

Dietary Iron Intakes in Men in Europe Are Distinctly Above the Recommendations: A Review of 39 National Studies From 20 Countries in the Period 1995 - 2016

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Abstract

The objective of this review was to assess whether dietary iron intake in men in Europe is in symphony with the dietary recommendations. A literature search of national dietary surveys reporting the intake of iron using PubMed, Google Scholar, National Nutrient Databases and previous literature on dietary reviews was performed. The subjects were men aged 18 - 70 years. A total of 39 national dietary surveys in 20 European countries in the period 1995 - 2016 were included. There were considerable differences between median/mean iron dietary intake in the 20 countries. Seven countries/regions, UK-Northern Ireland, UK-Wales, Sweden, Belgium, UK-Scotland, UK-England and Serbia reported median/mean iron intake ranging from 10.5 to 11.6 mg/day. Ten countries, Norway, Finland, Lithuania, Italy, Hungary, Portugal, The Netherlands, Denmark, Iceland and Austria reported iron intake from 12.0 to 13.5 mg/day. France, Germany, Ireland and Spain reported iron intake from 14.8 to 16.0 mg/day, while Poland and Slovakia reported the highest intake of 17.2 and 22.7 mg/day. In surveys from France and The Netherlands, intake of heme iron constituted 11% of total dietary iron intake. Nutrient density for iron, reported in five countries, varied from median 11.6 mg iron/10 MJ in Denmark to 16.0 in France. In all countries, the majority of men had a dietary iron intake markedly above a recommended intake of 9 mg/day. In Europe, 75-87% of men have a dietary iron intake above 9 mg/day. A high iron intake together with relatively high intakes of meat and alcohol contributes to a high iron status and a high frequency of body iron overload in many men. We need consensus on common European standardized dietary methods, uniform dietary reference values and uniform statistical methods to perform inter-country comparisons.

Keywords: Europe; Iron, dietary; Men

Introduction

Iron is an essential mineral, which is necessary for many vi-

tal functions in the human body [1], acting as cofactor in a plethora of metabolic activities, e.g., DNA synthesis and repair [2].

In healthy humans, the body iron content is generated by gastrointestinal absorption of dietary iron [1], which is a complex process involving multiple both dietary and systemic factors [3, 4].

Body iron losses consist of basal (obligatory) losses, which are quite similar in men and women, being approximately 0.8 - 1.0 mg iron/day [1]. In contrast to women in the reproductive age, men are not exposed to extra iron losses associated with menstruations and pregnancies [5, 6]. In recent papers, the author has reviewed the dietary iron intake in women of reproductive age and in postmenopausal women [7] as well as in pregnant women [8] in Europe.

The World Health Organization's (WHO) report on the global prevalence of anemia [9] reports the frequency of anemia among women, but not among men, in the European region. It is probably assumed that anemia and especially iron deficiency anemia in men is not a significant health problem.

However, both iron deficiency [10] and iron overload [11, 12] will affect body functions in negative ways and impair quality of life and survival.

The low physiological iron losses in men do not pose any high demands on dietary intake and iron absorption, which basically is dependent on the quantitative and qualitative intake of iron in the diet. In general, men of Western European descent do not face the problems of iron depletion and iron deficiency but rather cope with problems associated with the consequences of surplus body iron [11-14]. The frequency of high body iron reserves in men increases with age and is found in 15-20% of Danish men aged 50 - 60 years [13, 14]. The question is, to which extent habitual dietary iron intake may contribute to the occurrence of iron overload? Is dietary iron intake in European men in symphony with the national dietary recommendations? Or is it lower or higher than the recommendations?

To the knowledge of the author, there exists no previous overview focused on the dietary iron intake in men in the European countries. Therefore, the objective of this paper is to provide a review of national surveys assessing dietary iron intake in men in European countries, and to address to which degree dietary iron intake is in accordance with the recommended intake (RI) and the estimated average requirement (AR).

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Table 1. The 37 European Countries Investigated in This Review of National Nutrition Surveys of Dietary Iron Intake in Men

Data on dietary iron available (n = 20)		Data on dietary iron not performed or unavailable (n = 17)
Austria	Albania	No email contact
Belgium	Belarus	No email contact
Denmark	Bosnia and Herzegovina	No email contact
Finland	Bulgaria	Confirmed by email
France	Croatia	No email contact
Germany	Cyprus	Confirmed by email
Hungary	Czech Republic	Emailed, no response
Iceland	Estonia	Confirmed by email
Ireland	Greece	Confirmed by email
Italy	Latvia	Emailed, no response
Lithuania	Moldova	No email contact
Netherlands	Montenegro	No email contact
Norway	North Macedonia	No email contact
Poland	Romania	Confirmed by email
Portugal	Russia	Emailed, no response
Serbia	Slovenia	No email contact
Slovakia	Switzerland	Confirmed by email
Spain		
Sweden		
United Kingdom		

Methods

Literature searches were performed in PubMed, Google Chrome and Google Scholar applying the MeSH terms “dietary survey in...name of country”, “dietary iron intake” “iron intake” and “dietary iron intake in... name of country”. Search was performed for all the 37 European countries shown in Table 1. The search also included studies cited in “The European Nutrition and Health Report” 2009 [15], the review paper “Mapping Low Intake of Micronutrients Across Europe” 2013 [16], studies from “The European Food Safety Authority (EFSA): Scientific Opinion on Dietary Reference Values for Iron” 2015 [17] and the review paper “National Nutrition Surveys in Europe: a Review on the Current Status in the 53 Countries of the WHO European Region” 2018 [18].

