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Characteristics of under- and over-reporters of energy intake among 18–20-year-old males: the Gothenburg Osteoporosis and Obesity Determinants (GOOD) study

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Abstract

Objective: To identify and describe characteristics of the bias of reported energy intake of participants in the Gothenburg Osteoporosis and Obesity Determinants (GOOD) study.
Design: A validated diet history with a detailed questionnaire and an interview was used. Body fat was analysed by dual-energy X-ray absorptiometry. The ratio of energy intake (EI) to BMR was used to define under-reporters (EI:BMR < 1·30), acceptable reporters (EI:BMR ≥ 1.30 to <2.64) and over-reporters (EI:BMR ≥ 2.64).
Setting: Sahlgrenska University Hospital, Gothenburg, Sweden.
Subjects: A total of 695 males (18–20 years).
Results: Sixty-eight per cent were classed as acceptable reporters, 22 % as over-reporters and 10 % as under-reporters. The under-reporters had higher BMI and body fat percentage than acceptable reporters ($P < 0·001$), while over-reporters had lower BMI and body fat percentage ($P < 0·001$). Over-reporters had more frequent use of protein supplements than acceptable reporters and higher physical activity. Over-reporters had a more regular and under-reporters a less regular meal pattern compared with acceptable reporters.
Conclusions: Important knowledge of dietary reporting bias in a previously sparsely studied population has been provided. Over-reporting of energy intake was more common than under-reporting in the present population of young men and characteristics of under- and over-reporters were identified. The GOOD study was initiated with the central aim to determine environmental and genetic factors involved in the regulation of bone and fat mass, and the nutrient data of the acceptable reporters can be used for further investigation of the health effects of energy and nutrient intake.

Keywords
Over-reporting
Under-reporting
Dietary assessment
Energy intake
Body fat

Virtually all dietary assessments are based on self-reported dietary intake, which is frequently biased, resulting in over- or underestimation of the actual energy intake[1]. If subjects are in energy balance, i.e. weight-stable, the energy intake must correspond to the total energy expenditure. The doubly labelled water (DLW) technique is considered the 'gold standard' for determining total energy expenditure[2]; however, the method is expensive and therefore not used in large studies. As an alternative method for detecting misreported energy intake the Goldberg cut-off[3] can be used.

In a review, Black *et al.*[1] concluded that under-reporting and under-eating occur in most dietary assessments, but with varying frequency according to the dietary assessment method used. Several characteristics of under-reporters, such as high BMI, high body fat percentage, food-specific reporting, low intake of fat, and high intake of protein and micronutrients, have been presented[4–13].

Only a few studies have investigated the frequency and characteristics of over-reporting. Young, lean males have been found to be a group with a relatively high prevalence of over-reporting[9,12], but data are sparse. The interpretation of relationships between diet and other variables can lead to false conclusions if bias in reported energy intake is not identified[1].

The primary aim of the present study was to identify bias in reported energy intake and describe anthropometric and dietary characteristics of the over- and under-reporters in a group of young males participating in the Gothenburg Osteoporosis and Obesity Determinants (GOOD) study. Following this, the second aim was to

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identify the acceptable reporters for further evaluation of the association of energy and nutrient intake with bone status and fat mass investigated in the GOOD study.

Subjects and methods

Study design and subjects

The GOOD study was initiated with the aim to determine both environmental and genetic factors involved in the regulation of bone and fat mass[14–17]. The GOOD study was approved by the ethics committee at Göteborg University and data were collected between February 2003 and December 2003. To be included in the GOOD study, subjects had to be males between 18 and 20 years of age and willing to participate in the study. Study subjects were randomly identified using national population registers, contacted by telephone, and asked to participate in the study. Of the contacted study candidates 48·6 % agreed to participate. A total of 1068 men, mean age 18·9 (SD 0·6) years, from the greater Gothenburg area, were included. The majority (98 %) of the included subjects were white. The subjects underwent measurement of height and weight and a dual-energy X-ray absorptiometry (DXA) scan.

Of the total of 1068 subjects, 702 were randomly selected and asked to participate in the dietary assessment. Two trained dietitians informed the participants about the dietary assessment and asked about willingness of further participation. The dietitians administered the whole dietary assessment and the dietary assessment was performed on the same occasion as the other examinations.

