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The efficacy and safety of nutritional supplement use in a representative sample of adults in the North/South Ireland Food Consumption Survey

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Abstract

Objective: To describe the current use of nutritional supplements and their contribution to micronutrient intakes in a representative sample of Irish adults, to evaluate the impact of supplement use on the adequacy of micronutrient intakes and to assess the risk to supplement users of exceeding tolerable upper intake levels (UL).

Study design and subjects: Food intake data were collected in 1379 (662 male and 717 female) randomly selected Irish adults aged 18 to 64 years using a 7-day food diary. The current use of nutritional supplements was assessed using a self-administered questionnaire and respondents entered each supplement as it was consumed into the food diary.

Results: Twenty-three per cent of respondents regularly used nutritional supplements. Twice as many women used supplements as men. The intakes of micronutrients were significantly higher ($P < 0.001$) in supplement users than in non-users. Micronutrient intakes from food sources were similar in male users and non-users of supplements, but were significantly higher ($P < 0.01$) in female users, by 3 to 13%, for Fe, Mg, Mn, vitamins C and E and niacin than in non-users. The percentage of female users between 18 and 50 years who had mean Fe intakes below the average requirement (AR) (10 mg) decreased from 50 to 25 when the contribution from supplements was included. The use of supplements reduced the percentage of men who had mean intakes below the AR for Zn from 19 to 13, for riboflavin from 14 to 6 and for vitamin A from 20 to 5, and reduced the percentage of women with intakes below the AR for Ca from 23 to 16 and for riboflavin from 23 to 14. Twenty-one women out of 80 aged between 18 and 50 years, who consumed supplemental folate, achieved the intake of 600 μg recommended to prevent neural tube defects. Twenty-two per cent of the women who took iron and 15% of the women who took vitamin B_6 in supplemental form had mean daily intakes that exceeded that UL for these nutrients. Supplement users did not exceed the UL for the other micronutrients.

Conclusions: Supplementation appears to be beneficial in promoting adequate intakes of some micronutrients, particularly Fe and folate in women aged 18–50 years and vitamin A in men. There appears to be little risk to supplement users of experiencing adverse side effects due to excessive intakes of micronutrients.

Keywords
Nutritional supplements
Irish adults
Micronutrients
Adequate intakes
Safe intakes

Nutritional supplements constitute a sector of the dietary supplement market that is growing fast in all countries of the developed world[1]. In the USA, nutritional supplements have become the 'hottest item in the nutrition-related marketplace'[2]. In this rapidly expanding market, vitamins and minerals constituted 51% of sales in 1997, with herbal products and botanicals (the fastest-growing sector) amounting to 33%[2]. A recent

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evaluation of preliminary data from the European Prospective Investigation into Cancer (EPIC) study in the UK has indicated that the contribution from dietary supplements to nutrient intakes can be substantial, which suggests that gross misclassification of nutrient intakes can occur if supplements are not accounted for[3].

The motivating factors that encourage supplement use and the lifestyle characteristics of supplement users have been investigated[4]. Kirk *et al.*[4] showed that users were more likely to be vegetarian, vegan or fish consumers, to eat more fruit and vegetables, be more physically active and have a lower alcohol intake than non-users. However, the efficacy and safety of supplement consumption have not been evaluated sufficiently in representative population groups. There is a need for unbiased, peer-reviewed evaluations that assess the scientific evidence as to the efficacy and safety of dietary supplements[2]. Efficacy can be defined as the ability of a supplement to provide a health benefit related to either the prevention of a nutritional deficiency or reduction in the risk of disease, while safety denotes a reasonable certainty that there will be no adverse effects from excessive intake of a nutrient[5]. To date, there is very little information available on supplement use in Ireland. The North/South Ireland Food Consumption Survey has established a database of habitual food consumption in a representative sample of the Irish population aged 18 to 64 years. The use of dietary supplements in this population was assessed concurrently.

The aims of this report are to describe the current use of nutritional supplements in Irish adults and their contribution to micronutrient intakes, to assess the impact of supplement use on adequacy of micronutrient intakes and to evaluate the risk to supplement users of exceeding tolerable upper intake levels (UL).

