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Projected Prevalence of Inadequate Nutrient Intakes in Europe

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Key Words
Nutrient intake adequacy · Europe · Estimated average requirement cut point · EURRECA · Adults · Elderly

Abstract
Background: The purpose of this study was to analyze the prevalence of nutrient intake inadequacy in Europe, applying the Nordic Nutritional Recommendations in the context of the EURRECA Network of Excellence. ***Methods:*** Nutrient data was obtained from the European Nutrition and Health Report II. Those nutritional surveys using a validated food frequency questionnaire or diet history and a food diary/register with at least 7 days of registers or with an adjustment for intraindividual variability were included. The nutrients analyzed were: vitamin C, vitamin D, vitamin B_{12}, folic acid, calcium, iron, zinc, selenium, copper, and iodine. The estimated average requirement cut point was applied to estimate inadequacy. The Nordic and Institute of Medicine nutrient recommendations were used as references. ***Results:*** The mean prevalence of inadequacy was below 11% for zinc, iron, and vitamin B_{12} (only in the elderly), and it was 11–20% for copper in adults and the elderly and for vitamin B_{12} in adults and vitamin C in the elderly. The prevalence was above 20% for vitamin D, folic acid, calcium, selenium, and iodine in adults and the elderly and for vitamin C in adults. ***Conclusions:*** Vitamin C, vitamin D, folic acid, calcium, selenium, and iodine were the nutrients showing a higher prevalence of inadequate intakes in Europe.

Introduction

The EURopean micronutrient RECommendations Aligned (EURRECA; www.eurreca.org) Network of Excellence is working to provide an evidence-based framework for establishing micronutrient requirements [1]. A key focus of the Network is to identify vulnerable population groups who are at greater nutritional risk, with an analysis of nutrient adequacy assessment being a targeted activity [2, 3]. Tabbachi et al. [3] reviewed the methods used to estimate nutrient intake adequacy in nutrition surveys. Al-Tahan et al. [4] reviewed the studies evaluating vitamin B intake in European adolescents. Moreover, Fabian and Elmadfa [5] used the information of the European Nutrition and Health Report I to provide an overview of the micronutrient inadequacies in the European elderly. They all found large discrepancies in the prevalence of nutrient intake inadequacy across Europe due in

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part to the different methodologies for dietary intake and analysis that were applied as well as the nutritional recommendations used.

Comparing data on nutrient intake deficiencies and excesses across Europe is a task hampered by difficulties. Study methodologies and purposes vary from country to country. Not all European countries have conducted representative nutritional surveys at the national level, with some of them being only regional or local. In addition, the assessment of food intake varies from country to country and the purpose of the survey may not include the evaluation of nutritional status. Several efforts and expert appeals have been made that address the need to share a common methodology when conducting nutritional surveys [6, 7]. As these difficulties have been recognized, the need and methodology for the harmonization of pan-European nutrition surveillance has been addressed in the EC-funded EFCOSUM [7] and EFCOVAL [8] consortia and is incorporated into the EC policy [9]. However, for the time being, the comparison of nutrient intake and status across Europe has to rely on existing information. The objective of this study was to analyze the prevalence of inadequate intakes of a number of micronutrients in adult and elderly populations utilizing the most representative European data and applying the estimated average requirement (EAR) cut point and the Nordic Nutritional Recommendations.

Subjects and Methods

The data included were obtained from the European Nutrition and Health Report II (ENHRII) and the ILSI Europe Addition of Nutrients to Food Task Force report, based on the search strategy proposed by Blanquer et al. [10]. The ENHRII was a European funded project [11] with 25 participating countries (Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Norway, Poland, Portugal, Romania, Slovenia, Spain, Sweden, The Netherlands, and the UK). The ILSI Europe report provided information on the risk of excess intake in representative European countries [12].

Methods

The EAR cut point was applied to estimate the prevalence of nutrient intake adequacy [13]. To apply this method, information on usual intakes is needed in order to attenuate intraindividual variability [14]. When using diet recalls or registers, the usual intake is estimated by applying statistical methods [15, 16]. In the case of food frequency questionnaire (FFQ) administration, validation of the instrument is needed [17–19]. The nutritional studies represented by both European projects had different methodologies not only with regard to the food assessment method but also in relation to data analysis and the approach for presenting the results. Only those nutritional surveys using a validated FFQ or having applied a method of adjustment for individual variability were considered. Due to the limited number of studies using such methodologies, those studies that did not adjust for individual variability but had at least 7 days of registered intake were also included [20]. Only studies with a sample size of at least 100 individuals were considered for the analysis, as recommended by Murphy et al. [21].

Following the EURRECA research [22], the Nordic Recommendations were used as the reference values for comparison [23]. When no EAR was defined for the nutrient under study (vitamin D and calcium), the EAR defined by the Institute of Medicine (IOM) was used as a cut-off point [24].

The nutrients under study were those selected as priority micronutrients by the EURRECA project [25]: vitamin C, vitamin D, vitamin B_{12}, folic acid, iron, zinc, calcium, selenium, copper, and iodine.

The population groups analyzed were: adults (aged 19–64 years) and the elderly (aged more than 64 years).

To apply the EAR cut point, the requirement distribution for the nutrient under study must follow a symmetrical distribution. As the iron requirements in women of childbearing age are skewed, this population age group was excluded. For the remaining nutrients, a normal intake distribution was assumed.

As the information available consisted only of published data (i.e. mean and SD of the nutrient under study), the EAR cut point was calculated as follows: $z = (x - \mu)/SD$, with x being the EAR and μ the nutrient mean intake, and by calculating the area below the curve for the z value in a normal distribution of mean = 0 and SD = 1. The result was then expressed as a percent.

Given that not all countries had data for all ten micronutrients, a comparison was made for the countries having the most data for the same micronutrients of interest. Those countries were ranked according to the following ratio: number of nutrients with a prevalence of intake inadequacy above 20% of the population/total number of nutrients.

Results

The nutritional surveys were checked for compliance with the inclusion criteria. As the ENHRII contained more recent data, all nutrient intake data were obtained from such report except for the information from The Netherlands. As the study representing The Netherlands in the ENHRII (Dutch National Food Survey 1997–1998) was not adjusted for individual variability, the data was obtained from the Flynn report (Dutch National Food Survey 2003) which met the inclusion criteria [12]. For the UK, the nutritional information provided in the ENHRII represented a low income sample. As such, the data was obtained from the European Nutrition and Health Report I [26].