Only surveys reporting the intake of dietary iron *per se*, i.e., without supplementary iron, were included in this review. Several countries, e.g., Bulgaria, Estonia, Romania, Greece and Switzerland had performed national dietary surveys, which did not include the intake of micronutrients and iron.

Only nationwide surveys sampling populations from the entire country were included. None of the identified surveys had used food frequency questionnaires for dietary data collection.

Several national institutes of health and nutrition as well as key opinion persons were contacted by email to obtain information about dietary iron intake. The outcome is shown in Table 1.

In the statistical interpretation of the results, it is important to consider the overall distribution of dietary iron intake when evaluating the prevalence of an inadequate iron intake. If the distribution is normal, it is relatively simple to calculate and define inadequacy using parametric statistics with arithmetic mean and standard deviation (SD). In case of an asymmetric distribution skewed to the right, with a higher frequency of low values, the median is lower than the arithmetic mean. Therefore, using the arithmetic mean in skewed data will tend to underestimate the prevalence of inadequacy and non-parametric statistics should be used instead.

Results

Most surveys were reported in English language and those reports published in other languages were translated into English using Google Translate.

An overview of the 39 included European surveys on dietary iron intake in men performed in 20 countries during the period 1995 - 2016 is shown in Table 2 [16, 19-54].

The most frequent age interval for men participating in the dietary surveys was from 18 or 19 years to 64 or 65 years used in 19/39 studies (49%). The age intervals in the other surveys ranged from 18 to 80 years (Table 2).

The dietary methods varied between the surveys (Table 2). The most frequent method was food diary records for 2 - 7 days (22/39 surveys, 56%) followed by 24-h dietary recall 1 -

Table 2. National Nutrition Surveys Quoting Dietary Iron Intake in Men in 20 European Countries in the Period 1995 - 2016

Country (name) of survey	Study period	Men, n	Age range, years	Dietary method	Dietary iron intake, mg/day		Weighted data	Recommended intake of iron at time of study, mg/day	Iron intake in relation to recommended intake	References no.
					Mean ± SD ^a /CI ^c	Median IQR ^b				
Austria (Osterreichischer Ernahrungsbericht)	2007	2,398	18 - 64	24-h recall	About 13.6		No	RI 10	Mean intake 36% > RI	[19]
Austria (Osterreichischer Ernahrungsbericht)	2011	148	18 - 64	24-h recall × 2	About 11.9 (11.2 - 12.8) ^e		Yes	RI 10	Mean intake 19% > RI	[20]
Austria (Osterreichischer Ernahrungsbericht)	2016	736	18 - 64	24-h recall × 2	About 13.5 ± 4.5		Yes	RI 10	Mean intake 35% > RI; 75% had intake ≥ RI	[21]
Belgium (De Belgische Voedselconsumptiepeiling)	2004	829	19 - 74	24-h recall × 2	12.9 ± 3.2	12.5	No	RI 9	Median intake 39% > RI; 87% had intake ≥ RI	[22]
Belgium (De Belgische Voedselconsumptiepeiling)	2014	589	18 - 64	24-h recall × 2	11.2 (10.9 - 11.4) ^e	10.8	No	RI 9; AR 6	Median intake 20% > RI; 75% had intake ≥ RI	[23]
Denmark (Danskeskemes Kostvaner)	2003 - 2008	1,569	18 - 75	7 days food diary	11.4 ± 3.3	11.1	No	RDA 9; AR 7	Median intake 23% > RDA	[24]
Denmark (Danskeskemes Kostvaner)	2011 - 2013	1,464	18 - 75	7 days food diary	13.0 ± 3.9	12.7	No	RDA 9; AR 7	Median intake 41% > RDA	[25]
Finland (FINDIET)	2012	795	25 - 74	24-h recall × 2	12 ± 5		No	RDA 9; AR 7	Mean intake 33% > RDA	[26]
France (SU.VI.MAX)	1995 - 1996	3,283	45 - 60	6 days food diary	16.7 ± 5.7	16.3	No	RDA 10	Median intake 63% > RDA	[27]
France (INCA1)	1998 - 1999	613	18 - 79	7 days food diary	About 15.1 ± 4.5		No	RDA 10	Mean intake 51% > RDA	[28]
France (INCA2)	2006 - 2007	840	18 - 79	7 days food diary	About 14.8 ± 5.4		No	RDA 10	Mean intake 48% > RDA	[28]
Germany (GENUS)	1998	1,763	18 - 79	4 weeks dietary history interview DISHES 98	About 16.9 (16.7 - 17.2) ^e		Yes	RDA 10	Mean intake 69% > RDA	[29]
Germany (Ernahrungsverhalten in Deutschland)	1998	2,000	18 - 64	4 weeks dietary history interview DISHES 98		About 16.9	Yes	RDA 10	Median intake 69% > RDA; 4.5% had intake < RDA	[30]
Germany (Nationale Verzehrsstudie II)	2005 - 2006	4,912	19 - 64	4 weeks dietary history interview DISHES 98	About 15.7 ± 0.12 ^b	About 14.9	Yes	RDA 10	Median intake 49% > RDA; about 14% had intake < RDA	[31]
Hungary	2003 - 2004	473	18 - 64	3 days food diary	12.5 ± 3.4		Yes	RDA 10	Mean intake 25% > RDA	[32]
Hungary (OTAP)	2009	About 467	18 - 64	3 days food diary	About 13.2 ± 0.3 ^b		Yes	RDA 10	Mean intake 32% > RDA	[33]
Hungary (OTAP)	2014	About 360	18 - 64	3 days food diary	About 12.5 ± 0.4 ^b		Yes	RDA 10	Mean intake 25% > RDA	[34]
Iceland (Hvad borda Islendingar?)	2010 - 2011	481	18 - 60	24-h recall × 2	13.1 ± 6.9		No	RDA 9; AR 6	Mean intake 46% > RDA	[35]
Ireland (NISIFCS)	1997 - 1999	662	18 - 64	7 days food diary	14.4 ± 5.5	13.4	No			[36]
Ireland (NANS)	2008 - 2010	About 620	18 - 64	4 days food diary	15.0 ± 9.0		Yes			[37]
Italy (INRAN-SCAI)	2005 - 2006	1,068	18 - 64	3 days food diary	12.6	12.2	No			[38]
Lithuania	2013 - 2014	1,044	19 - 75	24-h recall	12.2		No			[39]
Netherlands (TNO Rapport)	1997 - 1998	1,836	19 - 65	2 days food diary	12.9 ± 4.3	12.4	No			[40]
Netherlands (DNFCS)	2007 - 2010	1,023	19 - 69	24-h recall × 2	13.1	12.7	No			[41]
Norway (NORKOST 3)	2010 - 2011	862	18 - 70	24-h recall × 2	13 ± 4	12	Yes	RDA 9; AR 6	Median intake 44% > RDA	[42]

