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Energy and nutrient intakes by pre-school children in Flanders-Belgium

Inge Huybrechts[1]* and Stefaan De Henauw[1,2]

[1]Department of Public Health, Ghent University, Ghent, Belgium
[2]Department of Health Sciences, Vesalius, Hogeschool Gent, Belgium

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The objective of this cross-sectional study was to investigate energy and nutrient intakes in pre-school children in Flanders-Belgium, using multi-stage clustered sampling. Diets of 661 children (338 boys; 323 girls) between 2·5 and 6·5 years old were assessed, with parentally reported 3 d estimated diet records. Usual energy and nutrient intakes were compared with national and international recommendations. Statistical modelling was used to account for within-individual variation. Mean daily energy intakes (boys, 6543 kJ; girls, 5757 kJ) approached the estimated energy requirements (EER) (boys, 6040 kJ; girls, 5798 kJ) for children <4 years old. For children at least 4 years old, mean energy intakes (boys, 6408 kJ; girls, 5914 kJ) were below the EER of 6995 and 6740 kJ/d, respectively. Mean energy percentage (en%) derived from saturated fatty acids (SFA) (13–14 en%) was above the acceptable macronutrient distribution range (AMDR) upper level of 12 en%. Mean percentages derived from MUFA (10–11 en%) and PUFA (4–5 en%) were below the AMDR lower levels of 12 and 8 en%, respectively. For fibre, iron and vitamin D intakes, <15 % of the children reached the recommended dietary allowances. Everybody exceeded the tolerable upper intake levels for sodium. Although diets in Belgian children were adequate in most nutrients, the implications of low iron, vitamin D and fibre intakes should be investigated. Furthermore, this affluent diet, characterised by SFA, MUFA and PUFA intakes differing from the recommendations and excessive sodium intakes, might increase the risk for CVD in later life.

Energy intake: Nutrient intake: Children: Belgium

Diet in childhood is not only of great importance to the well-being and growth of the child, it is also a potential determinant of adult morbidity and mortality.

Many chronic diseases occurring in later adult life – such as CVD, osteoporosis and some cancers – have been related to the diet or to the intake of specific dietary components, with protective or detrimental influence[1–6]. Some disease-promoting pathways are considered to be initiated early in life, in fact perhaps already during growth *in utero*[7–10]. At the same time, childhood is the period of life when dietary habits are being formed and may persist in later life. Hence, food consumption patterns in childhood tend to be associated with subsequent risk of developing these chronic diseases in adult life[11,12]. In other words, establishing a healthy diet in early childhood may be one way of contributing to the prevention of future morbidity and mortality.

From a public health viewpoint, long-term strategies aimed at prevention are urgently needed. However, in order to plan and develop targeted health promotion actions, a good description and identification of the major problems is necessary.

To date, with the exception of certain studies conducted in communities or cities, detailed information on dietary habits of young children does not exist in Flanders. In an attempt to bridge this gap in available descriptive data, a population-based survey has recently been carried out in pre-school children in Flanders, aimed at estimating nutrient and food intakes. Here, the results on energy and nutrient intakes from this study are reported and interpreted from the the perspective of existing national and international nutrient recommendations.

Subjects and methods

Study population

The target population for this study were all pre-school children living in Flanders – the northern Dutch-speaking part of Belgium. Using a cross-sectional epidemiological design, representative samples of pre-school children aged 2·5–6·5 years were selected on the basis of random cluster sampling at the level of schools, stratified by province and age. Cluster sampling was carried out in two stages: first, schools were selected as primary sampling units from lists made available by the Ministry of Flanders for Education; and, secondly, classrooms were selected as secondary sampling units. Within every school participating in the study, one class was

Abbreviations: AI, adequate intake; AMDR, acceptable macronutrient distribution range; AR, acceptable range; DRI, dietary reference intakes; EAR, estimated average requirement; EDR, estimated diet record; EER, estimated energy requirements; EI, energy intake; FCDB, food composition database; IOM, Institute of Medicine; LTI, lowest threshold intake; OEI, observed energy intake; PRI, population reference intake; SFA, saturated fatty acids; UL, tolerable upper intake level.

* **Corresponding author:** Inge Huybrechts, International Agency for Research on Cancer (IARC) – World Health Organization, Nutrition and Hormones Group, 150, cours Albert Thomas, 69372 Lyon Cedex 08, France, fax +33 (0) 472 73 83 61, email inge.huybrechts@ugent.be

randomly selected for each age group (secondary sampling unit), including all the children within the selected classes as final sampling units. Children were excluded from the study when: (1) they were staying in an institution (e.g. a hospital school), where the food was provided by the institution; (2) they were not attending school during the whole period of the fieldwork; (3) they were living abroad; and (4) when neither of their parents spoke Dutch.

Out of a sample of sixty-three eligible nursery schools, thirteen schools refused to participate in this dietary survey and seven schools refused to distribute food diaries (method described below), as this was considered too much of a burden for the children and their parents. The remaining forty-three schools that participated in the study were proportionally spread over the different provinces in Flanders. Within these forty-three schools, a total of 2095 children were invited to participate in this study.

Instruments

Both a semi-quantitative FFQ and an estimated diet record (EDR) method have been used. However, only the results of the EDR, collected over three consecutive days, are reported and discussed here. In a general questionnaire, asking about socio-demographic and lifestyle characteristics of the child and its parents, the parents were also asked to report the weight and height of their child.

In the structured EDR, days were subdivided into six eating occasions, namely breakfast, morning snacks, lunch, afternoon snacks, dinner and evening snacks. Detailed information on the type (including brand names) and portion size of the foods consumed was collected using an open entry format. On a separate sheet, parents were invited to give details on recipes, ingredients, cooking methods, etc. Only good quality food diaries (EDR), including three completed record days and containing sufficiently detailed descriptions of the food products and portion sizes consumed, were included in the analysis. Two dieticians, with long-standing experience in nutritional epidemiological fieldwork, carried out the exclusion procedure of the EDR. As a cross-check, average energy intake (EI) and nutrient intakes were calculated as the mean of the three recorded days. Diaries that produced very high or very low estimates of intake for some nutrients (e.g. energy, calcium and iron) were rechecked by the dieticians. This amounted to 5 % of the diaries. In this cross-check, only diaries having extremely low estimates for some nutrient intakes, explained by an exceptional day (such as sickness of the child), have been excluded from the study. After these quality checks, the remaining diaries were coded and entered in a ‘Diet Entry & Storage’ program (BECEL[13]). The food list and food composition data for this program were based on the following tables: the Belgian food composition database (FCDB)[14], the Dutch FCDB[15], the FCDB of the Belgian Institute Paul Lambin[16] and the UK McCance and Widdowson’s FCDB[17].