The following countries had studies that did not comply with the quality criteria: Austria [a single 24-hour recall (HR) for the adults and a 3-day dietary record (DR) for the elderly], Cyprus and Luxembourg (no data for the population groups analyzed), the Czech Republic, Esto-

Table 1. Vitamin C intake (mg/day) and prevalence of inadequate intake (% population below EAR) in Europe by gender and population group

Country	Study	Study year	Food intake method	Males (EAR = 60 mg/day)			Females (EAR = 50 mg/day)		
				n	mean ± SD	% below EAR	n	mean ± SD	% below EAR
Adults (age 19–64 years)									
BE	Belgian Food Consumption Survey [27]	2004	adj 2 × 24 HR	n.a.	88 ± 36	21.8	n.a.	92 ± 44	17.0
DE	German National Nutrition Survey II [31–33]	2005–2007	DH	4,912	153 ± 106	19.0	6,016	153 ± 84	11.0
DK	Danish National Survey of Dietary Habits and PA [28]	2000–2002	7 dDR	1,283	102 ± 56	22.7	1,486	107 ± 61	17.5
ES	ENCAT 2002–2003 [36–38]	2002–2003	adj 2 × 24 HR	706	97 ± 37	15.9	875	108 ± 42	8.4
FI	National FINDIET 2007 Survey [29, 30]	2007	adj 48 HR	730	98 ± 88	33.3	846	118 ± 82	20.3
GR	EPIC study [11]	1994–1999	FFQ	500	146 ± 130	25.4	451	145 ± 120	21.4
IR	SLAN 2007 [34]	2007	FFQ	662	116 ± 223	40.1	717	108 ± 183	37.6
IT	INN-CA Study [35]	1994–1996	7 dDR	660	122 ± 65	17.0	801	113 ± 58	13.9
NO	Norkost 1997 [11]	1997	FFQ	1,050	140 ± 95	20.0	1,146	149 ± 88	13.0
PT	EpiPorto [11]	1999–2003	FFQ	917	116 ± 54	15.0	1,472	131 ± 63	9.9
SE	Riksmaten 1997–1998 [39]	1997–1998	7 dDR	517	79 ± 45	33.6	575	90 ± 50	21.2
UK	Health Survey for England [42]	2000–2001	7 dDR	219	84 ± 66	36.0	210	85 ± 85	34.0
Elderly (age >64 years)									
BE	Belgian Food Consumption Survey [27]	2004	adj 2 × 24 HR	n.a.	91 ± 43	23.5	n.a.	87 ± 44	20.0
DE	German National Nutrition Survey II [31–33]	2005–2007	DH	1,469	142 ± 70	12.1	1,562	148 ± 81	11.3
DK	Danish National Survey of Dietary Habits and PA [28]	2000–2002	7 dDR	165	95 ± 52	25.0	164	115 ± 67	16.6
ES	Catalan Nutrition Survey [36–38]	2002–2003	adj 2 × 24 HR	163	126 ± 50	9.3	179	115 ± 38	4.4
FI	National FINDIET 2007 Survey [29, 30]	2007	adj 48 HR	229	92 ± 72	32.8	234	97 ± 68	24.5
NO	Norkost 1997 [11]	1997	FFQ	176	139 ± 81	16.5	176	160 ± 87	10.3
PT	EpiPorto [11]	1999–2003	FFQ	246	121 ± 57	14.2	339	118 ± 57	11.6

EAR = Estimated average requirement; BE = Belgium; DE = Germany; DK = Denmark; ES = Spain; FI = Finland; GR = Greece; IR = Ireland; IT = Italy; NO = Norway; PT = Portugal; SE = Sweden; UK = United Kingdom; adj = adjusted for intraindividual variability; HR = hour recall; DH = diet history; dDR = days dietary record; FFQ = food frequency questionnaire; n.a. = not available.

nia, Latvia, Lithuania and Poland (a single 24 HR), Hungary (3-day DR), Romania (no information on the food intake method), The Netherlands (2-day DR for the elderly), and the UK (4-day DR for the elderly). For the elderly group, the nutritional surveys from Sweden and Italy (for certain micronutrients in the male population) were not included (sample size lower than 100 individuals).

The countries that had studies with suitable data for the adults were: Belgium (Belgian Food Consumption Survey, 2004) [27], Denmark (Danish National Survey of Dietary Habits and Physical Activity, 2000–2002) [28], Finland (National FINDIET 2007 Survey) [29, 30], Germany (German National Nutritional Survey II, 2005–2007) [31–33], Greece (Greek EPIC study, 1994–1999) [11], Ireland (SLAN, 2007) [34], Italy (INN-CA study) [35], Norway (Norkost, 1997) [11], Portugal (EPI Porto study, 1999–2003) [11], Spain (ENCAT 2002–2003) [36–38], Sweden (Riksmaten 1997–1998) [39], The Netherlands (Dutch National Food Consumption Survey, 2003) [40, 41], and the UK (Health Survey for England, 2001–2002) [42], and for the elderly group: Belgium (Belgian Food Consumption Survey, 2004) [27], Denmark (Danish National Survey of Dietary Habits and Physical Activity, 2000–2002) [28], Finland (National FINDIET 2007 Survey) [29, 30], Germany (German National Nutritional Survey II, 2005–2007) [31–33], Italy (INN-CA study) [35], Norway (Norkost, 1997) [11], Portugal (EPI Porto study, 1999–2003) [11], and Spain (ENCAT 2002–2003) [36–38] [11].

The food intake data were obtained from food diaries in most of the countries. The data from The Netherlands (two 24 HR, only in the adult population group), Belgium (two 24 HR), Finland (a 48 HR), and Spain (two 24 HR) were obtained applying an adjustment for intra-individual variability. The studies from Italy, Denmark, the UK, and Sweden used 7-day DR. The following countries used a validated FFQ: Greece for the adult group [43], Ireland [44], Norway [45], and Portugal [46, 47]. Germany used a validated diet history (DISHES 98) [48].

The nutrient intake data included food supplement data in the nutritional surveys of Norway and Ireland (adults). None of the data provided excluded underreporters.

