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ORIGINAL CONTRIBUTION

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Underreporting of energy intake in 1 to 18 year old German children and adolescents

„Underreporting" der Energiezufuhr bei 1- bis 18jährigen deutschen Kindern und Jugendlichen

Summary It is generally accepted that self-reported food intakes underestimate habitual energy intake (underreporting). Underreporting is often addressed by computing the ratio of measured energy intake to predicted basal metabolic rate (EI:BMR). We used this ratio to study differences between not plausible records (NPR) and plausible records (PR) according to recalculated cut-off values for EI:BMR ratios (< 0.97 to 1.07; age- and sex-dependent) in cross-sectional data of 1 032 3d weighed diet records of 1 to 18 year old children and adolescents. Underreporting (in 5 % of total subjects) was age and sex dependent: about 1 % in the 1 to 5 year old children, 2 % (3 %) in the 6 to 13 year old males (females) and 12 % (20 %) in the adolescent males (females), respectively. To analyse differences between subgroups with PR vs. NPR we therefore concentrated on the 14 to 18 year olds. Male (female) subjects with NPR vs. PR had a 40 % lower total EI: 7.4 MJ/d (5.3 MJ/d) vs. 11.5 MJ/d (8.0 MJ/d), respectively. In both sexes with NPR vs. PR, EI per meal was lower. Females with NPR vs. PR had a higher body mass index (kg:m^2), recorded fewer meals per day, and had a shorter time span between the first and last meal per day. Furthermore, females with NPR vs. PR had higher intakes per MJ of water, protein, fiber, sodium, iron, niacin, zinc, and protein in percent of total EI, but a lower intake of added sugars per MJ. Males with NPR vs. PR answered significantly more often that they usually eat more, had a higher water intake per MJ, and a higher Ca:P.

The observed differences between groups with PR and NPR indicate different food habits or dietary recording behavior. Therefore, validity in dietary studies cannot be achieved by simply excluding underreporters.

Zusammenfassung In Ernährungserhebungen, in denen die Probanden ihren Lebensmittelverzehr selbst protokollieren, wird die Energiezufuhr meist unterschätzt („underreporting"). Zur Identifikation von „underreporting" kann der Quotient aus protokollierter Energiezufuhr und individuell berechnetem Grundumsatz (EI:BMR) herangezogen werden. In dieser Arbeit wurden die in der Literatur vorgeschlagenen Grenzwerte alters- und geschlechtsabhängig neu berechnet (0,97 < EI:BMR < 1,07) und bei Querschnittsdaten von 1 032 3-Tage-Wiegeprotokollen von 1- bis 18-jährigen Kindern und Jugendlichen angewendet. „Underreporting" (insgesamt bei 5 % der Probanden) war alters- und geschlechtsabhängig: 1 % der 1- bis 5-jährigen, 2 % (3 %) der 6- bis 13-jährigen Jungen (Mädchen) und 12 % (20 %) der männlichen (weiblichen) Jugendlichen hatten nicht plausible Protokolle (NPR). Unterschiede zwischen Probanden bzw. Protokollen mit plausibler Energiezufuhr (PR) und NPR wurden wegen der höheren Fallzahlen in der Gruppe der 14- bis 18-jährigen untersucht. Jungen (Mädchen) mit NPR vs. PR hatten eine um 40 % niedrigere Energiezufuhr: 7,4 MJ/d (5,3 MJ/d) vs. 11,5 MJ/d (8,0 MJ/d). Insgesamt war bei Probanden mit NPR vs. PR die Energiezufuhr pro Mahlzeit niedriger. Mädchen mit NPR vs. PR hatten einen höheren BMI (kg:m^2), verzehrten weniger Mahlzeiten pro Tag und hatten eine kürzere Zeitspanne zwischen erster und letzter Mahlzeit, ferner hatten sie höhere

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Zufuhrwerte pro MJ bei Wasser, Protein, Ballaststoffen, Na, Fe, Zn, Niacin und Energie aus Protein, aber eine niedrigere Zufuhr von zugesetztem Zucker/MJ. Jungen mit NPR vs. PR gaben häufiger an, normalerweise mehr zu essen und hatten eine höhere Wasserzufuhr/MJ und einen höheren Ca:P Quotienten.

Aufgrund der gezeigten unterschiedlichen Ernährungsgewohnheiten oder der Unterschiede im Protokollieren zwischen Probanden bzw. Protokollen mit PR vs. NPR kann die Validität der Ergebnisse aus Ernährungserhebungen nicht ohne weiteres durch Ausschluß von Probanden mit NPR verbessert werden.

Key words Children and adolescents – 3d weighed diet record – energy and nutrient intake – underreporting

Schlüsselwörter Kinder und Jugendliche – 3d-Wiege-Protokollmethode – Energie- und Nährstoffzufuhr – Unterprotokollierung

Introduction

Dietary surveys are an important tool in nutritional epidemiology and quite different methods have been developed in the past. But the validity of the dietary measurements is still difficult to assess, due to a lack of suitable reference techniques in free-living subjects. Black et al. (5) compared measured dietary energy intakes with calculated basal metabolic rates (BMR) and found severe underreporting even in very carefully designed nutritional surveys. Now it is generally accepted that self-reported food intakes underestimate habitual energy intake (6). Due to this common bias in nutritional epidemiology, there is an increasing scientific interest in underreporting and in underreporters.