Data collection

The directors of the schools and the teachers of the classes that participated in the study were given detailed information and instructions about the study. The teachers were asked to distribute the questionnaires and diaries among the children and to assist in motivating the parents to participate. Teachers were also asked to collect the completed questionnaires and diaries, which the parents could return in a sealed envelope for the sake of confidentiality. To ensure that all the days of the week would be covered equally, the research team determined beforehand the days to be registered by each child. In the EDR, detailed instructions were elaborated for the parents and they had to sign an informed consent in order to take part in the study.

The fieldwork of this study was carried out from October 2002 to February 2003. The Ethical Committee of the Ghent University Hospital granted ethical approval for the study.

Comparison with nutritional guidelines

In this report, adequacy of macro- and micronutrient intakes was primarily evaluated against the Belgian age-specific recommendations, which are mainly based on the RDA concept of the European Union ‘Scientific Committee on Food’[18,19]. This commonly used concept of RDA is based on three main dimensions: estimated average requirement (EAR), population reference intake (PRI) and lowest threshold intake (LTI) (Table 1) [18]. However, experimental data on the nutrient needs of children are more scarce and in general less reliable than for adults. The current information is inadequate to give EAR or LTI values for children and is limiting itself to giving PRI that have been derived (in the absence of reliable data) by extrapolation from the PRI of young adults on the basis of energy expenditure[18]. For some nutrients known to be essential, but with inadequate data to make EAR, PRI or LTI values, an acceptable range (AR) of intakes is given.

More recently, the Food and Nutrition Board of the Institute of Medicine (IOM) in the USA created the new dietary reference intakes (DRI) concept. The RDA and DRIs concept are explained in more detail in Table 1. When the DRI system included an EAR, adequate intake (AI) or tolerable upper intake level (UL) value for a nutrient, that differed importantly from our Belgian RDA recommendations, the proportion of the population having usual intakes below the EAR and/or above the UL were also calculated. This was the case for sodium, potassium, calcium, iron and magnesium. Since the Belgian RDA for children do not include an RDA for fibre intake, the AI of the DRI concept was used as reference value[20]. For macronutrients, AMDR for individuals as a proportion of total EI have been used (Table 1)[20].

Statistical analysis

Usual nutrient and energy intakes were computed based on the recommendation of the IOM regarding the need to determine the distribution of usual nutrient intakes for assessing diets of population groups in relation to the recommendations[21]. Because of day-to-day variations in individual nutrient intakes, a large number of days of intake data are typically needed to determine usual nutrient and/or energy intakes for an individual. Unfortunately, it is seldom feasible to collect these required long-term data for each person. Therefore, a statistical modelling method that accounts for within-individual variation in nutrient intakes while requiring relatively few days of intake

Table 1. Comparison between the RDA concept, used in Belgium and the more recently developed DRI concept of the Institute of Medicine

RDA	Dietary reference intakes (DRI)	Definitions
Lowest threshold intake (LTI)		The intake below which, on the basis of the current knowledge, almost all individuals will be unlikely to maintain metabolic integrity according to the criterion chosen for each nutrient[18].
Estimated average requirement (EAR)	Estimated average requirement (EAR)	The daily nutrient intake value that is estimated to meet the requirement of half of the healthy individuals in a specific life stage and gender group (used to assess dietary adequacy and as the basis for the RDA)[18,21].
Population reference intake (PRI)	RDA	The average daily dietary intake level that is sufficient to meet the nutrient requirement of nearly all (97–98 %) healthy individuals in a particular life stage and gender group (the PRI/RDA is two standard deviations above the EAR)[18,21].
	Tolerable upper intake level (UL)	The highest level of daily nutrient intake that is likely to pose no risk of adverse health effects for almost all individuals in the general population. As intakes increase above the UL, the potential risk of adverse effects increases[21].
	Adequate intakes (AI)	A value observed to be adequate among a particular age and gender group, that can be used in the absence of definitive data on which to base an EAR or a RDA[21].
Acceptable range (AR)		An acceptable range of intakes, based on evidence that intakes above or below this range may be associated with nutrient inadequacy and increased risk of developing diseases (e.g. coronary heart disease and/or diabetes). These acceptable ranges can be used for nutrients, known to be essential, but with inadequate data to make EAR or RDA values[18].
	Acceptable macronutrient distribution ranges (AMDR)	Distribution ranges of macronutrient intakes as a proportion of total energy intake, that minimise the potential for chronic disease over the long term, permit essential nutrients to be consumed at adequate levels, and should be associated with adequate energy intake and physical activity to maintain energy balance[20].

per individual was needed. In this survey, the NUSSER method (developed at Iowa State University) was used for estimating usual intake distributions and the proportion below or above defined cut-off values, based on the 3 d estimated diet records[22,23]. The software program used to carry out the method was the Software for Intake Distribution Estimation (C-side)[24]. This report presents estimates of usual energy and nutrient intakes, including the mean intakes, standard deviation (SD), median and standard error (SE) for gender/age groups for which RDA/DRI have been established: children 1–3 and 4–7 years old. In addition, the percentage below or above the reference values was calculated. The percentages of individuals with intakes below the EAR are estimates of the prevalence of inadequacy. Although the percentages of individuals with intakes below the PRI and AI are also presented herein, it should be noted that unlike an EAR, a PRI and AI cannot be used to estimate the prevalence of inadequacy in a population[21].

The Student's *t* test or Mann–Whitney *U* test was used to compare the means of different groups of children.

