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Prevalence and determinants of misreporting among European children in proxy-reported 24 h dietary recalls

C. Börnhorst[1], I. Huybrechts[2,3], W. Ahrens[1], G. Eiben[4], N. Michels[2], V. Pala[5], D. Molnár[6], P. Russo[7], G. Barba[7], S. Bel-Serrat[8], L. A. Moreno[8], S. Papoutsou[9], T. Veidebaum[10], H.-M. Loit[10], L. Lissner[3] and I. Pigeot[1]* on behalf of the IDEFICS consortium

[1]*BIPS – Institute for Epidemiology and Prevention Research, Achterstraße 30, 28359 Bremen, Germany*
[2]*Department of Public Health, Ghent University, 2 BlokA De Pintelaan 185, 9000 Ghent, Belgium*
[3]*Dietary Exposure Assessment Groups, International Agency for Research on Cancer, Lyon, France*
[4]*Department of Public Health and Community Medicine, University of Gothenburg, Box 454, 40530 Gothenburg, Sweden*
[5]*Nutritional Epidemiology Unit, Department of Preventive and Predictive Medicine, Fondazione IRCSS Istituto Nazionale dei Tumori, Via Venezian 1, 20133 Milan, Italy*
[6]*Department of Pediatrics, Medical Faculty, University of Pécs, József A.u.7 H-7623, Pécs, Hungary*
[7]*Institute of Food Sciences, CNR, Via Roma 64, 83100 Avellino, Italy*
[8]*GENUD (Growth, Exercise, Nutrition and Development) Research Group, Escuela Universitaria de Ciencias de la Salud, Universidad de Zaragoza, Corona de Aragón 42, 2nd floor, 50009 Zaragoza, Spain*
[9]*Research and Education Institute of Child Health, 8 Attikis Street, 2027 Strovolos, Cyprus*
[10]*Center of Health and Behavioral Science, National Institute for Health Development, Hiiu 42, 11619 Tallinn, Estonia*

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Abstract

Dietary assessment is strongly affected by misreporting (both under- and over-reporting), which results in measurement error. Knowledge about misreporting is essential to correctly interpret potentially biased associations between diet and health outcomes. In young children, dietary data mainly rely on proxy respondents but little is known about determinants of misreporting here. The present analysis was conducted within the framework of the multi-centre IDEFICS (Identification and prevention of dietary- and lifestyle-induced health effects in children and infants) study and is based on 6101 children aged 2–9 years with 24 h dietary recall (24-HDR) and complete covariate information. Adapted Goldberg cut-offs were applied to classify the 24-HDR as 'over-report', 'plausible report' or 'under-report'. Backward elimination in the course of multi-level logistic regression analyses was conducted to identify factors significantly related to under- and over-reporting. Next to characteristics of the children and parents, social factors and parental concerns/perceptions concerning their child's weight status were considered. Further selective misreporting was addressed, investigating food group intakes commonly perceived as more or less socially desirable. Proportions of under-, plausible and over-reports were 8·0, 88·6 and 3·4 %, respectively. The risk of under-reporting increased with age (OR 1·19, 95 % CI 1·05, 1·83), BMI *z*-score of the child (OR 1·23, 95 % CI 1·10, 1·37) and household size (OR 1·12, 95 % CI 1·01, 1·25), and was higher in low/medium income groups (OR 1·45, 95 % CI 1·13, 1·86). Over-reporting was negatively associated with BMI *z*-scores of the child (OR 0·78, 95 % CI 0·69, 0·88) and higher in girls (OR 1·70, 95 % CI 1·27, 2·28). Further social desirability and parental concerns/perceptions seemed to influence the reporting behaviour. Future studies should involve these determinants of misreporting when investigating diet–disease relationships in children to correct for the differential reporting bias.

Key words: **Energy intake: Goldberg cut-off: Parental perceptions: Social desirability**

Due to its low respondent burden and easy application, the 24 h dietary recall (24-HDR) is often the method of choice for short-term assessment of dietary intakes in large epidemiological studies. However, numerous sources of measurement error have been encountered when operating with 24-HDR data. Memory of consumption, estimation of portion sizes, decompositions of mixed dishes (unknown recipes), supplement use as well as instrument-based biases are common problems that researchers are confronted with[(1)]. As young children lack the cognitive skills to complete dietary assessments[(2)], 24-HDR data in children younger than 7 years old usually rely on proxy reporters, mainly the

Abbreviations: 24-HDR, 24 h dietary recall; IDEFICS, Identification and prevention of dietary- and lifestyle-induced health effects in children and infants; EI, energy intake; OVR, over-reports; PA, physical activity; PAL, physical activity level; PLR, plausible reports; SACINA, Self-Administered Children and Infants Nutrition Assessment; UNR, under-reports.