Methods

The methods used in the North/South Ireland Food Consumption Survey are comprehensively described elsewhere[6,7]. Briefly, food intake was measured in 1379 randomly selected adults aged 18–64 years using a 7-day estimated food diary. Additional information was collected from respondents using self-administered questionnaires, including socio-demographic data, habitual physical activity levels, attitudes, eating behaviours and health status. The food consumption data were processed using WISP© (Tinuviel Software, Warrington, UK), which uses *McCance & Widdowson's The Composition of Foods*, fifth edition[8] plus supplemental volumes[9–17] to generate nutrient intake data. The nutrient database was expanded to include generic Irish foods and new products that were commonly consumed. The data handling and data processing procedures used in the current study are described fully in an accompanying paper[6].

Assessment of supplement consumption

Current supplement use was assessed by respondents' answer to the question 'Do you take any vitamins, minerals or other food supplements currently?', which was included in the self-administered health and lifestyle questionnaire. Respondents also entered each supplement as it was consumed into the 7-day food diary. Researchers checked that respondents who had reported using supplements in the questionnaire, which was administered at the start of the recording week, entered the supplements into the food diary when they were consumed. In the respondent's home, the researcher transcribed the nutrient composition of each supplement from the product label. This method has been referred to as a 'gold standard' for the assessment of supplement use[18]. The data were checked centrally and added to the nutrient composition database. Each nutrient-containing supplement was assigned a new food code. Researchers entered supplements into the food consumption database in the same way as they entered foods from the 7-day diaries. In this way, supplement consumption was measured alongside food consumption.

Statistical analysis

The food consumption database was analysed using SPSS® for Windows™ Version 8.0 (SPSS Inc., Chicago, IL). Mean micronutrient intakes from food sources and supplements were compared with estimated average requirements (ARs)[19]. In addition, median values were reported and mean nutrient intakes at the 95th percentile were compared with tolerable upper intake levels (ULs)[20–28]. Differences between mean micronutrient intakes in men and women and between supplement users and non-users were tested using independent *t*-tests and Mann–Whitney *U*-tests (99% confidence interval (CI)) depending on whether the data were normally distributed or not. Differences in micronutrient intakes between supplement users before and after the inclusion of supplements were tested separately for men and women using repeated measures *t*-tests (99% CI). Owing to the large sample size, even a small difference between group means was highly statistically significant, so this paper focuses more on a descriptive analysis of the impact of supplement use on micronutrient intakes in users than on the statistical differences in group means between users and non-users.

Results

A description of the types of supplement consumed by supplement users in the current study is given in Table 1. Almost 27% of the total number of supplements used by respondents were single-vitamin preparations. Cod liver oil preparations retain their popularity despite the expanding variety of supplements available and 19 different products based on cod liver oil were used.

Table 1 Description of nutritional and non-nutritional supplements used by the population surveyed ($n = 1379$) during 7 days in the North/South Ireland Food Consumption Survey

Supplements	Number	% of total
Vitamins	49	26.6
Vitamin C	17	9.2
B/B complex	15	8.2
Vitamin E	9	4.9
Multivitamins	5	2.7
Folic acid	2	1.1
β-Carotene	1	0.5
Minerals	27	14.7
Iron	13	7.1
Calcium	9	4.9
Zinc	3	1.6
Magnesium	1	0.5
Selenium	1	0.5
Multivitamins & minerals	30	16.3
Fish oil/Cod liver oil	19	10.3
Primrose/Starflower oil	17	9.2
Protein powders	4	2.2
Slimming powders	1	0.5
Non-nutritional supplements*	37	20.1
Total	184	100

* Includes ginseng, garlic capsules, aloe vera juice, biodopholous and others that were not entered into the compositional database as they did not contain nutrients.

Non-nutritional supplements, e.g. garlic, ginseng and aloe vera juice, were also widely used and accounted for 20% of the 184 supplements recorded.

Table 2 shows that, according to the questionnaire, a total of 387 respondents (28%) said that they were currently using supplements, while 323 (23%) consumed supplements during the recording week. A total of 83.5% of the respondents who reported currently using supplements consumed them at least once during the subsequent week. Twice as many women used supplements as men and this ratio did not change with age.