Diet history

The dietary assessment consisted of a detailed questionnaire, previously validated with the DLW technique[18], and a personal complementary interview. In the original questionnaire the lunch section captured school meals and this section was revised to cover all participants, whether attending school or not.

The questionnaire was divided into seven sections: breakfast; lunch; dinner; in-between meals; weekends; other foods; and supplements (vitamin/mineral and protein). The definition of breakfast was the first meal eaten in the morning consisting of either sandwiches or cereals and at least one milk product or a fruit/juice or a meat/fish/egg product. Lunch was defined as a meal eaten in the middle of the day between 11.00 and 14.00 hours, and dinner as the main meal in the afternoon or in the evening. Both lunch and dinner could consist either of a prepared warm or cold meal, or a sandwich- or cereal-based meal. Other intake was defined as in-between meals. Portion sizes of foods were described in terms of household measures, standard weights and by photographs of portions of known weights.

Each record was checked by the dietitian and reviewed together with the subject for completion if necessary. The subjects were interviewed to obtain additional information about their food habits. An interview protocol was followed to assess the habitual size/amount of bread, cheese, ham, sausage and spread consumed, and utilised a pamphlet, from the Swedish National Food Administration, with pictures of various portion sizes to aid in the determination of food intake. The interview protocol also contained questions about frequency and amount of 'fast food' intake.

Anthropometric measurements

Height and weight were measured with subjects in underwear, without shoes, using standardized equipment. The CV values were below 1 % for these measurements.

Dual-energy X-ray absorptiometry

Body fat was analysed with the Lunar Prodigy DXA instrument (GE Lunar Corp., Madison WI, USA) using the method described elsewhere[19].

Physical activity and lifestyle factors

A standardized questionnaire was used to collect information about the amount of physical activity (hours per week, duration in years) and use of tobacco (cigarettes and moist snuff)[15].

Calculations and statistical analyses

BMI was calculated from weight (kg) divided by the square of height (m^2). BMR was calculated from the standard equation for men aged 18–30 years including weight and height[20]. Food intake level (FIL)[21] was calculated from the ratio of energy intake (EI; from the diet history) and predicted BMR.

Nutrient calculations were performed in the Diet 32 software package (Aivo, Solna, Sweden), which utilizes the Swedish Food Data Base (Updated 2001) of the Swedish National Food Administration. Intake of food and protein-based supplements was included in the calculations. Data on the nutrient content of protein supplements were added to the database. Intake of vitamin and mineral supplements was recorded but kept separate and not included in the analysis.

Energy density, as intake per 10 MJ, was used to adjust macro- and micronutrient intakes for energy intake.

Participants with an energy intake higher than the mean +2 SD or lower than mean −2 SD were considered to be extreme outliers and thus excluded from the analyses.

The classification of under-reporters, acceptable reporters and over-reporters was made according to the Goldberg cut-off[3,22]. The physical activity level (PAL)[23] used for the calculations was set to 1·85, which corresponds to an average PAL for males aged 18–29 years[24]. According to the calculation of the Goldberg cut-off, the lower cut-off limit of PAL was 1·30 and the upper

Table 1 Anthropometry and other characteristics of 18–20-year-old males by reporting status

	Under-reporters (*n* 69)			Acceptable reporters (*n* 476)			Over-reporters (*n* 150)			One-way ANOVA§
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	
Anthropometry										
Height (cm)	182·8	6·7	163·0, 200·0	181·4	6·7	161·0, 202·8	181·7	6·9	167·5, 203·0	0·259
Weight (kg)	82·7***	14·8	58·4, 127·0	74·1†††	11·3	47·6, 122·3	69·2‡‡‡	8·6	51·3, 104·7	<0·001
BMI (kg/m^2)	24·8***	4·1	18·7, 38·5	22·5†††	3·1	16·4, 36·5	20·9‡‡‡	2·4	16·1, 32·9	<0·001
Body fat (%)	24·0***	8·6	7·6, 39·7	17·5†††	7·0	5·2, 44·4	13·5‡‡‡	4·2	4·6, 31·8	<0·001
Behavioural factors										
Smoking (%)	10·1		–	6·9		–	8·0		–	0·615‖
Snuff (%)	21·7		–	26·5		–	32·7		–	0·181‖
Physical activity (h/week)	3·4	4·4	0, 24·5	4·4†	4·7	0, 24·0	5·6‡‡	6·2	0, 39·0	0·003
Age (years)	18·9	0·6	–	18·9†	0·5	–	18·7‡	0·5	–	0·012

