European Journal of Clinical Nutrition (2005) 59, 826–834

0954-3007/05 $30.00
www.nature.com/ejcn

ORIGINAL COMMUNICATION

Iron intake and dietary sources of iron in Flemish adolescents

I Pynaert[1]*, C Matthys[1], M Bellemans[1], M De Maeyer[1], S De Henauw[1,2] and G De Backer[1]

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

Objective: To investigate the dietary iron intake and food sources of iron in Flemish adolescents.
Design: Cross-sectional survey; dietary assessment method: a 7-day estimated food record.
Setting: Private and public secondary schools in Ghent, a city in the Dutch-speaking part of Belgium.
Subjects: A total of 341 adolescents (129 boys and 212 girls), 13–18 y, randomly selected by a multistage clustered sampling technique.
Results: The mean total iron intake (s.d.) for boys was 13.4 ($\pm$2.91) mg/day and for girls 10.1 ($\pm$2.79) mg/day. A proportion of 38.8% of the boys and 99.5% of the girls had a mean total iron intake below the Belgian Recommended Dietary Allowance and 3.1% of the boys and 71.2% of the girls below the British Estimated Average Requirement. When bioavailable iron intake is considered, 84.5% of the boys and only 16.5% of the girls met the age-specific requirement. The food groups with the highest mean proportional contribution to total iron intake in both males and females were bread, meat and meat products, cereals and potatoes. A comparison of adolescents from the highest tertile of iron intake (mg/day) with adolescents from the lowest tertile showed a significantly higher energy-adjusted intake of brown bread and a significantly lower intake of soft drinks in the former group in both boys and girls. A significantly higher energy-adjusted intake of breakfast cereals in adolescents of the highest tertile than those of the lowest tertile was seen in girls only. Analyses in consumers only did not change this overall picture.
Conclusions: One can conclude that the mean iron intake of Flemish girls is considerably lower than the current recommendations. An increased iron intake in this subgroup of the population is therefore advisable.
Sponsorship: This work was financially supported by the National Fund for Scientific Research (fund no. 31557898), the Kellogg's Benelux Company, Unilever Belgium and the Belgian Nutrition Information Center.
European Journal of Clinical Nutrition (2005) **59,** 826–834. doi:10.1038/sj.ejcn.1602149
Published online 18 May 2005

Keywords: iron intake; dietary sources; adolescents

Introduction

Iron is an essential nutrient for humans, having a non-replaceable position in a number of physiological processes, like oxygen transport and storage, oxidative energy production and others.

Deficient iron intake can in the long run lead to iron deficiency anaemia, which is in turn potentially associated with adverse health outcomes such as impaired work capacity, infectious disease, maternal and child mortality, low birth weight, preterm delivery and delayed infant and child development (Centers for disease control and prevention, 1998; FAO/WHO, 2002). Hence, prevention of iron deficiency anaemia could have potential benefits to human health and development and should be a continuous object of public health nutrition surveillance, for example, through monitoring iron intake and iron status in different subgroups of the population. This is *a fortiori* the case for young people at the verge of adulthood in view of their increased overall nutritional need.

***Correspondence: I Pynaert, Department of Public Health, Ghent University, UZ - 2 Blok A, De Pintelaan 185, B-9000 Ghent, Belgium. E-mail: Ilse.Pynaert@UGent.be**
Guarantor: I Pynaert.
Contributors: IP analysed and interpreted the data and wrote the initial draft of the manuscript. CM interpreted the data and assisted in preparing the manuscript. MB and MDM assisted in collecting data and in the preparation of the manuscript. SDH designed the study, interpreted the data and assisted in the preparation of the manuscript. GDB designed the study and assisted in the preparation of the manuscript.
Received 10 May 2004; revised 15 February 2005; accepted 28 February 2005; published online 18 May 2005

Iron is present in different forms and varying concentrations in a broad range of foods commonly consumed in the Belgian (Western) eating culture and tradition. Nevertheless, eating habits and food availability and choices can change rapidly, especially in particular subcultural segments of the younger population. It has, for instance, been shown that Western teenagers, particularly girls, sometimes adopt quite peculiar dietary habits in view of keeping their body weight balance or improving their physical appearance (Cuadrado *et al*, 2000).

The study of the main dietary contributors to iron intake in these adolescents may help in understanding the distribution of intakes and may be of use in developing strategies to improve their intake, if necessary.

In this paper, both iron intake and important food sources of iron are studied in a general population-based sample of Flemish adolescents. Based on the results, recommendations for public health action are given.

