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ORIGINAL ARTICLE

Usual energy and macronutrient intakes in 2–9-year-old European children

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OBJECTIVE: Valid estimates of population intakes are essential for monitoring trends as well as for nutritional interventions, but such data are rare in young children. In particular, the problem of misreporting in dietary data is usually not accounted for. Therefore, this study aims to provide accurate estimates of intake distributions in European children.
DESIGN: Cross-sectional setting-based multi-centre study.
SUBJECTS: A total of 9560 children aged 2–9 years from eight European countries with at least one 24-h dietary recall (24-HDR).
METHODS: The 24-HDRs were classified in three reporting groups based on age- and sex-specific Goldberg cutoffs (underreports, plausible reports, overreports). Only plausible reports were considered in the final analysis (*N* = 8611 children). The National Cancer Institute (NCI)-Method was applied to estimate population distributions of usual intakes correcting for the variance inflation in short-term dietary data.
RESULTS: The prevalence of underreporting (9.5%) was higher compared with overreporting (3.4%). Exclusion of misreports resulted in a shift of the energy and absolute macronutrient intake distributions to the right, and further led to the exclusion of extreme values, that is, mean values and lower percentiles increased, whereas upper percentiles decreased. The distributions of relative macronutrient intakes (% energy intake from fat/carbohydrates/proteins) remained almost unchanged when excluding misreports. Application of the NCI-Method resulted in markedly narrower intake distributions compared with estimates based on single 24-HDRs. Mean percentages of usual energy intake from fat, carbohydrates and proteins were 32.2, 52.1 and 15.7%, respectively, suggesting the majority of European children are complying with common macronutrient intake recommendations. In contrast, total water intake (mean: 1216.7 ml per day) lay below the recommended value for >90% of the children.
CONCLUSION: This study provides recent estimates of intake distributions of European children correcting for misreporting as well as for the daily variation in dietary data. These data may help to assess the adequacy of young children's diets in Europe.

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INTRODUCTION

Knowledge on population intakes of energy and macronutrients is essential for monitoring trends as well as for nutritional interventions. In particular in childhood, a balanced diet is of great importance to ensure optimum growth and development and to prevent childhood obesity.[1] However, assessment of long-term dietary information ('usual intakes') is challenging. Major problems emerge from the daily variation in diet, memory errors, and difficulties in estimation of long-term consumption frequencies/amounts, but also from misreporting.[2–4] As young children lack the cognitive skills for valid self-reports, dietary assessment is even more problematic in this age group. The age of 8–12 years is considered as transition period in which children develop the abilities for valid self-reports.[5] Dietary data in children younger than 8 years are commonly assessed through parental proxies, which may result in additional reporting errors for example due to unobserved meals. Hence, the problem of unintentional misreporting may be even more pronounced in data relying on proxies.[6]

In large epidemiological studies, food frequency questionnaires (FFQs) or single/repeated short-term measurements like 24-h dietary recalls (24-HDR) or food records are generally used for dietary assessment for cost and time reasons.[7] FFQs are limited to a finite food list and are hampered by the inability of individuals to accurately report their long-term consumption frequencies/amounts, in particular, for irregular or seasonally consumed foods. Both shortcomings introduce substantial error into usual energy and macronutrient intake estimates based on FFQ data.[8–11] In contrast, 24-HDRs and food records provide rich detail about the types and amounts of foods consumed and were shown to be less prone to systematic bias compared with FFQs.[10] However, due to the day-to-day variation in diet and additional sources of random errors, the within-person variation in short-term dietary data is large such that intakes measured on a single day may provide a poor estimate of long-term intake.[12,13] Repeated short-term measures are needed at least in a subgroup to validly estimate population distributions of usual dietary intake as the data need to be corrected for the increased within-person variation. Several

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methods have been proposed for the estimation of usual dietary intakes based on repeated short-term measures.[12–20] All methods share a common methodology but vary in statistical complexity and assumptions made about characteristics of the intake data. To date, these methods were rarely applied to real data. Consequently, there are few data on usual energy and macronutrient intake distributions in European children available.

Studies in children so far[21,22] often report only mean intakes either based on single 24-HDR, food diaries or FFQ data. Even though the population groups at risk are typically those at the upper or lower percentiles, information on the total intake distribution is rarely provided. Even in studies where repeated 24-HDRs are available, reported intakes are often not corrected for the variance inflation. In many cases, simply the mean of the measurements is used in the analysis, although it is well known that averaging of repeated 24-HDR data only removes part of the within-person variation. Consequently, such calculations may result in biased moment estimates (except for the mean) and biased estimates especially of low/high percentiles.[12]

In addition, the problem of misreporting in dietary data is seldom accounted for. Several studies revealed that especially underreporting of energy intake but also selective misreporting of single food items pose major challenges on dietary assessment.[4,23,24] It is likely that intake distributions estimated without accounting for misreporting may be shifted to the left or right where the direction depends on the degree of over- and underreporting. Given these problems, many published data may not adequately reflect real intakes.

Apart from the methodological limitations of available studies, the changes in lifestyle during the last decades, for example, increased sedentary behaviour[25–27] and the steadily increasing consumption of convenience food,[28] are likely to have changed usual energy and macronutrient intakes over years. The limited studies available in children from European countries report decreasing trends for overall energy and fat intake and increasing trends for carbohydrate intake[29–31] or stable fat intakes.[32] These studies were partially already conducted during the 90s[29,30] and are based on rather small data sets including only single countries. In a review on nutrient intake and dietary status, it was concluded that data are lacking to reasonably evaluate the diets of European children and adolescents.[33] Thus, recent information on usual intakes based on a large data set of European children would be desirable. The present study aims to provide such data for 2–9-year-old children from eight European countries.