* **Corresponding author:** I. Pigeot, fax +49 421 218 56 941, email pigeot@bips.uni-bremen.de

parents[3]. Here additional problems emerge from meals that are not under parental control (e.g. school meals), leading to unintentional misreporting[4–6].

Among these difficulties, biased assessment of energy intake (EI) is often a consequence of intentional under- or over-reporting attributed to specific groups. Anthropometry, for example the actual weight status of the study subject, is a well-known determinant of misreporting[7,8]. Age, sex, socio-economic status, psychosocial and behavioural characteristics are further factors that were found to be related to misreporting[9–11]. The validity of proxy-reported EI might additionally be affected by parental characteristics as well as by psychological factors such as parental perception of their child's weight status[3,12–14]. Further social desirability may result in over-reporting of food items perceived to be healthy while unhealthy/energy-dense food items might be under-reported at the same time[15,16]. Intentional misreporting introduces differential error that may attenuate or even hide associations between dietary factors and health outcomes, whereas non-differential error may distort such associations in any direction.

Recent validation studies based on the doubly labelled water technique in children have revealed inconsistent results concerning misreporting (under-reporting from 19 to 41 %; over-reporting from 7 to 11 % of reported EI)[17] where data relied mainly on self-reports – partially with parental assistance.

Whether the accuracy of proxy reports is comparable to that of self-reports and whether determinants of misreporting coincide for self- *v.* proxy-reports is yet unknown. Several studies have only addressed under-reporting; the nature and extent of over-reporting have rarely been addressed in young populations[10,18,19]. Knowing the degree and direction of misreporting is essential for the assessment of diet–disease relationships as well as for the evaluation of dietary guidelines and nutrition policies. Therefore, the present study aimed to investigate the prevalence and determinants of misreporting (including under- and over-reporting) in a large sample of European children.

Methods

Study population

The IDEFICS (Identification and prevention of dietary- and lifestyle-induced health effects in children and infants) study is a multi-centre setting-based study aiming to prevent and investigate the causes of diet- and lifestyle-related diseases such as overweight and obesity in 2–9-year-old European children. The baseline survey was conducted from September 2007 until June 2008; more than 31 500 children were invited, out of whom, finally, 16 220 participated and fulfilled the inclusion criteria of the IDEFICS study. Details on the design and objectives of the study have been given elsewhere[20–22]. Briefly, children were recruited through schools/kindergartens. Interviews with parents concerning lifestyle habits and dietary intakes as well as anthropometric measurements and examinations of the children were included in the survey. Biomarker information was collected via blood, urine and saliva samples. All measurements were conducted using standardised procedures by all eight centres participating in the study (Italy, Estonia, Cyprus, Belgium, Sweden, Germany, Hungary and Spain).

The present study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by the local ethics committees in each participating country. Parents provided written informed consent for all examinations and for the collection of blood, urine, saliva samples as well as subsequent analysis and storage. Each child was informed orally about the modules by fieldworkers and asked for its consent immediately before examination[22]. Verbal consent was witnessed and formally recorded.

Dietary data

Dietary data were assessed using the computerised 24-HDR 'SACINA' (Self-Administered Children and Infants Nutrition Assessment) based on the previously designed and validated YANA-C ('Young Adolescents' Nutrition Assessment on Computer') developed for Flemish adolescents and further adapted to European adolescents in the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) study[23,24]. The SACINA is structured according to six meal occasions (breakfast, morning snack, lunch, afternoon snack, dinner and evening snack) embedded in questions related to a range of chronological daily activities. Proxies, mainly the parents, completed the 24-HDR under the supervision of fieldwork personnel in about 20–30 min. Except for Cyprus, where school ends at 13.00 hours, school meals were additionally assessed by means of direct observation. Teachers and school kitchen staff were interviewed by trained survey personnel and data were documented using special documentation sheets including portion sizes. School meal data were merged with the parentally reported 24-HDR data to enhance completeness of dietary intakes. The 24-HDR were assessed on non-consecutive days over the whole week and over the complete IDEFICS assessment period. The assessment procedure in Hungary slightly differed from the other study centres. Here dietary information was recorded on documentation sheets and entered into the SACINA program afterwards.

The uniquely coded food items were linked to country-specific food composition tables. Missing quantities for single food items as well as obviously implausible data entries were imputed by country, food group and age-specific median intakes (0·01 % of the entries) to avoid excessive record exclusions. Although up to six repeated 24-HDR were carried out in a smaller sample, only the first recall day was included in the present analysis (including weekdays and weekend days) to obtain an equal number of 24-HDR for each child and to achieve an adequate statistical power for a cross-country analysis. Incomplete interviews were excluded, for example if the proxy did not know about at least one main meal or in case of missing school meal information. Further, intakes of more than 16 736 kJ/d (4000 kcal/d) were excluded (*n* 10).