Mean values were significantly different compared with those of the acceptable reporters: ***$P<0·001$.
Mean values were significantly different compared with those of the over-reporters: †$P<0·05$, †††$P<0·001$.
Mean values were significantly different compared with those of the under-reporters: ‡$P<0·05$, ‡‡$P<0·01$, ‡‡‡$P<0·001$.
§One-way ANOVA *post hoc* Bonferroni's *t* test.
‖χ^2 test.

cut-off limit was 2·64. Hence under-reporters, acceptable reporters and over-reporters were defined from the EI:BMR ratio: <1·30 for under-reporters, ≥1·30 to <2·64 for acceptable reporters and ≥2·64 for over-reporters.

The different groups were compared using one-way ANOVA. When the overall *P* from ANOVA was <0·05 the *post hoc* Bonferroni test was performed. Qualitative data differences between the groups were tested with the χ^2 test. For all statistical calculations the Statistical Package for the Social Sciences (SPSS for Windows) statistical software package version 11·5 (SPSS Inc., Chicago, IL, USA) was used.

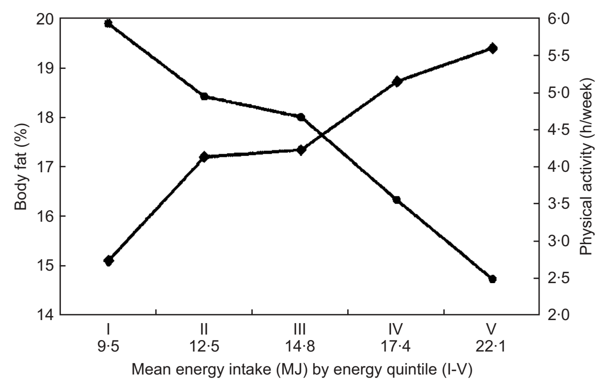

Fig. 1 Body fat percentage (—●—) and physical activity (—◆—), by energy quintile, among the total population (*n* 695) of 18–20-year-old males

Results

There was no difference in height, weight, BMI or percentage of body fat (using an independent samples *t* test) between the subjects participating in the dietary assessment and the other GOOD participants.

Of the 702 subjects who were asked to participate in the dietary assessment, two subjects did not want to participate and five subjects were excluded because of incomplete diet histories. Mean energy intake from food and protein supplements of the 695 participants was 15·9 (SD 5·6) MJ. Sixty-eight per cent were classed as acceptable reporters, 22 % as over-reporters and 10 % as under-reporters.

Anthropometry and other characteristics of the under-, acceptable and over-reporters are shown in Table 1. Compared with acceptable reporters, the under-reporters had significantly higher body weight, BMI and body fat percentage (all $P<0·001$) while the over-reporters had significantly lower body weight, BMI and body fat percentage (all $P<0·001$). Forty-one per cent of the under-reporters, 17 % of the acceptable reporters and 3 % of the over-reporters were overweight or obese (BMI ≥ 25 kg/m^2). None of the under-reporters, 6 % of the acceptable reporters and 11 % of the over-reporters were underweight, defined as BMI < 18·5 kg/m^2. The over-reporters were significantly more physically active than both acceptable reporters ($P<0·05$) and under-reporters ($P<0·01$). Forty-three per cent of the under-reporters reported no physical activity compared with 34 % of the acceptable reporters and 31 % of the over-reporters. Fifty-nine per cent of the under-reporters were physically active for <3.5 h/week compared with 49 % of the acceptable reporters and 40 % of the over-reporters. Sixteen per cent of the under-reporters reported to be physically active for ≥7 h/week compared with 27 % of the acceptable reporters and 37 % of the over-reporters. The relationship between body fat percentage and physical activity by energy quintile for the total population is presented in Fig. 1. Body fat percentage decreased while physical activity increased with increasing energy intake. Mean energy intake, BMR and FIL differed significantly by reporting group (under-, acceptable, over-reporters; Table 2).