Material and methods

The study was carried out in Ghent, a city in the Dutch-speaking part of Belgium, between March and May 1997. The study sample consisted of 656 adolescents (13–18 y) randomly selected on the basis of a multistage cluster-sampling technique. The design and methodology have been described in more detail elsewhere (Matthys *et al*, 2003). In brief, local private and public secondary schools ($n = 5$) were randomly selected. All contacted schools agreed to participate. Within each school, classes were randomly selected. This procedure resulted in a sample of 656 adolescents. Of the 656 adolescents, 565 were considered eligible. Noneligible students ($n = 91$) were on sickness leave or had moved to other schools. Of these 565 eligible students, 154 refused to take part in the study; thus, 411 (72.7%) actually participated. As a result of missing data in the food diaries (see below) 70 students — of the 411 who actually participated — were rejected. Hence, results are reported for 341 of the 565 eligible students (60.3%). In this paper, results are given separately for boys ($n = 129$) and girls ($n = 212$). A detailed description of the characteristics of the study population is published elsewhere (Matthys *et al*, 2003).

A 7-day estimated food record method (semistructured diary) was used to quantify food and nutrient intake. Each diary was divided into six eating occasions: breakfast, morning snack, lunch, afternoon snack, dinner and evening snack. Breakfast was defined as the first meal in the morning. Lunch and dinner could be either cold or hot meals; lunch was defined as a meal in the middle of the day before 1500 and dinner was served after 1500. The snacks refer to a summation of the morning, afternoon and evening snacks.

Calculations of iron intake were done on the basis of the Dutch Food Composition Table (NEVO, 1993) and the Belgian Food Composition Tables (NUBEL, 1992, 1995). Average total, haem and nonhaem iron intake and average intake of food items or food groups were calculated as the mean of the 7-day intake period.

For the purpose of determining the proportion of adolescents who had an iron intake below the recommendations, the Belgian Recommended Dietary Allowance (RDA) and the British Estimated Average Requirement (EAR) were used. Within the broad context of interpretation of Dietary References Intakes (DRIs), the RDA — the daily intake that is considered sufficient to meet the needs of almost all (97.5%) of the healthy persons in a population — is not used to assess intakes of groups. For the latter, the use of the EAR — the daily intake that is considered sufficient to meet the needs of 50% of the healthy persons in a population — is recommended (Food and Nutrition Board, 1994, 2000; Barr *et al*, 2002). However, such data are not available for Belgium.

Since, on average, 25% of haem iron (FAO/WHO, 2002) and 10% of nonhaem iron (Heath & Fairweather-Tait, 2002) are absorbable, bioavailable iron intake was estimated as follows: bioavailable iron intake = (haem iron intake $\times$ 0.25) + (nonhaem iron intake $\times$ 0.10).

The mean proportional contribution of a specific predefined food item or food group to the total iron intake on population level was estimated by the following formula:

$$\frac{\sum_{i=1}^{n}(Q_{ij}D_j)}{\sum_{j=1}^{k}\sum_{i=1}^{n}(Q_{ij}D_j)}$$

where Q is the amount of food consumed (grams), D is the amount of iron per gram of food, i is a specific subject, j is a specific food item, n is the number of subjects and k is the number of iron-containing food items (Krebs-Smith *et al*, 1989).

Specific food items were classified in different food groups according to the Dutch Food Composition Table (NEVO, 2001). In this table, bread and cereals are separated into two groups: (1) bread and (2) cereal products and binding agents. Cereal products are, for example, breakfast cereals, rice, pasta and binding agents are thickeners such as flour.

Statistical analysis was done with the SPSS software (SPSS, 1999).

Boys and girls were divided in tertiles on the basis of absolute total iron intake (mg/day) to compare groups. In order to search for potential confounders the number of adolescents in different categories of age, body mass index (BMI) (Cole *et al*, 2000) and education — 'classical' education (mainly theoretical courses) and vocational training (based on practical skills) — in the different tertiles were compared by use of a χ^2-test.

A Kolmogorov–Smirnov test was used to test for normality. To compare the means of different groups, the Independent-Samples T-Test was used in case of a normal distribution, otherwise the Mann–Whitney U test was used. In this paper, the energy intake and the absolute total, haem and nonhaem iron intake (mg/day) had a normal distribution.

Given the multitude of statistical tests, a P-value of <0.01 was taken in order to reduce the probability of false-positive findings.

The study was approved by the Ethical Committee of the Faculty of Medicine and Health Sciences of the Ghent University.

Results

Table 1 presents the number of adolescents in different categories of age, BMI and education in different iron intake tertiles. No significant differences between the tertiles for both age and BMI were found (for age: $P=0.583$ in boys and $P=0.813$ in girls and for BMI: $P=0.699$ in boys and $P=0.113$ in girls). A significant difference between the tertiles was seen for education in girls ($P=0.122$ in boys and $P=0.003$ in girls).

The absolute mean total iron intake for boys was on average 13 mg/day and for girls 10 mg/day. A statistically significant difference was found between boys and girls ($P=0.000$). Adjusted for energy intake, the mean total iron intake (mg/1000 kcal) for both boys and girls was approximately 5 mg/1000 kcal and no longer significantly different ($P=0.948$).