Adopted Goldberg's cut-offs have been used for the purpose of identifying under-reporters. Although Goldberg's cut-offs were developed for adults, they have been adopted for use in children[25,26]. Sichert-Hellert and colleagues used the physical activity level values for light physical activity, estimated by Torun *et al.* to recalculate the cut-offs for under-reporting in 3 d dietary records, according to the formulas proposed by Goldberg and colleagues. Using a CV for EI of 24 % for 1–5 year olds and 23 % for other age groups, as given by Nelson *et al.*[27], they considered records with EI/BMR ratios up to 0·97 or 1·07 depending on the subjects' age and sex, as an implausible measurement of the actual 3 d energy intake[25].

Results

Response rate

A total of 2095 children were invited to complete the 3 d food diaries (EDR). In total, 1052 of them returned a diary (participation rate = 50 %). As mentioned before, only good quality food diaries (EDR), containing sufficiently detailed descriptions of the food products and portion sizes consumed, were used for analysis. In total, the food diaries of twenty-six children had to be excluded because of quality problems.

Of the 1026 remaining children, 696 completed 3 d diaries, 208 completed 2 d diaries and 122 only 1 d. When using C-side, at least three recorded days are required when data are collected over consecutive days. Therefore, 31 % (330 children) of the returned questionnaires had to be excluded from the analyses since only one or two record days were completed. Characteristics of the children (e.g. age, BMI category) and socio-demographic characteristics of the parents registering a 3 d diary were compared with those of parents registering less than 3 d, and no significant differences were found (data not shown). Since only good quality 3 d diaries were included in these analyses, the total number of diaries of use for this study was reduced from 1052 to 696 diaries. Because age information was missing for thirty-five children, only 661 children were included in the analysis for age groups.

Characteristics of the study population

The characteristics of the study population are included in Table 2. Boys and girls were almost equally represented. In total, 30 % of the children were younger than 4 years old,

Table 2. Characteristics of the children and their parents

	Children reported	
	*n**	(%)
Gender		
Boys	339	(51·2)
Girls	323	(48·8)
Age (range: 2·5–6·5)		
< 4 years	197	(29·8)
≥ 4 years	465	(70·2)
Special diet		
Gluten-free diet (gluten-intolerance)	1	(0·1)
Lactose-free diet (lactose-intolerance)	3	(0·4)
Special diet for food allergies	6	(0·9)
Energy-restricted diet	2	(0·3)
Other diet	4	(0·6)
Total	16	(2·3)
Special eating pattern		
Vegetarian or semi-vegetarian (no red meat)	2	(0·2)
Biodynamic diet	5	(0·7)
Religious or other eating pattern	2	(0·2)
Total	9	(1·3)
Dietary supplements		
Iron	9	(1·3)
Calcium	8	(1·1)
Multi minerals	2	(0·3)
Vitamin C	34	(4·9)
Vitamin B complex	0	(0·0)
Multivitamins	96	(13·8)
Multiminerals and vitamins	74	(10·6)
Total	223	(32·0)
Parental educational level		
Low (highest degree of parents secondary education)	136	(20·9)
High (lowest degree of the parents at least secondary education)	516	(79·1)
Parental smoking		
Mother smoking	99	(14·2)
Father smoking	160	(23·0)

* *n* 696.

and 70 % were at least 4 years old. Fewer than 3 % of the children had to follow a medical diet (e.g. diabetes) and fewer than 2 % followed a special eating pattern (e.g. vegetarian, macrobiotic, etc.). Thirty-two percent of the children were taking dietary supplements. These supplements included mainly multivitamin supplements (Table 2). In total, 10 % of the children were overweight or obese.

The proportion of children studied in each province (30 % in Antwerp, 24 % in East-Flanders, 22 % in West-Flanders, 15 % in Flemish Brabant and 9 % in Limburg) compared well with the proportions derived from the target population, namely pre-school children in Flanders (28, 23, 18, 18 and 13 %, respectively).

In our study, the mean ratios of observed energy intake (OEI)/BMR were 1·7 (SD 0·4) for boys and girls younger than 4 years old, and 1·7 (SD 0·3) and 1·5 (SD 0·3) for boys and girls at least 4 years old, respectively. There were no children with a lower ratio than Goldberg's cut-off adapted for children in the group of children younger than 4 years old and only <2 % for children at least 4 years old (0·5 % in boys and 1·4 % in girls). The data presented in the rest of this report have not been adjusted for under-reporting.

Comparison with nutritional guidelines

Energy. Mean OEI (6543 (SD 1062) kJ for boys; 5757 (SD 926) kJ for girls) exceeded the estimated energy requirements (EER) for boys (6040 (SD 653) kJ) and approached the EER for girls (5798 (SD 649) kJ) in children younger than 4 years old (Table 3). However, for children at least 4 years old, the OEI (6408 (SD 932) kJ for boys; 5914 (SD 928) kJ for girls) was below the EER (6995 (SD 950) kJ for boys; 6740 (SD 950) kJ for girls).

Macronutrients. The mean and median macronutrient intakes in g/d have been summarised in Table 3, while the percentages of energy derived from the different macronutrients have been compared with the recommendations in Table 4.

Table 3. Usual energy (kJ/d) and macronutrient intakes in g/d calculated from estimated diet records

		Intake of macronutrients g/d								
		Boys		Girls		Boys		Girls		
Nutrient		Mean	SD	Mean	SD	Median	SE	Mean	SE	*P**
Energy (kJ/d)	<4 years	6543	1062	5757	926	6465	158	5660	130	<0·001
	≥4 years	6408	932	5914	928	6375	94	5874	92	<0·001
Protein (g/d)	<4 years	62·51	11·34	57·68	11·30	61·50	1·75	56·50	1·71	<0·001
	≥4 years	58·52	9·98	52·92	10·46	58·10	1·07	52·20	1·04	<0·001
Total fat (g/day)	<4 years	50·85	8·09	46·80	11·78	50·30	1·77	45·70	1·75	<0·001
	≥4 years	51·95	10·37	47·19	8·01	51·20	1·20	46·70	1·09	<0·001
Carbohydrates (g/d)	<4 years	212·06	46·78	180·83	32·64	209·00	6·05	178·00	4·44	<0·001
	≥4 years	206·42	36·01	193·39	35·96	205·00	3·29	191·00	3·27	<0·001
Fibre (g/d)	<4 years	14·63	3·41	12·96	2·84	14·40	0·50	12·80	0·46	<0·001
(IOM 2003)	≥4 years	14·61	3·30	13·93	3·21	14·40	0·33	13·70	0·32	<0·001
Water (ml/d)	<4 years	1386	292	1327	255	1362	36	1313	34	<0·001
	≥4 years	1390	298	1338	272	1374	25	1319	22	<0·001