Table 2. National Nutrition Surveys Quoting Dietary Iron Intake in Men in 20 European Countries in the Period 1995 - 2016 - (continued)

Country (name of survey)	Study period	Men, n	Age range, years	Dietary method	Dietary iron intake, mg/day		Weighted data	Recommended intake of iron at time of study, mg/day	Iron intake in relation to recommended intake	References no.
					Mean ± SD ^a /CI ^c	Median				
Poland (Household Food Consumption in Poland)	2000	1,098	18 - 60	24-h recall	17.2	5 th percentile 8.4	No	RNI 8.7; AR 6.7; LRNI 4.7	Mean intake 98% > RNI; 2% had intake < AR; 0.6% had intake < LRNI	[16]
Portugal (IAN-AF)	2015 - 2016	1,821	18 - 64	24-h recall × 2	13.3	10.0 - 15.9 ^g	Yes	AR 6	0.8% had intake < AR	[43]
Serbia (YUSAD)	2003	518	30 - 59	7 days household food consumption survey	16.6	5 th percentile 8.4	No	RNI 8.7; AR 6.7; LRNI 4.7	Mean intake 91% > RNI; 13% had intake < AR; 9% had intake < LRNI	[44]
Serbia	2013 - 2015	128	25 - 65	24-h recall × 3	11.6 ± 5.4		No	RNI 8; AR 6	Mean intake 45% > RNI	[45]
Slovakia (Dietary Habits of the Slovak Population)	1995 - 1999	439	18 - 80	24-h recall	22.7 ± 8.5		No		Mean intake 24% > RDA	[46]
Spain (ENIDE)	2009 - 2010	1,589	18 - 64	3 days food diary + 24-h recall	16.1 ± 6.5 (± 0.16) ^b	12 - 21 ^d	Yes	RNI 10; AR 6	Mean intake 61% > RNI	[47]
Spain (ANIBES)	2013	232 plausible	19 - 75	3 days food diary	14.7	12.4 - 17.1 ^g	No	RNI 10; AR 6	Median intake 47% > RNI	[48]
Sweden (Riksmaten)	2010 - 2011	792	18 - 80	4 days food diary	11.5 ± 4.1	6.2 - 18.8 ^d	No	RDA 9; AR 6	Median intake 20% > RDA	[49]
UK-Northern Ireland (NDNS RP)	2008 - 2012 combined	145	19 - 64	4 days food diary	11.0 ± 3.6	4.6 - 18.4 ^f	Yes	RNI 8.7; LRNI 4.7	Median intake 21% > RNI; 11% had intake < LRNI	[50]
UK-Scotland (NDNS RP)	2008 - 2012 combined	349	19 - 64	4 days food diary	About 11.5 ± 3.5	About 6.0 - 19.0 ^f	Yes	RNI 8.7	Median intake 32% > RNI	[51]
UK-Wales (NDNS RP)	2009/2010 and 2012/2013	130	19 - 64	4 days food diary	11.2 ± 4.3	4.2 - 20.0 ^f	Yes	RNI 8.7	Median intake 22% > RNI	[52]
UK (NDNS RP) years 1 - 2 and 2009/2010	2008/2009 and 2009/2010	534	19 - 64	4 days food diary	11.9 ± 4.3	5.7 - 22.6 ^g	Yes	RNI 8.7; LRNI 4.7	Median intake 32% > RNI; 1% had intake < LRNI	[53]
UK (NDNS RP) years 1 - 4 and 2011/2012	2008/2009 and 2011/2012	1,126	19 - 64	4 days food diary	11.7 ± 4.0	5.3 - 21.2 ^f	Yes	RNI 8.7; LRNI 4.7	Median intake 32% > RNI	[53]
UK (NDNS RP) years 5 - 6 and 2012/2013 and 2013/2014	2012/2013 and 2013/2014	373	19 - 64	4 days food diary	11.5 ± 4.0	4.9 - 19.8 ^f	Yes	RNI 8.7; LRNI 4.7	Median intake 26% > RNI; 1% had intake < LRNI	[54]