Table 2 presents the proportions of adolescents in different categories of total iron intake (mg/day) and the proportions of adolescents who did not meet the Belgian Recommended Dietary Allowance (RDA) (Nationale Raad voor de Voeding, 2000) and the British Estimated Average Requirement (EAR) (Committee on Medical Aspects of Food Policy, 1991) for iron in the total groups of boys and girls, and in different age categories by sex. In the total groups of males, most individuals had a total iron intake between 10 and 15 mg/day and almost 40% were below the age-specific RDA. In the total group of females, more than 50% had a total iron intake below 10 mg/day and almost all had an intake below the age-specific RDA. In the age category of 13–14 y, almost 20% of the boys and all the girls had a total iron intake below the RDA and in the age category of 15–18 y, more than 45% of the boys and all except one of the girls had a total iron intake below the RDA. When compared to the British EAR, the proportions of males and females with a mean total iron intake below the recommendation were lower, but still remarkable in girls.

Table 1 Number of adolescents in different categories of age, BMI and education in different tertiles[a], both boys ($n=129$) and girls ($n=212$)

	Boys				*Girls*			
	Total	T_1	T_2	T_3	*Total*	T_1	T_2	T_3
Age								
13–14 y	32	13	9	10	37	11	14	12
15–18 y	97	30	34	33	175	59	57	59
BMI[b,c]								
Normal	120	39	41	40	177	52	63	62
Overweight	9	4	2	3	31	15	8	8
Education								
Classical	112	36	35	41	101	23	34	44
Vocational	17	7	8	2	111	47	37	27

[a]Tertiles based on absolute total iron intake (mg/day); T_1, T_2 and T_3 : lowest, middle and highest tertile.
[b]BMI categories according to Cole *et al* (2000).
[c]Data of four girls are missing.

Table 2 Proportions of adolescents in different categories of total iron intake (mg/day) and proportions of adolescents who did not meet the Belgian RDA (mg/day) and British EAR (mg/day) for iron in the total group of boys ($n=129$) and girls ($n=212$), and in different age categories by sex

	Boys			*Girls*		
	Total	*13–14 y*	*15–18 y*	*Total*	*13–14 y*	*15–18 y*
Total iron intake (mg/day)						
<10	8.5	18.8	5.2	51.9	48.6	52.6
10–<15	64.4	56.2	67.0	44.8	48.7	44.0
15–<20	24.8	25.0	24.7	2.8	2.7	2.8
≥20	2.3	0.0	3.1	0.5	0.0	0.6
RDA[a] (mg/day)	Age specific	10	13	Age specific	21	22
% below the RDA	38.8	18.8	45.4	99.5	100	99.4
EAR[b] (mg/day)	8.7	8.7	8.7	11.4	11.4	11.4
% Below the EAR	3.1	6.3	2.1	71.2	70.3	71.4

[a]RDA: Recommended Dietary Allowance (Nationale Raad voor de Voeding, 2000).
[b]EAR: Estimated Average Requirement (Committee on Medical Aspects of Food Policy, 1991).

Table 3 shows the median bioavailable iron intake (mg/day) and the proportions of adolescents who did not meet the required intake for bioavailable iron (mg/day) in the total groups of boys and girls, and in different age categories by sex.

The median bioavailable iron intake in boys and girls was on average 1.8 and 1.3 mg/day, respectively. The difference between boys and girls was statistically significant ($P=0.000$). Most of the boys (84.5%) but only 16.5% of the girls met the age-specific requirement for intake of bioavailable iron (FAO/WHO, 2002).

In Table 4 the energy intake (kcal/day), the absolute (mg/day) and energy-adjusted (mg/1000 kcal) intake of total, haem and nonhaem iron, and the ratio of nonhaem/haem iron, intake in the total group and in the different tertiles in both boys and girls are shown.

The absolute mean intake of nonhaem iron and haem iron respectively was on average 10 and 3 mg/day for the boys and 8 and 2 mg/day for girls. The higher intake of nonhaem iron than haem iron was consistently observed over all the tertiles of absolute total iron intake (mg/day).

Individuals in the highest tertile — as compared to their counterparts of the lowest tertile — had a significant higher energy-adjusted (mg/1000 kcal) intake of total iron and

Table 3 Median bioavailable iron intake (mg/day) and proportions of adolescents who did not meet the median required intake for bioavailable iron (mg/day) in the total group of boys ($n = 129$) and girls ($n = 212$), and in different age categories by sex

	Boys			*Girls*		
	Total	*13–14 y*	*15–18 y*	*Total*	*13–14 y*	*15–18 y*
Median bioavailable iron intake[a] (mg/day)	1.77	1.73	1.79	1.32	1.34	1.30
Median required intake for bioavailable iron[b,c] (mg/day)	Age specific	1.17	1.50	Age specific	1.68	1.62
% Below the iron requirements	15.5	0	20.6	83.5	86.5	82.9

[a]Bioavailable iron intake = (haem iron intake × 0.25)[c] + (nonhaem iron intake × 0.10)[d].
[b]Required intake for bioavailable iron = requirement for basal losses + growth + menstrual losses (in girls).
[c]FAO/WHO (2002).
[d]Heath and Fairweather-Tait (2002).