Up to now there are many studies of underreporting in adults as can be seen by some recent examples (1, 8, 15, 16, 18, 26) and in children and adolescents (2, 10, 12, 20, 28, 29, 31).

Ideally underreporting is identified through comparing the measured total energy expenditure of an individual with the doubly labeled water method and the energy intake (EI) with dietary methods. However, this assessment is time consuming, expensive, and therefore exclusively used in small samples. Biomarkers (e.g., urinary nitrogen excretion) are used to validate nutrient intake (protein) measured with dietary methods (4), but at least one sample or preferably repeated collections of 24 hr urine are necessary. This is a considerable disadvantage of this validation procedure. Alternatively underreporting is often addressed by computing the ratio of measured energy intake to predicted basal metabolic rate (EI:BMR). A ratio below a special limit, i.e., a “CUT-OFF 2” according to Goldberg et al. (14), is taken as an indicator of an implausible individual measurement of EI. But this statistical method gives only a probability of underreporting in an individual and no quantification. Although these limits were developed for adults ignoring differences in energy expenditure due to sex or age, they were applied in children or adolescents too.

We, therefore, recalculated the tabulated “CUT-OFF 2” a for adults according to Goldberg’s method using new sex- and age-dependent estimations of energy expenditure in children and adolescents and applied these limits to investigate underreporting in a cross-sectional study. Since differences between not plausible records (NPR) and plausible records (PR) in dietary surveys are mostly studied on the basis of nutrient intake in the literature, we were interested in additional dietary informations (e.g., food habits) of underreporters in this paper.

Subjects and methods

Subjects

The sample for this report was partly from the DONALD Study (Dortmund Nutritional and Anthropometric Longitudinally Designed Study) and partly from the DAD Study (Dortmund ADolescent Study) both carried out by the Research Institute of Child Nutrition Dortmund. Details were described elsewhere (17). In short the DONALD Study sample is comprised of families who are interested in the long-term nutrition and health of their children and volunteered to take part. This report includes only cross-sectional data from the first examination of 791 subjects between 1985 and 1996 to exclude unknown follow-up effects. 608 records were from 1 to 5 year old children, 151 records from 6 to 13 year old children, and 32 from 14 to 18 year old adolescents. For the cross-sectional DAD Study school classes with nutritional lessons and sports clubs (e.g., hockey, swimming) were addressed. From the total of 241 diet records, 29 were collected from 6 to 13 year old children and 212 from 14 to 18 year old adolescents. Since the dietary pattern in the age groups studied did not vary with the year of recruitment (17) and moreover the period of recording was not of interest for this analysis, the two studies were combined here. Both studies were approved by the International Scientific Commission of the Research Institute of Child Nutrition.

Weighed diet record

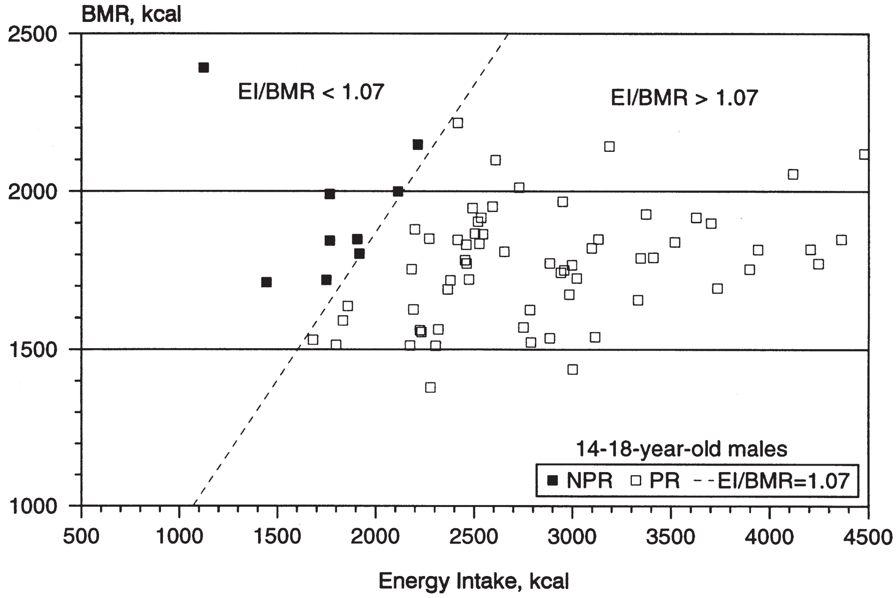
Details of the method were published in a recent paper (17). In short, time, place, and the amounts of all foods

Table 1 Frequency of NPR in children and adolescents using recalculated, age, and sex dependent cut-off values vs. "CUT-OFF 2" a for adults

	Males						Females					
Age	Total	Cut-off[1]	NPR		NPR		Total	Cut-off[1]	NPR		NPR	
Years	n		n	(n)	%	(%)	n		n	(n)	%	(%)
1–5	292	0.97	4	(5)	1.4	(1.7)	316	0.97	2	(4)	0.6	(1.3)
6–13	96	1.04	3	(4)	3.1	(4.2)	94	1.01	2	(5)	2.1	(5.3)
14–18	73	1.07	9	(8)	12.3	(11.0)	161	0.97	32	(48)	19.9	(29.8)
total	461		16	(17)	3.5	(3.7)	571		36	(57)	6.3	(10.0)

[1] Calculated assuming a coefficient of variation of 24 % for 1–5 y old children and 23 % for other age-groups (25) and assuming physical activity levels for light activity (30);
() n or % with NPR using "CUT-OFF 2" = 1.06 for adults (14)

Fig. 1 Scatterplot of predicted BMR on recorded energy intake (EI) of 14 to 18 year old males and females.