Table 2 Comparison of supplement use by age and sex in respondents who reported currently taking supplements in a questionnaire and in respondents who recorded them in the 7-day food diary during the North/South Ireland Food Consumption Survey

	Questionnaire		Food diary	
Population group	*n*	%	*n*	%
18–64 years				
All	387	28	323	23
Men	127	19	103	16
Women	260	36	220	31
18–35 years				
All	124	24	111	21
Men	42	17	37	15
Women	82	30	74	28
36–50 years				
All	162	31	134	26
Men	47	20	41	17
Women	115	40	93	33
51–64 years				
All	101	30	78	23
Men	38	22	25	14
Women	63	39	53	33

People in the 36–50 and 51–64 year age categories had a slightly higher rate of supplement use than the 18–35 year olds.

Table 3 shows the median intakes of six minerals and 11 vitamins in male and female users and non-users of supplements, and the percentage of each group that had mean daily intakes below the estimated average requirements (AR)[19]. The nutrient intakes of supplement users are presented from food sources plus supplements and from food sources only. Mean daily micronutrient intakes were significantly higher ($P < 0.01$) in men than in women, with the exception of iron and vitamin E in supplement users and carotene in users and non-users. In men and women, the mean daily intakes of micronutrients were significantly higher ($P < 0.001$) in users than in non-users when the contribution from supplements was included. In users, mean daily nutrient intakes from food sources only were significantly lower in men ($P < 0.01$) and women ($P < 0.0001$) than intakes from food sources plus supplements. In women, the mean daily intakes of iron, magnesium, manganese, vitamins C and E and niacin in users from food sources only were significantly higher ($P < 0.01$), by 3 to 12%, than in non-users.

Relatively small percentages of men (users and non-users) had mean nutrient intakes from food sources only that were below the AR, except for calcium, zinc, riboflavin and vitamin A. The inclusion of supplements in male users reduced the percentage below the AR for zinc from 19 to 13, for riboflavin from 14 to 6 and for vitamin A from 20 to 5, but had no effect on the adequacy of calcium intakes. In general, higher percentages of women had mean nutrient intakes from food sources below the AR than men, especially for calcium, iron, copper, folate and riboflavin. In women, the percentages of non-users who had mean nutrient intakes below the AR were larger than the percentages of users for calcium, iron, copper, vitamin C and folate. Over a quarter of female non-users had mean intakes of calcium and copper that were below the AR. Over half of female non-users aged 18 to 50 years had mean intakes of iron that were below the AR. In users, the addition of supplements reduced the percentage below the AR for calcium from 23 to 16, for iron from 50 to 25 (18–50 years), for copper from 20 to 15, for zinc from 15 to 12, for riboflavin from 23 to 14, and for vitamin A from 18 to 14.

Tables 4a and 4b show the mean micronutrient intakes in male and female users from supplements and food sources. Values were calculated per nutrient based on the number of users who consumed that nutrient in supplemental form. Vitamin E was the nutrient most frequently obtained from supplements in male (78%) and female (73%) users. In men, supplements contributed more to the mean intakes of thiamin, riboflavin, retinol and vitamins E, D and C than food did. In addition, over one-third of the mean intakes of iron, copper, zinc, folate

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Table 3 Median daily micronutrient intakes from food and nutritional supplements in male and female users ($n = 323$) and non-users ($n = 1056$) of supplements, and the percentage of each group with mean daily intakes below the estimated average requirements (ARs)[19], in the North/South Ireland Food Consumption Survey