Table 4 Energy intake (kcal/day), absolute (mg/day) and energy-adjusted (mg/1000 kcal) intake of total, haem and nonhaem iron and the ratio of nonhaem/haem iron intake (mean (s.d.)) in the total group and in different tertiles[a] in Flemish adolescents, both boys ($n = 129$) and girls ($n = 212$)

	Total	T_1	T_2	T_3	P-*value*[b]
Boys					
Energy (kcal/day)	2653 (516.2)	2366 (370.9)	2708 (526.6)	2885 (504.6)	0.000
Total iron (mg/day)	13.4 (2.91)	10.5 (1.27)	13.1 (0.73)	16.8 (1.83)	0.000
Haem iron (mg/day)	3.2 (1.24)	2.8 (1.10)	3.1 (1.33)	3.5 (1.21)	0.004
Nonhaem iron (mg/day)	10.3 (2.82)	7.7 (1.70)	9.9 (1.23)	13.2 (1.97)	0.000
Total iron (mg/1000 kcal)	5.1 (1.01)	4.5 (0.60)	5.0 (0.97)	5.9 (0.85)	0.000
Haem iron (mg/1000 kcal)	1.2 (0.50)	1.2 (0.50)	1.2 (0.55)	1.2 (0.46)	0.560
Nonhaem iron (mg/1000 kcal)	3.9 (0.99)	3.3 (0.71)	3.8 (0.87)	4.7 (0.84)	0.000
Nonhaem/haem iron	4.3 (3.93)	3.6 (3.26)	4.6 (5.01)	4.6 (3.28)	0.009
Girls					
Energy (kcal/day)	1970.2 (450.96)	1632.0 (397.07)	2016.2 (326.11)	2257.7 (388.40)	0.000
Total iron (mg/day)	10.1 (2.79)	7.2 (1.33)	9.9 (0.67)	13.0 (2.15)	0.000
Haem iron (mg/day)	2.0 (1.03)	1.5 (0.83)	2.1 (0.88)	2.5 (1.14)	0.000
Nonhaem iron (mg/day)	8.0 (2.54)	5.7 (1.15)	7.8 (1.07)	10.5 (2.30)	0.000
Total iron (mg/1000 kcal)	5.2 (1.26)	4.6 (1.24)	5.0 (0.82)	5.9 (1.31)	0.000
Haem iron (mg/1000 kcal)	1.0 (0.54)	0.9 (0.47)	1.1 (0.53)	1.1 (0.61)	0.037
Nonhaem iron (mg/1000 kcal)	4.4 (1.20)	3.7 (1.29)	4.0 (0.71)	4.8 (1.24)	0.000
Nonhaem/haem iron	6.4 (9.97)	7.5 (14.85)	5.2 (4.11)	6.4 (7.90)	0.233

[a]Tertiles based on absolute total iron intake (mg/day); T_1, T_2 and T_3: lowest, middle and highest tertile.
[b]Difference between T_1 and T_3.

nonhaem iron in both boys and girls. The energy-adjusted intake of haem iron was — in both boys and girls — not significantly different between the lowest and highest tertile.

Overall, the ratio nonhaem/haem iron intake was significantly higher in females than in males ($P = 0.001$). Boys in the highest tertile had a significantly higher ratio of nonhaem/haem iron intake than their counterparts of the lowest tertile. In girls, a higher ratio of nonhaem/haem iron intake was seen in the lowest tertile than in the highest tertile, but this difference was not significant.

As a result of a significant difference in energy intake between adolescents in the lowest tertile and adolescents in the highest tertile, in both boys and girls (see Table 2), the authors focused, in the remaining part of the paper, on the energy-adjusted intake of iron (mg/1000 kcal) and iron-containing food items (g/1000 kcal).

Dinner had the highest energy-adjusted total iron content (mg/1000 kcal), followed by lunch, breakfast and snacks for all subjects in the lowest and middle tertile. In the highest tertile, the meal with the highest energy-adjusted total iron content was breakfast, followed by dinner, lunch and snacks. Boys and girls in the highest tertile had a significant higher energy-adjusted total iron intake for each meal than adolescents in the lowest tertile. (Table 5).

The mean proportional contribution of different food groups to dietary iron intake in boys and girls is shown in Table 6. Food groups with the highest mean proportional contribution to dietary iron intake in both boys and girls were in the following order: bread, meat and meat products, cereals (cereal products and binding agents) and potatoes.

