups. No significant trends across quintiles were seen for the energy adjusted values, except for the groups 'bread and cereals', 'fat, mayonnaises, creams', and 'cakes, candy, and desserts' in women. Here, a slightly increasing trend appeared from the first to the last quintile for 'bread and cereals' and 'fat, mayonnaises, creams', and a decreasing trend for the group 'cakes, candy, and desserts'.

As BMI was the most important variable associated with EI/BMR all subjects were grouped into three categories of BMI. With increasing BMI categories subjects, both men and women, showed a higher percentage of body fat mass, lean body mass, and weight (Table 6). Calculated BMR was increasing across BMI categories as well as the estimated energy expenditure. Reported energy intake was decreasing across BMI categories. This trend corresponded with the ratio EI/BMR. The correlation between BMI and EI/BMR was found to be -0.28 ($p < 0.001$) in men, and -0.25 ($p < 0.001$) in women. Between BMI and EI the correlation coefficients were -0.09 ($p < 0.001$) for men and women.

Table 6 clearly shows contrary trends across BMI categories of estimated energy expenditure and reported energy intake. The difference between reported energy intake and estimated energy expenditure increased across

Table 6 Mean values (SD) of some physical variables and energy intake for men and women within categories of BMI

	men			women		
	BMI <25	25<=BMI<30	BMI >=30	BMI<25	25<=BMI<30	BMI >= 30
	n=379	n=578	n=146	n=814	n=447	n=166
weight (kg)	71.3 (7.1)	81.9 (6.9)	96.3 (9.4)*	59.5 (6.1)	70.1 (6.0)	85.9(10.1)*
body fat (%)	19.6 (4.5)	24.5 (4.9)	28.8 (3.4)*	30.7 (4.5)	36.3 (3.4)	41.2 (5.5)*
lean body mass (kg)	57.2 (5.5)	61.8 (5.6)	68.6 (6.7)*	41.1 (3.9)	44.6 (3.8)	50.6 (5.1)*
BMI (kg/m^2)	23.1 (1.5)	27.1 (1.3)	32.0 (1.9)*	22.4 (1.7)	27.0 (1.4)	33.2 (3.3)*
calculated BMR (MJ)	6.9 (0.5)	7.4 (0.5)	8.1 (0.6)$	5.5 (0.4)	5.8 (0.3)	6.4(0.4)$
EI/BMR	1.6 (0.5)	1.5 (0.4)	1.3 (0.4)	1.6 (0.5)	1.5 (0.4)	1.3 (0.3)
estimated energy expenditure (ME) (MJ/d)[1]	10.6 (0.7)	11.3 (0.7)	12.4 (0.8)$	8.4 (0.6)	8.8 (0.4)	9.6 (0.6)$
reported energy intake (EI) (MJ/d)	11.3 (3.0)	11.1 (3.1)	10.5 (3.0) **	8.8 (2.5)	8.4 (2.4)	8.3(2.1)**
EI - ME (MJ)	0.7 (3.0)	-0.3 (3.0)	-1.8(3.1)*	0.4 (2.5)	-0.3 (2.4)	-1.3(2.1)*
domestic work (h/d)	3.2 (2.2)	3.4 (2.4)	3.7 (2.3)**	3.8 (1.9)	4.4 (2.1)	4.4 (2.1)*
sports (h/week)	1.0 (2.4)	0.9 (2.0)	0.6 (1.4)**	0.9 (1.5)	0.8 (1.4)	0.5 (1.3)**

* means significantly different (p < 0.001, Kruskal-Wallis Test),
**means significantly different (p < 0.05, Kruskal-Wallis Test),
$ means significantly different (p< 0.05, Scheffé Test),
[1] calculated as estimated BMR x mean EI/BMR (men = 1.51, women= 1.53)

BMI categories, with the largest difference in the obese subjects (BMI ≥ 30).

Obese subjects – men and women – reported to be more active in domestic work, but spent less hours with sports.

Discussion

The present study was able to show that BMI and related measures of obesity were inversely related to the ratio EI/BMR. Evidence was found that macronutrient and food intake relative to total energy intake were not related to reporting low energy intake, at least in terms of energy adjusted values.

Dietary data for the current analysis were obtained by a self-administered SFFQ. Such questionnaire is appropriate for large-scale epidemiologic studies, but shows some limitations as well. These limitations might result in an underestimation of dietary intake due to inadequacies of the given food list, portion sizes, or to missing data as a result of recording errors. The design of our questionnaire and the procedure of data processing reduces these errors. The validity of this SFFQ has been demonstrated in a pilot study (5-7), but limitations in quantitative assessment of habitual food intake remain still inherent in the nature of a questionnaire of this type. However, it is generally assumed that a SFFQ of sufficient validity, is able to rank subjects according to their habitual dietary intake (35). This implies the assumption that systematic bias according to quantitative measurements apply to all subjects with the same probablility. This assumption cannot be maintained if bias operates not at random but differentiates across the members of the sample. Therefore, the understanding of measurement error associated with dietary instruments needs to be improved. Particular interest exists in identifying the characteristics of individuals reporting low energy intake.