Anthropometry

Height (cm) of the children was measured to the nearest 0·1 cm with a calibrated stadiometer (model: telescopic height measuring instrument SECA 225 Stadiometer; SECA).

Body weight (kg) was measured in the fasting state in light underwear on a calibrated scale accurate to 0·1 kg (model: electronic scale TANITA BC 420 SMA with an adapter; Tarita Europe GmbH).

Covariables

A set of covariables previously found to be related to misreporting in adults or expected to be relevant in children[9,11,23,24] was defined to explore the determinants of misreporting in this young study population: age, sex, BMI *z*-scores according to Cole *et al.*[25,26] and average audio-visual media time (h/week) of the child, age, sex and self-reported BMI of the proxy, educational level (maximum of both parents, dummy: high *v.* medium/low) according to the International Standard Classification of Education (ISCED 1997, UNESCO Institute for Statistics: Montreal, 2006), net household income (dummy: high *v.* medium/low) and number of persons below 18 years of age in the household as indicators for socio-economic status, the interview day (dummy: weekday *v.* Saturday/Sunday), assessment of a school meal (dummy: yes *v.* no) and the use of a day-care service or babysitter (dummy: yes *v.* no) were considered.

The following information on parental concerns/perceptions of their child's weight status was included where the questions were obtained from previously validated questionnaires[27,28] and slightly modified for use in IDEFICS: 'How concerned are you about your child' – (1) 'eating too much when you are not around him/her?'; (2) 'having to diet to maintain desirable weight?'; (3) 'becoming overweight?'; (4) 'becoming underweight?' (answer categories: 'Unconcerned', 'A little concerned', 'Concerned' or 'Very concerned'); 'Do you think your child is' – (1) 'Much too underweight?'; (2) 'Slightly too underweight?'; (3) 'Proper weight?'; (4) 'Slightly too overweight'; (5) 'Much too overweight?' (answer categories: 'Yes' or 'No'). The rationale behind this was the assumption of parental concerns/perceptions being associated with misreporting. Furthermore, the question 'Do you sit down with your child when he/she eats meals?' (answer categories: 'Never', 'Rarely', 'Sometimes', 'Often' or 'Always') was included as an indicator for family meal behaviours.

To investigate the degree to which given answers were influenced by social desirability, intakes of the following food items commonly perceived to be healthy/unhealthy were included as predictors for misreporting in a second step: chocolate products; other sugary products (e.g. cakes, biscuits, ice cream); carbonated soft drinks; fruits/vegetables; milk (all as the percentage from total EI per d); water (g/d).

Statistical methods

BMR was estimated using the equations published by Schofield[29] and recommended by the FAO/WHO/UNU (1985) taking into account age, sex, body height and weight. Goldberg *et al.*[30] defined cut-off values to classify the 24-HDR in under-reports (UNR), plausible reports (PLR) and over-reports (OVR), respectively. The cut-offs make allowance for the errors associated with the duration of dietary assessment (number of recall days), the sample size as well as the variation in BMR, physical activity (PA) level (PAL) and EI. Minimum/maximum plausible levels of EI are defined as multiples of BMR. Since these cut-offs were developed for adults without considering differences in EI due to age and sex, adaptations are required for application in children.

Upper and lower cut-off values to identify plausible/implausible reports of EI were calculated substituting Goldberg's single cut-off 2[30] by age- and sex-specific cut-offs for children, as suggested previously[11,31], using the following formula:

$$\text{Cut-off} = \text{PAL} \times \exp\left[\pm 1{\cdot}96 \times \frac{(S/100)}{\sqrt{n}}\right].$$

where

$$S = \sqrt{\frac{\text{CV}_{\text{wEI}}^2}{d} + \text{CV}_{\text{wBMR}}^2 + \text{CV}_{\text{PA}}^2}.$$

The within-subject CV for EI (CV_{wEI}), the within-subject CV for BMR (CV_{wBMR}) and the CV for PA (CV_{PA}) were replaced by age- and sex-specific reference values as given in Nelson *et al.*[32] and Black[33]. The number of days (d) was set to one as the analysis is based on one 24-HDR per child. Goldberg's overall level of 1·55 for PA was substituted by age- and sex-dependent levels of light PA (2–5 years: 1·45; 6–10 years: males 1·55, females 1·50) according to Torun *et al.*[34]. All reference values used are summarised in Table 1. The resulting age- and sex-specific cut-off values to define UNR, PLR and OVR are given in Table 2. Records were classified as UNR, PLR and OVR according to the recalculated cut-off values.