The iron contribution of cereals showed, on average, a large difference between adolescents of the lowest tertile and adolescents of the highest tertile. The iron contribution of cereals in the lowest tertile was 6.9% for boys and 5.0% for girls, whereas the contribution in the highest tertile was 12.0% for boys and 12.3% for girls. On the other hand, the iron contribution of meat and meat products in boys was on average much higher in the lowest tertile (21.0%) than in the

Table 5 Meal-specific intake of energy-adjusted total iron (mg/1000 kcal) (mean (s.d.)) in different tertiles[a] in Flemish adolescents, both boys ($n=129$) and girls ($n=212$)

	Total	T_1	T_2	T_3	P-*value*[b]
Boys					
Breakfast	5.9 (3.34)	4.8 (2.30)	5.2 (2.64)	7.8 (4.01)	0.000
Lunch	5.5 (1.54)	4.9 (1.35)	5.4 (1.39)	6.4 (1.51)	0.000
Dinner	5.9 (1.52)	5.4 (1.08)	5.8 (1.75)	6.5 (1.51)	0.002
Snacks	2.9 (1.20)	2.4 (1.10)	3.0 (0.93)	3.3 (1.39)	0.003
Girls					
Breakfast	5.3 (3.81)	3.9 (2.22)	4.9 (2.35)	7.0 (5.31)	0.000
Lunch	5.4 (1.64)	4.7 (1.46)	5.3 (1.59)	6.1 (1.59)	0.000
Dinner	6.1 (2.03)	5.5 (1.96)	6.0 (1.64)	6.8 (2.27)	0.000
Snacks	3.7 (1.75)	3.4 (1.98)	3.6 (1.47)	4.0 (1.74)	0.003

[a]Tertiles based on absolute total iron intake (mg/day); T_1, T_2 and T_3: lowest, middle and highest tertile.
[b]Difference between T_1 and T_3.

Table 6 Mean proportional contribution of different food groups[a] to dietary iron intake among Flemish adolescents in both boys ($n=129$) and girls ($n=212$)

	Boys	*Girls*
Bread	23.6	23.0
Meat and meat products	18.5	15.6
Cereal products and binding agents	9.5	8.7
Potatoes	8.9	8.4
Sugar, confectionery, sweet fillings and sweet sauces	7.6	6.8
Vegetables	6.9	8.3
Cakes and biscuits	4.4	6.1
Other products	20.5	23.2

[a]Food groups ordered from highest to lowest mean proportional contribution in boys.

highest tertile (16.2%). When absolute amounts of iron intake from different food items were considered, the difference between the lowest and highest tertile for iron intake from meat and meat products was in the opposite direction in both boys and girls. Boys in the lowest tertile had a daily iron intake from meat and meat products of 2.01 mg and boys in the highest tertile, 2.34 mg. The daily iron intake from meat and meat products in girls in the lowest and highest tertile was 1.01 and 1.73 mg, respectively. The absolute iron intake from cereals was — in line with the proportional iron contribution — highest in the highest tertile, compared to the lowest tertile, in both boys and girls. Boys and girls in the highest tertile had a daily iron intake from cereals of 1.74 and 1.41 mg, respectively and in the lowest tertile 0.69 and 0.32 mg, respectively.

Table 7 presents the percentage consumers of certain food groups in the total group of boys and girls, respectively, and the energy-adjusted intake of these food groups (g/1000 kcal) in different tertiles in both boys and girls. Boys in the highest tertile had a significantly higher energy-adjusted intake of brown bread and a significantly lower energy-adjusted intake of soft drinks than those in the lowest tertile. A borderline significant difference was seen for fruit with the highest intake in boys of the highest tertile compared to their counterparts of the lowest tertile. In girls of the highest tertile, a significantly higher energy-adjusted intake was seen for brown bread and breakfast cereals and a significantly lower energy-adjusted intake for soft drinks than in girls of the lowest tertile. The higher intake of vegetables in girls of the highest tertile than those of the lowest tertile was borderline significant.

No changes in significant differences were seen for consumers only, except for breakfast cereals and soft drinks in girls. The difference in energy-adjusted intake of breakfast cereals and soft drinks between girls in the lowest and highest tertiles was no longer significant ($P=0.199$ for breakfast cereals and $P=0.078$ for soft drinks) (data not shown).

Discussion

Iron deficiency is the most common micronutrient deficiency in the world. It affects all age groups in both developing and developed countries. Dietary iron intake is, close to other factors such as bioavailability and iron losses, one of the regulatory factors of iron status and therefore important in the prevention of iron deficiency. The main conclusion of this study is that — in view of the current recommendations — adolescent girls do not have sufficient iron intake.

However, before going into more detail on this and other results, a few methodological considerations have to be made.

A general concern in epidemiological research relates to the representativeness of the study population *vis-à-vis* the target population. The study population for this paper was the result of a random sampling recruitment procedure and the participation rate was 72.7%. Owing to the removal of a number of records ($n=70$) — because of low quality of the food diaries — only 60.3% of the eligible students were included in the final analyses. This issue of drop-out has been discussed in more detail in a previous paper on the same database (Matthys *et al*, 2003). In this paper, it was demonstrated that in both boys and girls, the participation rate was significantly lower among students from vocational education than among students from theoretical education. On the other hand, it was shown in a subsample that the proportion of overweight students was not significantly different between the subjects included in the analyses and those not included in the analyses. Taking into account the above considerations, it seems reasonable to assume that the study sample constitutes an overall acceptable representation of the target population of Flemish adolescent boys and girls.