Energy-adjusted intakes of macro- and micronutrients are presented in Table 3. Compared with acceptable reporters, the under-reporters had a significantly higher density of

Table 2 Energy intake, BMR and food intake level (FIL) of 18–20-year-old males by reporting status

	Under-reporters (*n* 69)			Acceptable reporters (*n* 476)			Over-reporters (*n* 150)			
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	One-way ANOVA§
Energy intake (MJ)	8·7***	1·6	4·2, 12·9	14·5†††	2·8	8·7, 22·3	23·9‡‡‡	5·0	16·7, 50·1	<0·001
BMR (MJ)	8·1***	0·9	6·6, 10·9	7·5†††	0·7	5·9, 10·6	7·2‡‡‡	0·5	6·1, 9·5	<0·001
FIL	1·07***	0·17	0·58, 1·30	1·92†††	0·36	1·31, 2·63	3·31‡‡‡	0·68	2·64, 6·67	<0·001

Mean values were significantly different compared with those of the acceptable reporters: ***$P<0·001$.
Mean values were significantly different compared with those of the over-reporters: †††$P<0·001$.
Mean values were significantly different compared with those of the under-reporters: ‡‡‡$P<0·001$.
§One-way ANOVA *post hoc* Bonferroni's *t* test.

carbohydrates, dietary fibre, Fe and vitamin C ($P<0·05$, $<0·05$, $<0·001$ and $<0·001$, respectively) and a significantly lower density of fat and Ca ($P<0·05$ and $<0·01$, respectively). The over-reporters had a significantly higher density of fat ($P<0·001$) and retinol ($P<0·01$), while the density of carbohydrates, protein, dietary fibre, Fe (all $P<0·001$) and vitamin C ($P<0·01$) was significantly lower compared with acceptable reporters.

Energy-adjusted intakes of different food groups are presented in Table 4. Compared with acceptable reporters the under-reporters had a significantly higher energy-adjusted intake of vegetables ($P<0·01$), fast foods ($P<0·05$) and potatoes/rice/pasta ($P<0·001$) while the intake of cheese was significantly lower ($P<0·01$). The over-reporters had a significantly higher intake of spreads and a significantly lower intake of vegetables and potatoes/rice/pasta (all $P<0·001$) than the acceptable reporters.

The over-reporters had the highest incidence of total supplement intake (Table 5). Weekly intake of protein supplements was reported by 15 % of the over-reporters, 6 % of the acceptable reporters and none of the under-reporters.

The over-reporters had a more regular meal pattern than both the under-reporters and the acceptable reporters (Table 6). Eighty-two per cent of the over-reporters ate breakfast, lunch and dinner five or more times per week compared with 70 % of the acceptable reporters and 52 % of the under-reporters.

Discussion

According to the present study over-reporting of energy intake is more common than under-reporting among males aged 18–20 years. Earlier studies of under- and over-reporters have mainly investigated either very wide age spans or younger ages. The prevalence of under-reporters in the present population was 10 % compared with 16 % seen in a group of 16–19-year-olds in a Norwegian study[9]. In the same age group in the Norwegian study, 23 % were classed as over-reporters *v.* 22 % in the present study.

A methodological limitation of the present study is that information about the participant's habitual total daily physical activity is lacking and therefore an estimation of individual energy requirements cannot be done. This means that there still can be unidentified under-reporters and over-reporters among the acceptable reporters. Despite this limitation we assume that the reported energy intake of the identified under-reporters and over-reporters is biased. A PAL of 1·35 is classed as the minimum for healthy individuals under normal circumstances[3] and the lower PAL cut-off in the present study was set to 1·30. The upper PAL cut-off was set to 2·64 and the highest PAL representing a sustainable lifestyle is 2·5[24]. An interesting finding was the inverse relationship between body fat percentage and physical activity when the population was divided into quintiles according to energy intake (as shown in Fig. 1). This shows that the physical activity captured could be a fair marker of the total physical activity.

There was no difference in height, weight, BMI or body fat between the subjects participating in the dietary assessment and the other GOOD participants, demonstrating that the dietary assessment group is representative of the whole GOOD cohort. Both mean BMI and body fat and the prevalence of overweight and obesity were markedly higher among the under-reporters, confirming the associations seen in earlier studies[4–7,9,10,13,25]. The over-reporters had significantly lower BMI and 97 % of them had a BMI below 25 kg/m^2, as compared with 88 % in the study by Johansson *et al.*[9]. The under-reporters spent less time on physical activities than others, which has also been seen in previous studies[9,10]. The lower physical activity could be related to the higher prevalence of overweight among the under-reporters.