^aMean ± SD: arithmetic mean ± standard deviation. ^bSEM: standard error of the mean. ^cCI: 95% confidence interval of the mean. ^d5 - 95 percentiles; ^e10 - 90 percentiles; ^f2.5 - 97.5 percentiles; ^gIQR: interquartile range = 25 - 75 percentiles. DRI: dietary reference intake; reference value used to plan and assess nutrient intake of healthy men (Institute of Medicine, USA). AR: estimated average requirement; daily intake levels estimated to meet the needs of half of the healthy men, provided a normal distribution of requirement. RDA: recommended dietary allowance; daily intake being sufficient to meet the nutrient requirements of nearly all (97-98%) healthy men. RNI: reference nutrient intake also named population reference intake; daily intake being sufficient to meet the nutrient requirements of nearly all (97.5%) healthy men. RI: recommended intake; daily intake being recommended to meet the nutrient requirements of healthy men. LRNI: lowest recommended nutrient intake; the amount of a nutrient, which is sufficient for only a few healthy men.

Table 3. Association Between Nutrient Density for Iron and Dietary Iron Intake in Men in the Three Nordic Countries Denmark, Sweden, Finland and in France

Country	Nutrient density iron in men, mg/10 MJ	Dietary iron intake in men, mg/day	Nutrient density iron in women, mg/10 MJ	References no.
Denmark	11.8 ± 2.2 ^a 11.6 ^b 9.2 - 14.5 ^c	13.0 ^a 12.7 ^b	12.0 ± 2.1 ^a 11.9 ^b	[25]
Sweden	12.5 ± 3.4 ^a 12.0 ^b 8.3 - 18.3 ^c	11.5 ^a 10.8 ^b	13.1 ± 4.5 ^a 12.4 ^b	[49]
Ireland	12.7 ± 3.0 ^a 12.2 ^b	14.4 ^a 13.4 ^b	13.5 ± 4.2 ^a 12.7 ^b	[36]
Finland	14.0 ± 4 ^a	12.0 ^b	14.0 ± 6 ^a	[26]
France	16.0 ^b 12.0 - 23.7 ^d	16.7 ^a 16.3 ^b	15.8 ^b 11.5 - 24.4 ^d	[27]
“Median”	12.7		13.5	

For comparison, nutrient density for women in the same surveys is shown. Correlation between nutrient density and dietary iron intake: Spearman's $r_s = 0.5$, $P < 0.4$. ^aArithmetic mean ± standard deviation. ^bMedian. ^c10 - 90 percentiles. ^d5 - 95 percentiles.

3 times (14/39 surveys, 36%) and dietary history interview in the surveys from Germany (3/39 surveys, 8%). A single 24-h dietary recall was used in four studies and 24-h dietary recall for 2 - 3 times in 10 studies.

The food composition tables used to calculate dietary iron intake were in most countries based on national nutrient databases. The Baltic Republics used Russian-based food composition tables from the early 1980s and some of the East European countries used USA-based food composition tables, which were adapted for national use.

In the statistical handling of the data, most of the studies used unweighted population data, while 18/39 (46%) studies used weighted data in order to adjust the study sample for the age and gender composition of the total population in the entire country.

Dietary intake of heme iron was reported in the French SU.VI.MAX survey [27]. Heme iron in percent of total iron intake in men constituted a geometric mean or median of 11% with 5 - 95 percentiles of 4-28% [27]. In the Dutch DNFCS survey [41], the median intake of heme iron in men was 11% with 5-95 percentiles of 8-14%.

In the Irish NSIFCS survey [36], in men, on the average 20.2% of dietary iron (non-heme, *plus* heme iron) came from meat and meat products, the corresponding figure in women being 15.6% [36]. In the Spanish ANIBES survey [48], in men, on the average 22.9% and 5.7% of dietary iron intake was derived from consumption of meat and fish, respectively.

In the Spanish ENIDE survey [47], in the entire series of men and women ($n = 2,998$), 16% and 19% of dietary iron intake came from meat and fish, respectively. The Norwegian NORKOST 3 survey [42] reported that in the entire series of men and women ($n = 1,787$), 20% and 2% of total iron intake was derived from consumption of meat and fish, respectively, and the Irish NANS survey [37] stated that in the entire series of men and women ($n = 2,651$), 18% of dietary iron intake came from meats.

Nutrient density is the content of a food component per

unit of energy. Nutrient density in men for iron in mg per 10 MJ was reported from the five countries shown in Table 3 [25-27, 36, 49]. The median or mean nutrient density varied from 11.6 mg/10 MJ in Denmark [25] to 16.0 mg/10 MJ in France [27].

