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Determinants of Obesity-related Underreporting of Energy Intake

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Data from an ongoing Dutch health examination monitoring project carried out in 1995 (n = 2,079 men and 2,467 women, aged 20–65 years) were used to study whether various determinants of underreporting of energy intake influenced the association between underreporting and body mass index. Further, the authors examined whether these determinants were mutually independent predictors of underreporting. As a measure for the degree of underreporting, they calculated energy ratios of reported daily energy intake divided by the estimated basal metabolic rate. They observed that underreporting occurred more with increasing degrees of overweight in men and women. Each increase in body mass index by 1 kg/m^2 was associated with a decrease in reported energy intake/basal metabolic rate (in men, $\beta = -0.0364$; standard error, 0.0024; in women, $\beta = -0.0262$; standard error, 0.0018). After adjustment for age, education, smoking habits, physical activity, dieting behavior, and dieting frequency during the last year, the slopes were reduced by 29% in men and 17% in women but remained negative and highly statistically significant. Adjustment for current dieting behavior particularly decreased the association between body mass index and underreporting. Age was another independent determinant of underreporting in men and women and, in men only, so were smoking habits and education level. In conclusion, overweight individuals give biased dietary information, and this may distort the relations between self-reported dietary intake and diseases related to body mass index. *Am J Epidemiol* 1998; 147:1081–6.

body mass index; diet; energy intake; obesity

Accurate assessment of dietary intakes is a prerequisite in nutritional epidemiology. In recent years, many reports have been published about the magnitude of the measurement error in dietary intake data and on studying the effect of random measurement error on diet-disease associations (1–4). However, evidence is mounting that measurement errors are often not randomly distributed because subgroups within study populations are more likely to underreport their intake than others. For the correct interpretation of diet-disease relations in epidemiologic studies, it is important to examine the determinants of underreporting.

Serious underreporting of energy intake has mostly been observed in obese people (5–13). Other factors that play a role in the degree of underreporting have been examined in only a few studies. Some studies observed that women underreport their energy intake to a greater extent than men (6–9), and this was also observed for those with a relatively low educational level (9). Ballard-Barbash et al. (10) showed that underreporting was more common among American white women with less education, who were less physically active, smoked, and had poorer self-reported health status. Moreover, they observed that controlling for low energy dieting reduced the inverse association between energy intake and body mass index.

In this study, we examine whether various determinants of underreporting influence the formerly described association between underreporting and body mass index in a population of about 5,000 Dutch men and women aged 20–65 years. Further, we report whether these determinants of underreporting are mutually independent. Data collection occurred within the framework of the Monitoring Project on Risk Factors for Chronic Diseases in the Netherlands (MORGEN) and the superimposed European Prospective Investigation into Cancer and Nutrition (EPIC) (14).

MATERIALS AND METHODS

The data in the present study were collected in 1995 in the Netherlands as part of MORGEN. The main purpose of the project is to determine the prevalence of (risk factors for) several chronic diseases. The project was approved by the Medical Ethical Committee of TNO (Netherlands Organization for Applied Scientific

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Abbreviations: MORGEN, Monitoring Project on Risk Factors for Chronic Diseases in the Netherlands; MJ, megajoule.

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Research). Participants in this project also form one of the cohorts of the European Prospective Investigation into Cancer and Nutrition. Random samples of men and women aged 20–59 years and stratified according to sex and 5-year age categories were taken in two towns, Amsterdam and Maastricht. In a third town, Doetinchem, men and women who were of the same age in 1991 were reexamined in 1995. Participants received a general and a dietary questionnaire to complete at home and attended a medical examination at the Municipal Health Service. Height was measured to the nearest 0.5 cm and weight to the nearest 0.1 kg, in subjects wearing light indoor clothing with pockets emptied and no shoes. To allow for the clothes, 1.5 kg were subtracted from the measured weight.

The general questionnaire collects data on demographic characteristics and risk factors for chronic diseases, such as smoking and physical activity. The dietary questionnaire is a semiquantitative food frequency questionnaire that was developed to assess the intake of total energy and various nutrients and food groups. In the questionnaire, information on the average consumption frequency and portion size of 178 food items over the past year is collected. Nutrient intake was calculated by use of an extended version of the Dutch food composition table (15). The questionnaire was validated and slightly adjusted before use in MORGEN (16, 17).

In 1995, a total of 5,108 subjects agreed to participate in the study (mean response rate, 43 percent). Those who were pregnant were excluded from analysis ($n = 30$). Subjects with incomplete data on sex, height, weight, energy intake, physical activity level, education level, age, dieting behavior, dieting frequency, or smoking were also excluded ($n = 532$). The final study population used for analysis included 4,546 subjects.