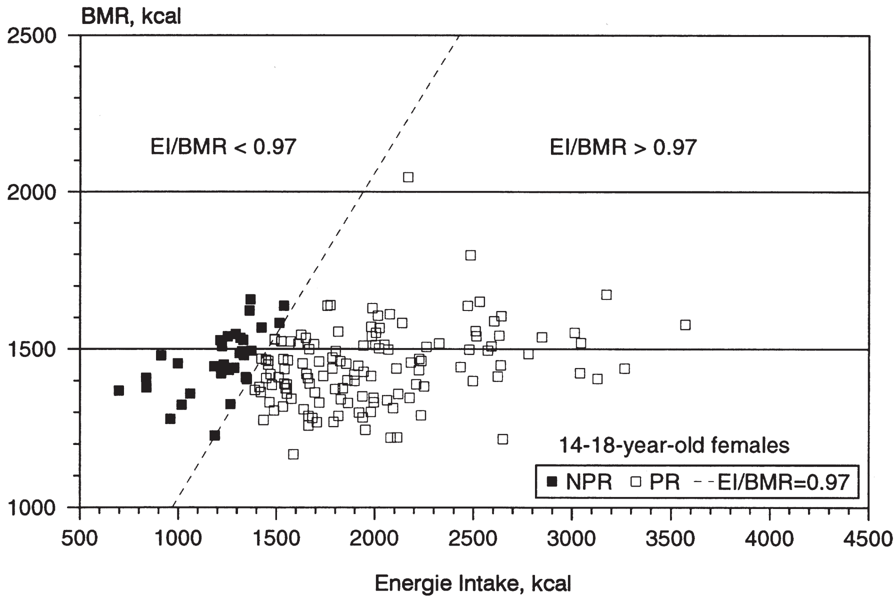


Table 2 EI and EI:BMR ratios in the total sample of 14 to 18 year old males (n = 73) and females (n = 161)

	Males			Females		
	MED	P10	P90	MED	P10	P90
EI (kcal/d)	2 548	1 836	3 899	1 776	1 266	2 575
EI (MJ/d)	10.66	7.68	16.31	7.43	5.3	10.78
EI:BMR	1.44	1.06	2.11	1.25	0.86	1.72

MED = Median; P10, P90 = 10th, 90th Percentile

and drinks (electronic food scales: 0–1000 g or 0–2000 g, accuracy 1 g) during 3 consecutive days were recorded. Participants were allowed to choose which day to start recording. Weekdays (76 %) and weekend days (24 %) were almost equally distributed in the sample. After recording the respondents were asked open ended questions in a cross-check (e.g., deviations from habitual food intake, life-style during the recorded period).

The responsibility for record keeping switched from the parents to the children/adolescents depending on age. Some children began to assist their parents in record keeping from the age of 7; already 80 % of the 10 to 12 year old children helped with the recording. In the adolescent groups totally self-reliant records were kept by 20 % of the males and 30 % of the females at the age of 13 to 14 and by 70 % of the males and 90 % of the females at the age of 15 to 18.

Measurement of plausibility of recorded EI

To check for underreporting, the ratio of reported EI and predicted BMR was used. BMR was estimated according to Schofield (27), taking into account age, sex, body weight, and height. According to the formulas proposed by Goldberg et al. (14), we calculated individual “CUT-OFF 2” values (Table 1) using coefficients of variation for EI (24 % for 1 to 5 year olds; 23 % for other age groups) given by Nelson et al. (25) and recently published levels of light physical activity (1.45 to 1.60 depending on age and sex) given by Torun et al. (30). We used these recalculated individual limits instead of the single “CUT-OFF 2” for adults as proposed by Goldberg et al. Thus, records with EI:BMR ratios up to 0.97 or 1.07 (Table 1) depending on the subject’s age and sex was considered as a not plausible measurement of the actual 3d energy intake in our further analysis.

Anthropometry

The subjects (undressed to vest and underpants) were weighed (to the nearest 0.1 kg) with an electronic scale (Seca 753 E) or alternatively with a supine infant weighing scale (Mettler PS 15) and had their height measured (to the nearest 1 mm) in a standing position using a digital telescopic wall-mounted stadiometer (Harpenden) or alternatively a supine measuring table for toddlers.

Data analysis

SAS procedures (Version 6.11) were used for data analysis. Age and sex group specific intakes were calculated from the individual means of the 3 record days. Differences between groups of not plausible (NPR) and plausible records (PR) were tested with Wilcoxon 2 samples test and Chi^2 and mean ranks of EI over the 3d recording period with Friedman test. P-values < 0.05 were taken as significant. Results throughout the text are median values.