Table 2. Vitamin D (μg/day) intake and prevalence of inadequate intake (% population below EAR) in Europe by gender and population group

Country	Study	Study year	Food intake method	Males (EAR = 10 μg/day)			Females (EAR = 10 μg/day)		
				n	mean ± SD	% below EAR	n	mean ± SD	% below EAR
Adults (age 19–64 years)									
DE	German National Nutrition Survey II [31–33]	2005–2007	DH	4,912	3.8 ± 3.6	95.7	6,016	2 ± 1.3	100.0
DK	Danish National Survey of Dietary Habits and PA [28]	2000–2002	7 dDR	1,283	3.6 ± 2.8	98.9	1,486	2.8 ± 2.3	99.9
ES	ENCAT 2002–2003 [36–38]	2002–2003	adj 2 × 24 HR	706	1.6 ± 0.8	100.0	875	1.2 ± 0.6	100.0
FI	National FINDIET 2007 Survey [29, 30]	2007	adj 48 HR	730	7.1 ± 5.7	69.5	846	5.2 ± 4.2	87.3
IR	SLAN 2007 [34]	2007	FFQ	662	3.7 ± 3.4	96.8	717	3.7 ± 8.7	76.6
IT	INN-CA Study [35]	1994–1996	7 dDR	660	3.5 ± 2.3	99.8	801	2.8 ± 1.8	100.0
NE	Dutch National Food Consumption Survey 2003 [40, 41]	2003	2 × 24 HR	352	3.7 ± 1.5	100.0	398	2.7 ± 1.5	100.0
NO	Norkost 1997 [11]	1997	FFQ	1,050	10.9 ± 10.7	46.6	1,146	10.1 ± 9.1	49.6
PT	EpiPorto [11]	1999–2003	FFQ	917	3.6 ± 1.7	100.0	1,472	3.5 ± 1.6	100.0
SE	Riksmaten 1997–1998 [39]	1997–1998	7 dDR	517	6.1 ± 2.7	92.6	575	4.8 ± 1.9	99.7
UK	Health Survey for England [42]	2000–2001	7 dDR	219	4.1 ± 3.2	96.7	210	2.7 ± 2.0	100.0
Elderly (age >64 years)									
DE	German National Nutrition Survey II [31–33]	2005–2007	DH	1,469	4.4 ± 4.1	91.4	1,562	3.4 ± 2.8	99.1
DK	Danish National Survey of Dietary Habits and PA [28]	2000–2002	7 dDR	165	3.9 ± 3.1	97.5	164	3.1 ± 2.1	99.9
ES	ENCAT 2002–2003 [36–38]	2002–2003	adj 2 × 24 HR	163	0.7 ± 0.1	100.0	179	0.7 ± 0.1	100.0
FI	National FINDIET 2007 Survey [29, 30]	2007	adj 48 HR	229	9 ± 8.2	54.9	234	6.5 ± 4.6	77.7
IR	SLAN 2007 [34]	2007	FFQ	580	3.5 ± 2.1	99.9	742	3.2 ± 1.9	100.0
IT	INN-CA Study [35]	1994–1996	7 dDR	60	2.5 ± 1.7	100.0	107	2.4 ± 1.8	100.0
NO	Norkost 1997 [11]	1997	FFQ	176	15 ± 11.4	33.0	176	12.9 ± 11.8	40.3
PT	EpiPorto [11]	1999–2003	FFQ	246	3.4 ± 1.6	100.0	339	3.3 ± 1.5	100.0
SE	Riksmaten 1997–1998 [39]	1997–1998	7 dDR	64	7.1 ± 2.6	86.8	58	6.1 ± 2.0	97.4

EAR = Estimated average requirement; DE = Germany; DK = Denmark; ES = Spain; FI = Finland; IR = Ireland; IT = Italy; NE = The Netherlands; NO = Norway; PT = Portugal; SE = Sweden; UK = United Kingdom; DH = diet history; dDR = days dietary record; adj = adjusted for intraindividual variability; HR = hour recall; FFQ = food frequency questionnaire.

Tables 1–8 show the intake and prevalence of inadequate intakes for vitamin C, vitamin D, vitamin B_{12}, folic acid, calcium, iron, zinc, selenium, iodine, and copper.

In the adult population, the prevalence of inadequate micronutrient intakes was higher in females than in males for all of the micronutrients except vitamin C. The prevalence of vitamin C inadequacy ranged from 10 to 20% in most of the nutritional surveys except for the study from Spain that had the lowest prevalence rates (table 1). A prevalence of inadequacy of 21–30% of the population was found in the nutritional surveys from Belgium (except females), Denmark (only males), Greece (adult population only), Sweden (female adults), and Finland (female elderly). The nutritional surveys from Finland (males only), the UK (except elderly males, with a prevalence above 40% of the population), Ireland (adult population), and Sweden (male adults) showed that 31–40% of the target population had usual vitamin C intakes below the EAR.

The prevalence of vitamin D inadequacy was above 40% of the population in all the surveys included in the analysis (table 2).

For vitamin B_{12} (table 3), the studies including subjects from Denmark (except female adults), Germany, Portugal, Spain, Sweden (male adults), and the UK (female adults) had a prevalence of inadequacy equal to or below 10%. Adult males from the nutritional surveys from Finland and adult females participating in the surveys from Ireland had a prevalence of inadequacy between 21 and 30% below the EAR, together with elderly females from the UK and Finland.

All (except adult Italian males) nutritional surveys showed an inadequate intake prevalence for folic acid above 15% of the population (table 4). The prevalence of inadequacy was between 21 and 30% in subjects comprising the nutritional surveys from Spain and Germany (except female adults in both surveys), Portugal, Finland (only male adults), and the UK (female adults). The adult females from Sweden, Greece, and The Netherlands and the elderly females participating in the surveys from Finland and the UK had a prevalence of inadequacy above 41%.

