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Title page

1. **Title:** A simple method for identification of misreporting of energy intake from infancy to school age: results from a longitudinal study

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9. **Running head**: Misreporting of energy intake in childhood

10. **List of abbreviations**: BMI: body mass index; BMR: basal metabolic rate; CHOP: European Childhood Obesity Programme; CV: coefficient of variation; DLW: doubly labelled water technique; ED: energy needed for deposition; EER: estimated energy requirement; EI: energy intake; HRM: heart rate monitoring; SEM: standard error of the mean; TEE: total energy expenditure

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Abstract

Background and aim: Misreporting is a major source of reporting bias in nutritional surveys. It can affect the analysis of associations between diet and disease. Although various methods have been proposed to identify misreporting, their application to infants and young children is difficult. We identify misreporting of energy intake in infants and young children and propose a simplified approach.

Methods: 1,199 children were enrolled in the Childhood Obesity Programme (CHOP) based in 5 European countries (Belgium, Germany, Italy, Poland and Spain) with repeated measurements of 3-day weighed food protocol and anthropometric indices at 10 time points between ages 1- 96 months. Individual cut-offs for the ratio of reported energy intake and estimated energy requirement were calculated to identify misreporters. Misreporting was studied according to age, gender, BMI z-scores and country.

Results: We identified a higher proportion of over-reporters (18.9%) as compared to under-reporters (10.6%). The proportion of over-reporting was higher among infants while under-reporting was more prevalent in school-aged children. Under-reporting was higher in boys (12.0%) and in obese/over-weight children (36.3%). Mean values for upper and lower cut-offs for the ratio of reported energy intake and estimated energy requirement in children ≤12 months were 0.80 and 1.20, and 0.75 and 1.25 for children >12 months, respectively. Using these fixed (mean) values, 90.4% (kappa statistic: 0.78) of all misreporters could be identified.

Conclusions: Despite intensive measures to obtain habitual intake of children, an essential proportion of nutritional reports were found to be implausible. Both over- and under-reporting should be carefully analysed, even in studies on infants. Fixed

cut-offs can be applied to identify misreporting if no individual variation in energy intake can be calculated.

Introduction

There are different dietary recall methods used in nutrition related studies, which are based on the assumption that reported dietary intake reflects habitual intake. However, it is well-known that obtaining accurate dietary data is difficult due to a number of reasons such as difficulties in recalling foods consumed, food recognition, estimation of portion size and consumption frequency (1). The process of obtaining the habitual intake becomes more complex in young children, for whom dietary recall methods are conducted on proxy-reporters such as parents or care-givers.

Even though parents can report accurately about their child's food intake in the home setting (2), misreporting of dietary intake is a major issue in dietary recall methods. Misreporting which comprises of under- and over-reporting leads to reduced validity of self-reported dietary recall methods and distorted analysis of relationships between nutrient intake and health (3, 4). Identification of misreporting is crucial in paediatric based nutritional studies on which policies, guidelines and programmes are set with a focus on optimal growth and development of children.

Several methods have been suggested to identify misreporting. The method given by Goldberg, known as 'CUT-OFF 2', is based on the principles of energy physiology, which includes basal metabolic rate (BMR) and physical activity levels (PAL) and is a modification of the original Goldberg method known as 'CUT-OFF 1'(5). It gives equations to derive lower cut-offs to identify under-reporting based on the assumption of sedentary lifestyle. This method was developed for identification of energy intake (EI) misreporting in adults and has been modified for use in children. It compares the ratio of EI:BMR against the estimated cut-offs based on PAL at a confidence level of 95% and takes into consideration both the biological variability and measurement errors in EI, BMR and PAL (6). However, it requires the use of appropriate PAL values which may not always represent the true activity level of an individual (7). The BMR can also have different values depending upon the method used for its estimation. While Schofield's BMR equations (8) have been applied widely, its validity has been questioned. They tend to underestimate BMR (9) and do not have a good agreement between measured and predicted BMR at early ages (10). Alternatively, misreporters can be identified by comparing EI directly with the measured or predicted total energy expenditure (TEE) or simply by using previously published cut-off values to identify misreporting. While the original Goldberg formula and most former reports on misreporting focused on under-reporting, the upper cut-off limit could also be calculated to identify over-reporting.

The method to identify energy intake misreporting in the paediatric population is important and can be complicated due to the various required components. Most methods to identify misreporting are based on data of an adult population and may not be applicable for young children. For infants and school age children, TEE can be estimated using equations given by Butte (9) and Torun (11) to which additional energy needs have to be added to compensate for energy deposition in new tissues. This results in estimated energy requirements and can be compared to the energy intake to identify misreporting at young ages.

In this study, we identify misreporting in a multicentre European cohort study with nutritional records at multiple time points between 1 to 96 months of age based on the individual ratio of reported energy intake and estimated energy requirement. We also recommend misreporting cut-off values based on mean population ratios for infants and young children for simple and direct identification of both under- and over-reporters that can be applied in studies with food protocols of less than 3 days or with food frequency protocols.

Materials and Methods

Study Design

The European Childhood Obesity Programme (CHOP) is an originally double-blind, randomized controlled trial which compared childhood risk of obesity in two groups of children fed cow-milk formula with either higher (n = 550) or lower (n = 540) protein content for the first year of life. Additionally, a group of breast-fed children was also included in the study (n = 588). Children were followed from birth until 8 years of age. A detailed description of the study has been published previously (12).