Results

From the total of 1 032 subjects 52 (5 %) were identified as underreporters because of NPR based on recalculated cut-off values (Table 1). Underreporting was age and sex dependent as shown by the proportion of underreporters of about 1 % in the 1 to 5 year old children, 2 % (3 %) in the 6 to 13 year old males (females), and 12 % (20 %) in the adolescent males (females), respectively. Using the tabulated “CUT-OFF 2” = 1.06 for adults (14), there was only a small difference of NPR in the age groups under 14, but female adolescents had quite lower incidences of NPR after recalculating cut-off values (Table 1). To analyse differences between subgroups with PR vs. NPR we, therefore, concentrated on the subsample of the 14 to 18 year old adolescents in this paper.

In the total sample of the 14 to 18 year olds, males had a higher total EI and EI:BMR ratio than females (10.7 MJ/d vs. 7.4 MJ/d; 1.44 vs. 1.25, respectively; Table 2). Without underreporters EI:BMR ratios were 1.51 (1.33) in males (females), respectively (Table 3). Male (female) subjects with NPR had a 40 % lower total EI than subjects with PR: 7.4 MJ/d (5.3 MJ/d) vs. 11.5 MJ/d (8.0 MJ/d), respectively, and there was no significant difference in age between the groups with NPR vs. PR of males or females (Table 3).

The range of the distribution of EI and predicted BMR was quite different for males or females (Fig. 1). Measurements of male underreporters scatter closer to the cut-off line (EI:BMR = 1.07) than those of females (EI:BMR = 0.97), suggesting only a slight underreporting of EI in males in comparison to a pronounced underreporting in females.

Table 3 Personal and dietary characteristics in the subgroups of 14 to 18 year old males and females with PR and NPR

	Males							Females						
		PR			NPR				PR			NPR		
	MED	P10	P90	MED	P10	P90	p-Value[1]	MED	P10	P90	MED	P10	P90	p-Value[1]
Age (Years)	15.7	14.3	18.4	14.8	14.1	18.1	0.3389	17.5	15.6	18.7	17.2	15.5	18.9	0.5265
BMI (kg:m^2)	20.3	17.9	23.5	20.7	18.3	32.6	0.1128	20.8	18.5	24.8	21.9	19.0	25.6	0.0312
EI:BMR	1.51	1.23	2.17	1.02	0.47	1.07	0.0001	1.33	1.04	1.79	0.85	0.62	0.96	0.0001
EI:Meal (MJ)	2.03	1.35	3.04	1.51	1.09	3.09	0.0184	1.34	0.9	1.94	1.09	0.82	1.28	0.0001
Meals (n:d)	5.7	4.0	8.7	5.0	3.0	7.3	0.0877	6.0	4.0	8.7	4.5	3.7	7.0	0.0001
Time range of meals (hrs)	12.5	10.8	14.2	10.7	8.5	19.2	0.0590	12.6	10.3	14.8	11.7	9.6	13.6	0.0032
Amounts as usual, %[2]	52	35	68	35	0	61	0.0064	48	35	65	39	26	68	0.0543
More as usual, %[2]	26	12	48	39	0	57	0.0312	35	14	52	36	12	59	0.2535

MED = Median; P10, P90 = 10th, 90th Percentile; [1] Wilcoxon 2-Sample Test; [2] in % of 25 food groups

Table 4 Record keeping and questionnaire results (% of subjects) in 14 to 18 year old males and females with PR and NPR

	Males			Females		
	PR %	NPR %	p-Value Chi² Test	PR %	NPR %	p-Value Chi² Test
Record Keeping						
Subject recorded	84.4	77.8	0.617	96.9	90.6	0.119
> 90 % weighed amounts	75.0	66.7	0.594	83.0	81.3	0.821
Record only on weekdays	51.6	88.9	0.035	57.4	62.5	0.598
Questionnaire						
Study influenced intake	24.6	66.7	0.010	24.4	22.6	0.831
No unusual record days	90.2	66.7	0.049	89.8	93.6	0.519
Healthy on record days	98.4	100.0	0.699	94.5	96.8	0.603
Normal eating behavior on record days	77.1	77.8	0.961	59.2	66.7	0.452

Female subjects with NPR had a significantly higher body mass index (BMI, kg:m^2), recorded fewer meals per day and had a shorter time span between the first and last meal per day than subjects with PR (Table 3). However, in male subjects there were no such differences. In both sexes EI per meal was significantly lower in NPR than in PR.

In the questionnaire male subjects with NPR answered significantly more often that they usually eat more from 25 food groups than subjects with PR. The results of food group questionnaire in females displayed the same tendency, however, without significance (Table 3).

Other dietary habits, for example, frequency of cold meals, snacks, and eating occasions (at home; not at home; food taken from home, eaten not at home; in restaurants or outdoors), showed no significant differences between NPR and PR (Table 4). Female subjects with NPR ate warm meals significantly more often than subjects with PR.

About 24 % of the females with PR and NPR and 25 % of males with PR stated in the questionnaire that record keeping had influenced their food habits (Table 4), whereas 67 % of males with NPR mentioned eating less than usual or modificating their usual diet.