Regarding the prevalence of calcium inadequacy, the percentage of individuals whose intake was below the

Table 3. Vitamin B_{12} (µg/day) intake and prevalence of inadequate intake (% population below EAR) in Europe by gender and population group

Country	Study	Study year	Food intake method	Males (EAR = 1.4 µg/day)			Females (EAR = 1.4 µg/day)		
				n	mean ± SD	% below EAR	n	mean ± SD	% below EAR
Adults (age 19–64 years)									
DE	German National Nutrition Survey II [31–33]	2005–2007	DH	4,912	6.6 ± 3.7	8.0	6,016	4.4 ± 2.1	7.7
DK	Danish National Survey of Dietary Habits and PA [28]	2000–2002	7 dDR	1,283	5.8 ± 3.3	9.1	1,486	4.3 ± 2.6	13.2
ES	ENCAT 2002–2003 [36–38]	2002–2003	adj 2 × 24 HR	706	5.0 ± 1.0	0.0	875	4.0 ± 0.8	0.1
FI	National FINDIET 2007 Survey [29, 30]	2007	adj 48 HR	730	6.6 ± 6.5	21.2	846	4.5 ± 3.4	18.1
GR	EPIC study [11]	1994–1999	FFQ	500	5.3 ± 11.4	36.6	451	3.8 ± 9.7	40.2
IR	SLAN 2007 [34]	2007	FFQ	662	5.4 ± 3.7	14.0	717	4.1 ± 3.6	22.7
PT	EPIPORTO [11]	1999–2003	FFQ	917	9.3 ± 4.1	2.7	1,472	8.8 ± 4.0	3.2
SE	Riksmaten 1997–1998 [39]	1997–1998	7 dDR	517	6.8 ± 3.8	7.8	575	5.9 ± 5.4	20.2
UK	Health Survey for England [42]	2000–2001	7 dDR	219	6.2 ± 4.3	13.2	259	6.1 ± 3.7	10.2
Elderly (age >64 years)									
DE	German National Nutrition Survey II [31–33]	2005–2007	DH	1,469	5.9 ± 2.5	3.6	1,562	4.3 ± 2.0	7.4
DK	Danish National Survey of Dietary Habits and PA [28]	2000–2002	7 dDR	165	6.0 ± 3.3	8.2	164	4.8 ± 2.7	10.4
ES	ENCAT 2002–2003 [36–38]	2002–2003	adj 2 × 24 HR	163	3.8 ± 0.6	0.0	179	3.5 ± 0.5	0.0
FI	National FINDIET 2007 Survey [29, 30]	2007	adj 48 HR	229	6.5 ± 6.0	19.8	234	5.2 ± 4.8	21.4
PT	EpiPorto [11]	1999–2003	FFQ	246	8.2 ± 3.8	3.7	339	7.5 ± 4.1	6.8
SE	Riksmaten 1997–1998 [39]	1997–1998	7 dDR	64	8.0 ± 3.9	4.5	58	7.4 ± 4.1	7.2

EAR = Estimated average requirement; DE = Germany; DK = Denmark; ES = Spain; FI = Finland; GR = Greece; IR = Ireland; PT = Portugal; SE = Sweden; UK = United Kingdom; DH = diet history; dDR = days dietary record; adj = adjusted for intraindividual variability; HR = hour recall; FFQ = food frequency questionnaire.

EAR defined by the IOM was above 20% of the population in most of the nutritional surveys analyzed (table 5)

Regarding the prevalence of iron intake inadequacy (table 6), the prevalence was at or below 10% of the population in most of the nutritional surveys. Elderly individuals from Denmark, Finland, Norway, Ireland, and Belgium (only females) and adult males from Finland, the UK, and Greece had a prevalence of inadequacy between 11 and 21%.

The prevalence of zinc inadequacy (table 7) was equal to or below 10% in all of the nutritional surveys included in the analysis except for those from Ireland, the UK, Spain (male elderly), and Germany (female elderly).

Adults from Finland and male adults from The Netherlands had a prevalence of selenium inadequacy equal to or below 10% of the population (table 8). The prevalence of inadequacy was at or above 30% in the nutritional surveys from Denmark, Sweden, and Italy (elderly females only).

Regarding iodine, only four countries had suitable data (table 8). The studies from Denmark (adults and elderly males) and Finland (only elderly) had 10% or less of the population with inadequate intakes. More than 20% of the adult population from Finland, the adult and elderly population from Germany, and the elderly from Ireland (female only) had iodine intakes below the EAR.

For copper (table 8), the prevalence of inadequacy was at or below 10% in Finnish males and male adults from Italy. The prevalence was above 20% in the nutritional surveys from Ireland (adult females and elderly males) and female adults from the UK.

The micronutrients that were included as study variables for the majority of countries were: vitamin C, vitamin D, vitamin B_{12}, folic acid, calcium, iron (males only), and zinc. The countries that had this information were Germany, Denmark, Spain, Finland, Ireland, Sweden, and the UK. Figure 1 shows the countries according to the number of nutrients whose intake was found to be inadequate (above 20% of the population) for both males and females. Finland and Sweden had the highest ratios of inadequate intakes among males and Ireland and the UK among females.

Discussion

The analysis of nutrient intake data in Europe showed a mean prevalence of inadequacy at or below 10% of the population for zinc, iron, and vitamin B_{12} (only in the elderly population); the prevalence was between 11 and 20% for copper in the adult and elderly populations, for

Table 4. Folic acid (μg/day) intake and prevalence of inadequate intake (% population below EAR) in Europe by gender and population group