Earlier studies have reported several differences in food and nutrient intake between under-, over- and acceptable reporters of which some were also found in the present study. The significantly higher percentage of energy derived from fat reported by the over-reporters was also seen in the study by Johansson *et al.*[9], as was the higher energy-adjusted intake of edible fats and the lower energy-adjusted intake of vegetables, fibre and vitamin C. The lower percentage of energy derived from fat as well as the higher energy-adjusted intake of Fe, vitamin C, vegetables and potatoes seen for the under-reporters in the current study have been described previously[6,7,9,11].

Table 3 Energy-adjusted daily intake of nutrients of 18–20-year-old males by reporting status and in total population

Nutrient	Under-reporters (*n* 69)			Acceptable reporters (*n* 476)			Over-reporters (*n* 150)			One-way ANOVA§	Total population (*n* 695)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range		Mean	SD	Range
Fat (g/10 MJ)	75**	17	29, 122	82†††	17	29, 141	95‡‡‡	19	48, 138	<0·001	84	19	29, 141
Carbohydrate (g/10 MJ)	304*	34	227, 373	290†††	37	169, 423	268‡‡‡	38	186, 367	<0·001	287	38	169, 423
Protein (g/10 MJ)	103	19	51, 141	102†††	19	43, 201	94‡‡	17	58, 149	<0·001	101	19	43, 201
Alcohol (g/10 MJ)	10·5	12·1	0, 54·8	10·5	11·3	0, 93·6	10·3	8·9	0, 49·4	0·984	10·5	10·9	0, 93·6
Sucrose (g/10 MJ)	52	27	15, 143	49	28	5, 183	48	28	2, 141	0·723	49	28	2, 183
Dietary fibre (g/10 MJ)	18·6*	5·4	8·6, 32·2	17·0†††	4·7	5·6, 46·8	15·2‡‡‡	3·9	6·6, 28·0	<0·001	16·8	4·7	5·6, 46·8
Ca (mg/10 MJ)	1301*	475	387, 2799	1482	514	304, 3298	1422	426	418, 3008	0·012	1451	495	304, 3298
Retinol (μg/10 MJ)	806	422	202, 2505	869††	378	107, 2955	973‡‡	348	284, 2557	0·003	885	379	107, 2955
Vitamin D (μg/10 MJ)	6·8	2·4	1·5, 12·2	7·3	2.9	0·8, 20·0	7·0	2·3	1·6, 13·9	0·240	7·2	2·8	0·8, 20·0
Fe (mg/10 MJ)	16·9***	4·1	10·3, 32·6	14·2†††	3·0	6·8, 26·7	12·2‡‡‡	2·3	7·4, 19·6	<0·001	14·0	3·2	6·8, 32·6
Vitamin C (mg/10 MJ)	187***	125	27, 583	150††	96	15, 739	121‡‡‡	74	12, 417	<0·001	147	97	12, 739

Mean values were significantly different compared with those of the acceptable reporters: *$P < 0·05$, **$P < 0·01$, ***$P < 0·001$.
Mean values were significantly different compared with those of the over-reporters: ††$P < 0·01$, †††$P < 0·001$.
Mean values were significantly different compared with those of the under-reporters: ‡‡$P < 0·01$, ‡‡‡$P < 0·001$.
§One-way ANOVA *post hoc* Bonferroni's *t* test.

Table 4 Energy-adjusted daily intake of food groups of 18–20-year-old males by reporting status and in total population