MATERIALS AND METHODS

Study population

Identification and Prevention of Dietary- and Lifestyle-Induced Health Effects in Children and Infants (IDEFICS) is a multi-centre population-based study aiming to investigate and prevent the causes of diet- and lifestyle-related diseases in 2–9-year-old children. The baseline survey (T0) was conducted from September 2007 to May 2008 in eight European countries ranging from North to South and from East to West (Sweden, Germany, Hungary, Italy, Cyprus, Spain, Belgium, Estonia); $>31\,500$ children were invited, out of whom finally 16 228 participated and fulfilled the inclusion criteria of the IDEFICS study. The study was not designed to provide a representative sample for each country, but socio-demographic characteristics of populations at the study locations were comparable to regional or national data. All children in the defined age group who resided in the defined regions and who attended the selected primary schools (grades 1 and 2), pre-schools or kindergartens were eligible for participation. Children were approached via schools and kindergartens to facilitate equal enrolment of all social groups. The survey included interviews with parents concerning lifestyle habits and dietary intakes as well as anthropometric measurements and examinations of the children. All measurements were taken using standardised procedures in all eight countries. Details on the design and objectives of the study can be obtained from Ahrens et al.[34]

The study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the local ethics committees in each participating country. Parents provided written informed consent for all examinations. Each child was informed orally about the modules by field workers and asked for its consent immediately before examination.

Anthropometry

Height (cm) of the children was measured to the nearest 0.1 cm with a calibrated stadiometer (model: telescopic height measuring instruments seca 225), body weight (kg) was measured in fasting state in light underwear on a calibrated scale accurate to 0.1 kg (model: electronic scale TANITA BC 420 SMA with adapter).

Body mass index was calculated as weight divided by height squared and categorised according to the extended International Obesity Task Force (IOTF) criteria.[35]

Dietary data

Dietary intake was assessed using the computerised 24-HDR 'SACINA' (Self-Administered Children and Infants Nutrition Assessment). This 24-HDR was recently validated by comparison of reported energy intakes with objective measures of energy expenditure.[36] The SACINA is based on the previously designed and validated 'YANA-C' developed for Flemish adolescents and further adapted to European adolescents in the HELENA study.[37,38] It is structured according to six meal occasions (breakfast, morning snack, lunch, afternoon snack, dinner, evening snack) embedded in questions related to a range of chronological daily activities. Standardised photographs are displayed on the screen to assist portion size estimation. Proxies, mainly the parents, completed the 24-HDR under supervision of fieldwork personnel in about 20–30 min. Except for Cyprus, where school ends at 1:05 pm, 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 the completeness of dietary recalls. The 24-HDRs were assessed on non-consecutive days over the whole week and over the complete IDEFICS assessment period. The assessment procedure in Hungary slightly deviated from the other study centres. Here, dietary information was recorded on documentation sheets and entered into the SACINA programme afterwards.

Simple foods or pan-European homogeneous multi-ingredient food items were linked to country-specific food composition tables (FCTs).[39–43] Estonia combined the Norwegian and Finnish FCTs,[44,45] Hungary used the German FCT,[41] Cyprus included foods from the German and Swedish FCTs.[41,42] If nutrient information of single food items was missing in the country-specific FCTs, nutrient information was added using values available from other countries' FCTs. 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 recall exclusions. 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.

According to the study protocol, it was envisaged to assess repeated 24-HDR data in ~20% of the sample. In the final database, one recall day is available in 9560 children and a second one in 2518 children where the second recalls were used to correct for the day-to-day variation.

Estimation of usual intakes

Usual intake distributions for energy and macronutrients were estimated based on the validated National Cancer Institute (NCI)-Method, which is one of the most sophisticated methods for this purpose. Details are given in Tooze et al.[19,46] In brief, the NCI-Method calculates estimates of usual intake based on non-linear mixed regression models. In addition to the correction for within-person errors in the dietary data, the statistical model includes a random effect to account for person-specific errors: in a preparatory step, initial adjustments are made and the data are transformed using a one-parameter Box-Cox transformation with a positive real-valued power parameter such that the transformed data are approximately normally distributed. In the second step, the variance is decomposed into within- and between-person variance and the distribution of usual intake is estimated by correcting for the variance inflation. Finally, the data are back-transformed to the original scale. It is assumed

Table 1. Lower and upper cutoff limits to classify 1-day 24-h dietary recalls in under-, plausible and overreports based on the ratio of energy intake over basal metabolic rate (Source: Börnhorst *et al.*[6])

Age (years)	*Sex*	*Underreport*	*Plausible report*	*Overreport*
2 to <6	Boys	EI/BMR$\leqslant$0.74	0.74$<$EI/BMR$<$2.85	2.85$\leqslant$EI/BMR
2 to <6	Girls	EI/BMR$\leqslant$0.78	0.78$<$EI/BMR$<$2.69	2.69$\leqslant$EI/BMR
6 to <10	Boys	EI/BMR$\leqslant$0.92	0.92$<$EI/BMR$<$2.61	2.61$\leqslant$EI/BMR
6 to <10	Girls	EI/BMR$\leqslant$0.93	0.93$<$EI/BMR$<$2.43	2.43$\leqslant$EI/BMR

Abbreviations: BMR, basal metabolic rate estimated from Schofield equations; EI, energy intake estimated from 24-h dietary recalls.