Study Population

Healthy, singleton, term infants were recruited shortly after birth between 1 October 2002 and 31 July 2004 from birth clinics in 8 urban areas of 5 European countries (Belgium, Germany, Italy, Poland, and Spain). All study centres used standardised procedures to follow children. Data on dietary intake was collected at time points 1, 3, 6, 12, 24, 36, 48, 60, 72 and 96 months of age. Anthropometric measurements were taken during study visits at recruitment (0 - 8 weeks of life) and otherwise at the same time points as the dietary protocols. Details of the study population have been described elsewhere (13).

A total of 1,358 children enrolled in CHOP had at least one food protocol at any given time point. We excluded all protocols of children of the breastfed group up to six months of age and those breastfeeding thereafter as human milk intake was not measured. It has been shown that 3 day food protocols are required to estimate the usual dietary intakes (14). Therefore, excluding also children with food protocols of less than 3 days, we had nutritional information of 1,212 children with 6,318 3-day food protocols. Since estimation of energy requirements requires a weight measurement, we excluded food protocols without concurrent weight (n=120 of 113 children). Sixty protocols of 46 children were excluded because exactly the same intakes were reported for all days resulting in a standard deviation of energy intake over the three food protocols equal to zero. Hence, we conducted this study on a total of 6,137 food protocols at ten follow-up time points from 1,199 children. Detailed participant flow diagram is available in **Supplemental Figure 1**.

Study procedures

Food intake was collected using weighed food record conducted on 3 days, including 1 weekend day and 2 weekdays, at ages 1, 3, 6, 12, 24, 36, 48, 60, 72 and 96 months. Parents of the enrolled children were instructed to weigh each single food item given to their child with a digital scale (Soehnle Unica, no. 66006, Murrhardt, Germany) before consumption and also weigh and record leftover food items. From 36 months onwards, parents had the possibility to fill out an alternative dietary record by comparing consumed food with pictures of standardized and weighed portion sizes, if weighing was not possible. Quality check of the reported data was done using standard operating procedures (15). It contained information on how to code a large range of ethnically and regionally differing foods, ingredients of recipes and their portion sizes, and how to add additional food items into the database. Each food protocol was checked by a nutritionist, who also discussed them with the parents before the details were entered into a database for further processing. The database was based on the BLS 2.3 (Bundeslebensmittelschluessel; German food database)(16) and was enriched by foods that were not found with their nutritional information based on manufacture information or other nutritional databases.

Estimated energy requirements

Energy requirement is the amount of energy needed to balance energy expenditure and includes energy needed for optimal growth and development in children (17). We estimated the energy requirement according to age and gender for each child at a given follow-up time point as (18):

$$\mathrm{EER} = \mathrm{TEE} + \mathrm{ED} \qquad [1]$$

EER denotes the estimated energy requirement, TEE denotes the total energy expenditure, and ED denotes the energy deposition, which is the amount of energy needed for deposition of energy in tissues. In our study, we report all values in kilocalories per day (Kcal/d).

Total energy expenditure

In children, total energy expenditure is a combination of energy expenditure due to basal metabolic rate, thermic effect of feeding, physical activity, and the energy cost of tissue synthesis (17). When TEE is not measured, it can be predicted using equations based on doubly labelled water (DLW) technique. The symbol ^ is used to indicate “estimated” in comparison to “measured” values. For children ≤12 months, we estimated TEE using Butte’s linear regression equations [equation 2] according to the equations for formula-fed children (9). This equation is based on DLW measures of 36 healthy infants followed longitudinally throughout the first 2 years of life:

$$\text{Formula-fed children: } \widehat{\text{TEE}}(\text{Kcal/day}) = 82.6 * \text{weight} - 29 \qquad [2]$$

For children >12 months, we estimated TEE using Torun's quadratic regression equations [equations 3-4] based on pooled weighted estimates of DLW studies on 1,129 healthy children (483 boys and 646 girls) aged 1 - 18 years (11):

$$\text{Boys: } \widehat{\text{TEE}}\,(\text{kcal/day}) = 310.2 + 63.3 * \text{weight} - 0.263 * \text{weight}^2 \qquad [3]$$

$$\text{Girls: } \widehat{\text{TEE}}(\text{kcal/day}) = 263.4 + 65.3 * \text{weight} - 0.454 * \text{weight}^2 \qquad [4]$$

Equations 2-4 use weight of the child in kilograms.

Energy needs for deposition

Energy deposition (ED) was estimated as a product of energy cost of tissue deposition and weight gain per day in grams (17). For infants, values for energy cost of tissue deposition were adapted from Butte (9). For children >12 months, energy cost of tissue deposition was taken as 2 Kcal per gram weight gain as suggested by Torun (11).

Weight-for-age of the WHO growth study (19) was used to estimate the values for weight gain per day (grams).