Country	Study	Study year	Food intake method	Males (EAR = 200 μg/day)			Females (EAR = 200 μg/day)		
				n	mean ± SD	% below EAR	n	mean ± SD	% below EAR
Adults (age 19–64 years)									
DE	German National Nutrition Survey II [31–33]	2005–2007	DH	4,912	321 ± 202	27.5	6,016	277 ± 124	26.7
DK	Danish National Survey of Dietary Habits and PA [28]	1997	7 dDR	1,283	323 ± 120	15.3	1,486	296 ± 111	19.4
ES	ENCAT 2002–2003 [36–38]	2002–2003	adj 2 × 24 HR	706	237 ± 45	20.5	875	220 ± 48	33.8
FI	National FINDIET 2007 Survey [29, 30]	2007	adj 48 HR	730	270 ± 120	28.0	846	226 ± 88	38.4
GR	EPIC study [11]	1994–1999	FFQ	500	283 ± 190	33.1	451	221 ± 184	45.5
IR	SLAN 2007 [34]	2007	FFQ	662	332 ± 128	15.1	717	260 ± 144	33.8
IT	INN-CA Study [35]	1994–1996	7 dDR	660	315 ± 91	10.3	801	283 ± 100	20.3
NE	Dutch National Food Consumption Survey 2003 [40, 41]	2003	2 × 24 HR	352	219 ± 73	39.8	398	146 ± 40	91.0
PT	EpiPorto [11]	1999–2003	FFQ	917	302 ± 130	21.6	1,472	304 ± 144	23.5
SE	Riksmaten 1997–1998 [39]	1997–1998	7 dDR	517	232 ± 73	33.1	575	215 ± 65	40.9
UK	Health Survey for England [42]	2000–2001	7dDR	219	376 ± 224	18.2	210	249 ± 113	25.8
Elderly (age >64 years)									
DE	German National Nutrition Survey II [31–33]	2005–2007	DH	1,469	276 ± 93	20.7	1,562	276 ± 93	20.7
DK	Danish National Survey of Dietary Habits and PA [28]	2000–2002	7 dDR	165	308 ± 122	18.8	164	297 ± 112	19.3
ES	ENCAT 2002–2003 [36–38]	2002–2003	adj 2 × 24 HR	163	236 ± 47	22.2	179	216 ± 28	28.4
FI	National FINDIET 2007 Survey [29, 30]	2007	adj 48 HR	229	243 ± 102	33.7	234	210 ± 96	45.9
IR	SLAN 2007 [34]	2007	FFQ	580	343 ± 148	16.7	742	335 ± 145	17.6
IT	INN-CA Study [35]	1994–1996	7 dDR	n.a.	n.a.	n.a.	107	279 ± 174	32.5
PT	EpiPorto [11]	1999–2003	FFQ	246	312 ± 156	23.6	339	290 ± 163	29.0
SE	Riksmaten 1997–1998 [39]	1997–1998	7 dDR	64	240 ± 75	29.7	58	237 ± 81	32.4

EAR = Estimated average requirement; DE = Germany; DK = Denmark; ES = Spain; FI = Finland; GR = Greece; IR = Ireland; IT = Italy; NE = The Netherlands; PT = Portugal; SE = Sweden; UK = United Kingdom; DH = diet history; dDR = days dietary record; adj = adjusted for intraindividual variability; HR = hour recall; FFQ = food frequency questionnaire; n.a. = not available.

vitamin B_{12} in the adult population, and for vitamin C in elderly Europeans. The micronutrients with a prevalence of inadequacy above 21% of the population were vitamin D, folic acid, calcium selenium, and iodine in the adults and elderly and vitamin C in the adults only.

When calculating nutrient intake adequacy, a decision must be made regarding the threshold to define an acceptable level of inadequacy for every nutrient under study. The World Health Organization (WHO) set a 2–3% level as the maximum desirable prevalence of inadequate intake when planning food supplementation [49]. The governmental institution Health Canada determined the level of less than 10% as the threshold to develop Canada's Food Guide [50]. In the present analysis, a more lenient threshold would be more appropriate because several methodological aspects affected the calculation of the number of individuals whose intake was below the EAR [14, 21]. In the first place, we used published data and had no access to raw data. Secondly, individuals underreporting their intake were not excluded from the analysis. Lastly, supplement intake or food fortification

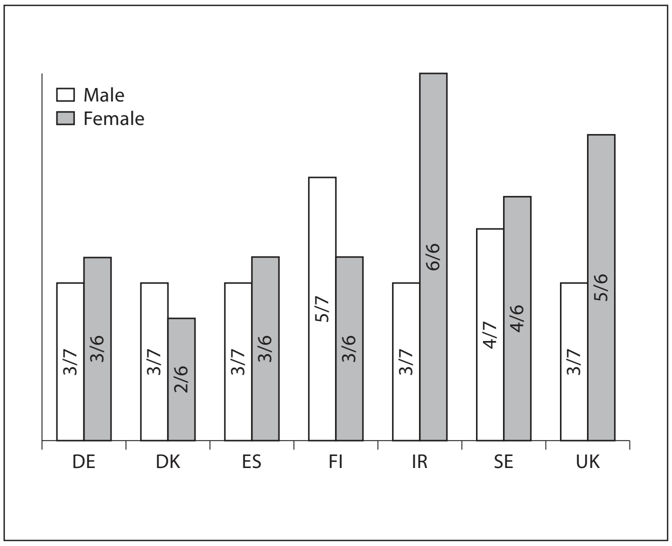

Fig. 1. Countries with data for 7 vitamins and minerals (6 for females) classified according to the number of nutrients with inadequate intakes above 20% of the population. DE = Germany; DK = Denmark; ES = Spain; FI = Finland; IR = Ireland; SE = Sweden; UK = United Kingdom.

Table 5. Calcium intake (mg/day) and prevalence of inadequate intake (% population below EAR) in Europe by gender and population group

Coun-try	Study	Study year	Food intake method	Males			Females		
				n	mean ± SD	% below EAR	n	mean ± SD	% below EAR
Adults (age 19–64 years)				EAR = 800 mg/day			EAR = 800 mg/day		
BE	Belgian Food Consumption Survey [27]	2004	adj 2 × 24 HR	n.a.	847 ± 326	44.3	n.a.	750 ± 260	57.6
DE	German National Nutrition Survey II [31–33]	2005–2007	DH	4,912	1,171 ± 556	25.2	6,016	1,047 ± 389	26.3
DK	Danish National Survey of Dietary Habits and PA [28]	2000–2002	7 dDR	1,283	1,055 ± 448	28.5	1,486	990 ± 389	31.3
ES	ENCAT 2002–2003 [36–38]	2002–2003	adj 2 × 24 HR	706	830 ± 200	44.0	875	778 ± 170	55.1
FI	National FINDIET 2007 Survey [29, 30]	2007	adj 48 HR	730	1,202 ± 592	24.9	846	1,007 ± 450	32.3
FR	National Nutrition and Health Survey [11]	2006–2007	3 × 24 HR	852	981 ± 16	0.0	1,499	841 ± 13	0.1
GR	EPIC study [11]	1994–1999	FFQ	500	991 ± 614	37.8	451	744 ± 438	55.1
IR	SLAN 2007 [34]	2007	FFQ	662	949 ± 354	33.7	717	742 ± 299	57.7
IT	INN-CA Study [35]	1994–1996	7 dDR	660	947 ± 309	31.7	801	851 ± 264	42.3
NE	Dutch National Food Consumption Survey [40, 41]	2003	adj 2 × 24 HR	352	1,101 ± 362	20.3	398	919 ± 356	36.9
NO	Norkost 1997 [11]	1997	FFQ	1,050	1,068 ± 460	28.0	1,146	833 ± 340	46.1
PT	EpiPorto [11]	1999–2003	FFQ	917	883 ± 354	40.7	1,472	963 ± 395	34.0
SE	Riksmaten 1997–1998 [39]	1997–1998	7 dDR	517	1,069 ± 395	24.8	575	922 ± 300	34.2
UK	Health Survey for England [42]	2000–2001	7 dDR	219	1,030 ± 606	35.2	210	736 ± 233	60.8
Elderly (age >64 years)				EAR = 1,000 mg/day			EAR = 1,000 mg/day		
BE	Belgian Food Consumption Survey [27]	2004	adj 2 × 24 HR	n.a.	698 ± 281	85.9	n.a.	615 ± 225	95.6
DE	German National Nutrition Survey II [31–33]	2005–2007	DH	1,469	970 ± 357	53.3	1,562	918 ± 342	59.5
DK	Danish National Survey of Dietary Habits and PA [28]	2000–2002	7 dDR	165	874 ± 359	63.7	164	900 ± 366	60.8
ES	ENCAT 2002–2003 [36–38]	2002–2003	adj 2 × 24 HR	163	757 ± 152	94.5	179	712 ± 108	99.6
FI	National FINDIET 2007 Survey [29, 30]	2007	adj 48 HR	229	1,032 ± 521	47.6	234	900 ± 426	59.3
FR	National Nutrition and Health Survey [11]	2006–2007	3 × 24 HR	130	893 ± 28	100.0	219	818 ± 22	100.0
IR	SLAN 2007 [34]	2007	FFQ	580	892 ± 403	60.6	742	823 ± 370	68.4
NO	Norkost 1997 [11]	1997	FFQ	176	861 ± 349	65.5	176	776 ± 266	80.0
PT	EpiPorto [11]	1999–2003	FFQ	246	853 ± 316	67.9	339	904 ± 375	60.1