	AR		Users (food + supplements)				Users (food sources)				Non-users			
			Men ($n = 103$)		Women ($n = 220$)		Men ($n = 103$)		Women ($n = 220$)		Men ($n = 559$)		Women ($n = 497$)	
Nutrient	Men	Women	Median	%<AR	Median	%<AR	Median	%<AR	Median	%<AR	Median	%<AR	Median	%<AR
Minerals														
Calcium (mg)	550	550	960	14	773	16	914	14	708	23	898	10	683	27
Iron (mg)	7	10 (18–50 years)	16.8	3	14.3	25	13.3	6	10.7*	50	13.1	2	9.5*	58
		6 (51–64 years)			12.7	4			10.4	4			9.5	10
Copper (mg)	0.8	0.8	1.6	7	1.2	15	1.4	8	1.2	20	1.3	8	1.0	27
Zinc (mg)	7.5	5.5	12.1	13	8.8	12	10.6	19	7.4	15	10.5	14	7.1	10
Magnesium (mg)	150–500		370	1	275	4	345	1	254*	4	337	1	237*	7
Manganese (mg)	–	–	4.2	N/A	3.5	N/A	3.6	N/A	3.1*	N/A	3.4	N/A	2.7*	N/A
Vitamins														
Vitamin C (mg)	30	30	116	2	103	3	77	5	68*	6	68	9	59*	12
Folate (μg)	140	140	387	2	297	4	293	3	225	6	302	3	208	11
Thiamin (mg)	0.8	0.6	2.7	1	1.9	1	1.9	2	1.5	1	1.9	1	1.4	1
Riboflavin (mg)	1.3	1.1	2.6	6	2.1	14	1.9	14	1.5	23	1.9	14	1.4	23
Niacin equivalents (mg)	15	11	53.5	0	37.9	0	45.8	1	33*	0	46.4	0	32.1*	0
Vitamin B_6 (mg)	1.3	1	4.2	2	2.7	2	1.9	4	2.0	2	2.9	2	1.9	1
Vitamin B_{12} (μg)	1	1	5.8	0	3.9	1	5.2	1	3.3	2	4.4	1	3.0	1
Vitamin E (mg)	–	–	10.1	N/A	11.9	N/A	6.6	N/A	5.7*	N/A	6.0	N/A	5.2*	N/A
Vitamin D (μg)	–	–	5.7	N/A	4.6	N/A	2.6	N/A	2.2	N/A	2.2	N/A	1.8	N/A
Vitamin A (μg) (retinol equivalents)	500	400	1381	5	1084	14	821	20	671	18	763	23	643	21
Carotene (μg)	–	–	2216	N/A	2120	N/A	2107	N/A	1953	N/A	2048	N/A	1846	N/A

Mean daily nutrient intakes were significantly higher ($P < 0.01$) in men than in women in Users (food + supplements), Users (food sources) and Non-users except for iron in Users (food + supplements), vitamin E in Users (food + supplements) and Users (food sources) and carotene.
Mean daily nutrient intakes were significantly higher in Users (food + supplements) than in Users (food sources) for men ($P < 0.01$) and women ($P < 0.0001$).
Mean daily nutrient intakes were significantly higher ($P < 0.001$) in Users (food + supplements) than in Non-users.
Mean daily intakes of some nutrients, denoted by *, were significantly higher ($P < 0.01$) in female Users (food sources) than in Non-users.

Table 4 Micronutrient intakes from nutritional supplements and food sources in men and women who took supplements during the North/South Ireland Food Consumption Survey