Identification of misreporting

In a healthy child the energy intake (EI) should to equivalent to EER (17), resulting in a ratio of 1. However, day-to-day variation of EI and EER (**Figure 1**) needs to be taken into consideration. The total variation is calculated as in equation 5:

$$CV_{total_{it}} = \sqrt{\frac{CV_{EI_{it}}^2}{d_{it}} + \widehat{CV}_{TEE}^2} \qquad [5]$$

$CV_{EI_{it}}$ denotes the within individual coefficient of variation for energy intake calculated for each child at a specific time point and is based on the observed day-to-day variation of the 3-day food protocols; d_{it} denotes number of days of dietary recall for each child at a specific time point; $\widehat{CV}_{TEE}$ denotes the within individual coefficient of variation for TEE and is taken as 8.2% (20).

Individual cut-offs for the ratio of energy intake to estimated energy requirements were calculated at a confidence level of 95% (Z_α = 1.96) based on individual coefficient of variation values.

$$\text{Under-reporting:} \frac{EI_{it}}{\widehat{EER}_{it}} < 1 - Z_\alpha * CV_{total_{it}} \qquad [6]$$

$$\text{Over-reporting:} \frac{EI_{it}}{\widehat{EER}_{it}} > 1 + Z_\alpha * CV_{total_{it}} \qquad [7]$$

Reported energy intake at a given follow up time point was regarded as under-reported if this ratio was smaller than the calculated individual lower cut-off. Similarly, reported energy intake was over-reported if the ratio was greater than the calculated individual upper cut-off. The mean reported energy intake was considered as plausible, if the ratio is within the individual confidence interval.

We present the distribution of individual cut-off values by sample mean±SD for each time point. We then summarised individual cut-off values by the mean upper and lower cut-offs for children ≤12 months of age and for children >12 months of age, to construct a simplified approach to identify misreporting. To compare both approaches, i.e. the use of individual cut-offs and the use of mean cut-offs, we used Cohen's kappa (κ) for the agreement of the reporting status. A step-by-step guide to identify misreporting in children has been provided in the supplements.

To test differences in mean values of weight, TEE, EER, EI and CV_{EI} between boys and girls at each follow up time point, we conducted two sample t tests. We applied Bonferroni correction to deal with the issue of multiple testing; p values less than 0.005 were considered statistically significant. WHO macros were used for the estimation of body mass index (BMI) z-scores according to age and gender. Children <5 years were defined to be overweight/obese at a given time point if BMI z scores were >2SD. Children >5 years were considered overweight/obese at a given time point if BMI z scores were >1SD.

All analysis was done using Stata 12.1 (StataCorp, College Station, Texas, USA).

Results

For the ten time points, a total of 6,137 food protocols could be included in our analyses. Out of a total of 1,199 children, 27.0% were from Spain followed by Italy (25.5%), Poland (17.7%), Germany (17.0%) and Belgium (12.8%), as shown in **Table 1**. Mothers had a mean age of 30.3 (SD 5.1) years and a mean pre-pregnancy BMI of 23.5 (SD 4.4) kg/m^2 with 7.9% being obese. Most mothers had at least an intermediate level of education (74.3%); about 60% women gave birth to their first child and 27% of the mothers consumed alcohol or smoked during pregnancy. The mean birth weight of the children was 3290 (SD 350) grams.

About 7% of these food protocols (n = 405) belonged to either obese or over-weight children. **Table 2** shows the mean energy intake of children at different time-points. Energy intake was statistically different between boys and girls at almost all time points (all p <0.005), except at ages 24 and 60 months. The standard deviation of intake increased with age leading to a higher within subject variation of EI in older children. Lowest values for $\mathrm{CV_{EI}}$ were found during the first 6 months of life. No significant difference in mean $\mathrm{CV_{EI}}$ was found between boys and girls.

Mean weight, estimated values for TEE and EER and $\mathrm{CV_{total}}$according to age and gender are given in **Supplemental Table 1**. Significant differences in $\widehat{\mathrm{TEE}}$ and $\widehat{\mathrm{EER}}$ was found between boys and girls (p<0.005). As compared to girls, boys were generally heavier and had a higher daily weight gain resulting in a higher $\widehat{\mathrm{TEE}}$ and $\widehat{\mathrm{EER}}$ throughout the follow-up time.

Table 3 provides mean values for the ratio of energy intake and expenditure, lower and upper misreporting cut-offs using $\mathrm{CV_{total}}$along with the proportion of misreporting. The mean ratio was highest at 6 and 12 months and lowest at 96 months of age. The mean lower and upper misreporting cut-off values were about 0.80 and 1.20, respectively, for children under 12 months of age. The cut-offs increased for children >12 months by about 5%, resulting in mean cut-off values of about 0.75 and 1.25.

Based on individual cut-offs, 70.5% of all food protocols can be considered plausible reports. Overall, we observed a higher proportion of over-reporting (18.9%) than under-reporting (10.6%). Under-reporting became more prevalent as age increased; over-reporting, on the other hand, was more prevalent at younger ages. The highest proportion of under-reporting (27.9%) and over-reporting (32.8%) was found at 96 months and 12 months, respectively. The lowest proportion of over-reporting was found at 96 months (3.2%). Misreporting proportion according to age is shown in **Figure 2**.