The most recent and largest studies from the 20 European countries arranged according to the magnitude of median or mean dietary iron intake are shown in Table 4 [16, 21, 23, 25, 26, 28, 31, 34, 35, 37-39, 41-43, 45-47, 49-53].

There were considerable differences between the reported median or mean iron dietary intake in the various countries. Seven countries/regions, UK-Northern Ireland, UK-Wales, Sweden, Belgium, Scotland, UK-England and Serbia reported median/mean iron intake ranging from 10.5 to 11.6 mg/day.

Ten countries, Norway, Finland, Lithuania, Italy, Hungary, Portugal, Netherlands, Denmark, Iceland and Austria reported iron intake from 12.0 to 13.5 mg/day. France, Germany, Ireland and Spain reported iron intake from 14.8 to 16.0 mg/day, while Poland and Slovakia reported the highest intake of 17.2 and 22.7 mg/day. The “estimated” median value of the reported median/mean dietary iron intake in all the countries shown in Table 4 was 12.6 mg/day.

The median/mean iron intake in percent above RI is shown in Tables 2 and 4. In all countries, median/mean intake was 20-98% higher than the country-specific RI, with an “estimated median” of 35% (Table 4). When a common RI of 9 mg/day is applied, median/mean intake was 17-152% higher than RI, with an “estimated median” of 36%. From a statistical point of view, a median/mean iron intake well above RI indicates that considerably more than 50% of the men have an intake above the RI.

The percent of men having an iron intake below RI were specifically stated in three surveys. In Austria, 25% had an intake less than reference nutrient intake (RNI) (10 mg/day) [21], in Belgium, 25% had an intake < RI (9 mg/day) [23] and in Germany 14% had an intake less than recommended dietary allowance (RDA) (10 mg/day) [31]; these figures suggest

Table 4. Dietary Iron Intake in Men in 20 European Countries, Arranged According to Median/Arithmetic Mean Iron Intake

Country (n = 20)	Iron intake median or mean ^a , mg/day	Iron intake above country specific RI, %	Iron intake above RI 9 mg/day, %	Iron intake above AR 6.4 mg/day, %	References no.
Slovakia	22.7 ^a		152	255	[46]
Poland	17.2 ^a	98	91	169	[16]
Spain	16.0	61	78	150	[47]
Ireland	15.0 ^a		67	134	[37]
Germany	14.9	49	66	133	[31]
France	14.8 ^a	48	64	131	[28]
Austria	13.5 ^a	35	50	111	[21]
Iceland	13.1 ^a	46	46	105	[35]
Denmark	12.7	41	41	98	[25]
Netherlands	12.7		41	98	[41]
Portugal	12.6		40	97	[43]
Hungary	12.5 ^a	25	39	95	[34]
Italy	12.2		36	91	[38]
Lithuania	12.2 ^a		36	91	[39]
Finland	12.0 ^a	33	33	88	[26]
Norway	12.0	44	44	88	[42]
Serbia	11.6 ^a	45	29	81	[45]
UK-England	11.5	32	28	80	[53]
UK-Scotland	11.5	32	28	80	[51]
Belgium	10.8	20	20	69	[23]
Sweden	10.8	20	20	69	[49]
UK-Wales	10.6	22	18	66	[52]
UK-Northern Ireland	10.5	21	17	64	[50]

When both median and mean intakes are reported, median intake is shown; mean intake is shown in surveys not reporting median intake. The overall RNI and AR are set at 9 mg/day and 6.4 mg/day, respectively, i.e., the median of the RNI and AR values in Table 5. ^aArithmetic mean. UK: United Kingdom; RI: recommended intake; AR: estimated average requirement; RNI: reference nutrient intake.

that in most surveys more than 75% of men had an iron intake above RI.

The estimated AR is the level of daily nutrient intake that is adequate for half of the people in a population group, provided a normal distribution of requirement [55]. Using an estimated AR of 6.4 mg/day for dietary iron intake in men, it is evident the vast majority of men in all countries had an intake above AR; median/mean intake was 64-255% above AR with an “estimated” median of 91%.

Iron intake below AR was specifically stated in three surveys. In Poland 2% had an intake < AR (6.7 mg/day) [16], in Portugal 0.8% had an intake < AR (6 mg/day) [43] and in Serbia 13% had an intake < AR (6.7 mg/day) [44] (Table 2); correspondingly, 98%, 99.2% and 87% of men, respectively had an iron intake above AR [16, 43, 44].

In the various surveys, there was poor consistency in the terminology and use of dietary reference values (DRVs) for dietary iron intake. The DRVs comprised RI, RNI, RDA, dietary reference intake (DRI) or lowest recommended nutrient intake (LNRI). None used the term “population reference intake” proposed by EFSA [55] and only 12/39 (31%) surveys

reported the country-specific AR. Several surveys referred to national DRV/RI/RNI/RDAs but without quoting the country-specific values. However, the daily recommended intake of dietary iron by the country-specific National Nutrition Boards in men was quite similar in most countries (Table 2). All surveys yielding information about RI recommended an RI/RNI/RDA between 8.7 and 10.0 mg iron/day.