EAR = Estimated average requirement; BE = Belgium; DE = Germany; DK = Denmark; ES = Spain; FI = Finland; FR = France; GR = Greece; IR = Ireland; IT = Italy; NE = The Netherlands; NO = Norway; PT = Portugal; SE = Sweden; UK = United Kingdom; adj = adjusted for intraindividual variability; DH = diet history; dDR = days dietary record; HR = hour recall; FFQ = food frequency questionnaire; n.a. = not available.

was not taken into account (only in the nutritional surveys from Ireland and Norway). The exclusion of underreporters and the inclusion of supplement intake and food fortification as part of the total intake would have reduced the prevalence of nutrient intake inadequacy [13]. A review by Poslusna et al. [51] evaluating the effect of misreporting on energy and nutrient intake estimation indicated that low energy reporters had lower mean intakes for several micronutrients (ranging from 25 to 36%) compared to nonunderreporters. Regarding supplement intake, the prevalence of consumption varies enormously across European countries, with a clear north-south gradient [52]. In the Nordic countries, more than 40% of the population is a usual consumer, whereas in Southern Europe the prevalence is quite low (5%). In countries with higher levels of consumption, dietary supplement intake might have contributed to improving the adequacy of diets [53–55]. In addition, we assumed that the nutrients of interest followed a symmetrical distribution as a condition to apply the EAR cut point, which may be too liberal an assumption given the high coefficient of variation found for certain nutrients, ranging from 30% for the studies evaluating zinc intake in the elderly population group to 79% for the intake of vitamin B_{12} in the adult population group (data not shown) [13, 49]. In the case of a skewed distribution for a given nutrient intake in any of the nutritional surveys analyzed, the true prevalence of inadequacy would be underestimated [14]. Another issue concerns data on vitamin D intakes. In the Nordic countries, vitamin D fortification of the food supply is mandatory.

The nutrients at risk in non-European developed countries are similar to those found in this analysis. In the USA, data from the NHANES III revealed that, among the adult and elderly, around 20% of females and 7% of males had folic acid intakes below the EAR [56]. Data from the

Table 6. Iron intake (mg/day) and prevalence of inadequate intake (% population below EAR) in Europe by gender and population group

Country	Study	Study year	Food intake method	Males (EAR = 7 mg/day)			Females (EAR = 6 mg/day)		
				n	mean ± SD	% below EAR	n	mean ± SD	% below EAR
Adults (age 19–64 years)									
BE	Belgian Food Consumption Survey [27]	2004	adj 2 × 24 HR	n.a.	13.3 ± 3.1	2.1			
DE	German National Nutrition Survey II [31–33]	2005–2007	DH	4,912	15.5 ± 5.8	7.1			
DK	Danish National Survey of Dietary Habits and PA [28]	2000–2002	7 dDR	1,283	11.1 ± 3.3	10.7			
ES	ENCAT 2002–2003 [36–38]	2002–2003	adj 2 × 24 HR	706	13 ± 1.8	0.0			
FI	National FINDIET 2007 Survey [29, 30]	2007	adj 48 HR	730	13.6 ± 5.7	12.3			
GR	EPIC study [11]	1994–1999	FFQ	500	13.7 ± 6.4	14.8			
IR	SLAN 2007 [34]	2007	FFQ	662	14.4 ± 5.5	8.9			
IT	INN-CA Study [35]	1994–1996	7 dDR	660	14.7 ± 3.9	2.4			
NE	Dutch National Food Consumption Survey [40, 41]	2003	adj 2 × 24 HR	352	12.2 ± 2.3	1.2			
NO	Norkost 1997 [11]	1997	FFQ	1,050	13.4 ± 5.1	10.5			
PT	EpiPorto [11]	1999–2003	FFQ	917	16.7 ± 4.6	1.7			
SE	Riksmaten 1997–1998 [39]	1997–1998	7 dDR	517	12.4 ± 3.4	5.6			
UK	Health Survey for England [42]	2000–2001	7 dDR	219	13.9 ± 7.5	17.9			
Elderly (age >64 years)									
BE	Belgian Food Consumption Survey [27]	2004	adj 2 × 24 HR	n.a.	11.6 ± 2.8	5.0	n.a.	8.7 ± 2.6	15.0
DE	German National Nutrition Survey II [31–33]	2005–2007	DH	1,469	13.6 ± 3.9	4.5	1,562	11.4 ± 3.5	6.1
DK	Danish National Survey of Dietary Habits and PA [28]	2000–2002	7 dDR	165	10.7 ± 3.7	15.9	164	8.5 ± 2.2	12.8
ES	ENCAT 2002–2003 [36–38]	2002–2003	adj 2 × 24 HR	163	11.2 ± 1.3	0.1	179	9.6 ± 1.0	0.0
FI	National FINDIET 2007 Survey [29, 30]	2007	adj 48 HR	229	12.6 ± 5.6	15.9	234	9.9 ± 3.6	13.9
IR	SLAN 2007 [34]	2007	FFQ	580	12.6 ± 6.8	20.5	742	12.1 ± 6.3	16.6
IT	INN-CA Study [35]	1994–1996	7 dDR	n.a.	n.a.	n.a.	107	11.5 ± 3.1	3.8
NO	Norkost 1997 [11]	1997	FFQ	176	12.3 ± 5.6	17.2	176	10.8 ± 4.6	14.8
PT	EpiPorto [11]	1999–2003	FFQ	246	16.3 ± 4.8	2.6	339	14.2 ± 4.7	4.1