Energy intake of obese/over-weight children was more likely to be under-reported (36.3%) (**Figure 3)**. The proportion of under-reporting in boys (12.0%) was found to be slightly higher than in girls (9.2%). However, over-reporting was almost equally present in both genders. Spain had the highest proportion of misreported records (35.9%), followed by Poland (30.6%), Belgium (27.7%), Italy (26.0%) and Germany (24.2%). The high proportion of misreporting in Spain was primarily due to a large number of over-reporters (28.8%). Even though Germany had the highest proportion of under-reporters (13.8%), only 10.4% of its reports were over-reported, the lowest compared to other countries. Misreporting proportion according to age and country has been given in **Supplemental Table 2**.

We also identified misreporting by using fixed lower and upper cut-offs, which are the mean values of all individual cut-offs. Using these fixed cut-offs of 0.80 and 1.20 for children aged ≤12 months and 0.75 and 1.25 for children >12 months, the proportion of children identified as under-reporters and as over-reporters was 10.5% and 17.1%, respectively. When compared for agreement between misreporters identified using individual cut-offs and fixed cut-offs using Cohen's Kappa, we obtained a κ of 0.78, with observed agreement of 90.4% (n = 5,546/6,137). A three-by-three cross tabulation for the agreement between the two methods has been given in **Supplemental Table 3**.

Discussion

In the current study we present a guideline and define a suitable approach to identify misreporting in infants and young children, based on reported energy intake (EI) and estimated energy requirements (EER). We identified about 30% of the 3-day food records taken at multiple time points as misreported. While over-reporting was more prevalent in the first year of life, under-reporting was more problematic in school age children. We also found considerable differences between study countries.

Our mean ratio of reported energy intake and estimated energy expenditure were close to the values from three reviews on misreporting in children (21-23). However, comparison of the proportion of misreporters with other studies is not straightforward. There are not only differences in terms of populations studied but more important the methods which have been used were quite diverse. Goldberg's method has been a foundation of several other methods used to identify misreporters. The Goldberg's equations require coefficient of variation values for basal metabolic rate (BMR) and physical activity level (PAL). Values suggested by different authors are high because both intra- and inter-individual variation was considered. Thus, these tend to give wider cut-offs for the agreement between reported energy intake (EI) and total energy expenditure (TEE) than those that only consider intra-individual variation. These wide cut-offs tend to only identify extreme misreporters such as in a Swedish cohort study by Patterson et al (24). If we used Goldberg's equations to calculate the cut-offs to compare EI against BMR and PAL, adding also wrongly the inter-individual variation, we would only identify 10.8% under-reporters and 2.4% over-reporters in our sample population. The use of higher variation values lead to a different proportion of under- and over-reporters and fails to identify many implausible reports.

Another important issue is the use of either estimated or measured PAL values to identify misreporting since both might introduce a bias into the estimation of TEE. When DLW method cannot be applied, PAL can be measured using techniques such as accelerometers and self-reported questionnaires. However, these methods have several disadvantages such as accuracy and data processing issues (25). Another technique is to use published PAL values, which have been suggested for specific age and gender groups. However, these values should be used with caution since physical activity is the most variable component of the total energy expenditure (17), differing not only by age and gender but also by ethnicity, parental education, type of preschool (26). This indicates that a certain PAL value may not be applicable for children of different populations. For example, several studies have found a higher proportion of under-reporting in young children (27-29). The use of estimated or predicted PAL values in these studies could contribute to contrasting findings as compared to our study. To avoid the use of inappropriate PAL values, we used a multiple of PAL and BMR i.e. TEE, to estimate energy requirement (EER) in young children as proposed by Black and Cole (20). Over-reporting was more prevalent in studies which compared energy intake of school age children against measured TEE based on DLW technique (30, 31).

Total energy expenditure is variable due to a range of tasks performed on a daily basis. To take into account this variation in energy expenditure, we used the combined within subject coefficient of variation ($\mathrm{CV_{TEE}}$) in TEE (20). The value of

8.2% could be regarded as appropriate because it is based on 25 DLW studies and includes both the biologic and the analytic variation. The substitution of only $\mathrm{CV}_{\mathrm{TEE}}$ and lower $\mathrm{CV}_{\mathrm{EI}}$ values resulted in narrower cut-offs to identify misreporting, allowing to identify misreporting more precisely.

In nutritional studies which do no capture the intra-individual day-to-day variation in energy intake (e.g. ≤2 day food protocols, 24 h protocols) the reporting status can be judged by using fixed upper and lower cut-offs to determine the plausible range of the individual energy intake. We would suggest different ranges for infant and for older children. Our ranges are generally tighter than those used by other authors (24, 32). This is mainly due to the fact that they referred to higher variation factors than we did, as explained above.

The current study confirms that misreporting is a problem in studies in infants and children. Once identified, adjustment methods should be applied to obtain misreporting bias-free results. Mendez et al (33) evaluated different strategies including multivariate models after exclusion of misreporters and inclusion of under- and over-reporting as dummy variables. Börnhorst et al (34) constructed propensity scores using variables found to be statistically significant with misreporting. They used different multilevel regression models with various combinations of inclusion and exclusion of the propensity scores and other reporting variables, such as reporting group. These studies found stronger associations between dietary intake and obesity by applying appropriate models and adjustment for misreporting.