Table 2. Study population including/excluding misreports by age, sex, region and body mass index category

	All	*2-<6 years*	*6-<10 years*	*Boys*	*Girls*	*North*[a]	*South*[a]	*Thin/normal weight*[b]	*Overweight/obese*[b]
	N	N *(%)*	N *(%)*	N *(%)*	N *(%)*	N *(%)*	N *(%)*	N *(%)*	N *(%)*
Whole sample									
1st 24-HDR	9560	4032 (42.2)	5528 (57.8)	4827 (50.5)	4733 (49.5)	4185 (43.8)	5375 (56.2)	7478 (78.2)	2082 (21.8)
2nd 24-HDR	2518	990 (39.3)	1528 (60.7)	1258 (50.0)	1260 (50.0)	489 (19.4)	2029 (80.6)	1995 (79.2)	523 (20.8)
Excluding misreports[c]									
1st 24-HDR	8611	3731 (43.3)	4880 (56.7)	4407 (51.2)	4204 (48.8)	3773 (43.8)	4838 (56.2)	6849 (79.5)	1762 (20.5)
2nd 24-HDR	1910	817 (42.8)	1093 (57.2)	983 (51.5)	927 (48.5)	381 (19.9)	1529 (80.1)	1574 (82.4)	336 (17.6)

[a]Southern Europe: Cyprus, Hungary, Italy, Spain; Northern Europe: Belgium, Estonia, Germany, Sweden [b]Classified according to the extended IOTF criteria[35] [c]Misreport: Under- or overreport classified according to adapted Goldberg cutoffs.[6]

that 24-HDRs form an unbiased estimator of usual intake on the original scale. The NCI-Method is superior to other methods as it, for example, allows the inclusion of covariates like age, sex or additional FFQ information and is able to provide estimates for subpopulations. It further accounts for nuisance effects like the day of the week. Moreover, it enables the estimation of usual intakes even if repeated 24-HDR data are only available in a subgroup, whereas other methods require at least two 24-HDRs for the whole study population.

The NCI-Method has been implemented in SAS macros, which were downloaded from the website http://riskfactor.cancer.gov/diet/usualintakes/macros.html (date of download: 19 september 2012). Based on these macros, usual intake distributions were estimated for energy (kcal per day), fat (g per day; percentage of total energy intake (%EI)), protein (g per kg per day; %EI), carbohydrate (g per day; %EI), fibre (g per day) and water intake (including water from foods; ml per day). Calculations were performed for the whole sample as well as stratified by sex, age group (pre-school vs school children, that is, 2 to <6 years vs 6 to <10 year olds) and by geographic region (Southern Europe: Cyprus, Hungary, Italy, Spain vs Northern Europe: Belgium, Estonia, Germany, Sweden). The given age groups were chosen as it is likely that the dietary behaviour changes when children enter school due to the resulting changes in their daily routines. Separate estimations for single countries were not feasible. The numbers of repeated recalls needed for the variance decomposition were too small in case of Belgium, Estonia, Cyprus and Sweden such that the estimation procedures did not converge.

All models considered nuisance effects (day of the week, interview sequence) and were adjusted for age and sex—when not stratifying by age and sex. Furthermore, all models were run assuming the within-person variances between the subgroups to be equal. The analyses were performed using the statistical software package SAS (version 9.2; SAS Institute, Cary, NC, USA).

Handling of misreporting

Intentional as well as unintentional misreporting, which comprises over- and underreporting, are well-known problems in dietary assessment and may be even more pronounced in data relying on proxy reports.[6] Black[47] and Goldberg *et al.*[48] defined cutoff values to classify 24-HDRs in energy underreports (UnR), plausible reports and overreports (OvR), respectively. The cutoffs allow for the errors associated with the duration of dietary assessment (number of recall days), the sample size as well as variation in basal metabolic rate, physical activity level and energy intake. Minimum/maximum plausible levels of energy intake are defined as multiples of basal metabolic rate. The Goldberg cutoffs were confirmed to have good predictive value and hence to be an appropriate alternative for characterising misreporting in the absence of objective validation data.[49] As these cutoffs were developed for adults and do not consider differences in energy intake due to age and sex, the original cutoffs were recently adapted for use in children. Details are given elsewhere.[6,50] For the sake of convenience, the adapted Goldberg cutoffs are given in Table 1. Based on these age- and sex-specific cutoffs, the 24-HDRs were classified in UnR, plausible reports and OvR. In the following, the term ‘misreports’ will be used to indicate UnR and OvR of total energy intake.