Discussion

The European Food Consumption Survey Method (EFCOSUM) group concluded that “the most suitable method to get internationally comparable new data on population means and distributions of actual intake is 24-h recall, to be conducted at least twice” [56]. Nearly all the surveys in this review fulfilled these criteria. Repeated 24-h dietary recalls were used in 26% of the surveys, only four used a single 24-h dietary recall; 56% of the surveys used repeated food diary records. Therefore, comparison of results between countries should be possible with a reasonable reliability.

However, a study comparing two 24-h dietary recalls with 5 days food records found that in both methods, about 35% of participants had ratios of energy intake/total energy expenditure above or below the 95% confidence interval (CI), suggesting misreporting of energy intake [57]. Significant differences between the two dietary methods were found for energy, fat, alcohol, vitamin C, some vitamin Bs and iron. In general, intakes from 24-h dietary recalls, including iron, were higher compared to food records and the correlation coefficient ($r_s = 0.47$) for iron intake in men between the two methods was significant, but not impressive [57].

The German surveys [29-31] used a dietary history interview covering the recent 4-week period, resembling a food frequency questionnaire interview; a validation study showed that these results are not directly comparable with those from food dietary records and 24-h dietary recalls [58]. Food frequency questionnaires tend to estimate higher intakes for most nutrients compared to the 24-h dietary recall method [7, 59]. However, as these [29-31] appeared to be the only national food surveys in Germany, the author decided to include them.

The calculation of dietary intake of micronutrients including iron is dependent on the quality and representativeness of the food composition tables. The food composition tables used to calculate dietary iron intake are in most countries based on national food databases and the food composition could therefore vary between countries due to the different methodologies used in the analyses of the various food items and in the sampling of food items. As an example, the Baltic Republics used elderly Russian food composition tables and some eastern European countries used food databases from USA, which were "adapted to regional conditions". However, since the previous dietary iron review in women in Europe [6], it appears that an increasing number of European countries have established national food composition tables.

Food composition tables reflect the composition of the most common staple foods available in a specific country. Usually, mandatory fortification of foods is included in the food composition tables, whereas optional fortification is not. In some countries, there exist foods, which are iron-fortified on a voluntary basis, and this iron will not be included in the food composition tables. Iron fortified foods will contribute to a higher iron nutrient density and consequently to a higher dietary iron intake.

Adding vitamins and minerals to food is permitted in the European Union [60]. Within the European Union legislation, European countries have chosen different recommendations concerning iron fortification of foods. According to the Food Fortification Initiative, among the countries included in this review, only UK has mandatory iron fortification of wheat flour [61]. In UK fortification of wheat flour with iron has been practiced since the 1940s and the present recommendation is that the iron content must not be less than 16.5 mg/kg flour, while no upper limit is specified [62]. Additionally, in UK, there is mandatory fortification of all flours with calcium (2,350 - 3,900 mg calcium/kg flour) [62], a special combination, as calcium is an inhibitor of iron absorption [4, 63]. Denmark had mandatory fortification of flour with iron from 1954 to 1987 (30 mg elemental iron as carbonyl iron/kg flour). The general effect of mandatory iron fortification in Europe has not been

systematically evaluated. However, in Denmark, from 1984 to 1994, body iron status (i.e., serum ferritin) and the prevalence of iron overload in both men [14] and postmenopausal women [64] increased significantly, while iron status was unchanged in premenopausal women [64]. These population changes in iron status occurred despite the abolition of iron fortification in 1987, suggesting a negligible effect of this specific form of fortification [14, 64].

In many countries, especially in UK and Ireland, but also including Denmark, it is permitted to fortify breakfast cereals with iron on an optional basis [65]. According to the British National Diet and Nutrition Surveys [53, 54] mandatory and optional fortification contribute to approximately 20% of the average iron intake of British adults.

As seen in Table 2, the dietary iron intake expressed as the median was consistently lower than the arithmetic mean. This indicates that iron intake in the male populations, like in the female populations [7] does not follow a normal distribution. In men, the distribution of iron intake is skewed to the right just like the distribution of the iron status biomarker serum ferritin in the population surveys of Danish men [13, 14].

Therefore, the distribution of iron intake would be better described with non-parametric statistics as median and 2.5 - 97.5 or 5 - 95 percentiles or as geometric mean and SD. Geometric mean \pm SD is calculated as the mean \pm SD of \log_{10} values of iron intake. In distributions skewed to the right, the geometric mean value is close to the median value. Among the surveys 21/39 (54%) quoted the median and percentiles, none used geometric mean values. The inconsistency of the used statistical methods may to some degree impede direct comparison of the results of different surveys.

Only few of the national dietary surveys did correct for under-reporting of energy intake [66]. Under-reporting is assumed to be present in 20-30% of the participants, especially in women and obese persons [67] and appears to be less frequent in men than women [67]. Under-reporting means that the lowest percentiles for dietary iron intake should be taken with considerable reservation. Under-reporting is a confounding factor and a limitation of self-reported dietary intake [67]. Various levels of under-reporting in the different studies may contribute to the different results concerning dietary iron intake. Correcting for under-reporting will push the population mean and median intakes upwards but could be necessary to get a more accurate picture of intakes in a population.

There were marked differences between median/mean dietary iron intake in the various countries, ranging from 10.5 mg/day in UK-Northern Ireland to 22.7 mg/day in Slovakia. In all countries, median/mean iron intake was above 9 mg/day, indicating that more than 50% of the men had a dietary iron intake above 9 mg/day (Tables 2 and 3). However, there were no consistent differences between dietary iron intake across the different European regions (Western, Middle and Eastern Europe).