Multi-level logistic regression analysis was conducted to identify factors statistically significantly associated with misreporting. Determinants for UNR and OVR were investigated in separate models (model 1a: outcome UNR, reference PLR; model 2a: outcome OVR, reference PLR). In the model addressing UNR, records classified as OVR were excluded and the other way around. All covariables mentioned earlier were entered into the two models except for the dietary variables and the backward selection procedure was applied to screen out the relevant factors. Under this approach, one starts fitting a model that contains all covariables. The least significant one is dropped except if it is significant at the critical level of 0·05. The reduced models are successively refitted applying the same rule until all the remaining variables are statistically significant.

Table 1. Reference values to recalculate the Goldberg cut-offs for application in children

Age (years)	Sex	CV_{wEI}* (%)	CV_{wBMR}† (%)	PAL‡	CV_{PAL}§ (%)
2 to <6	Boys	24·0	6·8	1·45	23·8
2 to <6	Girls	24·0	7·6	1·45	19·1
6 to <10	Boys	22·5	6·8	1·55	12·6
6 to <10	Girls	21·3	7·6	1·50	9·5

EI, energy intake; PAL, physical activity level.
* Within-subject CV of energy intake; values obtained from Nelson *et al.*[32].
† Within-subject CV of BMR; values obtained from Black[33].
‡ PAL; values obtained from Torun *et al.*[34].
§ CV of PAL; values obtained from Black[33].

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Table 2. Lower and upper cut-off limits to classify 1 d 24 h dietary recalls (24-HDR) as under-, plausible and over-reports based on the ratio of energy intake (EI*):BMR†

Age (years)	Sex	Under-report	Plausible report	Over-report
2 to <6	Boys	EI:BMR ≤ 0·74	0·74 < EI:BMR < 2·85	2·85 ≤ EI:BMR
2 to <6	Girls	EI:BMR ≤ 0·78	0·78 < EI:BMR < 2·69	2·69 ≤ EI:BMR
6 to <10	Boys	EI:BMR ≤ 0·92	0·92 < EI:BMR < 2·61	2·61 ≤ EI:BMR
6 to <10	Girls	EI:BMR ≤ 0·93	0·93 < EI:BMR < 2·43	2·43 ≤ EI:BMR

* EI estimated from 24-HDR.
† BMR estimated from Schofield equations[29].

In a next step, the dietary variables were added to the resulting models (including only the relevant covariables now) to investigate their predictive power for misreporting (model 1b: outcome UNR; model 2b: outcome OVR). Random effects for the study centre and setting (schools/kindergartens) were entered in all models to account for the clustered study design.

The present analysis only includes children with 24-HDR and complete covariable information (n 6101).

All analyses were performed using the statistical software package SAS (version 9.1; SAS Institute).

Results

Both the prevalence of UNR (1·2–16·4 %) and OVR (1·5–5·4 %) strongly differed between the study centres (Table 3). UNR was highest in the Hungarian study centre, OVR in the Italian one. UNR and OVR were higher in girls and UNR was higher in older children. Regarding the total study group, 8·0 % of the reports were classified as UNR and 3·4 % as OVR.

Descriptive statistics of all covariables can be obtained from Tables 4 and 5 stratified by reporting group (UNR, PLR and OVR). The mean BMI of children and their proxies were highest in UNR, whereas the percentage of proxies with a high income or educational level was highest in PLR. In UNR, a higher percentage of proxies were male and the use of day-care services was less frequent. The percentage of recalls assessed on weekends was highest in OVR. Furthermore, proxies of UNR were more likely to perceive their child as overweight/obese and stated more often to be concerned about their child becoming overweight, whereas proxies of OVR were more concerned about their child becoming underweight. Percentages of daily EI from chocolate products and sugary products increased with reporting group (lowest in UNR and highest in OVR), whereas percentages of EI from fruits/vegetables decreased with reporting group (Table 5).

Application of the backward selection procedure including all covariables except the dietary ones revealed that different factors were significantly associated with UNR compared with the model addressing OVR (models 1a and 2a; Table 6). The risk of UNR increased with age (OR 1·19, 95 % CI 1·11, 1·27), BMI z-score of the child (OR 1·23, 95 % CI 1·10, 1·37), the number of persons below 18 years of age in the household (OR 1·12, 95 % CI 1·01, 1·25) and was higher in the low/medium income group (OR 1·45, 95 % CI 1·13, 1·86; reference: high income group) as well as on interview days without additional school meal assessment (OR 1·58, 95 % CI 1·17, 2·13). Sitting always (OR 0·61, 95 % CI 0·43, 0·85) or often down while eating (OR 0·62, 95 % CI 0·44, 0·87; reference: sitting sometimes down while eating) turned out to be negatively associated with UNR. Proxies perceiving their child as slightly (OR 1·63, 95 % CI 1·03, 2·56) or much too overweight (OR 3·30, 95 % CI 1·51, 7·18; reference: slightly too underweight) were more likely to under-report. On the other hand, OVR was higher in female children (OR 1·70, 95 % CI 1·27, 2·28; reference: male children). BMI z-scores of children (OR 0·78, 95 % CI 0·69, 0·88) were negatively associated with