Strengths and limitations

The current study comprises of a large number of data collected at multiple time points over a wide age range. All data has been collected by highly trained and constant personnel who followed standardized procedures in all five countries. Although our EER values were comparable to the values given by the authors who formulated these equations, they were only estimated. For studies with exactly monitored physical activity levels, other estimates might be more applicable. There might be also some differences between our population and the reference populations used. Nevertheless, those reference populations present the current basis of international recommendations for energy requirements in healthy infants and children. Our study has differential loss to follow-up seen between countries with higher attrition rates in Italy and Belgium due to logistical problems at 96 months only. Also children from families with higher educated parents were more likely to stay in the study. Furthermore, the definitions used to identify misreporting might not be applicable in special circumstances, like in ill-patients or undernourished children because nutritional requirements in these groups are generally different from a normal population which we assumed for our group of children.

Conclusions

Misreporting of energy intake is a major source of bias in nutritional studies in the paediatric population. Our approach to identify misreporting in children is not only robust and simple but has been shown to be effective in the European Childhood Obesity Programme. The fixed cut-offs (children >12 months = ±20%; children >12 months ±25%) for the agreement between energy intake and estimated energy expenditure can be easily adapted for use in studies with less than 3 day dietary recall, when a computation of the individual variance is not sensible. Particularly in infants, comparison of energy intake should be made against the energy requirements, which include additional energy needed for growth and development.

Steps should be taken to deal with misreporting, which will strengthen research in the field of nutritional epidemiology by reducing bias.

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Statement of Authorship

The authors' responsibilities were as follows: DG, BK, UB, VG: conception and design of work; PS, VL, AX, EV: acquisition of data; VG prepared data and DG analyzed data and wrote paper.

Conflict of Interest Statement

All authors read, critically revised and approved the final manuscript. None of the authors reported a conflict of interest.

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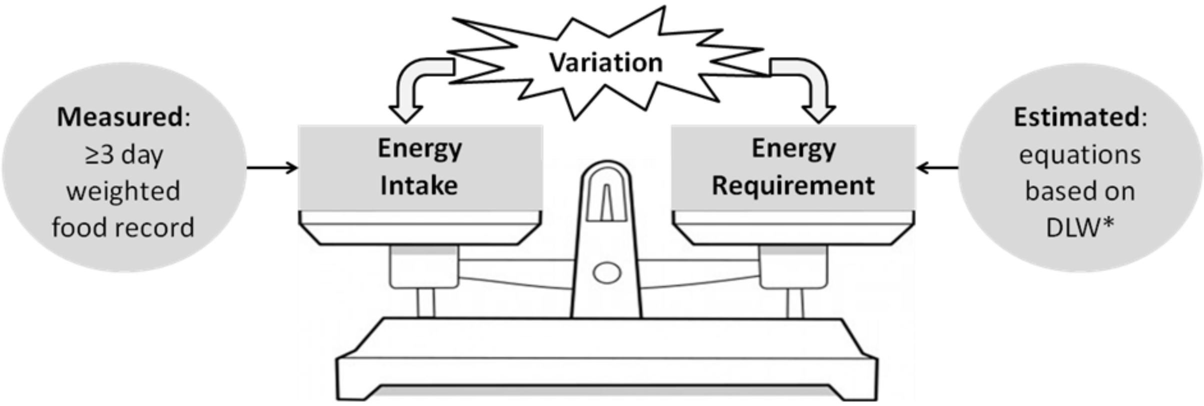
Figure 1: Relationship between energy intake and energy requirement