	Consumers		Nutritional supplements			Food sources			Total		
Nutrient	*n*	%	Mean	SD	Median	Mean	SD	Median	Mean	SD	Median
(a) Men (*n* = 103)											
Minerals											
Calcium (mg)	39	38	98	82	82	911	332	884	1009	355	1005
Iron (mg)	44	43	9.5	5	10	13.2	4	13.4	22.6	7	22.4
Copper (mg)	35	34	0.9	1	0.6	1.6	1	1.4	2.5	1	2.4
Zinc (mg)	39	38	8.1	6	5	10.3	3	10.6	18.4	7	17.9
Magnesium (mg)	25	24	75	81	86	357	101	351	432	112	449
Manganese (mg)	22	21	1.7	1	1.4	3.8	1.6	3.6	5.5	2	5.5
Vitamins											
Vitamin C (mg)	68	66	343	596	60	85	46	74	427	598	169
Folate (μg)	46	45	199	113	200	307	131	286	506	154	495
Thiamin (mg)	50	49	2.6	4	1.4	2.2	2	2.0	4.8	4	3.5
Riboflavin (mg)	49	48	2.4	4	1.6	2.1	1	2.0	4.5	4	3.8
Niacin equivalents (mg)	51	50	13.6	10	12.9	46.9	13	44.7	60.4	15	59.4
Vitamin B_6 (mg)	51	50	3.8	4	2	2.9	1	2.9	6.8	5	5.4
Vitamin B_{12} (μg)	48	47	2.9	5	1.3	5.2	4	4.3	8.1	6	6.7
Vitamin E (mg)	80	78	37.5	102	7.4	7	3	6.9	44.5	101	14.8
Vitamin D (μg)	74	72	4.2	3	2.8	3.2	3	2.4	7.4	4	6.5
Retinol (μg)	76	74	692	290	760	646	891	413	1338	909	1188
Carotene (μg)	17	17	412	534	200	2230	1283	1913	2643	1194	2471
(b) Women (*n* = 220)											
Minerals											
Calcium (mg)	79	36	240	380	162	778	328	681	1017	486	911
Iron (mg)	96	44	29.8	42	13.8	10.5	4	9.8	40.4	42	22.7
Copper (mg)	60	27	1.1	1	0.9	1.1	1	0.9	2.3	1	2.1
Zinc (mg)	68	31	9.9	10	9.3	7.7	3	7.1	17.6	11	18.2
Magnesium (mg)	59	27	93	61	100	272	103	251	364	125	335
Manganese (mg)	55	25	2.4	2	2	3	0.9	2.9	5.4	2	4.9
Vitamins											
Vitamin C (mg)	113	51	231	390	60	83	48	72	315	393	153
Folate (μg)	96	44	258	212	200	235	74	231	493	231	433
Thiamin (mg)	98	45	4.8	10	1.4	1.5	0.8	1.4	6.3	10	2.9
Riboflavin (mg)	96	44	3.9	8	1.6	1.6	0.6	1.5	5.5	8	3.2
Niacin equivalents (mg)	94	43	16.3	14	15.6	34.5	10	33.4	50.7	19	47.4
Vitamin B_6 (mg)	94	43	9.3	15	2	2.1	0.7	2	11.4	15	4.2
Vitamin B_{12} (μg)	92	42	3.6	6	1	3.9	3	3.2	7.5	7	4.9
Vitamin E (mg)	160	73	23.1	53	10	6.4	3	5.8	29.4	54	15.3
Vitamin D (μg)	133	60	4.8	4	4.3	2.8	2	1.9	7.4	5	6
Retinol (μg)	122	55	754	496	777	498	664	301	1251	968	1047
Carotene (μg)	45	20	432	705	229	2354	2295	1634	2787	2593	1923

and vitamins B_6 and B_{12} were supplied by supplements. In general, the contribution of supplements to mean nutrient intakes was higher in women than in men. The contribution of supplements to mean intakes of iron, copper, zinc, folate, thiamin, riboflavin, retinol and vitamins B_6, C, E and D was equal to or higher than that of food and at least a third of the mean intakes of magnesium, manganese, niacin and vitamin B_{12} were provided by supplements.

In Table 5, the mean daily intakes of micronutrients at the 95th percentile in male and female supplement users are compared with the UL[20–28]. Values were calculated for food plus supplements and for food sources only. Women at the 95th percentile of iron intake from food plus supplements exceeded the UL of 45 mg by over 65 mg. Mean iron intakes at the 95th percentile from food sources in this group were almost 28 mg lower than the UL. Mean vitamin B_6 intakes at the 95th percentile from food plus supplements were 41.4 mg, which exceeded the UL of 25 mg by over 16 mg. The mean vitamin B_6 intake at the 95th percentile in this group from food only was 3.1 mg. Mean intakes of pre-formed niacin at the 95th percentile in men and women exceeded the UL of 35 mg, when intakes from food plus supplements were considered, and in men from food sources only. In men, mean intakes of retinol at the 95th percentile approached the UL of 3000 μg when supplements were included. No other UL for minerals or vitamins was exceeded at the 95th percentile of mean intakes.

Discussion

This report describes dietary supplement use in a representative sample of the Irish adult population with specific emphasis on evaluating the efficacy of supplements in promoting adequate micronutrient intakes and

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Table 5 Mean daily intakes of micronutrients at the 95th percentile in male and female supplement consumers in the North/South Ireland Food Consumption Survey compared with the tolerable upper intake levels (ULs)