Body mass index was calculated as weight (kg)/height (m)^2; the basal metabolic rate was estimated using the Schofield equations (18) based on weight, height, age, and sex. As a measure for the degree of underreporting, we calculated the energy ratios of reported daily energy intake divided by the basal metabolic rate. The population subjects were divided into subgroups of body mass index, physical activity, education level, age, dieting behavior, dieting frequency, and smoking. Classification of the body mass index was made into normal ($\leq$25 kg/m^2), overweight ($>$25–$\leq$30 kg/m^2), and obese ($>$30 kg/m^2) (19). The physical activity level was classified into inactive (no heavy, strenuous activities and no sports in leisure time), partially active (heavy, strenuous activities or sports in leisure time), and active (heavy, strenuous activities and sports in leisure time). Three classes of education level were defined: low (lower vocational and primary), medium (intermediate vocational and secondary), and high (higher vocational and university). Two age categories were made, namely, 40 years or younger and older than 40 years. Three classes of current dieting behavior were created: trying to lose weight, trying to keep constant weight, and paying no attention to weight. Dieting frequency was classified as zero, once, and more than once trying to lose weight during the past 12 months. Classification of cigarette smoking was made into current, former, and never.

For statistical analysis, the SAS version 6.11 software package (SAS Institute, Inc., Cary, North Carolina) was used. In all analyses, p values below 0.05 were considered to be statistically significant. Differences in the energy ratio between various subgroups of the population were studied using analysis of variance. Adjustments for body mass index and adjustments for all the variables mentioned above were made in separate models. To study the determinants of body mass index-related underreporting, linear regression analysis was performed with the energy ratio as the dependent variable and body mass index as (a continuous) independent variable. The effect of adjustment for age and classes of physical activity level, education level, dieting behavior, dieting frequency, and smoking habits on the regression coefficient for body mass index was examined.

RESULTS

The sample of 4,546 subjects in this analysis included 2,079 men and 2,467 women. For men, the mean body mass index was 25.5 (standard error, 3.6) kg/m^2, and the mean energy intake was 11.06 (standard error, 3.07) megajoules (MJ)/day. For women, the mean body mass index was 24.6 (standard error, 4.2) kg/m^2, and mean energy intake was 8.52 (standard error, 2.17) MJ/day. Table 1 shows the percentages of participants in the various categories of selected variables. Obesity was present in about 10 percent of the subjects. About 26 percent of the men and 36 percent of the women reported being on a weight-reducing diet.

Table 2 illustrates that, while the mean basal metabolic rate increased with higher body mass index, the mean reported energy intake decreased. Consequently, the mean energy ratio decreased across the three body mass index categories (table 3). Further, mean energy ratios were lowest among men and women older than 40 years, those who currently tried to lose weight, and who had been dieting the past 12 months (table 3). After adjustment for body mass index, men with a high level of education had lower energy ratios than less educated men. Male smokers had higher adjusted

TABLE 1. Population characteristics: percentages of participants across categories of selected variables, in 2,079 men and 2,467 women, MORGEN* project, the Netherlands, 1995

	Men (%)	Women (%)
BMI* (kg/m²)		
≤25	46.7	62.2
>25–≤30	43.3	28.1
>30	10.0	9.7
Age (years)		
≤40	36.5	40.8
>40	63.5	59.2
Educational level		
Low	43.3	51.9
Medium	28.9	25.3
High	27.8	22.8
Smoking		
Never	30.4	36.9
Former	35.4	26.2
Current	34.2	36.9
Activity level		
Inactive	46.7	50.3
Partially active	40.6	37.0
Active	12.7	12.7
Current dieting behavior		
No	52.5	35.8
Trying to keep constant weight	21.5	27.9
Trying to lose weight	26.0	36.3
Dieting frequency during last year		
0 times	73.8	55.1
1 time	13.0	18.1
>1 time	13.2	26.8

* MORGEN, Monitoring Project on Risk Factors for Chronic Diseases in the Netherlands; BMI, body mass index.

TABLE 2. Mean basal metabolic rate and energy intake (MJ*/day) across tertiles of body mass index (BMI) for men and women, in a Dutch population study of 2,079 men and 2,467 women, 1995

BMI class (kg/m²)	No.	Basal metabolic rate (MJ)		Energy intake (MJ)	
		Mean	SD*	Mean	SD
Men					
≤25†	972	7.22	0.42	11.42	3.13
>25–≤30	900	7.72	0.48	10.73	2.85
>30	207	8.54	0.73	10.80	3.49
Women					
≤25†	1,534	5.68	0.32	8.63	2.17
>25–≤30	693	6.08	0.36	8.40	2.14
>30	240	6.62	0.55	8.14	2.23

* MJ, megajoule; SD, standard deviation.
† Reference category.

energy ratios than male nonsmokers. In women, there was a smaller difference in the mean energy ratio between nonsmokers and smokers.