IOM, Institute of Medicine.
* Significance level of the differences between boys and girls according to *t*-test or Mann–Whitney U-test.
n (boys <4 years old) 102.
n (boys ≥4 years old) 236.
n (girls <4 years old) 95.
n (girls ≥4 years old) 228.

Table 4. Usual macronutrient intakes calculated from estimated diet records, compared with reference values and the proportion of the population with usual intakes greater than the upper intake levels (UL)

			Intake of macronutrients																
			Boys		Girls		Boys		Girls		Boys		Girls		Boys		Girls		
Nutrient		Reference values	Mean	SD	Mean	SD	Median	SE	Median	SE	$<$EER/AI/ $AMDR_{LL}$	SE†	$<$EER/AI/ $AMDR_{LL}$	SE†	$>$UL/ $AMDR_{UL}$	SE†	$>$UL/ $AMDR_{UL}$	SE†	*P**
Energy	$<$4 years	Kcal/kg per day‡	107·65	19·94	96·72	17·85	106·00	2·90	95·00	2·36	NA	NA	NA		NA		NA		$<$0·001
	$\geq$4 years	(age and sex specific)	84·42	17·92	77·10	18·08	83·00	1·58	76·00	1·56	NA	NA	NA				NA		$<$0·001
Protein§	$<$4 years	10–15 %	16·20	2·41	16·72	1·64	16·10	0·36	16·60	0·31	0·2	0·4	0·0		67·8	6·4	85·7	8·1	0·002
	$\geq$4 years		15·45	2·24	15·12	2·01	15·40	0·24	15·00	0·23	0·4	0·5	0·2	0·3	56·5	4·3	50·0	4·7	0·004
Total fat§	$<$4 years	30–40 %	29·22	3·82	30·30	4·96	29·30	0·66	30·30	0·75	57·8	7·3	47·4	6·0	0·3	0·6	2·4	2·5	0·004
	$\geq$4 years	30–35 %	30·09	3·94	29·68	3·25	30·00	0·46	29·60	0·42	50·0	4·6	54·9	5·3	10·8	4·4	5·5	3·8	0·035
Saturated fatty acids§	$<$4 years	8–12 %	13·03	2·67	13·76	2·63	12·90	0·37	13·70	0·43	2·3	2·2	0·7	1·1	63·8	5·7	73·5	6·8	0·001
	$\geq$4 years		13·39	1·99	13·46	1·72	13·30	0·22	13·40	0·23	0·2	0·3	0·0		75·3	4·0	79·9	6·0	0·495
MUFA§	$<$4 years	$>$12 %	10·45	1·31	10·84	1·95	10·42	0·29	10·80	0·33	88·1	9·7	73·2	7·3	NA		NA		0·004
	$\geq$4 years		10·81	1·39	10·62	1·50	10·76	0·19	10·54	0·20	80·7	6·5	82·4	5·8	NA		NA		0·014
PUFA§	$<$4 years	$>$8 %	4·37	1·37	4·33	1·11	4·19	0·19	4·24	0·18	98·5	1·8	99·7	0·6	NA		NA		0·687
	$\geq$4 years		4·54	1·16	4·37	1·00	4·42	0·12	4·27	0·12	99·3	0·8	99·8	0·4	NA		NA		0·003
Cholesterol	$<$4 years	$<$300 mg (UL)	159·44	32·27	165·49	37·48	157·00	7·24	161·00	8·20	NA		NA		0·0		0·3	0·9	0·037
	$\geq$4 years		171·04	36·34	144·54	29·99	168·00	5·03	141·00	4·32	NA		NA		0·3	0·5	0·0		$<$0·001
Carbohydrates§	$<$4 years	$\geqq$ 50 %	54·24	5·23	52·92	5·36	54·20	0·82	52·90	0·81	21·0	6·8	29·2	6·5	NA		NA		0·003
	$\geq$4 years		54·19	4·53	54·87	4·10	54·30	0·49	55·00	0·48	17·7	4·5	11·9	4·6	NA		NA		0·003
Simple carbohydrates§	$<$4 years	No natural RDA	31·55	5·21	29·74	5·39	31·40	0·79	29·70	0·78	NA		NA		NA		NA		$<$0·001
	$\geq$4 years		31·40	5·16	31·33	5·10	31·30	0·50	31·30	0·53	NA		NA		NA		NA		0·813
Complex carbohydrates§	$<$4 years	No natural RDA	22·62	3·41	23·04	4·07	22·60	0·53	22·70	0·61	NA		NA		NA		NA		0·176
	$\geq$4 years		22·74	3·28	23·39	3·45	22·50	0·32	23·20	0·37	NA		NA		NA		NA		$<$0·001
Fibre	$<$4 years	14 g/1000 kcal¶	10·72	3·12	9·79	2·33	10·40	0·43	9·70	0·39	85·6	5·7	95·6	4·0	NA		NA		$<$0·001
(IOM 2003)	$\geq$4 years		9·02	2·23	8·81	2·50	8·90	0·22	8·50	0·23	97·8	1·5	96·8	1·9	NA		NA		0·087
Water	$<$4 years	75–100 ml/kg per day‖	76·93	16·38	78·78	17·10	76·00	2·15	78·00	2·41	48·5	5·3	44·0	5·7	8·8	4·5	11·2	5·3	0·180
	$\geq$4 years		64·45	15·68	64·83	13·82	63·00	1·31	63·90	1·12	76·3	3·7	78·9	3·8	2·1	1·3	1·4	1·0	0·628

* Significance level of the differences between boys and girls according to *t*-test or Mann–Whitney U-test.
† Standard error not displayed when percentage is 0 or 100.
‡ Estimated energy requirement (EER).
§ Percentage of total energy intake supplied by the nutrient in question and the recommended intake expressed as acceptable macronutrient distribution ranges (AMDR).
¶ Adequate intake (AI).
‖ Acceptable range (AR).
n (boys $<$4 years old) 102.
n (girls $<$4 years old) 95.
n (boys $\geq$4 years old) 236.
n (girls $\geq$4 years old) 228.