		Food plus supplements			Food only		
	UL	Total $n = 323$	Men $n = 103$	Women $n = 220$	Total $n = 323$	Men $n = 103$	Women $n = 220$
Minerals							
Calcium (mg)	2500*	1578	1653	1450	1433	1652	1255
Iron (mg)	45†	84.6	30.4	110.4	19.7	25.9	17.2
Copper (mg)	10†	3.4	4	3	2.7	3.2	2.1
Zinc (mg)	40†	25.5	27.9	23.1	14.9	20	12
Magnesium (mg)	350* (supplemental)	555	600	428	484	581	385
Manganese (mg)	11†	7.7	8.3	6.6	5.8	7.9	5.1
Vitamins							
Vitamin C (mg)	2000‡	1036	1202	660	185	194	185
Folic acid (μg)	1000‡	692	724	693	467	561	377
Thiamin (mg)	None§	10.9	7.4	11.3	3.1	4	2.3
Riboflavin (mg)	None§	6.8	5.7	6.9	3.1	3.9	2.7
Pre-formed niacin (mg)	35¶	58.2	60	57.2	39.2	42	29.2
Vitamin B_6 (mg)	25§	18.2	11.6	41.4	4.3	5.7	3.1
Vitamin B_{12} (μg)	None§	16.7	21.4	16.1	9.7	14.4	7.6
Vitamin E (mg)	1000‡	133	273	72	11	11.9	10.7
Vitamin D (μg)	50*	14.5	14	14.9	7.4	10.6	6.3
Retinol (μg)	3000†	2529	2974	2359	1691	2067	1135
Carotene (μg)	None§	6334	5789	6582	6227	5788	6401

* Food and Nutrition Board (1997)[20].
† Food and Nutrition Board (2001)[21].
‡ Food and Nutrition Board (2000)[22].
§ Opinion of the Scientific Committee for Food (2000)[23–27].
¶ Food and Nutrition Board (1998)[28].

assessing the risk of adverse effects to supplement users at the 95th percentile of micronutrient intakes.

A recent report[29] indicated that it might be necessary to use a combination of several approaches to gain an accurate assessment of supplement use. In the present study, 28% of respondents reported that they were currently using dietary supplements, and 23% of respondents recorded consuming a supplement during the week of data collection. All of the respondents who consumed a supplement during the recording week had reported in the questionnaire that they were currently taking supplements. A longer period of data collection may be necessary to gain an accurate record of the types and doses of supplements consumed by all supplement users. Other studies of habitual supplement use in the USA[30], Germany[31], The Netherlands[32] and Sweden[33] have reported similar rates of consumption. In the UK, the Dietary and Nutritional Survey of British Adults[34], published in 1990, reported that 15% of the respondents were currently taking supplements. Preliminary results from the first 2000 participants in the EPIC study in Norfolk showed that 37.5% of respondents regularly consumed a supplement[3], suggesting that the rate of supplement use in the UK is increasing. In the current survey, twice as many women used supplements as men. In addition, the prevalence of supplement use was slightly higher in the older age groups compared with the 18–35 year age category. These trends have been observed previously[30,31,34].

The mean intakes of micronutrients were higher in supplement users than non-users when the contributions from supplements were included. When intakes in users from food sources only were compared with those of non-users, the values in men were similar. However, in women, the intakes of iron, magnesium, manganese, niacin and vitamins C and E were significantly higher in users (by 3 to 12%) from food sources only than in non-users. Results from a recent study[4] showed that, before supplements were taken into account, supplement users had higher intakes than non-users of all micronutrients, apart from vitamin B_{12}. Another study in the USA[30] showed that female supplement users had higher intakes of calcium and vitamins A, C and E from food sources than non-users. These observations appear to support the hypothesis that supplement users eat diets that are at least as nutritious as those of non-users, and may be unnecessarily consuming supplements to correct nutritional deficiencies[4]. While the adequacy of nutrient intakes was not evaluated in the above studies, the present study shows that the adequacy of intakes in female supplement users (from food sources only) was better for calcium, iron, copper, vitamin C, folate and vitamin A, as indicated by the percentages who had mean daily nutrient intakes lower than the average requirements.