Table 3. Prevalence of misreporting by study centre, sex and age group
(Total numbers and percentages)

	Under-report		Plausible report		Over-report		Total study group
	n	%	n	%	n	%	n
Study centre							
Belgium	26	9·7	239	88·8	4	1·5	269
Cyprus	50	16·1	256	82·3	5	1·6	311
Estonia	24	4·9	446	90·8	21	4·3	491
Germany	137	10·3	1149	86·3	46	3·5	1332
Hungary	144	16·4	708	80·8	24	2·7	876
Italy	69	5·0	1239	89·7	74	5·4	1382
Spain	6	1·2	459	94·6	20	4·1	485
Sweden	30	3·1	911	95·4	14	1·5	955
Boys	218	7·1	2779	90·3	79	2·6	3076
Girls	268	8·9	2628	86·9	129	4·3	3025
2 to <6 years	130	4·9	2442	91·5	98	3·7	2670
6 to <10 years	356	10·4	2965	86·4	110	3·2	3431
Total study group	486	8·0	5407	88·6	208	3·4	6101

Table 4. Descriptive analysis of categorical covariates by reporting group
(Percentages and total numbers)

	Under-report (*n* 486)		Plausible report (*n* 5407)		Over-report (*n* 208)		Total study group (*n* 6101)	
	%	*n*	%	*n*	%	*n*	%	*n*
Sex of the child								
Male	44·9	218	51·4	2779	38·0	79	50·4	3076
Female	55·1	268	48·6	2628	62·0	129	49·6	3025
Sex of the proxy								
Male	18·5	90	17·2	931	16·3	34	17·3	1055
Female	81·5	396	82·8	4476	83·7	174	82·7	5046
Income level								
Low/medium	75·3	366	68·4	3698	77·9	162	69,3	4226
High	24·7	120	31·6	1709	22·1	46	30·7	1875
ISCED level*								
Low/medium	53·3	259	46·7	2523	59·6	124	47·6	2906
High	46·7	227	53·3	2884	40·4	84	52·4	3195
Use of day-care service or babysitter								
Yes	28·6	139	42·7	2311	41·3	86	41·6	2536
No	71·4	347	57·3	3096	58·7	122	58·4	3565
Day of the interview								
Weekday	81·7	397	82·9	4484	78·8	164	82·7	5045
Saturday/Sunday	18·3	89	17·1	923	21·2	44	17·3	1056
School meal assessment†								
No school meal	69·8	339	63·1	3414	67·3	140	63·8	3893
With school meal	30·2	147	36·9	1993	32·7	68	36·2	2208
Parents sit down with the child when eating								
Never	2·9	14	2·2	121	1·9	4	2·3	139
Rarely	2·5	12	2·5	134	1·0	2	2·4	148
Sometimes	12·8	62	7·6	411	11·5	24	8·1	497
Often	35·0	170	33·9	1833	35·6	74	34·0	2077
Always	46·9	228	53·8	2908	50·0	104	53·1	3240
Perception of the child's weight								
Much too underweight	1·4	7	1·3	72	2·4	5	1·4	84
Slightly too underweight	14·8	72	16·8	910	27·4	57	17·0	1039
Proper weight	55·6	270	70·8	3826	63·5	132	69·3	4228
Slightly too overweight	24·5	119	10·3	558	5·3	11	11·3	688
Much too overweight	3·7	18	0·8	41	1·4	3	1·0	62
Concerned – child eating too much when parents not around								
Unconcerned	57·8	281	62·5	3377	57·2	119	61·9	3777
A little concerned	17·3	84	19·9	1074	26·9	56	19·9	1214
Concerned	15·4	75	12·4	668	12·5	26	12·6	769
Very concerned	9·5	46	5·3	288	3·4	7	5·6	341
Concerned – child having a diet to maintain desirable weight								
Unconcerned	58·2	283	66·6	3602	64·9	135	65·9	4020
A little concerned	16·7	81	13·6	738	17·8	37	14·0	856
Concerned	16·3	79	12·6	681	11·5	24	12·9	784
Very concerned	8·8	43	7·1	386	5·8	12	7·2	441
Concerned – child becoming overweight								
Unconcerned	43·0	209	55·6	3004	53·8	112	54·5	3325
A little concerned	18·7	91	16·7	903	23·1	48	17·1	1042
Concerned	20·2	98	15·1	815	9·6	20	15·3	933
Very concerned	18·1	88	12·7	685	13·5	28	13·1	801
Concerned – child becoming underweight								
Unconcerned	55·1	268	52·0	2809	37·0	77	51·7	3154
A little concerned	16·7	81	16·6	899	18·3	38	16·7	1018
Concerned	13·4	65	14·6	787	25·0	52	14·8	904
Very concerned	14·8	72	16·9	912	19·7	41	16·8	1025

ISCED, International Standard Classification of Education.
* Low/medium education is defined as ISCED levels 1–3; high education is defined as ISCED levels 4 and 5 (ISCED 1997, UNESCO Institute for Statistics: Montreal, 2006).
† Days without school meals relate either to weekend days or to working days where the child had no lunch or lunch at home.