*DLW = doubly labelled water technique

Figure 2: Proportion of misreporting according to age

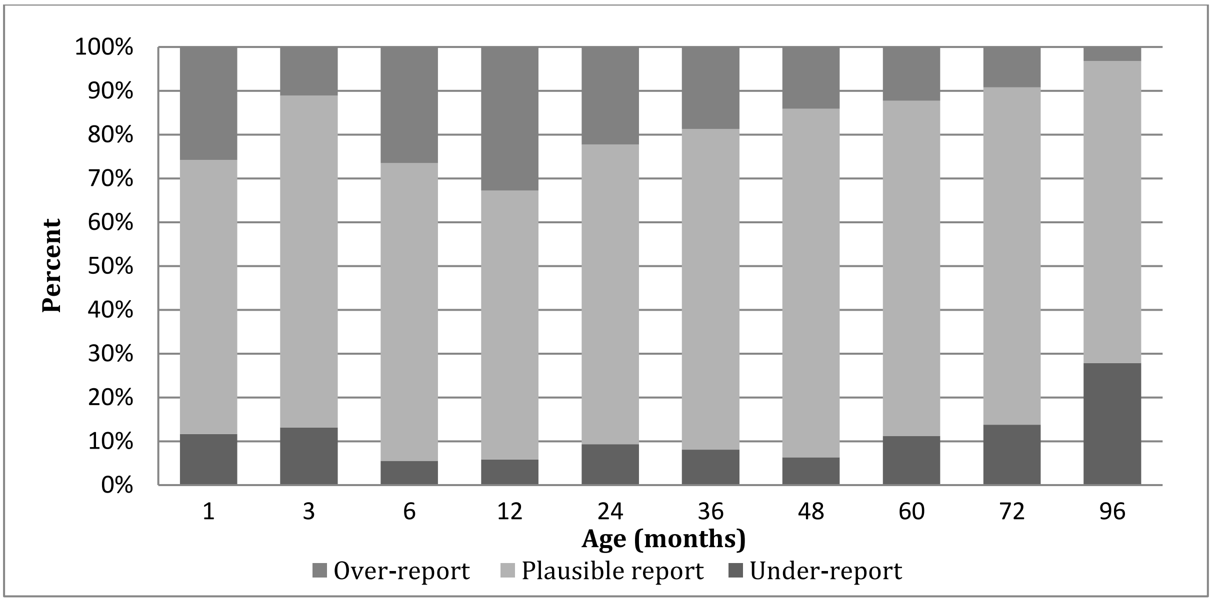
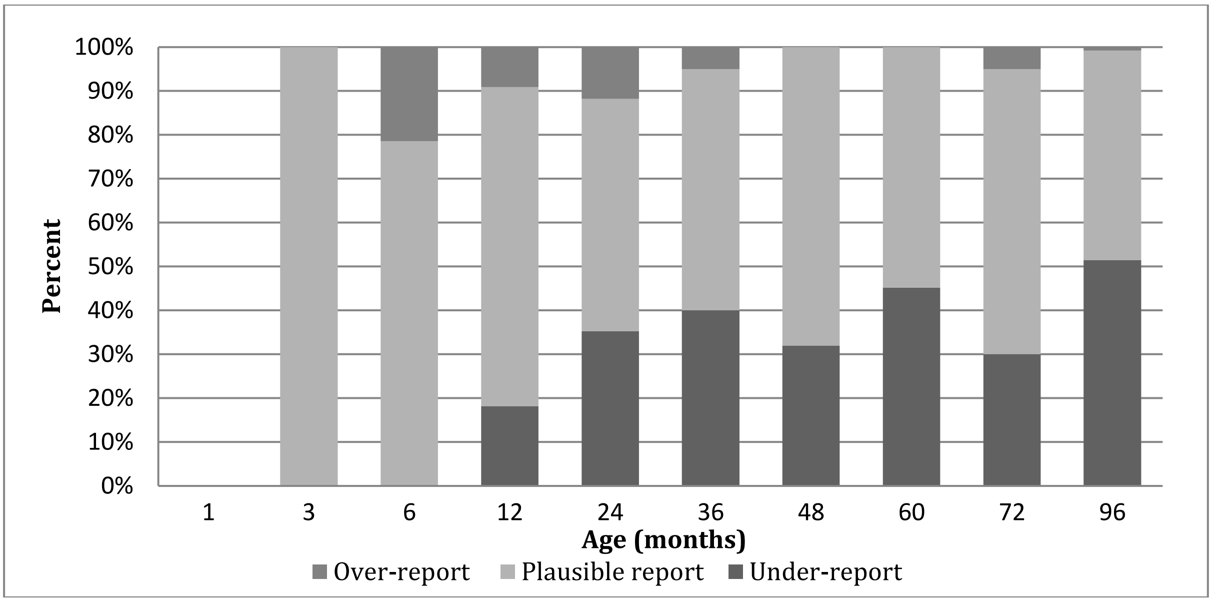


Figure 3: Proportion of misreporting in obese and over-weight children* according to age



*Based on WHO cut-offs: for children <5 years: obese: >+3SD, overweight (OW): +2SD to ≤+3SD, normal: -3SD to ≤+2SD; for children >5 years: obese: >+2SD, overweight (OW): +1SD to ≤+2SD, normal: -2SD to ≤+1SD

Table 1

Characteristics of children and number of food protocols by BMI categories according to country