RESULTS

The study sample comprises of 9560 children out of which a second 24-HDR was completed for 2518 children (12 078 24-HDRs in total). Table 2 displays numbers of children with a first/second 24-HDR stratified by age, sex, region and body mass index category. Males and females are almost equally represented in the sample, whereas the percentage of children in the older age group (1st 24-HDR: 57.8%; 2nd 24-HDR: 60.7%) is higher compared with the percentage in the lower age group (1st 24-HDR: 42.2%; 2nd 24-HDR: 39.3%). Further numbers are shown excluding 24-HDRs classified as misreports. In total, 1150 (9.5%) of the 12 078 24-HDRs were classified as UnR and 407 (3.4%) were classified as OvR. As misreporting is likely to introduce systematic errors,[51,52] only 24-HDRs classified as plausible reports were used to estimate the usual intake distributions (1st 24-HDR: $N=8611$; 2nd 24-HDR: $N=1910$). The age and sex distributions in the samples including/excluding misreports are almost equal, only the weight status distribution differs to a small degree. The percentage of overweight/obese study subjects is slightly lower after exclusion of misreports.

Mean values, s.d., kurtosis, skewness, minima, maxima and selected percentiles of energy and macronutrient intakes estimated based on the first recall days (empirical distributions) are shown in Table 3, both, for the samples including and excluding misreports. Exclusion of misreports resulted in narrower intake distributions and in a decrease of the skewness and kurtosis. For all absolute intakes (kcal per day, g per day), mean/median intakes were slightly higher after exclusion of misreports, whereas lower

Table 3. Empirical distributions of energy intake and macronutrients estimated based on single 24-HDRs including ($N = 9560$) and excluding ($N = 8611$) 24-HDRs classified as misreports

	MR	*Min*	*Max*	*Mean (s.d.)*	*P1*	*P3*	*P10*	*P25*	*P50*	*P75*	*P90*	*P97*	*P99*	*Skewness*	*Kurtosis*
EI (kcal per day)	Incl	71.6	6076.5	1519.8 (532.4)	483.4	657.4	887.1	1150.4	1475.7	1822.0	2200.6	2635.5	2992.0	0.7	1.8
	Excl	573.7	3886.3	1550.7 (428.4)	743.1	861.9	1034.6	1238.4	1508.1	1816.7	2134.0	2451.6	2667.4	0.5	0.2
Fat (g per day)	Incl	0.3	254.5	54.9 (27.1)	10.7	16.6	25.2	35.8	50.7	68.8	89.4	115.1	140.3	1.2	3.1
	Excl	5.3	221.0	55.9 (23.6)	16.4	21.4	29.2	38.5	52.2	69.0	87.3	108.7	124.9	0.9	1.3
Carbs (g per day)	Incl	7.1	839.5	193.7 (77.6)	54.6	73.7	105.0	139.2	184.3	236.7	294.8	363.0	425.4	0.9	2.0
	Excl	27.3	563.6	197.9 (67.1)	74.8	93.7	119.7	149.9	189.3	237.1	287.9	344.1	383.1	0.7	0.7
Protein (g per day)	Incl	2.4	334.7	58.6 (25.3)	15.0	20.5	29.6	40.9	55.5	72.4	90.4	112.6	134.7	1.2	4.2
	Excl	8.6	195.3	59.7 (22.5)	20.9	25.7	33.6	43.6	56.7	72.4	88.8	108.1	127.0	0.9	1.8
Protein (g per kg per day)	Incl	0.1	17.2	2.7 (1.3)	0.6	0.8	1.2	1.7	2.4	3.3	4.3	5.6	6.9	1.5	5.8
	Excl	0.4	10.7	2.7 (1.2)	0.9	1.1	1.4	1.9	2.5	3.3	4.3	5.4	6.4	1.2	2.8
Fibres (g per day)	Incl	0.0	52.5	12.2 (5.9)	2.4	3.6	5.6	8.0	11.3	15.3	19.7	25.3	30.2	1.1	2.6
	Excl	0.0	52.5	12.4 (5.5)	3.1	4.4	6.2	8.5	11.6	15.4	19.5	24.5	29.2	1.1	2.4
Water (g per day)	Incl	22.4	4761.6	1194.4 (469.2)	294.6	422.6	623.9	876.0	1162.7	1466.6	1783.9	2165.5	2505.5	0.8	2.1
	Excl	141.1	4757.1	1218.7 (441.2)	373.2	494.7	679.9	913.8	1185.4	1473.2	1779.7	2138.4	2444.5	0.7	1.9
Fat (%EI)	Incl	1.3	67.4	31.4 (9.0)	12.3	15.3	20.1	25.2	31.2	37.1	43.2	49.3	53.7	0.2	0.1
	Excl	5.7	67.4	31.5 (8.8)	12.7	15.9	20.4	25.4	31.3	37.1	43.1	49.1	53.7	0.3	0.1
Carbs (%EI)	Incl	8.6	84.8	52.0 (10.7)	25.8	30.9	38.2	45.1	52.3	59.3	65.6	71.6	75.5	− 0.2	0.0
	Excl	13.5	84.7	52.0 (10.5)	26.0	31.3	38.5	45.2	52.2	59.2	65.5	71.1	74.7	− 0.2	0.0
Protein (%EI)	Incl	2.3	54.6	15.9 (4.8)	7.4	8.7	10.6	12.5	15.2	18.3	22.0	27.0	31.1	1.1	2.6
	Excl	4.0	45.2	15.8 (4.7)	7.5	8.8	10.6	12.5	15.1	18.2	21.7	26.6	30.3	1.0	1.9

Abbreviations: Carbs, carbohydrates; EI, energy intake; MR, misreport. Misreport, that is under- or overreport classified according to adapted Goldberg cutoffs.[6]