OVR. Being very concerned about the child becoming overweight (OR 0·44, 95 % CI 0·23, 0·84) decreased the risk for OVR, whereas being very concerned about the child becoming underweight increased the risk (OR 1·77, 95 % CI 1·10, 2·85).

Adding the dietary variables to the models showed that percentages of total EI from chocolate products, soft drinks and sugary products were negatively associated with the risk of UNR, whereas percentages of EI from fruits/vegetables were

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Table 5. Descriptive analysis of continuous covariates and dietary intakes by reporting group

(Mean values and standard deviations)

	Under-report (*n* 560)		Plausible report (*n* 5308)		Over-report (*n* 228)		Total study group (*n* 6096)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age of the child (years)	6·8	1·5	6·0	1·8	6·0	1·8	6·1	1·8
BMI *z*-score of the child*	0·8	1·6	0·2	1·3	-0·2	1·2	0·2	1·3
Media consumption time (h/week)	12·6	7·6	11·5	7·1	11·0	6·5	11·6	7·1
Age of the proxy	35·3	5·1	35·9	5·2	35·6	5·1	35·8	5·2
BMI of the proxy	25·1	4·8	24·2	4·4	24·0	4·5	24·3	4·4
Number of persons $<$18 years of age in household	2·1	1·1	2·0	0·8	1·9	0·9	2·0	0·9
Energy (kcal/d)	774·1	220·5	1563·0	425·5	2757·0	429·9	1541·0	517·9
Energy (kJ/d)	3238·8	922·6	6539·6	1780·3	11535·3	1798·7	6447·5	2166·9
Water (g/d)	310·5	330·9	337·9	347·4	406·5	450·6	338·1	350·4
Chocolate products (% of total EI)	2·5	6·6	3·1	5·9	3·7	7·1	3·1	6·0
Milk (% of total EI)	9·6	13·3	10·6	9·8	8·2	8·3	10·4	10·1
Soft drinks (% of total EI)	2·8	6·6	2·8	5·8	2·3	4·1	2·8	5·8
Sugary products (% of total EI)	6·7	11·2	9·8	11·6	12·6	12·4	9·6	11·7
Fruits/vegetables (% of total EI)	10·4	12·4	8·4	7·8	7·3	6·3	8·6	8·2

EI, energy intake.

* According to Cole *et al.*[25,26].

positively associated (model 1b). The OR for the other covariables changed only slightly in model 1b compared with model 1a. Inclusion of the dietary variables in model 2a revealed no significant associations between the percentages of EI and OVR for any of the considered food items except for milk (OR 0·97, 95 % CI 0·95, 0·98) and sugary products (OR 1·01, 95 % CI 1·00, 1·02).

Discussion

In general, proportions reported for UNR and OVR vary widely between publications (UNR 2–85 % and OVR 3–46 %, obtained from a current review including children and adolescents[18]) where the proportion of UNR is usually higher than that of OVR. The proportions of UNR (8·0 %) and OVR (3·4 %) found in the present study sample are

Table 6. Results of the multi-level logistic regression applying backward selection: factors significantly associated with under-reports/over-reports (models 1a and 2a) and predictive value of selected food items for misreporting (models 1b and 2b)*

(Odds ratios and 95 % confidence intervals)