Food group (g/10 MJ)	Under-reporters (*n* 69)			Acceptable reporters (*n* 476)			Over-reporters (*n* 150)			One-way ANOVA§	Total population (*n* 695)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range		Mean	SD	Range
Vegetables	170**	136	0, 541	133†††	98	0, 587	96‡‡‡	67	0, 375	<0·001	129	99	0, 587
Fruits	66	100	0, 485	41	96	0, 1638	26‡‡	38	0, 204	0·008	40	88	0, 1638
Cheese	15**	18	0, 71	27	28	0, 177	30‡‡‡	30	0, 155	<0·001	27	28	0, 177
Milk products‖	550	411	0, 1607	680	442	0, 2479	633	385	0, 2424	0·045	657	429	0, 2479
Crisps and other snacks	11	14	0, 75	13	17	0, 124	13	16	0, 83	0·476	13	16	0, 124
Soft drinks	233	317	0, 1397	215	293	0, 2748	221	273	0, 1419	0·880	218	291	0, 2748
Fast foods	76*	83	0, 439	55	54	0, 469	53‡	48	0, 371	0·008	57	57	0, 469
Potatoes, rice, pasta	338***	137	41, 656	263†††	100	0, 918	193‡‡‡	77	0, 439	<0·001	255	107	0, 918
Spreads	11	10	0, 40	14†††	12	0, 99	19‡‡‡	15	0, 81	<0·001	15	13	0, 99

Mean values were significantly different compared with those of the acceptable reporters: *$P < 0·05$, **$P < 0·01$, ***$P < 0·001$.
Mean values were significantly different compared with those of the over-reporters: †††$P < 0·001$.
Mean values were significantly different compared with those of the under-reporters: ‡$P < 0·05$, ‡‡$P < 0·01$, ‡‡‡$P < 0·001$.
§One-way ANOVA *post hoc* Bonferroni's *t* test.
‖Including milk, soured milk and yoghurt.

Table 5 Weekly intake of supplements of 18–20-year-old males by reporting status

	Under-reporters (*n* 69)		Acceptable reporters (*n* 476)		Over-reporters (*n* 150)		
	%	*n*	%	*n*	%	*n*	χ^2 test
Supplements in total	14	10	16	78	26	39	0·020
Vitamin/mineral supplements	14	10	12	56	13	20	0·750
Energy supplements	0	0	6	27	15	23	<0·001

Table 6 Meal pattern of 18–20-year-old males by reporting status

	Under-reporters (*n* 69)		Acceptable reporters (*n* 476)		Over-reporters (*n* 150)	
Intake	%	*n*	%	*n*	%	*n*
Breakfast						
≤2 times/week	7	5	7	35	3	5
≥5 times/week	86	59	85	406	91	136
Lunch						
≤2 times/week	12	8	4	21	1	2
≥5 times/week	71	49	87	416	94	141
Dinner						
≤2 times/week	3	2	1	7	0	0
≥5 times/week	86	59	92	440	93	140
Main meals						
Breakfast, lunch and dinner ≥5 times/week	52	36	70	335	82	123

The over-reporters had the most regular meal pattern but a significantly lower energy-adjusted intake of vegetables, pasta, potatoes and rice, indicating that a considerable part of their energy intake does not originate from traditional main meals, e.g. lunch and dinner. The high intake of spreads could indicate that intake of in-between meals constitutes a large part of their energy intake. The under-reporters had the most irregular meal pattern but significantly higher energy-adjusted intakes of vegetables, pasta, potatoes and rice which are foods often consumed as part of prepared main meals. An irregular meal pattern does not necessarily correspond to a low energy intake but an irregular meal pattern could affect the ability to report food intake correctly because the diet history method in many ways is dependent on regularity. The fact that the under-reporters had higher mean BMI could possibly affect their ability to report food intake accurately because of a potential desire for weight loss, which has been described earlier[9]. The use of protein supplements in the over-reporters could be an effect of a desire to gain weight in combination with the higher physical activity level.

Despite different dietary assessment methods, PAL cut-offs and study populations, several characteristics of under- and over-reporters found previously were also found in the present study. Characterization of bias in dietary assessment is important in the development of reliable methods and in the analysis of dietary data. Identification of acceptable reporters has provided us with reliable dietary data to be used in further investigations.

Important knowledge of dietary reporting bias in a previously sparsely studied population has been provided. Over-reporting was more common than under-reporting in the present population of young men and characteristics of the over-reporters and under-reporters were identified. The GOOD study was initiated with the central aim to determine both environmental and genetic factors involved in the regulation of bone and fat mass, and the nutrient data of the acceptable reporters can be used for further investigation of the health effects of energy and nutrient intake.

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Author contributions: M.L., D.M. and C.O. were responsible for the design and performance of the GOOD study. S.K., E.H. and L.H. were responsible for the dietary assessment. S.K. and E.H. administered the dietary assessment and analysed the data. S.K., E.H. and L.H. wrote the paper with contributions from the other co-authors.

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