Almost all females (about 90 to 94 %) with PR and NPR as well as males with PR (90 %) but only 67 % of males with NPR remembered no unusual situations (i.e., parties, holidays, activity) on the days of recording (Table 4). Almost all (95 to 100 %) respondents correspondingly stated they were in good health during the recording period.

Of the female subjects 59 % (PR) vs. 67 % (NPR) but about 78 % of males (PR, NPR) thought they were persons with normal eating behavior and about 20 % vs. 22 % of females and 15 % vs. 22 % of males (PR vs. NPR respectively) considered themselves to be a person eating too much. About 2 % of females with PR vs. 10 % with NPR supposed they were eating too little. Male subjects never mentioned eating too little (Table 4).

Of the female subjects 57 % with PR vs. 62 % with NPR recorded on weekdays only and of the male subjects 52 % with PR but 89 % with NPR. We found no influence of season on the frequency of NPR in females or males (Table 4).

In about 83 % of the records from the females with PR and NPR, more than 90 % of the food consumed was weighed, whereas 75 % of the males (PR) vs. 67 % (NPR) weighed more than 90 % of their food items. In

Table 5 EI and nutrient intake as percent of energy (% EI) or as nutrient density (g, mg, ug:MJ) in the subgroups of 14 to 18 year old males and females with PR and NPR

	Males							Females						
	PR			NPR				PR			NPR			
	MED	P10	P90	MED	P10	P90	p-Value[1]	MED	P10	P90	MED	P10	P90	p-Value[1]
EI (kcal/d)	2 743	2 193	3 941	1 769	1 125	2 216	0.0001	1 918	1 490	2 633	1 264	914	1 375	0.0001
EI (MJ/d)	11.48	9.18	16.49	7.40	4.71	9.27	0.0001	8.02	6.24	11.02	5.29	3.82	5.75	0.0001
Water (g/MJ/d)	165	130	226	195	125	376	0.0487	189	122	282	208	157	378	0.0202
Carbohydrates (% EI)	48.1	42.2	56.5	47.9	41.3	58.6	0.5403	48.1	42.5	56.8	46.1	42.2	55.3	0.1898
Carboh. (g/MJ/d)	27.9	24.2	32.8	28.0	24.0	34.0	0.5971	27.9	24.5	32.8	26.6	24.8	32.2	0.1986
Sugars (g/MJ/d)	8.1	4.2	13.0	7.1	2.5	18.4	0.6088	7.7	4.5	12.9	4.4	1.9	8.5	0.0001
Fiber (g/MJ/d)	1.8	1.4	2.6	1.9	1.5	2.4	0.6206	1.9	1.5	2.9	2.2	1.6	3.3	0.0397
Protein (% EI)	12.4	10.5	15.6	12.5	9.0	15.2	0.7562	12.9	10.2	15.8	14.1	11.6	16.2	0.0081
Protein (g/MJ/d)	7.2	6.1	9.0	7.3	5.2	8.7	0.7309	7.5	5.9	9.1	8.1	6.7	9.4	0.0082
Animal Prot. (g/MJ/d)	4.5	2.9	6.6	4.8	2.6	5.7	0.6445	4.5	3.0	6.5	5.0	3.3	6.4	0.3310
Animal Protein (% of Protein)	63.1	48.3	72.6	60.9	47.8	70.7	0.4353	62.8	47.6	72.5	60.8	44.1	69.9	0.2680
Fat (% EI)	38.8	31.2	45.4	38.5	32.4	44.9	0.4353	38.0	31.2	45.5	39.2	31.6	43.8	0.8771
Fat (g/MJ/d)	10.0	8.0	11.5	9.9	8.3	11.5	0.4062	9.8	8.0	11.6	10.1	8.1	11.3	0.8538
SFA (g/MJ/d)	4.2	3.3	5.2	4.1	3.6	5.5	0.8078	4.2	3.2	5.2	4.1	3.1	5.2	0.6703
PFA (g/MJ/d)	1.4	0.90	1.9	1.1	0.81	2.7	0.5627	1.5	0.94	2.1	1.5	0.90	2.1	0.7491
MUFA (g/MJ/d)	4.1	3.4	4.9	4.6	3.8	4.9	0.1332	4.1	3.1	5.0	4.0	3.0	5.1	0.9848
P:S	0.33	0.20	0.49	0.26	0.21	0.66	0.4158	0.3	0.21	0.5	0.35	0.21	0.6	0.6734
Cholesterol (mg/MJ/d)	31.6	23.6	48.9	31.2	11.3	42.5	0.6325	29.3	18.9	49.3	29.0	16.0	40.4	0.3933
Sodium (mg/MJ/d)	217	166	290	270	145	322	0.0950	217	148	326	266	189	341	0.0005
Potassium (mg/MJ/d)	283	230	376	274	252	384	0.7690	311	244	404	324	240	426	0.4939
Magnesium (mg/MJ/d)	30.1	24.8	40.8	30.2	27.4	38.1	0.5971	33.0	25.1	40.7	33.4	27.3	47.1	0.1205
Calcium (mg/MJ/d)	90.3	51.5	147	104	68.4	155	0.2867	101	60.3	145	89.6	56.7	163	0.4598
Phosphate (mg/MJ/d)	133	102	176	138	89.9	169	0.7309	137	105	177	138	99.9	190	0.7814
Ca:P	0.68	0.50	0.86	0.82	0.50	1.2	0.0468	0.71	0.5	0.91	0.71	0.42	0.95	0.4649
Iron (mg/MJ/d)	1.2	0.91	1.5	1.1	0.91	1.9	0.9265	1.2	0.93	1.5	1.3	1.1	1.6	0.0068
Zinc (mg/MJ/d)	0.84	0.73	1.2	0.92	0.65	1.1	0.5075	0.86	0.63	1.1	0.95	0.77	1.2	0.0213
Copper (mg/MJ/d)	0.18	0.14	0.24	0.18	0.12	0.24	0.9265	0.17	0.14	0.22	0.18	0.15	0.23	0.1693
Manganese (µg/MJ/d)	287	222	421	269	227	339	0.5292	312	217	512	303	225	578	0.7879
Iodine (µg/MJ/d)	4.4	3.5	8.4	4.4	2.5	6.0	0.5183	4.8	3.6	10.7	4.6	3.5	11.3	0.4345
Vit. A µg/MJ/d)	55.6	36.0	111	62.0	16.9	453	0.7948	63.3	32.7	165	66.7	43.8	131	0.4859
Vit. E (µg/MJ/d)	741	465	1 481	733	565	2 603	0.7058	857	525	1 480	767	498	1 874	0.5688
Thiamin (µg/MJ/d)	104	72.8	151	104	66.5	146	0.4758	104	71.9	163	108	73.69	198	0.9140
Riboflavin (µg/MJ/d)	149	96.0	245	142	83.2	228	0.7562	147	90.6	216	134	82.5	254	0.2848
Vit. B6 (µg/MJ/d)	117	90.3	195	112	92.0	380	0.9933	127	87.6	204	123	87.2	273	0.9510
Niacin (mg/MJ/d)	2.7	2.0	3.9	2.6	2.3	5.1	0.6934	2.7	2.0	3.5	2.9	2.3	4.6	0.0287
Vit. C (mg/MJ/d)	8.7	4.4	14.6	9.3	3.9	30.1	0.4062	10.8	5.3	21.2	10.1	4.8	23.1	0.5377
Folate (µg/MJ/d)	14.5	10.6	30.8	16.5	12.5	55.0	0.2238	15.6	9.9	27.5	17.1	12.1	35.7	0.2466