	OR for under-reports (*n* 5893)				OR for over-reports (*n* 5615)			
	Model 1a: backward selection		Model 1b: adding food items to model 1a		Model 2a: backward selection		Model 2b: adding food items to model 2a	
Covariates	OR	95 % CI	OR	95 % CI	OR	95 % CI	OR	95 % CI
Age of the child (years)†	1·19	1·11, 1·27	1·20	1·12, 1·29				
Sex of the child: female *v.* male					1·70	1·27, 2·28	1·69	1·26, 2·26
Sex of the relative: female *v.* male	1·38	1·05, 1·83	1·44	1·09, 1·91				
BMI *z*-score of the child (Cole)†	1·23	1·10, 1·37	1·23	1·10, 1·37	0·78	0·69, 0·88	0·77	0·68, 0·87
Income level: low/medium *v.* high	1·45	1·13, 1·86	1·48	1·15, 1·91				
Number of persons $<$18 years of age in household†	1·12	1·01, 1·25	1·11	1·00, 1·24				
School meal assessed‡: no *v.* yes	1·58	1·17, 2·13	1·63	1·21, 2·21				
Sitting down while eating: always *v.* sometimes	0·61	0·43, 0·85	0·59	0·42, 0·83				
Sitting down while eating: often *v.* sometimes	0·62	0·44, 0·87	0·62	0·44, 0·87				
Perception: much too overweight *v.* slightly too underweight	3·30	1·51, 7·18	3·26	1·49, 7·16				
Perception: slightly too overweight *v.* slightly too underweight	1·63	1·03, 2·56	1·56	0·99, 2·46				
Child becoming overweight: concerned *v.* very concerned					0·44	0·23, 0·84	0·43	0·22, 0·83
Child becoming underweight: concerned *v.* very concerned					1·77	1·10, 2·85	1·71	1·06, 2·76
Water (g/d)†			1·00	1·00, 1·00			1·00	1·00, 1·00
Chocolate products (% of total EI)†			0·97	0·95, 0·99			1·01	0·99, 1·03
Milk (% of total EI)†			0·99	0·98, 1·00			0·98	0·96, 0·99
Soft drinks (% of total EI)†			0·98	0·96, 0·99			0·97	0·94, 1·01
Sugary products (% of total EI)†			0·98	0·97, 0·99			1·01	1·00, 1·02
Fruits/vegetables (% of total EI)†			1·02	1·00, 1·03			0·98	0·96, 1·00

EI, energy intake.

* All models include random effects for study centre and setting.

† Effects of continuous variables are assessed as one unit offsets from the mean.

‡ Days without school meals relate either to weekend days or to working days where the child had no lunch or lunch at home.

difficult to compare with other studies due to differences in age groups, number of assessment days, cut-off values applied and the respondent status (self *v.* proxy). The relatively low proportions of UNR and OVR in the present data may be a consequence of cooperation with parents/caregivers, which has been shown to be associated with a lower risk of UNR/OVR previously[35]. The present data revealed a decreased risk of UNR on days with additional school meal assessment (days without school meal assessment relate either to weekend days or to working days where the child had no lunch or lunch at home). Lioret *et al.*[11] reported proportions for UNR and OVR of 4·9 and 1·4 %, respectively, in 3–10-year-old French children. This study was similar to the present one in terms of sample size, cut-off values and instruments applied. In the study by Murakami *et al.*[36], UNR ranged from 2·9 to 28·0 % and OVR from 3·0 to 28·1 % depending on the considered age group (children aged 6–15 years, stratified by 1-year age groups). UNR increased and OVR decreased with age, which agrees with the present results (Table 3). The increase in UNR with age may be explained by reduced parental control and a higher frequency of out-of-home meals in older children.

The notably high proportion of UNR in the Hungarian study centre (16·4 %) may be a consequence of the slightly different study protocol. As opposed to the paper-based assessment in Hungary, the computerised SACINA program used in the other study centres included reminders for certain foods and already some checks for plausibility. Further pictures with increasing portion sizes were displayed to facilitate the estimation of portion sizes. These differences in the assessment procedure may explain the discrepancy between the proportion of UNR in Hungary and the other study centres. In Cyprus, schools do not offer meals and therefore no additional information on school meals was assessed, which may explain the high percentage of UNR (16·1 %) in this study centre.

Over-reporting was found to be higher in children and adolescents compared with adults, which has been suggested to be rather a consequence of intrusion of foods that were not actually consumed than errors in portion size estimation[18,37]. However, these studies relied on self-reports. In proxy reports, over-reporting could be suspected to be either a result of intrusion due to the lack of parental control or a result of over-eating due to increased energy requirements during growth. The latter would result in misclassifications of records, for example OVR in spite of correct parental reports. Difficulties such as decreasing metabolic costs of movement during maturation and heavier children spending more energy at the same intensity of PA than peers may further affect classifications of UNR/OVR[38]. Moreover, it cannot be precluded that the 24-HDR was assessed on an exceptional day resulting in very high or low reported intakes (for example, child was ill).

Though the mean BMI of the child and of its proxy were both highest in the group of UNR in the descriptive analysis, the multivariate analysis revealed only the BMI of the child being significantly associated with misreporting. It is likely that similar dietary patterns within a family as well as shared genetic/environmental factors lead to correlations between parental and children's BMI[39], which may explain the bivariate association between UNR and parental BMI. Previous findings on the association between parental obesity and misreporting are inconsistent in children and adolescents[3,14,40]. Nevertheless, the strong association between parental concerns/perceptions of their child's weight status and misreporting rather suggests that, actually, the BMI of the child is the determining factor. To date, no other study has examined parental concerns/perceptions in relation to misreporting of EI by proxy respondents.