In order to search for potential confounders, the number of adolescents in different categories of age, BMI and

Table 7 Percentage consumers of food groups in the total group of boys ($n = 129$) and girls ($n = 212$), and energy-adjusted intake of food groups (g/1000 kcal) (mean (s.d.)) in different tertiles[a] in Flemish adolescents, both boys and girls (consumers and nonconsumers)

	Boys					Girls				
	% Consumers	T_1	T_2	T_3	P-value[b]	% Consumers	T_1	T_2	T_3	P-value[b]
Bread	100.0	69 (23.9)	71 (23.9)	82 (29.4)	0.043	99.5	75 (29.5)	73 (20.8)	78 (26.3)	0.931
Brown bread	75.2	21 (19.7)	25 (25.6)	50 (35.0)	0.000	80.2	17 (21.2)	30 (25.3)	36 (31.7)	0.000
Breakfast cereals	53.5	4 (6.7)	6 (9.2)	6 (8.8)	0.037	41.5	2 (3.5)	3 (4.1)	5 (8.4)	0.001
Meat and meat products	100.0	57 (18.4)	56 (24.4)	53 (18.7)	0.256	98.6	44 (22.0)	50 (26.4)	48 (24.8)	0.413
Fish	63.6	8 (10.5)	6 (7.0)	7 (7.2)	0.954	64.6	7 (9.1)	8 (9.5)	7 (8.0)	0.502
Poultry	76.7	9 (8.4)	12 (13.4)	13 (13.0)	0.418	67.9	12 (16.2)	12 (12.2)	12 (11.1)	0.630
Potatoes	100.0	56 (25.7)	54 (28.5)	58 (31.4)	0.894	99.1	52 (26.5)	49 (28.3)	55 (28.0)	0.627
Vegetables	100.0	46 (24.0)	47 (29.6)	53 (23.2)	0.168	100.0	50 (34.8)	55 (27.5)	59 (30.7)	0.011
Fruit	92.2	23 (22.1)	38 (38.9)	37 (27.2)	0.011	94.8	58 (60.3)	56 (52.3)	67 (54.2)	0.070
Cheese	91.5	10 (7.9)	9 (8.7)	10 (9.1)	0.819	93.4	14 (11.9)	14 (9.8)	13 (11.0)	0.337
Milk and milk products	98.4	90 (60.8)	98 (76.9)	119 (83.7)	0.119	95.8	102 (91.3)	117 (97.9)	141 (121.5)	0.071
Cakes and biscuits	89.9	14 (13.6)	14 (11.6)	14 (8.8)	0.688	91.0	15 (11.6)	15 (11.0)	15 (11.9)	0.659
Sugar, confectionery, sweet fillings and sweet sauces	99.2	15 (11.3)	17 (10.7)	20 (11.9)	0.019	99.5	15 (9.6)	18 (10.1)	16 (9.9)	0.333
Water	93.0	176 (207.6)	155 (141.6)	183 (138.3)	0.179	97.6	278 (250.7)	260 (243.4)	257 (157.7)	0.754
Fruit juices	73.6	49 (56.5)	52 (72.0)	60 (75.5)	0.761	77.4	70 (74.1)	71 (77.1)	72 (71.2)	0.553
Soft drinks	92.2	202 (118.7)	186 (142.3)	111 (92.5)	0.000	85.4	156 (170.8)	115 (109.4)	90 (110.2)	0.001

[a]Tertiles based on absolute total iron intake (mg/day); T_1, T_2 and T_3: lowest, middle and highest tertile.
[b]Difference between T_1 and T_3.

education in the different iron intake tertiles were compared (see Table 1). As a result of a significant difference between the tertiles for education in females, analyses in girls were stratified according to education and the results were compared to those of unstratified analyses (data not shown). Since no differences were seen for the overall conclusions of the paper and because of small numbers of girls in the different groups, the results of unstratified analyses are presented.

The data presented in this paper do not include the use of iron supplements as this information was not available from the survey. However, the authors do not expect that this would have influenced the overall conclusions in this paper, since a minority of adolescents is expected to use iron-containing supplements on a regular basis (Stang *et al*, 2000; Cogswell *et al*, 2003).

The observed differences between the different tertiles of iron intake need some specific attention. Individuals do not consume the same food from day to day. This day-to-day variability affects the precision and accuracy for a dietary assessment method to estimate the 'usual intake' of nutrients (Basiotis *et al*, 1987; Nelson *et al*, 1989). To estimate true average intake for an individual, a wide range in number of days is necessary and this varies across different nutrients. The required number of days to estimate iron intake varied in the literature from 18 to 130 days for adult men and from 28 to 142 for adult women (Basiotis *et al*, 1987). However, for the purpose of estimating group means, a substantially smaller number of days are required. In order to estimate true average iron intake accurately for a group of male adults ($n = 13$), 7 days, and for a group of female adults ($n = 16$), 6 days, have been reported in the past (Basiotis *et al*, 1987). However, to the authors' knowledge, no specific figures on this topic are available for adolescents. On the basis of the above, the authors conclude that the instrument used in this study (a self-administered 7-day estimated dietary record) allows valid comparisons between groups of individuals (tertiles).