Table 4 illustrates the crude and adjusted relations between energy ratio and body mass index; for men, these relations were more negative than for women (crude $\beta = -0.0364$ vs. -0.0262). Adjustment for age, dieting frequency during the past year, and particularly current dieting behavior reduced, while adjustment for educational level slightly increased, the slope of the association in both men and women. The variables body mass index, age, and dieting behavior, and for men also smoking and education level, significantly contributed to the variance in energy ratio (table 5). All selected variables together explained 16 percent and 11 percent of the variance in energy ratio in men and women, respectively, of which the greatest part was explained by body mass index (10 percent in men and 8 percent in women).

DISCUSSION

The main findings of this study are that increasing underreporting of energy intake with increasing degree of overweight was present in women and, even more pronounced, in men. These findings were not substantially altered after adjustment for a number of potentially confounding factors. We are not aware of other studies that observed similar sex differences in body mass index-dependent underreporting. Second, we showed that the slope of the association between body mass index and underreporting was reduced by about 15–20 percent when adjusted for dieting behavior. This finding is in accordance with a reduction of 20 percent in the slope between energy intake and body mass index among North American women when controlling for low-energy dieting (10). It suggests that part of body mass index-related low energy ratios may not be regarded as underreporting but may reflect negative energy balance in dieting subjects at the time of the survey. Further adjustment for age, dieting frequency, physical activity, education, and smoking behavior had only minor effects on the association between underreporting and body mass index.

The observed inverse association between energy ratio and body mass index is consistent with reports from some (6, 7, 9, 10, 12), but not all (20–22), population-based studies. We identified several other independent determinants of underreporting; for example, lower energy ratios were observed at higher age, in exsmokers and with current dieting in both sexes, and in current smoking and more highly educated men. Two other studies among women (9, 10) observed that underreporting was more common among younger women and those who smoked and who were less educated.

There are some comments to be made with regard to measurement error in the numerator and denominator of the outcome measure in the current study. First, the food frequency questionnaire has been validated against twelve 24-hour recalls (16, 17), in which cor-

TABLE 3. Energy ratios (reported energy intake/basal metabolic rate) across categories of selected variables, with and without adjustment for body mass index (BMI) in 2,079 men and 2,467 women, MORGEN† project, the Netherlands, 1995

	Men				Women			
	Unadjusted		Adjusted‡		Unadjusted		Adjusted‡	
	Mean	SE†	Mean	SE	Mean	SE	Mean	SE
BMI* (kg/m²)								
≤25§	1.58	0.014			1.52	0.010		
>25–≤30	1.39	0.012***			1.39	0.014***		
>30	1.27	0.028***			1.23	0.022***		
Age (years)								
≤40§	1.59	0.016	1.55	0.014	1.51	0.013	1.47	0.012
>40	1.40	0.010***	1.42	0.011***	1.42	0.010***	1.44	0.010
Educational level								
Low§	1.47	0.015	1.50	0.013	1.43	0.011	1.46	0.011
Medium	1.49	0.017	1.47	0.016	1.49	0.016**	1.46	0.015
High	1.45	0.015	1.41	0.017***	1.48	0.015*	1.44	0.016
Smoking								
Never§	1.46	0.016	1.45	0.016	1.43	0.013	1.44	0.012
Former	1.41	0.014	1.44	0.015	1.45	0.015	1.47	0.015
Current	1.53	0.017**	1.52	0.015**	1.48	0.013*	1.47	0.012*
Activity level								
Inactive§	1.45	0.014	1.46	0.013	1.45	0.012	1.47	0.011
Partially active	1.48	0.013	1.47	0.014	1.45	0.012	1.43	0.012*
Active	1.50	0.024	1.46	0.024	1.50	0.020	1.46	0.021
Dieting behavior								
No§	1.56	0.013	1.52	0.012	1.56	0.014	1.53	0.013
Constant weight	1.42	0.018***	1.41	0.018***	1.46	0.013***	1.43	0.014***
Trying to lose weight	1.33	0.016***	1.40	0.018***	1.35	0.012***	1.40	0.013***
Dieting frequency during last year								
0 times§	1.52	0.011	1.49	0.010	1.52	0.011	1.49	0.010
1 time	1.34	0.019***	1.39	0.024***	1.40	0.017***	1.42	0.018***
>1 time	1.33	0.025***	1.42	0.025**	1.37	0.014***	1.42	0.015***

* Statistically significant from reference at $p < 0.05$; ** statistically significant from reference at $p < 0.01$; *** statistically significant from reference at $p < 0.001$.

† MORGEN, Monitoring Project on Risk Factors for Chronic Diseases in the Netherlands; SE, standard error.