Mean intakes in supplement users and non-users in the present study were compared with estimated average requirements. The AR is defined as the nutrient intake value that is estimated to meet the requirement, defined by a specified indicator of adequacy, in 50% of the individuals in a life-stage and gender group. At this level of intake, the remaining 50% of the specified group would not meet their nutrient needs. The percentage of persons with intakes that are lower than the AR is useful for assessing the prevalence of inadequate intakes within a group[20]. Carriquiry has explained this concept clearly and in more detail in a recent paper[35]. In men, the percentage of users and non-users of supplements with micronutrient intakes (from food only) below the AR was generally below 10, except for calcium, zinc, riboflavin and vitamin A. In users, supplements had no effect on the adequacy of calcium intakes, but did reduce the percentages below the AR from 19 to 13 for zinc, from 14 to 6 for riboflavin and from 20 to 5 for vitamin A.

Overall, the percentage of women who had mean nutrient intakes below the AR was higher than that of men and this was particularly evident with regard to minerals. In female users of supplements aged 18–50 years, the proportion with mean iron intakes below the AR (10 mg)[19] was 50% from food only, which was reduced to 25% when supplements were included. A much smaller percentage of women in the 51–64 year age group had mean iron intakes that were lower than the AR for non-menstruating women (6 mg)[19]. These data indicate that supplements containing iron make an important contribution to the diets of menstruating women, but they may be largely unnecessary in post-menopausal women, whose iron intakes reach adequate levels in most cases. The impact of supplement use on reducing the percentages of women whose mean intakes did not reach the AR for calcium (from 23 to 16), copper (from 20 to 15), zinc (from 15 to 12), riboflavin (from 23 to 14) and vitamin A (from 18 to 14) was smaller than the impact of supplements on iron intakes in menstruating women (from 50 to 25).

In the current study, the contribution of supplements to the mean daily intake of each nutrient was evaluated for supplement users who obtained that nutrient from a supplement. Although twice as many women as men used supplements, the percentage obtaining individual nutrients in supplemental form was similar for men and women (Tables 4a and 4b). Supplements provided a substantial proportion of the mean daily intake of individual nutrients among consumers of that nutrient in supplemental form. For example, supplements contributed more than food to the mean intakes of iron, zinc and folate in women, and of thiamin, riboflavin, retinol and vitamins B_6, C, D and E in men and women who obtained these nutrients in supplemental form. This observation highlights the importance of the careful recording of supplement use in studies that measure dietary intake to correctly classify respondents by intake.

In an accompanying paper[36], data from the current study are presented which indicate that the recently published recommendation from COMA[37], that total folate intake should be about 600 μg day^{-1} in women of childbearing potential to reduce the risk of neural tube defects (NTD), was met only by a very small percentage of Irish women aged 18–50 years. The data show that in females aged 18–50 years who consumed supplemental folate ($n = 80$ out of 555), mean intakes of folate were 480 μg (233 μg from food and 248 μg from supplements), indicating a reduced risk of NTD in this group. However, only 21 (26%) of these women achieved a mean daily folate intake ≥600 μg. Of the women who did not take supplements, none had mean intakes that approached this level.

The criteria of adequacy for setting ARs do not take into account potential health benefits of higher intakes of some nutrients, e.g. vitamins C and E, which may have protective effects against certain ageing-related chronic diseases. Vitamin E acts as a physiological antioxidant that prevents the propagation of lipid peroxidation. Oxidation of low-density lipoproteins may be a key step in the development of coronary atherosclerosis. Epidemiological evidence indicates a protective effect of dietary vitamin E against cardiovascular disease and some authors[38,39] believe that the evidence is already convincing enough to recommend intakes of at least 87 mg day^{-1}. However, the four large-scale intervention studies published to date do not provide sufficient data to confirm a protective effect of vitamin E against heart disease[22]. The attainment of vitamin E intakes of 87 mg day^{-1} is not feasible in the population without the use of supplements. In men who consumed supplemental vitamin E ($n = 80$ out of 662), the total mean daily intake of vitamin E was 44.5 mg. Only eight of these men achieved mean intakes that exceeded 87 mg day^{-1}.