A comparison of the iron intake of the Flemish adolescents with adolescents of other European countries is difficult to make and needs to be interpreted carefully, mainly because of potential differences in methodology and study population. With this in mind, it seems that the daily iron intake in other European countries is comparable. In 1990, a study to the nutritional pattern of 344 school-children 8–15 y of age was performed in Spain (in Cadiz). Dietary intake was assessed by a 24 h recall and showed an iron intake of 13 mg/day for the boys and 12 mg/day for the girls (Failde *et al*, 1997). In France (in the Paris area), a longitudinal study of growth and nutrition was started in 1985 in 10-month-old infants. These children were followed up until the age of 16 y. Food intake was assessed on the basis of the dietary history method conducted by a dietician. At the ages of 10, 14 and 16 y, the mean iron intake in boys was 11.2, 12.3 and 13.5 mg/day, respectively. In girls, the mean iron intake at the ages of 10, 14 and 16 y was 10.5, 12.1 and 10.9 mg/day, respectively, (Deheeger *et al*, 2002). Nutrient intake data of Scottish adolescents were cross-sectionally collected in the 1970 Birth Cohort Study at the ages of 16–17 y. The mean iron intake — measured by a 4-day unweighed dietary record — of boys and girls, respectively, was 12.9 and 10.4 mg/day (Belton *et al*, 1997). In the DONALD study — a longitudinal cohort study in Germany — detailed data were collected on diet, metabolism, growth and development from healthy subjects between infancy and adulthood. Food consumption was assessed with a 3-day weighed dietary record. For the period 1995–2000, the mean iron intake in the age category 15–18 y was 13.2 mg/day for males and 10.4 mg/day for females (Sichert-Hellert & Kersting, 2003). A nutritional survey of 15-y-old adolescents was carried out in two different regions of Sweden (Uppsala and Trollhattan) in 1993–1994 — the beginning of a longitudinal nutritional survey. The iron intake was calculated from a 7-day dietary record and showed a daily median intake of 18.7 mg in boys and 14.2 mg in girls (Samuelson *et al*, 1996).

As in other European countries, a high proportion of the Flemish adolescents had an iron intake below the national recommendations, particularly adolescent girls. Except for one, all the Flemish girls had an iron intake below the Belgian RDA. In France, 80% of the girls had an iron intake below the French recommendations (Rolland-Cachera *et al*, 2000). In comparison with the British EAR, fewer Flemish adolescents had an iron intake below the recommendations, but the proportion was still remarkable.

The conclusion that iron intake in Flemish girls is not sufficient in view of the current recommendations is confirmed by the finding that a huge proportion of Flemish females had a bioavailable iron intake below the age-specific requirement.

A remark on the above is that the RDA and the required intake for bioavailable iron used to compare the iron intake of girls are the ones for menstruating girls — which are higher than those for nonmenstruating girls (Nationale Raad voor de Voeding, 2000; FAO/WHO, 2002). The authors did not obtain data on the menstruating status of the girls in the study. However, the mean age at menarche in Belgium is approximately 13 y, from which it can be assumed that the majority of the girls in the study were menstruating (Vercauteren & Susanne, 1985; Wellens *et al*, 1990).

Thus, in the light of the above findings, one can conclude that an increased iron intake is needed in this subgroup of the population.

A comparison of individuals of the highest tertile with their counterparts of the lowest tertile showed a significant difference for energy-adjusted total iron intake and energy-adjusted nonhaem iron intake in both males and females. The difference in energy-adjusted haem iron intake between individuals in the highest compared to the lowest tertile was not significant. The differences in energy-adjusted total iron intake between individuals of the third tertile and their counterparts of the first tertile are thus mainly explained by differences in energy-adjusted nonhaem iron intake.

The results have shown a significant difference in the ratio of the less available nonhaem and more available haem iron intake (Lynch, 1997; Heath & Fairweather-Tait, 2002) between boys and girls on the one hand and between the lowest and highest tertile in boys on the other hand. The females — who already had a lower total iron intake than the males — had a higher ratio of nonhaem/haem iron intake than the males. Thus, in comparison with males, females consume less iron and, in addition, the iron that is consumed is on average likely to have a lower bioavailability. In boys, adolescents of the highest tertile had a higher total iron intake, but also a higher ratio of nonhaem/haem iron intake than their counterparts in the lowest tertile. Thus, the iron consumed by adolescent boys with the highest iron intake, compared to adolescent boys with the lowest iron intake, has on average a lower bioavailability. This reflects also in the contribution of different food groups to dietary iron intake. In boys, the contribution of cereals (nonheam iron) was much higher in the highest tertile than in the lowest tertile and also the absolute iron intake from cereals was highest in the highest tertile. Despite the fact that contribution of meat and meat products (heam iron) was much lower in the highest tertile than in the lowest tertile, no big differences were seen in the absolute iron intake from meat and meat products in boys. This again shows that differences in iron intake between tertiles are mainly explained by differences in nonhaem iron intake. In girls, an opposite relationship between adolescents in the lowest tertile and their counterparts in the highest tertile was seen, but was not significant: females with the lowest iron intake consume relatively more iron that is on average less available than females with the highest iron intake.