		Country											
		Belgium		Germany		Italy		Poland		Spain		Total	
		Children n (% in country)											
Total children		154	(12.8)	204	(17.0)	306	(25.5)	212	(17.7)	323	(27.0)	1,199	
Gender													
Boys		60	(39.0)	96	(47.1)	164	(53.6)	115	(54.2)	156	(48.3)	591	(49.3)
Girls		94	(61.0)	108	(52.9)	142	(46.4)	97	(45.8)	167	(51.7)	608	(50.7)
Feeding group at infancy													
Breast-fed[1]		46	(29.9)	50	(24.5)	98	(32.0)	47	(22.2)	57	(17.7)	298	(24.9)
Formula-fed		108	(70.1)	154	(75.5)	208	(68.0)	165	(77.8)	266	(82.4)	901	(75.1)
Age (m)	BMI categories[2]												
1	Normal	84	(100.0)	105	(100.0)	133	(100.0)	50	(100.0)	198	(100.0)	570	(100.0)
	OW/Obese	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
3	Normal	86	(100.0)	133	(100.0)	187	(99.5)	156	(99.4)	219	(99.1)	781	(99.5)
	OW/Obese	0	(0.0)	0	(0.0)	1	(0.5)	1	(0.6)	2	(0.9)	4	(0.5)
6	Normal	83	(100.0)	120	(99.2)	181	(96.8)	145	(98.0)	204	(98.1)	733	(98.1)
	OW/Obese	0	(0.0)	1	(0.8)	6	(3.2)	3	(2.0)	4	(1.9)	14	(1.9)
12	Normal	92	(96.8)	126	(96.2)	224	(93.0)	140	(92.7)	190	(96.0)	772	(94.6)
	OW/Obese	3	(3.2)	5	(3.8)	17	(7.0)	11	(7.3)	8	(4.0)	44	(5.4)
24	Normal	88	(100.0)	119	(99.2)	237	(97.9)	132	(96.4)	167	(96.5)	743	(97.8)
	OW/Obese	0	(0.0)	1	(0.8)	5	(2.1)	5	(3.6)	6	(3.5)	17	(2.2)
36	Normal	66	(100.0)	75	(97.4)	170	(95.5)	78	(94.0)	121	(96.0)	510	(96.2)
	OW/Obese	0	(0.0)	2	(2.6)	8	(4.5)	5	(6.0)	5	(4.0)	20	(3.8)
48	Normal	66	(100.0)	54	(94.7)	160	(94.1)	71	(93.4)	134	(95.0)	485	(95.1)
	OW/Obese	0	(0.0)	3	(5.3)	10	(5.9)	5	(6.6)	7	(5.0)	25	(4.9)
60	Normal	56	(100.0)	48	(98.0)	155	(93.9)	63	(90.0)	120	(90.2)	442	(93.5)
	OW/Obese	0	(0.0)	1	(2.0)	10	(6.1)	7	(10.0)	13	(9.8)	31	(6.4)
72	Normal	58	(95.1)	49	(87.5)	113	(72.0)	68	(74.7)	101	(70.1)	389	(76.4)
	OW/Obese	3	(4.9)	7	(12.5)	44	(28.0)	23	(25.3)	43	(29.9)	120	(23.6)
96	Normal	36	(85.7)	52	(85.7)	64	(63.4)	55	(67.9)	100	(65.4)	307	(70.3)
	OW/Obese	6	(14.3)	8	(13.3)	37	(36.6)	26	(32.1)	53	(34.6)	130	(29.7)

[1]Children with current breast-feeding are not included

[2]Based on WHO cut-offs: for children <5 years: obese: >+3SD, overweight (OW): +2SD to ≤+3SD, normal: -3SD to ≤+2SD; for children >5 years: obese: >+2SD, overweight (OW): +1SD to ≤+2SD, normal: -2SD to ≤+1SD

Table 2

Reported energy intake (mean ± SD) and its mean coefficient of variation according to age and gender

Age (months)	Overall EI (Kcal/d)	Overall CV_{EI} (%)[1]	Boys EI (Kcal/d)	Boys CV_{EI} (%)[1]	Girls EI (Kcal/d)	Girls CV_{EI} (%)[1]
1	515.0 ± 101.0	10.1	534.0 ± 99.0	10.3	496.4 ± 99.5	9.9
3	587.6 ± 114.5	8.7	605.5 ± 124.2	8.8	569.9 ± 101.2	8.6
6	717.0 ± 153.7	9.2	741.5 ± 161.2	9.5	692.3 ± 141.7	8.9
12	881.3 ± 180.7	12.3	902.9 ± 185.7	11.7	861.8 ± 173.9	12.7
24	1,099.1 ± 242.2	15.3	1,106.7 ± 239.2	15.1	1,092.1 ± 245.1	15.4
36	1,209.0 ± 253.3	15.7	1,243.1 ± 265.7	15.7	1,177.0 ± 237.1	15.7
48	1,304.9 ± 248.5	15.3	1,341.1 ± 268.5	15.4	1,269.8 ± 222.5	15.3
60	1,380.4 ± 264.0	15.7	1,411.4 ± 276.8	15.4	1,351.3 ± 248.4	16.1
72	1,466.2 ± 260.9	15.2	1,500.8 ± 251.0	14.8	1,435.6 ± 266.2	15.6
96	1,572.8 ± 303.1	14.2	1,643.6 ± 311.1	14.6	1,508.0 ± 280.9	13.8

[1]Within-individual coefficient of variation in energy intakes at a given time-point 't' (%) calculated using equations given by Black and Cole, 2000 (20): $CV_{EI_{it}} = \sqrt{\sigma_{EI_{it}}/\mu_{EI_{it}}}*100$ and $CV_{EI} = \sqrt{\sum_{i=1}^{n}(CV_i^2)/n}$; EI, Energy Intake.

Table 3
Ratio of energy intake and requirement, total coefficient of variation, misreporting cut-offs and proportion of misreporters at an α level of 0.05