As shown in Table 4, the mean percentage of energy derived from carbohydrates was above the recommended minimum level of 50 en%. The mean percentage of energy derived from proteins reached the AMDR upper level of 15 en%, while the mean percentage of energy derived from total fat just reached the AMDR lower level of 30 en%. The mean percentage of energy derived from saturated fatty acids (SFA) was above the AMDR upper level of 12 en%, while the mean percentage derived from MUFA and PUFA was below the AMDR lower level of 12 and 8 en%, respectively. The mean fibre intake observed was much lower than the recommended level of 14 g/1000 kcal (or 3·35 g/1000 kJ). The mean water intake for children at least 4 years old was lower than the AR lower level of 75 ml/kg per day. However, the mean water intake for children younger than 4 years old reached this AR lower level (Table 4).

In the observed intake distribution, more than two-thirds of the children did not reach their AMDR lower level for PUFA, MUFA and fibre intakes (Table 4), while almost two-thirds and a half of the children exceeded the AMDR upper level for SFA and proteins, respectively. Almost half of the children and more than half of the children did not reach the minimum recommendation for total fat (30 % of energy) and water intakes (75 ml/kg per day), respectively (Table 4).

Micronutrients. Examination of mean micronutrient intakes showed that these exceeded the RDA for most nutrients (Table 5). For mineral intakes, only the mean iron intake (7–8 mg) was below the RDA of 10 mg/d. For vitamin intakes, only the mean vitamin D intake (2 μg) was below the AR lower level of 5 μg/d. In the observed intake distribution, < 15 % of the children had vitamin D and iron intakes above the Belgian recommended level and < 70 % had calcium intakes above the recommended levels (Table 5). Although most of the children did not reach our Belgian RDA for iron intakes (Table 6), when comparing them with the iron EAR from the IOM, almost all of them reached this EAR value (Table 6). Since the AI for calcium intake in children younger than 4 years old from the IOM is much lower (500 mg) than our Belgian RDA value (800 mg), the proportion of this population with usual calcium intakes lower than the AI is only 5 % in comparison with > 30 % below our Belgian RDA.

Mean sodium, potassium and magnesium intakes exceeded the Belgian AR upper level. It should be noted that sodium derived from table salt was not included in these analyses (Table 5).

When comparing sodium intakes with the UL of the IOM, more than three-quarters of the children younger than 4 years old and > 40 % of the children at least 4 years old exceeded these UL (Table 6). Although almost all the children exceeded the Belgian AR upper levels for potassium, in comparison with the potassium AI from the IOM, more than three-quarters of the children did not reach this AI value (Table 6). Almost all the children reached the IOM magnesium EAR (Table 6).

Nutrient intakes from dietary supplements were not included in these analyses. However, as mentioned before (Table 2), around one-third of the children were recorded in the general questionnaire as receiving vitamin and/or mineral supplements (18 % daily; 4 % 4–6 times a week; 8 % 2–3 times a week; 2 % once a week and 2 % less than once a week).

Discussion

Main results

In our study, both sexes were almost equally represented and one-third of the children were younger than 4 years old. Although recommendations differed for pre-school children younger than 4 years old and children at least 4 years old, they did not differ between sexes. In this population-based sample of pre-school children, the mean dietary intakes of energy and most nutrients, estimated from parental records of foods and drinks consumed, were higher in boys than in girls (Tables 3 and 5). However, from Table 4, it could be concluded that the quality of the diet, as judged by the percentage of energy contributed by each of the macronutrients, was not always higher in boys than in girls.

Although mean daily EI approached the EER for children younger than 4 years old, for children between 4 and 6·5 years old, the mean OEI were below the EER in both sexes. A possible reason why the EER was higher than the recorded EI might be that children nowadays are less active than in the past, when the EER were calculated[18,26,28,29]. The contribution from SFA was higher than the AMDR upper level of 12 en% for children, while that from MUFA and PUFA was lower than the AMDR lower levels of 12 and 8 en%, respectively. Although issues related to fat in the diet of children are controversial, different studies indicate that the quality of fat in the diet strongly influences the lipid profiles in children. Shea *et al.* showed that, just like in adults, the consumption of SFA is positively correlated with total and LDL-cholesterol levels in pre-school children[30]. In addition, there is evidence that high LDL-cholesterol levels are an important risk factor for CVD in later life[9,31,32]. Recently, Zhang indicated that high intakes of PUFA may contribute to an improved performance of cognitive functioning in pre-school children, in contrast to SFA and cholesterol intakes[33]. Consequently, the opposite percentages of energy derived from SFA, MUFA and PUFA, in comparison with the recommendations, might be a source of concern for the health of our Belgian pre-school children.

Only a small number of children reached the recommended daily level of fibre intake, and more than two-thirds of the children between 4 and 6·5 years old had a total daily water intake lower than the AR lower level. Gomes *et al.* found that intakes of dietary fibre below the minimum recommendation are an important risk factor for chronic functional constipation in children[34]. In addition, a low water (fluid) intake might also be related to medical dysfunction such as constipation, kidney stones and abdominal pain, and increased risk of a urinary tract infection. Since experimental and clinical data on some of these subjects are conflicting[35–39], the low fibre and water intakes found in our Belgian pre-school children's diet underline the necessity for further investigations.