Bread and cereals (cereal products and binding agents) were important iron sources in both boys and girls. However, because of the presence of phytates in these food items, it can be anticipated that the absorption of nonhaem iron will be reduced. On the other hand, meat and meat products were the second important iron source (after bread and before cereals) in both boys and girls. These food items are considered to have a beneficial effect on the iron status as they supply haem iron and enhance nonhaem iron absorption within a meal (Lynch, 1997; Heath & Fairweather-Tait, 2002).

Phytates and meat and meat products are only two examples of iron absorption modifiers. The Western diet is highly varied, which leads to interactions between various enhancers and inhibitors. These interactions between nutrients at the level of the GI tract are extremely complex and beyond the scope of this paper (Lynch, 1997; Heath & Fairweather-Tait, 2002).

Flemish adolescents from the highest tertile had breakfast as the meal with the most energy-adjusted iron content, probably due to the intake of brown bread and cereals, particularly breakfast cereals, whereas in adolescents from the lowest tertile it was dinner that had the highest energy-adjusted iron content. Thus having breakfast can be important towards iron intake, depending on the composition of the meal.

On the whole, the iron intake in adolescent girls is low in comparison with the current recommendations for this nutrient. Since no data are available on iron status in our study population, it is not clear to what extent the observed intake also translates into poor overall iron status. From the literature it is known that the risk for low iron status is apparent, especially in adolescent girls. For instance, in Great Britain, a National Diet and Nutrition Survey of young people (aged 4–18 y) was performed in 1997. A low iron status (serum ferritin $<15\,\mu$g/l) was seen in 22% of adolescent girls (15–18 y) and in 5% of adolescent boys (15–18 y) (Thane *et al*, 2003). And in Sweden, for example, a longitudinal study was started in 1993–1994 in 15-y-old adolescents (209 girls and 185 boys). A proportion of 19.6% girls and 8.6% boys had serum ferritin levels below 15 μg/l and 13.9% girls and 3.7% boys below 12 μg/l (Samuelson *et al*, 1996). In the follow-up study, at 17 and 21 y, fewer adolescents participated (the complete longitudinal cohort comprised 126 adolescents, 60 males and 66 females). The proportions of females with low serum ferritin values ($<12\,\mu$g/l) at ages 15, 17 and 21 y were 18, 26 and 21%, respectively. In boys, they were 3, 2 and 2%, respectively (Samuelson *et al*, 2003).

Despite the regulation of the iron status in the human body being a complex interplay of different factors, it seems useful to consider ways of improving iron intake — which is one of these factors — in this population. For the purpose of increasing the intake of iron on a population level, different strategies can be followed. One may try to influence the percentage of consumers for food items rich in iron or alternatively try to increase portion sizes and frequency of consumption for iron rich foods, taking into account the energy balance (Sandström, 2001).

Public health actions to improve iron intake in adolescent girls could be focusing on an increase of the intake of food items with a high iron content (eg lean meat), an increase of the intake of food items which enhance nonhaem iron absorption (eg animal tissue, fruit, vegetables), a decrease of the intake of food items which inhibit nonhaem iron absorption (eg coffee, tea) and a change in the time some food items are consumed: thus, enhancers of iron absorption within a meal (eg fruit) and inhibitors between meals (eg milk and milk products), taking into account the recommendations of a healthy diet (Heath *et al*, 2001).

According to the results of the present study (see Table 7) iron intake in girls could be improved by increasing the consumption of haem iron sources such as meat (particularly lean meat), fish and poultry. In addition, and particularly for individuals who consume no or little meat, the consumption of nonhaem iron could be improved by increasing consumption of brown bread, preferably in combination with enhancers of nonhaem iron absorption such as fruit and vegetables. Brown bread has a prominent position in the category of wholemeal cereal products on most food guides not only as a good source of nonhaem iron, but also as a vehicle for other minerals, vitamins, complex carbohydrates and fibre. Evidently, recommendations to increase iron intake should be compatible with overall considerations regarding healthy diet, giving particular attention also to the energy balance (Vlaams Instituut voor Gezondheidspromotie, 2003).

Acknowledgements

This work was financially supported by the National Fund for Scientific Research (fund no. 31557898), the Kellogg's Benelux Company, Unilever Belgium and the Belgian Nutrition Information Center.

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