‡ Adjusted for body mass index.

§ Reference category.

TABLE 4. Regression coefficients (β) obtained from regressing energy ratio (reported energy intake/basal metabolic rate) on body mass index (kg/m²), with and without adjustments for other variables, in 2,079 men and 2,467 women, MORGEN* project, the Netherlands, 1995

	Men		Women	
	β	SE*	β	SE
Crude	−0.0364	0.0024	−0.0262	0.0018
Adjusted for age	−0.0297	0.0025	−0.0254	0.0019
Adjusted for education	−0.0387	0.0025	−0.0270	0.0019
Adjusted for smoking	−0.0362	0.0024	−0.0260	0.0018
Adjusted for physical activity	−0.0364	0.0026	−0.0268	0.0018
Adjusted for dieting behavior	−0.0301	0.0026	−0.0215	0.0019
Adjusted for dieting frequency	−0.0330	0.0026	−0.0236	0.0019
Adjusted for all above variables	−0.0259	0.0028	−0.0217	0.0021

* MORGEN, Monitoring Project on Risk Factors for Chronic Diseases in the Netherlands; SE, standard error.

relation coefficients of 0.71 for males and 0.58 for females were found for energy intake. The median difference in energy intake as estimated by the questionnaire and 24-hour recalls was −47 kJ for men (25th percentile = 1,587; 75th percentile = −2,000) and 351 kJ for women (25th percentile = 1,493; 75th percentile = −635). Second, although some investigators have expressed their concern about the validity of the Schofield equations for estimating the basal metabolic rate (23), the estimated mean basal metabolic rate for subgroups of body mass index is virtually identical to the basal metabolic rates in similar groups as measured by the doubly labeled water method (24). This indicates that, on a group level, our estimates of basal metabolic rate are probably valid and accurate. On the individual level, the estimated basal metabolic rates include random error; Schofield observed correlation coefficients of about 0.65 between the estimated and the measured basal metabolic rate (18). Third, differences in energy expenditure other than basal metabolic rate might exist between subgroups of the study population and partly explain observed differences in the energy ratio. Given the random measurement error in the measure for under-

TABLE 5. Regression coefficients (β) obtained from regressing energy ratio (reported energy intake/basal metabolic rate) on multiple variables, in 2,079 men and 2,467 women, MORGEN* project, the Netherlands, 1995

Independent variable	Men			Women		
	β	SE*	*p* value	β	SE	*p* value
BMI* (kg/m²)	−0.0259	0.003	0.0001	−0.0217	0.002	0.0001
Age (years)	−0.0077	0.0009	0.0001	−0.0017	0.0007	0.02
Education level (low)†						
Medium	−0.0583	0.021	0.06	−0.0069	0.020	0.73
High	−0.0838	0.022	0.0001	−0.0312	0.020	0.13
Smoking (nonsmoker)†						
Exsmoker	−0.0466	0.022	0.03	0.0454	0.019	0.02
Smoker	0.0589	0.021	0.006	0.0245	0.017	0.15
Activity level (inactive)†						
Partially active	0.0161	0.018	0.38	−0.0232	0.017	0.16
Active	0.0030	0.028	0.91	0.0056	0.025	0.82
Current dieting behavior (no dieting behavior)†						
Constant weight	−0.0826	0.022	0.0002	−0.0943	0.019	0.0001
Trying to lose weight	−0.0915	0.027	0.0007	−0.128	0.022	0.0001
Dieting frequency (0 times)†						
1 time	−0.0562	0.028	0.05	−0.0279	0.022	0.20
>1 time	−0.0138	0.031	0.66	−0.0095	0.022	0.67

* MORGEN, Monitoring Project on Risk Factors for Chronic Diseases in the Netherlands; SE, standard error; BMI, body mass index.
† Reference group.

reporting, body mass index, age, dietary behavior, and for men education and smoking probably explain a considerably larger part of the variation in true underreporting than the 11–16 percent that we observed.

The implications of occurrence of body mass index-dependent underreporting on the associations between diet and disease have been simulated by Prentice (25). The postulated association between dietary fat and postmenopausal breast cancer was reviewed, and it was concluded that relations between diet and obesity-related diseases may well be underestimated because of the occurrence of body mass index-related underreporting. This is also the case if adjustment is made for body mass index. Knowledge about the determinants of underreporting of energy is therefore important for the evaluation of diet-disease relations. Our main findings were that body mass index is the main determinant of underreporting of energy intake and that about 18 percent of this suspected underreporting may be explained by dieting. Various other lifestyle and sociodemographic characteristics had minor effects on the body mass index-related underreporting. Some of these characteristics, however, were independent of body mass index in their association with suspected underreporting. These findings should be taken into consideration when interpreting diet-disease relations.

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