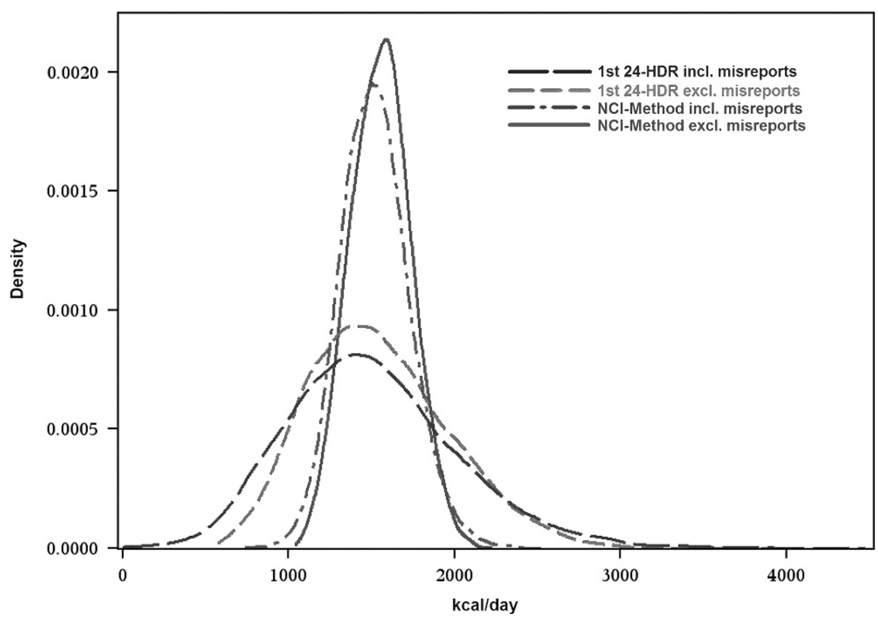

Figure 1. Kernel densities of total daily energy intakes (kcal per day) estimated based on single-day 24-HDRs or based on the National Cancer Institute (NCI)-Method[19] including/excluding 24-HDRs classified as underreports or overreports based on adapted Goldberg cutoffs.[6]

and upper percentiles changed markedly. Percentiles and means of relative fat, carbohydrate and %EI remained almost unchanged.

Figure 1 exemplarily visualises the changes in the estimated distributions of energy intake (kcal per day).

(a) using single day 24-HDR data including misreports (empirical distribution)
(b) using single day 24-HDR data excluding misreports (empirical distribution)
(c) applying the NCI-Method including misreports
(d) applying the NCI-Method excluding misreports.

Exclusion of misreports resulted in a shift of the energy intake distribution to the right and led to exclusion of extreme values, that is, mean values and lower percentiles increased, whereas upper percentiles decreased. When applying the NCI-Method, the correction for the variance inflation resulted in a markedly narrower energy intake distribution.

Percentiles and mean values of the distributions of absolute macronutrient, energy and water intake estimated by means of the NCI-Method after exclusion of misreports are presented in Table 4. Table 5 further shows the results for relative fat, carbohydrate and protein intakes (%EI). Estimates are given for the whole study group ($N = 8611$) as well as stratified by age and sex and region. Means and percentiles of absolute intakes (kcal per day, g per day) increase with age and are higher in boys compared with girls, whereas the %EI from fat, carbohydrates and protein remain relatively constant for all age and sex groups. The protein intake slightly decreases with age and is again higher in boys compared with girls. Comparing Northern and Southern

Table 4. Population distribution of energy intake (kcal per day), fat (g per day), carbohydrate (g per day), protein (g per kg per day), water intake (ml per day) and fibre intake (g per day) stratified by age group, sex and region estimated applying the NCI-Method (means and selected percentiles)