	N	Ratio EI:EER	CV_{total}%[1]	Misreporting cut-offs		Misreporting proportion		
				Lower cut-off[2]	Upper cut-off[3]	Under-reporting[4]	Plausible reporting[5]	Over-reporting[6]
	(obs)	(mean ± SEM)		(mean)		% (95% CI)		
Age (months)								
1	570	1.05 ± 0.009	10.3 ± 0.13	0.80	1.20	11.7 (9.1 – 14.4)	62.5 (58.5 – 66.4)	25.8 (22.2 – 29.4)
3	785	0.98 ± 0.007	10.0 ± 0.09	0.80	1.20	13.1 (10.8 – 15.5)	75.8 (72.8 – 78.8)	11.1 (8.9 – 13.3)
6	747	1.10 ± 0.009	10.1 ± 0.09	0.80	1.20	5.5 (3.9 – 7.1)	68.0 (64.7 – 71.4)	26.5 (23.3 – 29.7)
12	816	1.11 ± 0.009	11.3 ± 0.12	0.78	1.22	5.8 (4.2 – 7.4)	61.4 (58.1 – 64.7)	32.8 (29.6 – 36.1)
24	760	1.06 ± 0.009	12.5 ± 0.16	0.76	1.24	9.3 (7.3 – 11.4)	68.4 (65.1 – 71.7)	22.3 (19.3 – 25.2)
36	530	1.04 ± 0.009	12.6 ± 0.18	0.75	1.25	8.1 (5.8 – 10.4)	73.2 (69.4 – 77.0)	18.7 (15.4 – 22.0)
48	510	1.02 ± 0.009	12.5 ± 0.19	0.75	1.24	6.3 (4.2 – 8.4)	79.6 (76.1 – 83.1)	14.1 (11.1 – 17.1)
60	473	0.99 ± 0.009	12.7 ± 0.21	0.75	1.25	11.2 (8.4 – 14.1)	76.5 (72.7 – 80.4)	12.3 (9.3 – 15.2)
72	509	0.96 ± 0.008	12.5 ± 0.18	0.76	1.24	13.8 (10.8 – 16.7)	77.0 (73.4 – 80.7)	9.2 (6.7 – 11.8)
96	437	0.87 ± 0.009	12.1 ± 0.21	0.76	1.24	27.9 (23.7 – 32.1)	68.9 (64.5 – 73.2)	3.2 (1.6 – 4.9)
BMI categories[7]								
Obese	110	0.73 ± 0.012	11.6 ± 0.39	0.77	1.23	65.5 (56.5 – 74.4)	34.5 (25.6 – 43.5)	0.0 (0.0 – 0.0)
OW	295	0.89 ± 0.011	11.7 ± 0.22	0.77	1.23	25.4 (20.4 – 30.4)	68.8 (63.5 – 74.1)	5.8 (3.1 – 8.4)
Normal	5,732	1.04 ± 0.003	11.5 ± 0.05	0.77	1.23	8.8 (8.0 – 9.5)	71.3 (70.1 – 72.5)	19.9 (18.9 – 21.0)
Gender								
Boys	2,983	1.02 ± 0.004	11.5 ± 0.07	0.77	1.23	12.0 (10.9 – 13.2)	69.9 (68.2 – 71.5)	18.1 (16.7 – 19.5)
Girls	3,154	1.04 ± 0.004	11.5 ± 0.07	0.77	1.23	9.2 (8.2 – 10.2)	71.2 (69.6 – 72.8)	19.6 (18.2 – 21.0)
Country								
Belgium	727	1.01 ± 0.008	11.8 ± 0.16	0.77	1.23	11.7 (9.4 – 14.0)	72.3 (69.1 – 75.6)	16.0 (13.3 – 18.6)
Germany	909	0.97 ± 0.007	12.5 ± 0.16	0.76	1.24	13.8 (11.5 – 16.0)	75.8 (73.0 – 78.6)	10.4 (8.5 – 12.4)
Italy	1,762	1.00 ± 0.005	11.4 ± 0.09	0.78	1.22	11.5 (10.0 – 13.0)	74.0 (72.0 – 76.1)	14.5 (12.8 – 16.1)
Poland	1,044	1.04 ± 0.007	10.7 ± 0.08	0.79	1.21	11.0 (9.1 – 12.9)	69.4 (66.6 – 72.1)	19.6 (17.2 – 22.0)
Spain	1,695	1.10 ± 0.006	11.5 ± 0.09	0.77	1.23	7.1 (5.9 – 8.4)	64.1 (61.8 – 66.4)	28.8 (26.6 – 30.9)
Total observations	6,137	1.03 ± 0.006	11.5 ± 0.05	0.77	1.23	10.6 (9.8 – 11.3)	70.5 (69.4 – 71.7)	18.9 (17.9 – 19.9)

[1]Total within-individual variation at a given time-point, taking into consideration the CV in energy intake according to number of days of dietary records and total energy expenditure (%) calculated using equation: $\mathrm{CV}_{\mathrm{total}_{\mathrm{it}}} = \sqrt{\mathrm{CV}_{\mathrm{EI}_{\mathrm{it}}}^2/\mathrm{d}_{\mathrm{it}} + \mathrm{CV}_{\mathrm{TEE}}^2}$;

[2]Individual lower cut-off calculated using equation: $1 - Z_\alpha * \mathrm{CV}_{\mathrm{total}_{\mathrm{it}}}$;

[3]Individual upper cut-off calculated using equation: $1 + Z_\alpha * \mathrm{CV}_{\mathrm{total}_{\mathrm{it}}}$;

[4]Under-reporting proportion if ratio EI:EER<lower cut-off;

[5]Plausible reporting proportion if lower cut-off< ratio EI:EER>upper cut-off;

[6]Over-reporting proportion if ratio EI:EER>upper cut-off;

[7]Based on WHO cut-offs: for children <5 years: obese: >+3SD, overweight (OW): +2SD to ≤+3SD, normal: -3SD to ≤+2SD; for children >5 years: obese: >+2SD, overweight (OW): +1SD to ≤+2SD, normal: -2SD to ≤+1SD;

Obs, observations