For most vitamins and minerals, the mean and median intakes were in excess of the RDA, implying that the chances of any of the children in this study having inadequate intakes of one of these nutrients are rather small. The exceptions to this were iron and vitamin D. The mean and median iron intakes were approximately 30 % lower than our national RDA, and about 90 % of the children had an iron intake lower than this RDA. However, in comparison with the iron EAR from the IOM, the mean iron intake of our Belgian pre-school children was above the EAR and almost all children reached this EAR value[40].

Table 5. Usual micronutrient intakes calculated from estimated diet records, compared with reference values and the proportion of the population with usual intakes greater than the upper intake levels (UL)

			Intake of macronutrients																
			Boys		Girls		Boys		Girls		Boys		Girls		Boys		Girls		
Nutrient		Reference values	Mean	SD	Mean	SD	Median	SE	Median	SE	< PRI/ AI/AR_{LL}	SE†	< PRI/ AI/AR_{LL}	SE†	> UL/ AR_{UL}	SE†	> UL/ AR_{UL}	SE†	*P**
Vitamin D	< 4 years	5–10 µg‡	2·81	2·39	2·26	2·26	2·07	0·22	1·61	0·15	86·2	5·4	92·5	4·4	2·1	2·1	1·5	1·6	0·004
	≥ 4 years		1·95	1·15	1·55	0·80	1·67	0·09	1·37	0·07	97·6	1·7	99·4	0·7	0·1	0·2	0·0		< 0·001
Vitamin C	< 4 years	40 mg§	91·02	46·06	90·16	39·68	82·00	6·25	85·00	5·39	9·5	5·0	7·7	4·4	NA		NA		0·809
	≥ 4 years	45 mg§	97·05	48·83	90·54	36·30	88·00	4·28	86·00	3·76	11·6	3·4	8·5	3·3	NA		NA		0·005
Thiamin	< 4 years	0·5 mg§	1·18	0·39	1·10	0·36	1·10	0·05	1·06	0·04	0·1	0·1	1·2	1·4	NA		NA		0·012
	≥ 4 years	0·7 mg§	1·11	0·28	0·97	0·25	1·07	0·03	0·93	0·02	4·0	2·4	12·5	3·9	NA		NA		< 0·001
Riboflavin	< 4 years	0·8 mg§	1·65	0·59	1·55	0·49	1·58	0·06	1·49	0·06	2·6	2·1	3·9	2·8	NA		NA		0·016
	≥ 4 years	1·0 mg§	1·58	0·45	1·35	0·41	1·54	0·04	1·30	0·04	7·8	3·0	20·7	4·0	NA		NA		< 0·001
Sodium	< 4 years	225 – 500 mg¶	1819·10	414·81	1925·90	374·88	1783·00	71·70	1899·00	71·40	0·0		0·0		100·0		100·0		0·001
	≥ 4 years	300 – 700 mg¶	1958·90	364·32	1817·70	387·08	1937·00	47·50	1790·00	43·90	0·0		0·0		100·0		100·0		< 0·001
Potassium	< 4 years	800–1000 mg¶	2671·00	527·16	2387·40	524·77	2621·00	72·50	2350·00	72·70	0·0		0·0		100·0		100·0		< 0·001
	≥ 4 years	1100–1400 mg¶	2547·20	521·48	2434·30	477·35	2518·00	48·40	2406·00	46·50	0·0		0·0		99·3	0·6	99·3	0·7	< 0·001
Calcium	< 4 years	800 mg§	952·70	302·22	929·42	298·47	924·00	38·50	904·00	40·10	33·2	5·5	35·8	5·7	NA		NA		0·347
	≥ 4 years		880·00	252·72	799·68	268·25	866·00	23·30	778·00	24·50	39·6	3·8	53·3	3·6	NA		NA		< 0·001
Phosphorus	< 4 years	700 mg§	1112·60	221·47	1050·30	234·93	1092·00	30·60	1027·00	32·40	1·3	1·5	4·5	3·4	NA		NA		0·001
	≥ 4 years		1083·30	212·40	982·12	212·16	1072·00	20·70	968·00	19·80	2·5	1·7	8·0	3·0	NA		NA		< 0·001
Iron	< 4 years	10 mg§	7·70	2·21	7·12	2·08	7·40	0·28	6·80	0·28	86·7	5·7	90·8	4·9	NA		NA		0·001
	≥ 4 years		7·51	1·67	6·85	1·56	7·30	0·17	6·69	0·14	92·1	3·5	96·4	2·1	NA		NA		< 0·001
Magnesium	< 4 years	80–85 mg§	212·40	41·79	196·20	37·15	208·00	5·74	193·00	5·06	0·0		0·0		100·0		100·0		< 0·001
	≥ 4 years	120–150 mg§	204·63	38·31	190·33	36·50	203·00	3·69	188·00	3·23	0·6	0·6	1·7	1·2	93·0	2·8	86·9	3·4	< 0·001
Zinc	< 4 years	4 mg§	8·51	1·81	8·52	2·00	8·30	0·35	8·30	0·37	0·0		0·1	0·2	NA		NA		0·933
	≥ 4 years	6 mg§	8·69	2·29	8·20	1·77	8·40	0·25	8·00	0·22	9·6	4·1	8·9	4·6	NA		NA		< 0·001

* Significance level of the differences between boys and girls according to *t*-test or Mann–Whitney U-test.
† Standard error not displayed when percentage is 0 or 100.
‡ Adequate intake (AI).
§ Population reference intake (PRI).
¶ Acceptable range (AR).
n (boys < 4 years old) 102.
n (girls < 4 years old) 95.
n (boys ≥ 4 years old) 236.
n (girls ≥ 4 years old) 228.