	Mean	*P1*	*P3*	*P10*	*P25*	*P50*	*P75*	*P90*	*P97*	*P99*
Energy intake (kcal per day)										
All	1546.2	1027.5	1111.9	1234.8	1370.4	1533.7	1708.0	1857.6	2042.2	2176.9
2 to < 6, boys	1471.7	1042.5	1109.7	1215.2	1329.8	1463.0	1602.5	1742.0	1876.8	1984.9
2 to < 6, girls	1361.1	960.4	1026.6	1122.4	1226.1	1351.1	1484.0	1600.0	1749.6	1858.6
6 to < 10, boys	1704.4	1218.3	1306.5	1416.2	1544.5	1692.6	1853.0	1989.2	2165.7	2288.8
6 to < 10, girls	1578.9	1126.3	1200.9	1308.5	1427.9	1569.3	1720.0	1847.1	2011.8	2128.1
North	1537.2	1026.9	1105.2	1223.9	1358.2	1525.2	1701.6	1865.3	2034.3	2170.0
South	1552.6	1036.5	1121.2	1243.9	1378.0	1542.2	1714.3	1874.2	2042.0	2172.3
Fat (g per day)										
All	56.0	34.9	38.3	43.2	48.7	55.4	62.5	69.4	76.6	82.3
2 to < 6, boys	52.8	35.0	37.7	42.0	46.8	52.3	58.2	64.2	70.0	74.7
2 to < 6, girls	49.1	32.4	35.1	39.1	43.4	48.7	54.3	59.8	65.8	70.5
6 to < 10, boys	61.5	41.3	44.9	49.4	54.8	61.0	67.8	74.1	81.1	86.5
6 to < 10, girls	57.8	38.7	41.8	46.3	51.3	57.3	63.7	70.0	76.4	81.5
North	56.8	35.9	39.0	43.9	49.4	56.3	63.6	70.5	77.8	83.6
South	55.3	34.6	38.0	42.8	48.2	54.8	61.8	68.4	75.3	80.9
Carbohydrates (g per day)										
All	197.1	111.0	124.6	144.5	166.9	194.1	224.0	253.2	284.2	309.6
2 to < 6, boys	188.7	111.5	122.9	141.4	162.0	186.5	212.7	239.5	265.8	287.2
2 to < 6, girls	173.8	101.7	112.9	129.7	148.3	171.3	196.4	221.2	248.1	269.8
6 to < 10, boys	218.0	131.4	146.3	165.4	188.2	215.2	245.0	273.3	304.4	328.7
6 to < 10, girls	199.2	119.0	131.5	150.1	171.2	196.8	224.7	251.0	280.1	302.9
North	197.6	112.3	125.3	144.6	166.9	194.8	224.8	254.1	285.4	309.7
South	196.6	110.9	124.6	144.5	166.5	193.8	223.8	252.4	282.3	307.0
Protein (g per kg per day)										
All	2.7	1.3	1.5	1.8	2.1	2.6	3.2	3.8	4.4	5.0
2 to < 6, boys	3.2	1.7	1.9	2.3	2.6	3.1	3.7	4.3	4.9	5.4
2 to < 6, girls	3.1	1.7	1.9	2.2	2.5	3.0	3.5	4.1	4.7	5.3
6 to < 10, boys	2.4	1.3	1.5	1.7	2.0	2.4	2.8	3.2	3.8	4.2
6 to < 10, girls	2.3	1.2	1.4	1.6	1.9	2.3	2.7	3.1	3.6	4.0
North	2.6	1.3	1.4	1.7	2.0	2.5	3.0	3.6	4.2	4.7
South	2.8	1.4	1.6	1.9	2.2	2.7	3.3	3.9	4.5	5.1
Water (ml per day)										
All	1216.7	586.9	685.2	832.2	996.7	1196.8	1414.9	1626.7	1849.4	2030.1
2 to < 6, boys	1162.1	566.0	653.2	795.3	954.7	1145.0	1348.3	1554.5	1755.5	1918.6
2 to < 6, girls	1121.7	542.6	631.7	766.3	916.7	1102.3	1303.9	1501.5	1714.9	1885.6
6 to < 10, boys	1311.2	663.9	775.0	917.6	1088.5	1290.7	1513.7	1723.8	1953.9	2131.6
6 to < 10, girls	1233.3	616.3	711.9	854.7	1017.6	1215.3	1430.3	1631.6	1852.8	2024.9
North	1224.3	593.3	694.0	837.7	1003.0	1205.7	1423.8	1635.2	1858.5	2038.7
South	1211.1	584.9	681.4	828.9	992.0	1189.6	1410.1	1619.0	1838.9	2015.0
Fibre intake (g per day)										
All	12.2	6.1	7.0	8.4	10.0	11.9	14.1	16.3	18.7	20.7
2 to < 6, boys	11.7	6.0	6.8	8.1	9.6	11.4	13.5	15.6	17.7	19.5
2 to < 6, girls	11.1	5.7	6.5	7.7	9.1	10.9	12.9	14.9	17.1	18.9
to < 10, boys	13.2	6.9	7.9	9.3	10.9	12.9	15.2	17.4	19.9	21.8
6 to < 10, girls	12.4	6.5	7.3	8.7	10.2	12.2	14.4	16.4	18.8	20.7
North	13.1	6.7	7.7	9.1	10.7	12.8	15.1	17.4	19.8	21.8
South	11.6	5.8	6.7	8.0	9.4	11.3	13.4	15.5	17.7	19.6

The estimates are based on 8611 children out of which a second 24-HDR was available in 1910 children; 24-HDRs classified as misreport were excluded.

European countries, the total energy intake is slightly higher in Southern countries, which is mainly due to a higher intake of proteins.

DISCUSSION

This paper provides recent estimates of energy and macronutrient intake distributions based on a large data set of European children accounting for the well-known problem of misreporting as well as for the variance inflation in short-term dietary data. In a recent article, Lambert *et al.*[33] evaluated published data on nutrient intake and status of children and adolescents across Europe. It was stated that almost all included studies assumed their intake data to be 'representative and valid measures of habitual food consumption' though it is 'widely accepted that misreporting is a major problem' and may hence result in bias. In proxy-reported data for young children misreporting may be even more pronounced, which underlines the importance to correct for the reporting errors caused for example, by meals not under parental control. Apart from the misreporting problem, Lambert *et al.*[33] pointed to the lack of standardised intake measurements in children across Europe. Both shortcomings are mitigated in the study presented here. Exclusion of misreports mainly affected the absolute intake distributions, whereas the relative intake

Table 5. Population distributions of relative fat, carbohydrate and protein intake (% of total energy intake; %EI) stratified by age group, sex and region estimated applying the NCI-Method (means and selected percentiles)