MED = Median; P10, P90 = 10th, 90th Percentile; [1] Wilcoxon 2-Sample Test

females 97 % with PR vs. 91 % with NPR kept the 3d dietary records themselves and 78 % vs. 84 % of the males respectively (Table 4).

Grouping according to EI of NPR vs. PR necessarily leads to significant differences if absolute nutrient intakes are tested. We, therefore, used energy related variables, i.e., nutrient intake:MJ, energy-yielding nutrient intake in percent of total EI or nutrient ratios like calcium to phosphate (Ca:P), total to animal protein (T-Prot:A-Prot), and polyunsaturated to saturated fatty acids (P:S).

Male subjects with NPR had a significantly higher water intake per MJ and a higher Ca:P than subjects with PR (Table 5). According to the other nutrients or ratios there were no significant differences in males with PR and NPR.

Female subjects with NPR had significantly higher intakes per MJ of water, protein, fiber, sodium, iron, niacin, zinc, and of protein in percent of total EI, but a significantly lower intake of added sugars per MJ than subjects with PR (Table 5).

In male subjects we found significantly higher coefficients of variation in NPR for vitamin B_1, niacin, folate, vitamin B_6, manganese, calcium, and fiber in comparison to PR. With a few exceptions only, NPR of female subjects had significantly higher coefficients of variation than PR (figures not shown).

In all of the four adolescent sub-samples ranking individual EI over the 3d recording period showed a characteristic tendency (significant in females with PR) of a decreasing EI over the period of time (Fig. 2).

Discussion

Even in nutrition surveys with motivated participants and carefully collected dietary data, bias due to underreporting was observed (3, 5), especially when EI was validated against the doubly labeled water method to measure energy expenditure (20). We have chosen a statistical validation procedure ("CUT-OFF 2") as proposed by Goldberg et al. (14) to identify not plausible dietary records. This method is highly recommended for the validation of nutritional surveys (13) and can be applied ex post. Other techniques, e.g., biochemical markers (mostly urinary nitrogen excretion or doubly labeled water) are compli-

