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Foods, Fortificants, and Supplements: Where Do Americans Get Their Nutrients?[1–3]

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Abstract

Limited data are available on the source of usual nutrient intakes in the United States. This analysis aimed to assess contributions of micronutrients to usual intakes derived from all sources (naturally occurring, fortified and enriched, and dietary supplements) and to compare usual intakes to the Dietary Reference Intake for U.S. residents aged ≥2 y according to NHANES 2003–2006 (*n* = 16,110). We used the National Cancer Institute method to assess usual intakes of 19 micronutrients by source. Only a small percentage of the population had total usual intakes (from dietary intakes and supplements) below the estimated average requirement (EAR) for the following: vitamin B-6 (8%), folate (8%), zinc (8%), thiamin, riboflavin, niacin, vitamin B-12, phosphorus, iron, copper, and selenium (<6% for all). However, more of the population had total usual intakes below the EAR for vitamins A, C, D, and E (34, 25, 70, and 60%, respectively), calcium (38%), and magnesium (45%). Only 3 and 35% had total usual intakes of potassium and vitamin K, respectively, greater than the adequate intake. Enrichment and/or fortification largely contributed to intakes of vitamins A, C, and D, thiamin, iron, and folate. Dietary supplements further reduced the percentage of the population consuming less than the EAR for all nutrients. The percentage of the population with total intakes greater than the tolerable upper intake level (UL) was very low for most nutrients, whereas 10.3 and 8.4% of the population had intakes greater than the UL for niacin and zinc, respectively. Without enrichment and/or fortification and supplementation, many Americans did not achieve the recommended micronutrient intake levels set forth in the Dietary Reference Intake. J. Nutr. 141: 1847–1854, 2011.

Introduction

Americans are urged to meet their nutrient needs by consuming foods that provide a well-balanced, nutrient-dense diet (1,2). However, many individuals have diets that are lower in one or more nutrients and higher in energy than recommended (2–10). The *2010 Dietary Guidelines for Americans* identified 4 nutrients of public concern: dietary fiber, vitamin D, calcium, and potassium. For certain subgroups in the population, several additional under-consumed nutrients were also identified: vitamin A, vitamin C, folate, vitamin K, and magnesium (2).

Most foods contain several naturally occurring nutrients at relatively low levels. The addition of nutrients to foods, either by enrichment (replacing nutrients lost in processing) or fortification (adding nutrients at higher levels than naturally occur in the food), enhances levels of one or more nutrients in certain foods that are widely consumed, thus raising intakes to more desirable levels. Most grain products are enriched and a variety of other food products are fortified. For example, bread is enriched with thiamin, niacin, riboflavin, and iron; most RTE[8] cereals are fortified with added iron and B vitamins, including folate, and most milk is fortified with vitamin D.

In addition to obtaining nutrients from foods, many Americans use nutrient-containing dietary supplements (11,12). According to 2003–2006 NHANES data, one-half of Americans (aged ≥1y) used dietary supplements, with multivitamin/mineral supplements being the most common (33% of the U.S. population) (12). Very limited information exists on usual micronutrient intakes in the U.S. from naturally occurring, enriched and/or fortified foods, and dietary supplement sources, with the exception of folate (13).

In Europe, fortified foods do not contribute significantly to high intakes for any nutrient, and even with the inclusion of dietary supplements most children and adults do not exceed the

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[3] Supplemental Tables 1 and 2 are available from the "Online Supporting Material" link in the online posting of the article and from the same link in the online table of contents at jn.nutrition.org.
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[8] Abbreviations used: AI, adequate intake; EAR, estimated average requirement; FNDDS, Food and Nutrient Database for Dietary Studies; NCHS, National Center for Health Statistics; SR, Nutrient Database for Standard Reference; RTE, ready to eat; UL, tolerable upper intake level.

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UL (14). Given that fortification practices and dietary supplement use are very different in the U.S. compared to Europe, this study aimed to determine total usual nutrient intakes for 19 micronutrients from all sources as well as the relative contributions of foods (including both naturally occurring nutrients and those added via enrichment and/or fortification) and of dietary supplements within a nationally representative sample of the U.S. population aged ≥2 y.