	Mean	*P1*	*P3*	*P10*	*P25*	*P50*	*P75*	*P90*	*P97*	*P99*
%EI from fat										
All	32.3	23.1	24.7	27.0	29.4	32.2	35.0	37.6	40.2	42.2
2 to < 6, boys	32.0	22.8	24.4	26.7	29.2	31.9	34.7	37.4	39.8	41.7
2 to < 6, girls	32.1	23.0	24.6	26.9	29.3	32.0	34.8	37.4	40.1	42.1
6 to < 10, boys	32.3	23.0	24.8	27.0	29.4	32.2	35.0	37.6	40.3	42.3
6 to < 10, girls	32.7	23.4	25.1	27.4	29.8	32.6	35.4	38.0	40.6	42.6
North	32.9	23.7	25.3	27.6	30.0	32.8	35.6	38.2	40.8	42.7
South	31.9	22.7	24.4	26.6	29.0	31.8	34.6	37.1	39.7	41.7
%EI from carbohydrates										
All	52.1	38.8	41.4	44.9	48.4	52.2	55.9	59.2	62.4	64.7
2 to < 6, boys	52.4	39.1	41.6	45.2	48.7	52.5	56.2	59.5	62.5	64.8
2 to < 6, girls	52.1	38.9	41.5	45.0	48.4	52.2	55.9	59.1	62.4	64.8
6 to < 10, boys	52.4	38.9	41.8	45.1	48.7	52.4	56.2	59.4	62.7	65.0
6 to < 10, girls	51.7	38.4	41.0	44.4	48.0	51.8	55.5	58.7	62.0	64.3
North	52.4	39.2	41.7	45.2	48.7	52.5	56.2	59.5	62.6	64.9
South	51.9	38.6	41.3	44.7	48.2	52.0	55.8	59.0	62.2	64.5
%EI from protein										
All	15.7	10.4	11.2	12.4	13.8	15.5	17.4	19.2	21.3	23.0
2 to < 6, boys	15.9	10.5	11.3	12.5	14.0	15.7	17.5	19.5	21.4	23.0
2 to < 6, girls	16.0	10.6	11.5	12.7	14.0	15.8	17.6	19.5	21.7	23.4
6 to < 10, boys	15.5	10.2	11.1	12.2	13.6	15.3	17.1	19.0	21.0	22.7
6 to < 10, girls	15.6	10.4	11.2	12.4	13.8	15.4	17.3	19.1	21.2	22.8
North	14.7	10.0	10.7	11.8	13.0	14.5	16.1	17.8	19.5	21.0
South	16.5	11.2	12.1	13.3	14.6	16.3	18.1	19.9	21.9	23.5

The estimates are based on 8611 children out of which a second 24-HDR was available in 1910 children; 24-HDRs classified as misreport were excluded.

distributions remained almost unchanged. Distributions of energy intake, absolute macronutrient intake and water were shifted to the right, which reflects the higher prevalence of underreporting compared with overreporting observed in the IDEFICS study.[6] In all cases, population mean/median intakes changed only slightly after exclusion of misreports, suggesting that means/medians may serve as good indicator of population intakes even in the presence of misreporting. However, this result may also depend on the rather small degree of misreporting observed in the study at hand.

Application of the NCI-Method as well as (to a smaller extent) exclusion of misreports led to narrower intake distributions and hence corrected for the variance inflation such that the data presented in Tables 4 and 5 are likely to reflect the true population distributions of intake to a satisfactory degree. Still it should be kept in mind that the true intake distributions remain unknown because of the lack of objective validation data.

Data on intake distributions in European children corrected for the day-to-day variation as well as for misreporting are rarely published. Huybrechts and De Henauw[53] calculated mean and median usual energy and nutrient intakes in Belgian pre-school children accounting for the mentioned problems but percentile estimates were not reported. The enKid Study conducted in 718 children and adolescents from Northern Spain was the only study identified that showed two percentiles (25th and 75th) apart from the mean adjusting for the variance inflation in dietary data and excluding UnR.[54] In that study, for all participants aged 2–24 years, the same cutoff value for the identification of UnR was applied, that is, differences in energy intake due to age and sex were not accounted for. This may result in misclassifications especially in young children; furthermore, OvR were not identified.

Comparison of our results with other studies on dietary intakes in children is difficult due to differences in dietary assessment methods, underlying FCTs, study populations, statistical estimation procedures as well as in the final presentation of results (mainly only mean/median intakes reported). Also the comparison of the obtained intake estimates with reference values for adequate intake is challenging. There are considerable disparities between the perceived requirements of European children when comparing reference values suggested by different countries or organisations:[55] The intake recommendations differ by the underlying concepts and definitions (for example, definition of the 'lowest threshold intake', 'average requirement', 'safe level of intake', 'tolerable upper intake level', and so on.) and even if the same definition is used, recommended intake levels often differ between countries. Differences between the chosen age categories further complicate comparisons. These limitations should be kept in mind when reading the subsequent sections.