The country-specific RI for dietary iron was quite similar in the various countries ranging from 8 mg/day in Serbia [45] to 10 mg/day in many countries and the AR ranging from 6 to 7 mg/day (Table 2). The recommendations for dietary iron intake from different institutions in Europe and USA are listed in Table 5 [17, 68-75]. According to the most recent European

Table 5. RNI and AR for Dietary Iron in Men 18 - 70 Years Old in Europe and USA

Institution	Iron intake, mg/day		References no.
	RNI	AR	
IOM 2001	8*	6	[68]
FAO/WHO 2001	9.1**		[69]
NNR 2012	9**	7	[70]
COMA-DH 1991, SACN 2010, BNF 2019	8.7**	6.7	[71, 72, 73]
SCF-EU 1993	9	7	[74]
EFSA 2015, 2017	11***	6	[17, 75]
Median	9	6.4	

*Provided 18% food iron bioavailability; **15% bioavailability; ***16% bioavailability. IOM: Institute of Medicine (USA); FAO: Food and Agriculture Organization of the United Nations; WHO: World Health Organization; NNR: Nordic Nutrition Recommendations; COMA: Committee on Medical Aspects of Food and Nutrition Policy for the Department of Health UK; SACN: Scientific Advisory Committee on Nutrition (UK); BNF: British Nutrition Foundation; SCF-EU: Scientific Committee for Food of the European Community; EFSA: European Food Safety Authority; AR: estimated average requirement; RNI: reference nutrient intake.

recommendations for dietary iron intake in men from the Nordic Nutrition Recommendations (NNF) [70], EFSA [17, 75] and the Scientific Advisory Committee on Nutrition in UK (SACN) [72, 73], the RNI is ranging from 8.7 to 11 mg/day and the AR from 6 to 7 mg/day (Table 5). In order to make an estimated comparison between countries, the author has chosen to apply a “common” RI for iron of 9.0 mg/day and a “common” AR of 6.4 mg/day in this review.

RI/RNI/RDA is used for assessment of the individual’s daily intake, while the estimated AR is the daily level of intake that is adequate for 50% of the individuals in a population group [17, 75]. From this aspect, AR is an important DRV in population surveys [17, 75].

When the median/mean iron intake in a population is well above AR and RI, then more than 50% of the men will be meeting and even exceeding their requirements. The higher above the AR/RI the intake is, the greater the proportion of men that will exceed their requirements. This assumption is valid in populations where nutrient requirements display a normal distribution.

The variations in dietary iron intake are the resultant of different factors, of which the nutrient density for iron is important. Dietary iron intake in women is closely associated with nutrient density for iron [7]. In men, the association is less pronounced, probably due to the low number of reported values (Table 3). The nutrient density for iron is dependent on the dietary habits, which differ from country to country, especially

concerning the intake of meat, poultry and fish, which contain easily absorbed heme iron vs. intake of foods containing non-heme iron, which has a lower absorption ratio. Nutrient density is also influenced by mandatory and/or optional fortification of various food items.

Nutrient density for iron in men in Europe varied from 11.8 to 16.0 mg iron/10 MJ with an “estimated median” of 12.7 mg/10 MJ (Table 3), while women in the same surveys displayed a slightly higher nutrient density with an “estimated median” of 13.5 mg/10 MJ. From the previous review [7], it appears that women in Europe apparently consume a food with a higher nutrient density than men, varying from 11.8 to 23.0 mg/10 MJ with an “estimated median” of 14.1 mg/10 MJ [7]. This is somewhat surprising because women have a lower intake of meat than men as shown in Table 6 [25, 26, 28, 36, 49, 76]. Possibly the higher nutrient density in women could be caused by a higher intake of iron-containing cereals and vegetables than in men. The results of the surveys also showed that, in general, men had a significantly higher energy intake, a higher meat intake and a higher alcohol consumption than women [25, 26, 28, 36, 49, 76], factors which increase iron intake, especially of heme iron as well as iron absorption in general [3]; examples are shown in Table 6.

In men, the intake of heme iron in percent of total dietary iron intake was median 11.3-11.0% [27, 41] with 5 - 95 percentiles of 4-28% [27] and 9-16% [41]. Accordingly, due to the lower consumption of meat, heme iron intake in women

Table 6. Intake of Energy, Meat and Alcohol in Men and Women (Arithmetic Mean \pm Standard Deviation) in Five European National Dietary Surveys

Country	Energy, MJ/day		Meat, g/day		Alcohol, g/day		References no.
	Men	Women	Men	Women	Men	Women	
Denmark	11.2 \pm 3.2	8.4 \pm 2.3	172 \pm 88	99 \pm 53	20 \pm 21	11 \pm 13	[25]
Finland	9.4 \pm 2.9	7.3 \pm 2.1	182 \pm 126	105 \pm 74	8 \pm 18	3 \pm 9	[26]
Sweden	9.6 \pm 2.8	7.5 \pm 2.2	88 \pm 58	55 \pm 36	13 \pm 17	7 \pm 11	[49]
Ireland	11.0 \pm 3.1	7.6 \pm 2.0			23 \pm 30	9 \pm 13	[36]
France	10.5 \pm 2.2	8.4 \pm 1.7	166	126	25 \pm 24	20 \pm 20	[28, 76]

was lower, ranging from 9.1% to 10.2% [27, 41] with 5 - 95 percentiles of 3-27% [27].