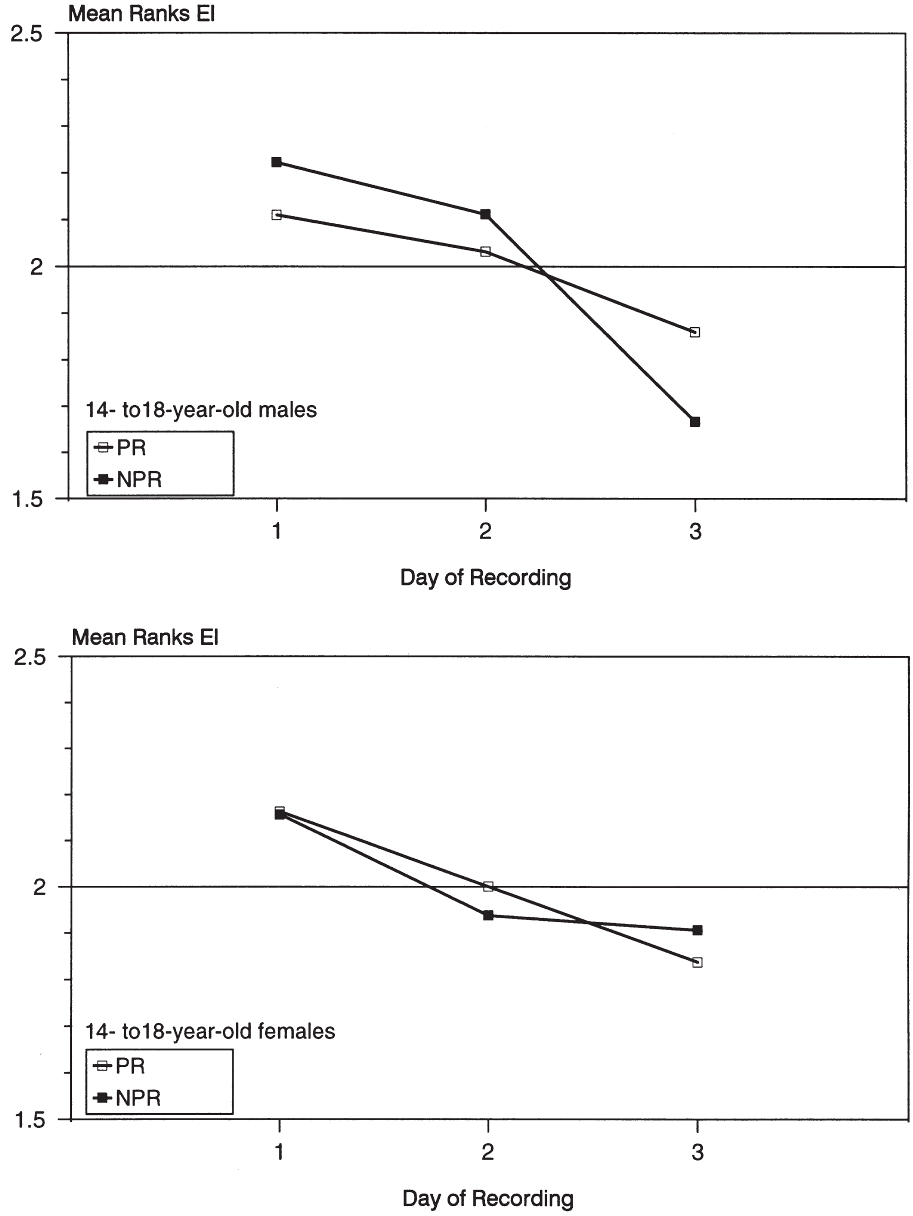


Fig. 2 Mean ranks of energy intake of the 3 record days in 14 to 18 year old males and females with PR and NPR.

cated, more expensive or unsuited for large population studies.

The calculations of Goldberg et al. refer to an assumed habitual physical activity level (Total Energy Expenditure:BMR) in adults of 1.55. For our study population the recent published physical activity levels of light physical activity in children and adolescents (1.45 for 1 to 5 year old children, 1.55 (1.50) for 6 to 13 year old males (females) and 1.60 (1.45) for 14 to 18 year old males (females) estimated to update the 1985 WHO/FAO energy requirement data seemed to be most appropriate (17). With these physical activity levels the recalculated cut-off values are lower than the single cut-off according to Goldberg et al. (14) with the exception of 14 to 18 year old males (cf. Table 1). Furthermore, age-specific coefficients of variation in EI can be taken into account with recalculation. And since the cut-off values given by Goldberg et al. are only tabulated for recording periods of 1 day or 4, 7, 14, and 28 days, recalculating cut-off values for a 3d dietary record seemed appropriate in the present study.

Even with the recalculated age- and sex-specific cut-off values, we found increasing proportions of NPR with age. Furthermore, there were slightly less frequent NPR in under 14 year old girls compared with boys. In contrast the 14 to 18 year old female adolescents had about twice as much NPR as males. All in all, recalculation of cut-off values reduced the proportion of NPR in females from 10 % to 6 % (and from 30 % to 20 % in the 14 to 18 year old sub-group) but not in males. Nevertheless, considerable underreporting is still present in our adolescents especially in females.

Other studies in children and adolescents used cut-off values without taking into account age and sex of the subjects. In a study with the dietary history method in 12 and 15 year old boys and girls in Northern Ireland a cut-off of 1.14 (i.e., a "CUT-OFF 2" tabulated for a 28d recording period according to Goldberg et al.) was applied (29). The authors found fewer underreporters in 15 year old girls and boys (13.4 % and 5.6 % NPR, respectively) than we found in our study. In a study with a food frequency questionnaire in Norwegian adolescents (median age 18) a cut-off of 1.35 was used to reflect unlikely habitual dietary intake. The authors report 9 % males and 20 % females with an EI:BMR ratio below this limit (12), which corresponds to our data. In a study of 15 to 18 year old Austrian adolescents with 7d weighed diet records, a cut-off of 1.10 was applied (31). The authors found 18 % and 27 % NPR in males and females, respectively, that is about 40 % more than in the present study.