Table 6. Proportion of population with usual intakes of sodium, potassium, calcium, iron and magnesium below the EAR/AI and above the UL of the IOM recommendations

				Proportion of population with usual intakes							
				Boys		Girls		Boys		Girls	
Nutrient		EAR/AI	UL	< EAR/AI	SE*	< EAR/AI	SE*	> UL	SE*	> UL	SE*
Sodium	< 4 years	1000 mg†	1500 mg‡	0·9	1·5	0·1	0·4	77·1	7·8	88·0	7·8
	≥ 4 years	1200 mg†	1900 mg‡	0·8	1·1	4·0	2·6	54·0	5·2	38·9	4·7
Potassium	< 4 years	3000 mg†	NA	75·5	6·1	87·6	5·4	NA		NA	
	≥ 4 years	3800 mg†	NA	98·6	1·1	99·4	0·6	NA		NA	
Calcium	< 4 years	500 mg†	2500 mg‡	4·6	3·1	5·8	3·7	0·0		0·0	
	≥ 4 years	800 mg†	2500 mg‡	39·6	3·8	53·3	3·6	0·0		0·0	
Iron	< 4 years	3·0 mg§	40 mg‡	0·1	0·1	0·1	0·2	0·0		0·0	
	≥ 4 years	4·1 mg§	40 mg‡	0·2	0·3	1·7	1·3	0·0		0·0	
Magnesium	< 4 years	65 mg§	NA	0·0		0·0		NA		NA	
	≥ 4 years	110 mg§	NA	0·2	0·2	0·65	0·6	NA		NA	

IOM, Institute of Medicine.
* Standard error not displayed when percentage is 0 or 100.
† Adequate intake (AI).
‡ Upper level (UL).
§ Estimated average requirement (EAR).
n (boys < 4 years old) 102.
n (boys ≥ 4 years old) 236.
n (girls < 4 years old) 95.
n (girls ≥ 4 years old) 228.

While no EAR values are available in Belgium for iron intakes in young children, our RDA value for children younger than 4 years old (10 mg) is much higher than the RDA value of the IOM (7 mg). Although part of the differences in Fe recommendations between countries may be explained by the different assumptions made about Fe absorption from local diets[41], these low Fe intakes in comparison with our Belgian recommendation might indicate the need to reconsider our current Fe recommendation.

The mean vitamin D intake was roughly half of the AR lower level, and more than 90 % of the children had vitamin D intakes lower than the AR lower level. However, our low estimated vitamin D intakes do not necessarily imply a problem with vitamin D deficiency, as in practice most vitamin D is derived from the action of sunlight on the skin. Although no intakes of vitamin D supplements have been reported, it is noteworthy that possible contributions from multivitamin supplements have not been taken into account, which might also cause an underestimation of the true vitamin D intake. However, very young children (up to 4 years of age) in Belgium might risk having an inadequate vitamin D intake during winter months, when there is less exposure to sunlight[42,43].

Further, our results revealed that more than three-quarters of the children younger than 4 years old and > 40 % of the children at least 4 years old exceeded the sodium UL from the IOM. Although mean potassium intakes exceeded our Belgian AR upper levels, more than three-quarters of the children did not reach the IOM potassium AI. It is important to note that some studies indicate that elevated blood pressure, which may lead to stroke, CHD and kidney disease, is associated with increased sodium and inadequate potassium intakes[37]. Taking into account that sodium derived from table salt was not included in the analyses, the estimated sodium intakes are probably an underestimation of the real sodium intake. Consequently, these increased sodium and inadequate potassium intakes, in comparison with the IOM recommendations, are a cause for concern for the health of our Belgian pre-school children.

Stengths and limitations of the study

While 10 % of the children were found to be overweight or obese, it should be noted that the weight and height of the children were reported by the parents. Since the ability of parents to estimate the weight and height of their pre-school child is only limited, this percentage should be interpreted with caution[44].

The representativeness of our study was tested by comparing our study sample with some characteristics of the target population, namely pre-school children in Flanders. First, the proportion of children attending schools in Flanders at the considered age was calculated. Data from the Ministry of Flanders for Education revealed that about 94 % of the children between 2·5 and 6·5 years old were attending schools in Flanders in 2003[45,46]. This percentage is a rough estimation, based on the total population of pre-school children (age 2·5–6·5 years old) in Flanders in 2003 and the number of pre-school children attending schools at that time. It is noteworthy that the majority of the children not attending schools are in the age group of 2·5–3 years old, since most children start attending schools between the age of 2·5 and 3. This might explain why only 30 % of the children studied were younger than 4 years old. When taking into account that about 6 % of Flemish pre-school children are not attending schools, it should be noted that our sampling frame ‘the lists of schools made available by the Ministry of Flanders for Education’ might introduce some selection bias, since children not attending schools might differ from pre-school children attending schools. Although our primary education in Belgium is free of charge, it is possible for instance that children from the lower socio-economic classes are less represented in the total population of pre-school children attending schools.

Secondly, the proportion of Flemish pre-school children in the different provinces was compared with the proportions in our study population, and this comparison confirmed good demographic representativeness of our study sample[45].

While the response rate in our study reached 50 %, the total number of children included in the analysis was further reduced, since several children did not reach the stringent inclusion criteria specified for the analysis in C-side: an EDR, including three 'good-quality' record days. Although, no doubt, willingness to participate leads to some selection bias, these data represent a more general population of pre-school children in Flanders, in comparison with other food consumption surveys in children, which are mostly restricted to local areas.

It is also noteworthy that like any dietary assessment methodology, the EDR is prone to a degree of misreporting which may have influenced our classification of compliance and non-compliance with dietary reference intakes. However, the percentage of under-reporters in our study sample was rather low, and exclusion of presumed misreporters could also bias the results[47]. In addition, a 3 d EDR does not necessarily reflect individuals' usual intake. However, a statistical modelling method (the NUSSER method) that accounts for within-person variability was used in order to calculate valid usual nutrient and energy intakes. Since all days of the week were included in the study, it was possible to adjust our data to remove the effect of day of the week. Unfortunately, it was impossible to correct for seasonal variations, because our fieldwork was conducted only during autumn and winter time. No data were found about potential seasonal influences on nutrient intakes in this population group in Belgium. However, from our National Food Consumption Survey in 2004, it could be concluded that seasonal variations were only limited for nutrient intakes in our Belgian population of at least 15 years old[48]. These low seasonal variations in our Belgian population could be due to the widespread availability of most foods all year round.

Another potential limitation encountered was that EAR values for pre-school children are still lacking for most of the nutrients in the RDA concept, as well as in the DRI concept, which made it difficult to establish inadequacy. However, when comparing with a PRI or AI value, it is still possible to say if the intake of an individual is adequate, when intakes are above the PRI/AI[41].