Comparison with previous studies

Consistently, with our results, Lambert *et al.*[33] reported higher absolute carbohydrate and protein intakes in boys compared with girls but almost equal relative intakes (%EI). In course of the Dortmund Nutritional and Anthropometric Longitudinally Designed (DONALD) Study,[29] 15-year time trends (1985–2000) in mean energy and macronutrient intakes in 2–18-year-old German children and adolescents were presented based on 3-day weighted records. Mean %EI from fat, carbohydrates and protein over the whole time span were 37.1, 50.3 and 12.6%, respectively, in the group of 4–8-year-old children. In general, decreasing trends for fat intake and increasing trends for carbohydrate intake during the considered time span were suggested. In our study, the mean %EI from fat was lower (32.2%), whereas the %EI from carbohydrates was slightly higher (52.1%), which agrees with the time trends indicated in the DONALD Study. The mean total energy intake reported in the DONALD Study was similar to our results (6.64 MJ per day ~ 1586 kcal per day in 4–8 year olds vs 1546 kcal per day). In a study by Maillard *et al.*[56] conducted in 500 non-obese pre-pubertal French children aged 5–11 years as well as in the enKid Study,[54] mean %EI from fat and mean energy intakes were higher and %EI from carbohydrates lower compared with our data. Such differences in intakes may be a consequence of temporal changes in lifestyle, for example, increased time spent in sedentary behaviours like screen time,[57] leading to decreased energy requirements. Partially these changes may also result from prevention strategies and interventions targeting reductions in fat intake, especially saturated fatty acids.[58,59] The different study populations, instruments and estimation methods are likely to be additional reasons for the observed differences. The mean fibre intake in our population was 12.2 g per day. This almost agrees with the mean intakes of 10-year-old US children (11.9 g per day) published in course of the Bogalusa Heart Study.[60] The DONALD Study found a median intake of 11.6 g per day in 4–6-year-old German children and 14.1 g per day in 7–9-year olds,[58] that is, a higher intake in older children compared with our data. The mean total water intake in our study was 1217 ml per day, which is less compared with the results of the NHANES 2005–2010 survey in US children (4–8 years: 1447 ml per day)[61] and of the DONALD Study (4–8 years: 1363 ml per day).[62]

Comparison with intake recommendations

The D-A-C-H reference values[63] (nutritional guidelines for Germany, Switzerland and Austria) were used for the subsequent comparison as these recommendations include age-specific reference values for almost all nutrients considered in this manuscript and are generally accepted in Europe.

D-A-C-H suggests consuming >50%EI from carbohydrates, 30–40%EI from fat for children aged 1–3.9 years and 30–35%EI from fat for children aged >3.9 years. This means that the carbohydrate intake in 34% of our study population still lies below the recommendation (not in the tables). Regarding fat intake, 29% of the children consumed <30%EI from fat, 25% consumed >35%EI from fat and 4% consumed >40%EI from fat. The protein intake recommended in the D-A-C-H reference values (1.0 g per kg per day for children aged <4 years; 0.9 g per kg per day for children aged 4 to <15 years) was met by all children in our study. The reference values given for total water intake are 1600 ml per day for 4–6.9-year olds and 1800 ml per day for 7–9.9-year olds. In the present study, only 7% of the children in the younger age group and 6% in the older age group complied with the water recommendation.

Also in a study by Huybrechts and De Henauw, the mean usual water intake of Belgian children aged 4–6 years lay below the lower value of the acceptable range of at least 75 ml per kg per day (Belgian age-specific recommendation).[53] These results may to some extent be a consequence of reporting errors. Water and other beverages are typically consumed along the way and may not be completely observed by the parents. Another possibility is that the recommendations for total water intake are actually too high to be reached by paediatric populations.

Strengths, limitations and future perspectives

The standardised dietary assessment and linkage to country-specific FCTs using validated 24-HDR software as well as the cooperation with schools, which enabled the assessment of school meal information, are great strengths of this study. The assessment period covered almost an entire year taking into account seasonal variations in diet. Only few dietary data are available in young children due to the difficulties in dietary assessment in that age group, that is, pan-European studies in children with large data sets are rare. Especially the use of age- and sex-specific cutoff values for the identification of misreports is a strength because few studies consider the age dependencies in energy intakes when applying the Goldberg procedure in young populations.

Like the majority of epidemiological studies, the study sample was not completely random due to cost restrictions and for feasibility reasons. As recently reported for the Swedish IDEFICS sample,[64] the proportion of children with well-educated, high-income parents may be higher in our sample compared with the general population. These shortcomings may impact the representativeness of the sample and may hence limit the generalisability of the results. In addition, the assumption of the NCI-Method that 24-HDRs provide an unbiased estimate of usual intake is likely to be violated.[19] The authors tried to account for bias resulting from misreporting by application of adapted Goldberg cutoffs and exclusion of respective recalls. After exclusion of misreports the weight status distribution changed slightly, which was expected as overweight/obesity was repeatedly shown to be a major determinant of misreporting. Nevertheless, a selection bias resulting from differential misreporting cannot completely be precluded. The Goldberg cutoffs were shown to have good accuracy in detecting misreports of energy,[49] but still misclassifications of under- or overreporters may have occurred. This method does also not account for selective misreporting of specific nutrients or foods (for example, presumably water in this study). However, in the absence of objective measures of intake the Goldberg cutoffs may be a good alternative to account at least partially for the problem of misreporting.

Future research is needed to accurately estimate intakes on a food basis, that is, to estimate usual intakes of single foods like for example, fruits or vegetables, which is challenging due to non-daily consumers as well as non-consumers. Although the NCI-Method is also applicable to episodically consumed foods and can even incorporate information from FFQs to enhance estimations,[46] it unfortunately is not able to account for selective misreporting yet.

CONCLUSION

This paper provides recent estimates of energy and macronutrient intake distributions of 2–9-year-old European children correcting for energy misreporting as well as for the variance inflation in short-term dietary data. Except for water intake, the majority of European children complied with common intake recommendations. The identification of appropriate approaches to correct for selective misreporting is still a task for future research. Finally, it would be desirable that methods correcting for the variance inflation in short-term dietary data would be applied more routinely.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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