EAR = Estimated average requirement; BE = Belgium; DE = Germany; DK = Denmark; ES = Spain; FI = Finland; GR = Greece; IR = Ireland; IT = Italy; NE = The Netherlands; NO = Norway; PT = Portugal; SE = Sweden; UK = United Kingdom; adj = adjusted for intraindividual variability; DH = diet history; dDR = days dietary record; HR = hour recall; FFQ = food frequency questionnaire; n.a. = not available.

NHANES 2001–2002 indicated that 31% of the population consumed vitamin C in amounts below the EAR, and 12% had zinc intakes and 8% had folic acid intakes below the EAR [57]. In Canada, the Canadian Community Health Survey conducted in 2004 showed that, among adult Canadians, 10–35% of the population had vitamin B_{12} and vitamin C intakes below the EAR. Similarly, 10–35% of Canadians from most age and sex groups consumed folic acid, vitamin B6, and zinc in inadequate amounts [58].

Although a cross-country comparison of nutritional surveys conducted following different methodologies represents a great challenge, such an analysis can offer interesting results. Ideally, in nutritional data on all European countries derived from studies using the same methodology, the main difference in nutrient intake would basically be from the variation in food availability for the countries analyzed. In the present analysis, the fact that data were derived from studies conducted with different methodologies, as well as the distinct dietary intake methods used, seemed to impact on some of the results obtained. For certain nutrients (vitamin C and iron), countries using a register or diary as the dietary intake instrument had mean nutrient intake values lower than those of countries using an FFQ. The intake variability was also higher in those nutritional surveys using a FFQ (for vitamin C, folic acid, and iron) as the method to estimate the dietary intake, which can be attributed to random measurement error [18]. When conducting nutritional surveys, the main purpose of the study will determine the study design and thus the dietary intake method to be used. If the purpose of the nutritional survey is to estimate the prevalence of nutrient intake inadequacy, the validation study should address questions such as the sensitivity and specificity of the questionnaire [59]. To overcome any possible measurement error in the estimation of the usual intake, we included only those

Table 7. Zinc intake (mg/day) and prevalence of inadequate intake (% population below EAR) in Europe by gender and population group

Country	Study	Study year	Food intake method	Males (EAR = 6.4 mg/day)			Females (EAR = 5.7 mg/day)		
				n	mean ± SD	% below EAR	n	mean ± SD	% below EAR
Adults (age 19–64 years)									
DE	German National Nutrition Survey II [31–33]	2005–2007	DH	4,912	12.6 ± 4.9	10.3	6,016	9.7 ± 3.1	9.8
DK	Danish National Survey of Dietary Habits and PA [28]	2000–2002	7 dDR	1,283	12.3 ± 3.6	5.1	1,486	9.7 ± 2.6	6.2
ES	ENCAT 2002–2003 [36–38]	2002–2003	adj 2 × 24 HR	706	9.4 ± 1.4	1.6	875	7.8 ± 1.2	4.0
FI	National FINDIET 2007 Survey [29, 30]	2007	adj 48 HR	730	13.6 ± 4.8	6.7	846	10.0 ± 3.3	9.6
IR	SLAN 2007 [34]	2007	FFQ	662	11.6 ± 4.4	11.9	717	8.5 ± 5.0	28.8
IT	INN-CA Study [35]	1994–1996	7 dDR	660	12.9 ± 3.2	2.1	801	10.7 ± 2.8	3.7
NE	Dutch National Food Consumption Survey [40, 41]	2003	adj 2 × 24 HR	352	11.2 ± 2.0	0.8	398	8.3 ± 2.0	9.7
SE	Riksmaten 1997–1998 [39]	1997–1998	7 dDR	517	12.7 ± 3.4	3.2	575	9.9 ± 2.4	4.0
UK	Health Survey for England [42]	2000–2001	7 dDR	219	10.7 ± 4.4	16.4	210	7.1 ± 2.9	31.0
Elderly (age >64 years)									
DE	German National Nutrition Survey II [31–33]	2005–2007	DH	1,469	10.9 ± 3.2	8.0	1,562	8.8 ± 2.8	13.4
DK	Danish National Survey of Dietary Habits and PA [28]	2000–2002	7 dDR	165	11.0 ± 3.6	10.1	164	9.1 ± 2.6	9.5
ES	ENCAT 2002–2003 [36–38]	2002–2003	adj 2 × 24 HR	163	7.5 ± 1.0	13.6	179	6.8 ± 0.7	5.8
FI	National FINDIET 2007 Survey [29, 30]	2007	adj 48 HR	229	12.3 ± 4.3	8.5	234	9.4 ± 2.9	10.1
IR	SLAN 2007 [34]	2007	FFQ	580	11.9 ± 5.0	13.6	742	11.2 ± 4.9	13.1
IT	INN-CA Study [35]	1994–1996	7 dDR	60	12.2 ± 3.5	4.9	107	9.8 ± 2.5	5.1

EAR = Estimated average requirement; DE = Germany; DK = Denmark; ES = Spain; FI = Finland; IR = Ireland; IT = Italy; NE = The Netherlands; SE = Sweden; UK = United Kingdom; DH = diet history; dDR = days dietary record; HR = hour recall; FFQ = food frequency questionnaire; adj = adjusted for intraindividual variability.

nutritional surveys using a validated FFQ, although the purpose of the validation study could have been something other than to estimate nutrient intake adequacy. Thus, even having been validated, the FFQ could be a good instrument to estimate dietary intake or to rank individuals but would not be valid for estimating nutrient intake. The number of food items included, the portion size estimation, the food composition table used, etc., are factors related to the validation protocol that can affect the estimation of nutrient intake. For those nutrients found in a limited number of foods, using a method of register or a diary will probably miss information on days of intake registered, whereas an FFQ will overestimate the intake of certain food groups such as vegetables [60]. These misreporting errors will affect the analysis of the prevalence of nutrient intake adequacy when applying the EAR cut point method.