Finally, it should be noted that food composition data, used for calculating nutrient intakes, might also introduce some bias in dietary surveys reporting nutrient intakes. In particular, our assessment of fibre intake could be distorted by the use of inadequate FCDB, since these databases have limited information on fibre contents, which could contribute to underestimates of intakes of this nutrient[49].

Comparison with previous studies

The authors compared their study results with other studies concerning nutrient intake in pre-school children, namely the enKID Study[50], the DONALD study[51] and the different studies reported in the review of Lambert *et al.*[52] For the comparison with the study of Lambert *et al.*, it is noteworthy that a variety of collection methods were used in this review and there was no consistency in the ages of the children surveyed or the age cut-off points. However, most surveys gave data for males and females separately at all ages. Just under half of the surveys were nationally representative and most of the remainder were regional. In addition it is important to note that each country used a different set of food composition data, which differ in definitions, analytical methods, units and modes of expression[52]. The enKid study is a population-based, cross-sectional nutrition survey in Spanish children and adolescents (2–24 years old) conducted between 1998 and 2000. In the enKID study, dietary assessment was completed by means of a 24 h recall and an FFQ completed in an interview with the mother or caregiver for children under 13 years old. A second 24 h recall was completed on 25 % of the sample, allowing for adjustment of intakes for random intraindividual variation[50].

The DONALD study (which started in 1985) is a cohort study collecting detailed data on diet, metabolism, growth and development from healthy subjects between infancy and adulthood (3 months to 18 years old). Parents of the children or the older subjects themselves kept 3 d weighed dietary records, weighing and recording all foods and fluids consumed as well as leftovers using electronic food scales[51].

Our results for EI fell in the ranges reported by Lambert *et al.* for the same age and gender groups, and our finding that the EI expressed relative to body weight decreased with increasing age was also in agreement with the findings of Lambert *et al.*[52]. It is noteworthy that also for the analyses in the 80 dietary surveys reported by Lambert *et al.* under-reporters have not been excluded. The enKid study reported slightly higher EI in children 2–5 years old. However, in the enKid study, the under-reporters (18·7 % calculated with a Goldberg cut-off of 1·14 for EI/BMR) have been excluded for these analyses[53]. Although, in contrast to our study, the under-reporters in the DONALD study have been excluded for the analyses, the total EI of pre-school children was slightly lower in the DONALD study than in our study[54].

Our results for fatty acid intakes were comparable with the studies reported by Lambert *et al.*, except from the Southern Mediterranean countries, which had higher MUFA intakes. The cholesterol intake was comparable with the intakes from The Netherlands, the UK and Denmark reported by Lambert *et al.*[52]. Total fat and cholesterol intakes reported in the enKid study were much higher in comparison with our data[53]. When comparing our results with the DONALD study, we found that the percentage of energy derived from fat in the DONALD study was much higher than in our study[55,56]. This higher fat intake was mainly attributable to higher SFA and MUFA intakes in the DONALD study[56]. Also the total cholesterol intake was much higher in the DONALD study than in our study[56].

Our finding that the contribution to EI from proteins exceeded the AMDR upper levels was comparable with most of the studies reported by Lambert *et al.*, except from Sweden and France where the protein intakes were higher than 16 % of the energy. Also the protein intakes reported in the enKid study were slightly higher than those reported in our study[53]. The percentages of energy derived from proteins in the DONALD study were much lower than in our study[55,56].

Although the contribution to EI from total carbohydrates was comparable with the results reported in other studies[52], the contribution to EI from simple carbohydrates was high in comparison with other studies[52]. Even though the total carbohydrate intake in Spanish children (in g/d) was comparable with our results, because of the higher fat and protein intakes, the percentage of energy derived from total carbohydrates in Spanish children was much lower than in our study[53]. The percentage of energy derived from carbohydrates in the DONALD study was much lower than in our study[55,56].

For the children younger than 4 years old, our fibre intake results were slightly higher than those reported by Lambert *et al.* For children at least 4 years old, our results were comparable with those of Lambert *et al.*[52]. Fibre intakes in young children from the enKid study were lower than in our study[53] and also fibre intakes in the DONALD study were much lower than in our study[56].

Since most food consumption studies in children do not provide information about the water or fluid intake[52], we were not able to compare the low water intakes in our Belgian pre-school children with other studies in pre-school children. However, as mentioned before, the importance of fluid (water) intake in pre-school children should be further investigated.

The sufficient intakes of most micronutrients (except from iron and vitamin D intakes) found in our pre-school children were comparable with other studies also reporting sufficient intakes for most micronutrients, except for iron and/or vitamin D intakes[42,52,53]. Our results for vitamin D and iron were comparable with those from France, The Netherlands and the UK, as reported by Lambert *et al.*[52]. In the DONALD study, however, not only the iron intake, but also the intake of all micronutrients studied (vitamin C, thiamine, riboflavin, calcium and iron) was much lower than in our study[57].

The high sodium intakes in our study were comparable with those reported by Lambert *et al.*[52], while the low potassium intakes estimated in our study were still somewhat higher than those reported by Lambert *et al.*[52].

The high magnesium intakes found in our study were comparable with those reported by Lambert *et al.*, while the phosphorus intakes in our study were a little higher for children younger than 4 years old and slightly lower for those at least 4 years old in comparison with the results reported by Lambert *et al.*[52].

Finally, the authors would like to underline that methods of measuring food intake in children are not standardised across Europe and intake data are generally poor. This can make comparisons between countries difficult and inaccurate, creating uncertainties over the true nutrient intakes of children and adolescents across Europe. These uncertainties should be kept in mind in the comparison with other studies described above.

Conclusion

Although diets of pre-school children in Flanders were adequate in most nutrients during autumn and winter time, it is necessary to revise our national iron recommendations and to analyse the implications of low iron, vitamin D and fibre intakes in pre-school children. Also the effect of low water intakes in pre-school children should be investigated. Furthermore, the SFA, MUFA and PUFA intakes, which were opposite to the recommendations, and the excessive sodium intakes might be potentially modifiable risk factors for CVD in later life.

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