Excluding subjects with NPR in our sample of 14 to 18 year olds increases EI by about 8 % and EI:BMR ratio by about 6 % in comparison to the total sample. In both sexes subjects with NPR had about 40 % lower EI and about 35 % lower EI:BMR ratios than subjects with PR. In our total sample of 14 to 18 year old adolescents we found a reported EI of 10.7 MJ/d and 7.4 MJ/d for males and females, respectively, (cf. Table 2), which is confirmed by the literature: Briefel et al. (8) reported EI from a 24hr recall in 16 to 19 year olds with 12.2 MJ/d (7.5 MJ/d) in males (females) and Bull et al. (9) found 10.1 MJ/d (7.8 MJ/d) for males (females) in a 14d diary. In a 7d weighed diet record male (female) 15 to 18 year old adolescents with PR vs. NPR had a mean EI of 12.1 MJ/d (8.8 MJ/d) vs. 7.0 MJ/d (5.2 MJ/d), respectively (31). However, in controlled studies with doubly labeled water measuring total energy expenditure:BMR directly, mean ratios in males (females) of 1.75 (1.73) in 13 to 17 year olds (7), 1.81 (1.84) in 15 year olds, and 2.13 (1.77) in 18 year olds (19), respectively, were found. These data are considerably higher than EI:BMR ratios in our total sample of male (female) adolescents of 1.44 (1.25) and in the sub-groups with PR of 1.51 (1.33), respectively, and confirm underreporting in these age groups in our study.

In the present study males and females with NPR had a significantly higher intake of water per energy, lower EI per meal and EI per kg body weight than subjects with PR. For some other variables differences were only significant for females, but showed a similar tendency for males, too, which could not be confirmed due to the small male subgroup with NPR. This was also true for a lower meal frequency, a shorter time span between the first and last meal per day, a lower energy related intake of sugar and for higher energy related intakes of protein, fiber, sodium, zinc and for a higher BMI in subjects with NPR (cf. Table 3, 5). NPR in males had significantly higher Ca:P ratios; NPR in females had significantly higher energy related intakes of iron and niacin, and subjects with NPR ate warm meals more often than subjects with PR. Significant differences in energy related nutrient intakes or other ratios between groups with PR and NPR indicate different food habits or dietary recording behavior in the two samples, as also found by other investigators (31). Therefore, validity in dietary studies cannot be achieved by simply excluding underreporters.

Although there are quite similar results between NPR and PR, we found some pronounced differences between males and females. Males with NPR stated more often that record keeping had influenced intake (cf. Table 4), had more records on weekdays, and more unusual days during the recording period than females with NPR. In the questionnaire concerning consumption of different food groups during the survey, males with NPR said they had eaten normal amounts in 35 % of the food groups (subjects with PR: 52 %). Males with NPR (PR) stated for 39 % (26 %) of food groups that they usually ate more, whereas in females there was no significant difference. This is an important result of the study, because males in contrast to females explained their underreporting to some extent in the questionnaire. EI on the 3rd day ranked lower than on the preceding two days in every sub-group. But only the female adolescents with NPR had about the same level of EI during the last two days of the recording period. Whether this behavior is an indicator of underreporting or not remains unclear.

The observed smaller difference in time range from a day's first to the last meal and a lower meal frequency points to skipping or not recording of meals especially in female adolescents with NPR. Adolescents with NPR had about one meal less and an about 25 % lower EI per meal than adolescents with PR. If subjects with NPR skipped meals (lower meal frequency), this would not necessarily lead to the lower mean EI per meal such as we observed. The observed lower EI per meal points to underrecording during a meal, or subjects with NPR prefer low calorie food or skipped energy rich meals. But females with NPR had warm meals more often than females with PR and warm meals may contain less energy than common cold ones. Other studies in the literature give some explanations for the differences between males and females found in our study. Girls are more concerned about their body image (especially weight) than boys (12, 23). Even subjects of normal weight, who are practicing dietary restraint or are embarrassed about their weight, appear much more likely to generate records with not valid reflection of their habitual diet (22). Studies indicate that dieting accompanied by a fear of obesity is very common among adolescent girls, even in normal or underweight girls (11, 21). In a questionnaire study dietary restraint scores were significantly higher in females than in males. Furthermore, BMI and restraint scores were positively correlated (24). In addition Price et al. (26) identified high BMI as a significant risk factor for NPR in dietary surveys. Therefore, underreporting can be expected in studies with female adolescents to a high degree, because record keeping may be used consciously or sub-consciously to assist in losing weight. Then NPR may be valid – but do not represent the subject's usual intake.

There is still debate as to how to deal with underreporters in dietary studies. Exclusion of underreporters from further analysis reduces the number of subjects markedly (up to 20 %). Bias like underreporting becomes important if absolute levels of intake are to be measured and the presence or absence of deficient intakes are to be determined. At present it remains unclear if underreporting is an observer effect operating on everyone, or if it is attributable to a group of individuals who can be identified and excluded from analysis, or if it is a continuum from poor to good compliance (6). If there are both low eaters and underreporters in the same study the two groups are difficult to identify, epecially due to the small numbers of cases in a sample. To overcome this problem large studies are needed. Additionally, special questionnaires have to be designed to differentiate between the two groups. Ideally underreporting needs to be studied in direct observation of the respondents. However, this is hardly feasible in field studies.

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