Finally, the method used to estimate nutrient intake adequacy (EAR cut point) is a key determinant of the results shown. Using such a method, the distribution of the nutrient intake in the population under study affects the resulting prevalence of inadequacy almost as much as the level of mean intake. Before the definition of the EAR cut point, the adequacy of nutrient intake in the population was calculated using several methods, such as certain cut points of the individual nutrient level (INL_{98}) (2/3, 1/3, etc.), diverse indexes, or comparison of the mean intake against the INL_{98}. Several authors have shown how the method used can affect the estimation of nutrient intake inadequacy [61, 62]. The use of a cut point at INL_{98} overestimates the true prevalence of inadequate intakes when compared to the EAR cut point method [62]. Due to the between-person variability, comparing the mean intake of the nutrient of interest against the EAR for that nutrient can lead to misinterpretation of the true prevalence of inadequacy [61]. As the EAR cut point method has been adopted as the best method to estimate nutrient intake inadequacy [13], the comparison of nutritional surveys will be clearly affected by the study design and methodology.

Conclusions

Although cross country comparability is limited by the heterogeneity in study designs, study purposes, and methodologies, the present analysis showed that the following four micronutrients had higher risk of inadequate intakes in Europe: folic acid, selenium, iodine and vitamin C (the latter only in the elderly).

Table 8. Intake of selenium (μg/day), iodine (μg/day), and copper (mg/day) and prevalence of inadequate intake (% population below EAR) in Europe by gender and population group

Country	Study	Study year	Food intake method	Male			Female		
				n	mean ± SD	% below EAR	n	mean ± SD	% below EAR
Selenium									
Adults (age 19–64 years)				EAR = 35 μg/day			EAR = 30 μg/day		
DK	Danish National Survey of Dietary Habits and PA [28]	2000–2002	7 dDR	1,283	42 ± 14	30.9	1,486	34 ± 11	35.8
FI	National FINDIET 2007 Survey [29, 30]	2007	adj 48 HR	730	73 ± 27	8.0	846	54 ± 19	10.3
IT	INN-CA Study [35]	1994–1996	7 dDR	660	48 ± 20	25.8	801	39 ± 16	28.7
NE	Dutch National Food Consumption Survey 2003 [40, 41]	2003	adj 2 × 24 HR	352	51 ± 11	8.4	398	38 ± 6	11.6
SE	Riksmaten 1997–1998 [39]	1997–1998	7 dDR	517	36 ± 12	46.7	575	31 ± 11	46.4
Elderly (age >64 years)									
DK	Danish National Survey of Dietary Habits and PA [28]	2000–2002	7 dDR	165	39 ± 13	37.9	164	34 ± 11	35.8
FI	National FINDIET 2007 Survey [29, 30]	2007	adj 48 HR	229	66 ± 26	11.7	234	49 ± 17	13.2
IR	SLAN 2007 [34]	2007	FFQ	580	62 ± 27	15.9	742	55 ± 24	14.9
IT	INN-CA Study [35]	1994–1996	7 dDR	60	43 ± 18	32.8	107	37 ± 15	32.0
SE	Riksmaten 1997–1998 [39]	1997–1998	7 dDR	64	40 ± 14	36.0	58	37 ± 14	30.9
Iodine									
Adults (age 19–64 years)				EAR = 100 μg/day			EAR = 100 μg/day		
DE	German National Nutrition Survey II [31–33]	2005–2007	DH	4,912	108 ± 46	43.1	6,016	101 ± 40	49.0
DK	Danish National Survey of Dietary Habits and PA [28]	2000–2002	7 dDR	1,283	213 ± 74	6.3	1,486	175 ± 58	9.8
FI	National FINDIET 2007 Survey [29, 30]	2007	adj 48 HR	730	253 ± 220	24.3	846	194 ± 121	21.9
Elderly (age >64 years)									
DE	German National Nutrition Survey II [31–33]	2005–2007	DH	1,469	107 ± 40	43.1	1,562	97 ± 38	53.1
DK	Danish National Survey of Dietary Habits and PA [28]	2000–2002	7 dDR	165	194 ± 65	7.4	164	167 ± 56	11.6
FI	National FINDIET 2007 Survey [29, 30]	2007	adj 48 HR	229	226 ± 94	9.0	234	182 ± 62	9.3
IR	SLAN 2007 [34]	2007	FFQ	580	169 ± 74	17.6	742	155 ± 67	20.6
Copper									
Adults (age 19–64 years)				EAR = 0.7 mg/day			EAR = 0.7 mg/day		
FI	National FINDIET 2007 Survey [29, 30]	2007	adj 48 HR	730	1.6 ± 0.7	9.9	846	1.3 ± 0.5	11.5
IR	SLAN 2007 [34]	2007	FFQ	662	1.5 ± 0.8	15.9	717	1.2 ± 0.7	23.8
IT	INN-CA Study [35]	1994–1996	7 dDR	660	1.6 ± 0.7	9.9	801	1.3 ± 0.5	11.5
UK	Health Survey for England [42]	2000–2001	7dDR	219	1.4 ± 0.7	15.9	210	1.0 ± 0.4	22.7
Elderly (age >64 years)									
FI	National FINDIET 2007 Survey [29, 30]	2007	adj 48 HR	229	1.4 ± 0.5	8.1	234	1.2 ± 0.5	15.9
IR	SLAN 2007 [34]	2007	FFQ	580	1.4 ± 0.9	21.8	742	1.3 ± 0.7	19.6

EAR = Estimated average requirement; DK = Denmark; FI = Finland, IT = Italy; NE = The Netherlands; SE = Sweden; IR = Ireland; DE = Germany; UK = United Kingdom; dDR = days dietary record; adj = adjusted for intraindividual variability; HR = hour recall; DH = diet history; FFQ = food frequency questionnaire.

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The authors have no conflicts of interest to report.

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