UNR was higher in low/medium income groups, whereas educational level was neither found to be associated with UNR nor with OVR. Previous studies in children reported no association between misreporting and income level[11,14,40]. In adults also inconsistent results concerning socio-economic variables have been reported in a review investigating markers on the validity of reported EI[9]. The authors assumed that poor literacy skills in the less well-educated group and better health and diet consciousness in the better-educated group might both result in misreporting leading to contradictory results. To the authors' knowledge, the effect of household size on misreporting, which may either serve as an indicator for socio-economic status or for parental control, has rarely been addressed in children. The present data suggest a positive relationship with UNR. Opposed to the present results, Vagstrand *et al.*[41] found UNR based on self-reports to be more likely in adolescents from one-child families. Nevertheless, in proxy reports, the impact of household size may be different as a high number of children may reduce parental control over each single child's food intakes. Parental control may also explain the effect of the 'sitting while eating' variable. Children sitting often or always down while eating had a reduced risk to be classified as UNR.

The present analysis revealed that OVR was higher in girls, whereas UNR was not associated with the sex of the child. It is likely that the determinants of misreporting may differ by sex and also by age group. Unfortunately, stratified analyses were not possible since corresponding models did not converge due to the high number of covariables and the comparably low number of UNR/OVR.

In a literature review mainly relying on self-reports, sex and social desirability have been reported to be consistent predictors for misreporting in adults but not in children and adolescents[18]. When adding the dietary variables to our models, results pointed to intentional, selective misreporting in the UNR group reflecting socially desirable answer behaviour. Food items commonly perceived to be unhealthy were negatively associated with UNR (chocolate products, sugary products and soft drinks), whereas fruit/vegetable intake showed a positive association. Although the SACINA instrument (retrospective) does not influence the child's eating behaviour, it seems to encourage socially desirable answers of the parents.

Some studies have already applied adapted validation procedures in children substituting Goldberg's single cut-off 2 by individual limits for children[11,31,42,43]. Sichert-Hellert *et al.*[31,43], for example, applied recalculated Goldberg cut-offs based on three assessment days in a German sample of 695 children aged 1–18 years but only addressing under-reporting. UNR ranged from 1·2 to 19·2 % depending on the respective age group and was lower compared with the proportions obtained when applying the original Goldberg cut-offs[30] (1 d cut-off; UNR, EI:BMR ≤0·9; OVR, EI:BMR ≥2·68). Also in the present study, the recalculated cut-offs revealed a slightly lower proportion of UNR (8·0 *v.* 8·3 %) and a higher proportion of OVR (3·4 *v.* 3·1 %) compared with the original Goldberg cut-offs, as expected (data not shown in the tables).

Limitations and strengths

Only one record day per child was used in the present analysis, which does not reflect usual intakes. Black & Cole[7] found that under-reporting is subject-specific, concluding that subjects who under-report on the first 24-HDR accordingly tend to under-report on additionally assessed 24-HDR as well. Therefore, a single 24-HDR can be considered as a reliable instrument for the identification of determinants of misreporting. Nevertheless, an additional analysis was run including only children with at least two 24-HDR. The study sample was markedly reduced (*n* 6101 *v.* 1644) and the number of study subjects strongly differed between the study centres (for example, Estonia *n* 3; Hungary *n* 828), which resulted in unstable model estimates. This corroborated the decision to include all children with at least one 24-HDR where only the first recall day was used in the analysis.

Sensitivity of the cut-off technique is limited, as it aims only to identify UNR resulting in physiologically implausible low EI[44]. By the application of the cut-off technique, varying degrees of misreporting cannot be distinguished, for example under-reporting from a high intake level such that the ratio of EI:BMR does not fall below the cut-off will not be detected. Further cut-off values were calculated assuming light PAL for all children which may result in misclassifications. The likelihood to classify a record as UNR increases with increasing energy expenditure of the child[9]. As PA is a relevant determinant of energy expenditure, classification into UNR, PLR and OVR should consider individual PAL by applying different cut-off values depending on a child's PAL. Unfortunately, due to the lack of valid PAL information, this approach was not feasible. Moreover, differentiation between undereaters (EI actually lower than energy expenditure) and under-reporters is not possible so that some part of UNR may be attributed to undereaters[9]. The same applies analogously to overeaters. Future research should include special questions for the identification of low/high eaters.

The large study sample, the additional assessment of school meals and measured anthropometry can be considered as strengths of the present study. Further, the huge number of covariables should be highlighted, as it facilitated a comprehensive analysis of the determinants of misreporting covering various aspects.

Conclusion

Misreports differ from plausible proxy reports with respect to children's characteristics (age, sex and weight status) as well as social factors (number of persons below 18 years of age in household and net household income). Determinants for UNR and OVR only partly agree where UNR seems to be strongly affected by social desirability. Furthermore, parental concerns/perceptions of their child's weight status had a strong impact on misreporting. Researchers should bear this differential reporting bias in mind when investigating diet–disease relationships in children. Identification of influencing factors may help to improve study designs and to interpret potentially biased results.

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