Subjects reporting comparatively low energy intake were characterized by the ratio EI/BMR. Using BMR as the denominator largely corrects for differences in lean body mass. By doing so it is possible to compare subjects with respect to energy intake without giving particular reference to height, weight, sex, or age (9). The overall mean EI/BMR of 1.51 for men and 1.53 for women was found to be in the range of 1.5 to 1.7 suggested as adequate for a population leading a sedentary lifestyle (13) and is close to the average values for of 1.55 for men and 1.56 for women suggested by FAO/WHO/UNU (10).

It was demonstrated by biological data and also by measurements of dietary intake that with increasing body weight energy expenditure is increasing (4, 18, 25, 26). These results are in contrast to studies that found no linear relationship between relative body weight and energy intake. Even inverse relations between relative weight and reported energy intake were found (1, 2, 15, 16, 21, 28).

Our data confirmed the existence of even a negative association between relative body weight and energy intake and also revealed a discrepancy between reported energy intake and estimated energy requirements in connection with body weight. Underreporting of food intake dependent on obesity was suggested as the most likely explanation for these conflicting findings (26).

Another factor explaining such findings could be a reduced level of physical activity in obese subjects resulting in lower energy requirements. However, according to our data overweight or obese individuals even spent more time with activities like housework, gardening, etc. The reduced sport activities compared to normal weight subjects, being observed in our sample, were not able to account for a significantly reduced energy intake. Shetty et al. (31) claimed that the physical activity level (PAL), corresponding to EI/BMR, could be increased by 0.3 units by 30 to 60 minutes of active sport 4 to 5 times a week. Applied to our data the observed EI/BMR differences of 0.3 units between normal weight and obese subjects were not associated with such vigorous exercise.

Apart from physical activity energy requirements are mainly determined by BMR that is characterized by large individual variation (31). Therefore, prediction equations for BMR are only imperfect estimates of true BMR. Measurement errors might be related to relative body weight. To check the underlying associations we refered to data of Goldberg et al. (13), and looked specifically for the relation between the differences of BMR calculated by the equations of Schofield and BMR measured by indirect calorimetry on one hand and body weight on the other hand. The results gave no evidence of a nonlinear association between BMR and relative body weight since we found no positive correlation between the calculated differences and body weight.

Energy adjusted dietary variables characterize nutrient intake of subjects independent of total energy intake. The residual method (33) allows a comparison of subjects' nutrient intakes independent of being classified into categories of energy intake. Our findings showed that adjusted macronutrient intakes are independent of the parameter EI/BMR. It was also reported that underestimation of food intake is food specific (3, 11, 12). Food items that are generally considered as unhealthy, particularly high-fat or sweet foods, may be more often misreported than 'healthy foods'. According to our data there is no evidence that food specific underreporting happens necessarily in every study on a larger extent, at least in terms of energy adjusted food intake. In the present study food intake data did not reveal significant differences between subjects with low compared to high energy intakes even if slight trends of over- and underreporting were suggested for some food groups, especially in women.

For methodological reasons all subjects had been excluded from the analysis who reported a weight change of more than 5 kilograms during the last two years. In order to see if the excluded subjects show characteristics different from the subjects under study, we repeated the analyses also for this group. No significant differences in results between weight changers and subjects stable in weight were seen, indicating that our conclusions can be applied to the total population.

Even if we cannot rule out that some of the obese subjects were much less active or show increased metabolic efficiency, we conclude that a considerable proportion of the individuals in our study population underreported energy intake compared to their requirements. Although obese subjects do not necessarily underestimate dietary intake and, on the other hand, underreporting is not restricted to the obese, it is evident that being overweight or obese enhanced the likelihood of underreporting considerably. Apart from obesity we were not able to find other variables determining underreporting. Energy adjusted intake values were found to be independent of the level of reported energy intake. They also did not reveal that underestimation of food intake is disproportional to a large extent.

In this respect it appears to be useful to employ energy adjusted dietary variables to assess diet-disease relationships in future studies since they were found to be independent of the methodological influences of the underreporting phenomenon. Moreover, our findings suggest to include BMI or related measures of obesity in the multivariate model if estimates of relative risk will be obtained for energy or absolute dietary variables irrespective of BMI as a confounder in a biological sense. However, even this model will not allow one to estimate the effect of these dietary variables on risk estimates correctly because the biological interaction of absolute food intake with obesity is mixed with methodological effects. It will be a future task to find statistical solutions for this problem, if we would like to proceed with the current methodology in obtaining dietary data.

Generally, it seems mandatory to prove to what exent a specific dietary instrument is susceptible to underreporting and which characteristics are particular for subjects who tend to underreport their habitual dietary intake. Here, obesity should be of special interest. Such a methodological examination will allow more unbiased statistical analyses and interpretation of the obtained results.

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