Overall, the percent intake of easily absorbed iron from meat and meat products in men was on the average 20-23% [36, 48]. Other surveys reported that in the entire series of men and women, on the average about 18-20% of total dietary iron came from meats [37, 42, 47].

The basal or obligatory daily iron losses in men and women occur from the skin, hair, sweat, urine and feces [77]. As reported in the study of Green et al in 1968 [77], measured by an isotope dilution method in 12 white US men, basal iron losses amount 0.012 - 0.014 mg iron/kg/day in a 70-kg man with a normal iron balance, corresponding to arithmetic mean losses of 0.95 ± 0.30 (SD) mg/day [77]. These results have been the principal basis for factorial estimations of dietary iron requirements and recommendations for men from the majority of the institutions cited in Table 5 [68-75] and using assumed iron absorption rates of 15-18% to convert the physiological requirements into dietary requirements.

The EFSA papers on the DRVs for iron [17, 75] used the individual data on basal iron losses from the isotope dilution study performed in 29 men (ethnicity not stated) in North Dakota by Hunt et al in 2009 [78]. They reported slightly higher values for iron excretion, compared to the study of Green et al [77]. The basal iron losses were arithmetic mean 1.07 ± 0.47 (SD) mg/day with a median of 1.18 mg/day (range 0.11 - 2.07 mg/day) and 90, 95 and 97.5 percentiles of 1.48, 1.61 and 1.72 mg/day, respectively [78]. Using an assumed iron absorption of 16% to convert the physiological requirements into dietary requirements resulted in a calculated median dietary requirement of 5.9 mg/day with a 97.5 percentile of 10.8 mg/day [17, 75].

The results of this review show that in general, men in Europe have a quantitative and qualitative (meats, heme iron) dietary iron intake, which in the majority of men is adequate to compensate for basal iron losses and fulfill the recommended requirements, and in a considerable fraction of the men even exceeds the RI. These findings are reflected in the few studies of iron status performed in men in Europe; as an example, in Danish men 40 - 70 years of age (non-blood donors, n = 1,103), 0.4% had iron depletion (serum ferritin < 15 µg/L), 1.5% had small iron reserves (ferritin 15 - 30 µg/L), 79.2% had an adequate iron status and 18.9% had ferritin > 300 µg/L, indicating body iron overload [14]. The dietary iron intake was associated with dietary energy intake, as serum ferritin displayed a positive correlation with body mass index ($P < 0.0001$) [14]. Likewise, the significant influence of alcohol on dietary iron absorption was confirmed by the positive correlation between ferritin and the amount of alcohol consumed ($P < 0.0001$) [14].

The high prevalence of body iron overload in men is probably also associated with the high frequency of the genetic hemochromatosis mutations C282Y, H63D and S65C on the *HFE*-gene in the ethnic Northern European populations [11, 12]. Approximately 15-18% of the population is heterozygous for one of the mutations and approximately 0.4-0.8% are homozygous or compound heterozygous [11, 12].

In women of reproductive age, the situation concerning body iron status is reversed compared to men [79]. A recent review of body iron status in women of reproductive age in Eu-

rope showed that approximately 40-55% had small or absent body iron reserves (serum ferritin ≤ 30 µg/L). The prevalence of iron deficiency was 10-32% and of iron deficiency anemia 2-5% [79].

Limitations of this review

This review has several limitations, due to the heterogeneous methods used in the surveys. The age groups and the dietary methods differed between surveys, statistical methods were different, most surveys used parametric, and some non-parametric statistics, most surveys used unweighted, and some weighted data, few surveys had corrected for underreporting, and furthermore, there was an inconsistent terminology regarding the use of DRVs of dietary iron. These factors make it difficult to directly compare the results of the various surveys. Furthermore, the contribution of optional food iron fortification was not evaluated in the surveys and the country-specific food composition tables were not standardized.

Conclusions

This review demonstrates that in Europe, a high proportion of men have a dietary iron intake equal to or above an AR of 6.4 mg/day and an RI of 9 mg/day. The quantitative and qualitative high iron intake contributes to an adequate body iron status in the majority of men. However, in an appreciable fraction of men, approximately 15-20% [13, 14], iron intake exceeds RI to such a degree that they over time may develop body iron overload. Mutations on the *HFE*-hemochromatosis gene are frequent in European men [11, 12] and will contribute to an increased iron absorption and predispose to iron overload.

In European countries and within the European Union, there is still a need for development and implementation of common standardized dietary methods [56, 57] and for standardization of food composition tables as introduced by EFSA [80]. It is also important to obtain consensus on the use of the different DRVs [75] and to agree on the use of uniform statistical methods in order to obtain reliable inter-country comparisons of dietary intakes of both macro- and micronutrients.

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Conflict of Interest

The author declares no conflict of interest.

Informed Consent

Not applicable.

Author Contributions

NT Milman performed the literature search and wrote the manuscript.

Data Availability

This review is based on literature searches in the PubMed and Google Scholar databases as well as literature references cited in published articles and review papers. The data used to support the findings of this study are included within the article.

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