In the current study, the mean daily micronutrient intakes of supplement users at the 95th percentile from food and supplements were compared with tolerable upper intake levels (ULs)[20–28]. Mean intakes of micronutrients at the 95th percentile exceeded the UL for pre-formed niacin, vitamin B_6 and iron (in women only). While there were no female non-users of supplements who exceeded the UL for iron, 21 out of the 96 women who consumed supplemental iron exceeded the UL[21] of 45 mg. Gastrointestinal side effects were selected as the critical adverse effects on which to base the UL for iron[21]. Apart from the well-documented Bantu haemosiderosis, there are only a few case reports on prolonged iron therapy and iron overload. Calculations in fertile women of the expected body iron burden at different doses of iron taken over periods of up to 15 years have concluded that 60 mg iron daily over 5 years might lead to body iron stores that are close to the cut-off values for serum ferritin in iron overload, but would not result in iron overload[40]. It should be noted that in the current users of supplemental iron who exceeded the UL, most of the iron supplements used were prescribed for iron deficiency

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anaemia. In addition, estimations of Fe intake were carried out over a 7-day period and may not represent chronic iron supplement use in these particular women.

The UL[25] for vitamin B_6 of 25 mg was exceeded by one man and by 14 of the 94 women who consumed this vitamin in supplemental form. Exceeding the UL of 25 mg was associated with the consumption of supplements that contained 25 to 50 mg of vitamin B_6, as opposed to multivitamin preparations which usually contain quantities of B_6 that are similar to the recommended dietary allowances of 15 μg B_6 per g protein. A chronic mean daily intake of 25 mg B_6 has not been associated with any adverse effects in any published studies. However, minor neurological symptoms may be apparent at doses of 100 mg day^{-1} over a prolonged period[25]. These symptoms are reversible on cessation of supplementation.

The UL[28] for niacin of 35 mg was exceeded at the 95th percentile from food plus supplements in men and women. In total, 44 out of 51 male and 41 out of 94 female users of supplemental niacin exceeded the UL. The maximum daily intake of pre-formed niacin from the sum of food sources and supplements was 91.5 mg and from supplements was 66.6 mg. The critical adverse effect for this UL is flushing, which is a transient effect resulting in a reddened flush primarily on the face, arms and chest[28]. There is no evidence of adverse effects from the consumption of naturally occurring niacin in foods, and the UL has been set based on evidence of flushing from the intake of nicotinic acid as a supplement, food fortificant or pharmacological agent[28]. Supplemental nicotinic acid provided about one-third of the mean daily intake of niacin at the 95th percentile of niacin intakes. Over 40% of pre-formed niacin from food sources came from meat, meat products and fish[28], in which it is present mainly in the form of nicotinamide[41], which is not associated with flushing[28]. Thus, although it was not possible to quantify the proportions of nicotinamide and nicotinic acid consumed in food, the estimates of those who exceeded the UL for pre-formed niacin appear to considerably overestimate the risk of exposure to excess nicotinic acid. Mean niacin intakes from food sources only exceeded the UL in a small number of men but this included a substantial contribution of nicotinamide from meat, indicating that the risk of adverse effects from intake of nicotinic acid in foods is low.

Conclusions

This study found that nutritional supplements are regularly used by 23% of the Irish adult population. Twice as many women as men are supplement users. Mean intakes of micronutrients were higher in supplement users than non-users when the contribution from supplements was included. Female supplement users had slightly higher mean intakes of some micronutrients from food sources compared with non-users. Supplementation appears to be beneficial in promoting adequate intakes of some micronutrients, particularly iron and folate in women aged 18–50 years and vitamin A in men. Among consumers of specific nutrients in supplemental form, supplements provided a substantial proportion of the mean daily intakes of those nutrients. Although the consumption of folate supplements increased total folate intake by an average of two-fold in consumers, the recommendation that folate intakes should be 600 μg in women of childbearing potential for the prevention of NTD was only met by 26% of women aged 18 to 50 years who consumed supplemental folate (and by none who did not). Twenty-two per cent of women who consumed supplemental iron exceeded the UL for iron, and 15% of women who consumed supplemental vitamin B_6 exceeded the UL for B_6. A high proportion of male and female consumers of supplemental niacin exceeded the UL for niacin. However, since the estimate of niacin intake includes a substantial contribution from nicotinamide, which is not associated with flushing, the number of people with intakes of pre-formed niacin above the UL appears to considerably overestimate the risk of exposure to excess nicotinic acid. The risk of adverse effects from exposure to nicotinic acid in foods is low. Other than these findings for iron, vitamin B_6 and niacin, there was little risk of exceeding the UL for other micronutrients among users of nutritional supplements.

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