Participants and Methods

Study population. The NHANES data are collected by the NCHS of the CDC. All participants or proxies provided written informed consent and the Research Ethics Review Board at the NCHS approved the survey protocol. We combined data from NHANES 2003–2004 and 2005–2006 for these analyses (15). The combined sample included 18,063 participants who had complete 24-h dietary intake data. Of these, 1241 infants or children aged <2 y and 712 pregnant and/or lactating females were excluded from the analyses, resulting in 16,110 participants aged ≥2 y in the analytic sample (n = 7250 for ages 2–18 y; n = 8860 for ages ≥19 y). Participants completed an in-person health examination in a Mobile Examination Center that included an in-person 24-h dietary recall. A second 24-h dietary recall was collected via telephone ~3–10 d after the Mobile Examination Center exam. Both 24-h dietary recalls were collected using the USDA's automated multiple-pass method.

Nutrients from foods. Various USDA food composition databases were used to determine the micronutrients derived from foods consumed by NHANES participants and reported in the 24-h recall dietary interview. The USDA estimated the nutrient content of NHANES foods in recipes by linking the ingredients in survey food recipes to food composition data provided by the SR. The SR-Link file of the FNDDS version 2.0 was used in conjunction with SR release 18 to determine the nutrient content of NHANES 2003–2004 foods. FNDDS 3.0 and SR release 20 were used to determine the composition of foods reported by NHANES 2005–2006 survey participants (16–19). An addendum to FNDDS 3.0 provided the vitamin D content of foods reported in NHANES 2005–2006 (20). Foods reported in NHANES 2003–2004 were matched to the vitamin D addendum, and if there was no match, recipe calculations were performed using the SR-Link file of the FNDDS 2.0. Because SR releases 18 and 20 did not include the new vitamin D values, SR release 22 was used (21).

Folate food composition values in the SR and FNDDS were separated into amounts added as synthetic folic acid compared to food folate (i.e. folate naturally occurring in food). Added vitamin B-12 and vitamin E data were also readily available and naturally occurring amounts were determined by the difference between the total and added vitamin content of these nutrients. To estimate intakes of all other nutrients that are added through enrichment and/or fortification of foods, we used various approaches to separate the nutrient content of foods into naturally occurring and added components. Data available from the SR and FNDDS food composition databases as well as the MyPyramid Equivalent Database 2.0 (22), which gives equivalent amounts of MyPyramid food groups contained in survey foods, were used to accomplish this task.

For example, if a food contained synthetic folic acid according to the FNDDS and grain according to the MyPyramid Equivalent Database and if the food was not a fortified grain product, such as bread, the recipe was then examined to determine whether the synthetic folic acid was coming from enriched flour or another source. We determined the amounts of added thiamin, riboflavin, niacin, folate, and iron per 100 g of the enriched grain product by calculating the difference between the enriched and unenriched SR values. Therefore, given the amount of added folate per 100 g of the survey food and the proportionate amounts of folate and other nutrients that were added to the enriched ingredient, we could also then determine the proportionate amounts of other nutrients added by enriching the survey food.

We used a different approach to determine the amounts of nutrients added to fortified grain products, such as RTE cereals and cereal bars. In this case, the amount of any nutrient added by fortification was obtained by calculating the difference between the total nutrient content and an amount determined to be naturally occurring in the food. We assumed the difference was added by fortification if it exceeded 5% of the Daily Value (used in food labeling) per serving of the food. Otherwise, it was assumed to be zero if the difference was a trace amount or <5% of the Daily Value/serving, because errors may have been introduced into calculation by rounding or making assumptions regarding the formulation. The ingredients of the formulation for manufactured foods, such as RTE cereals and cereal bars, were not listed in the SR-Link of the FNDDS. Therefore, we used information from the MyPyramid Equivalent Database regarding the cup-equivalent amounts of fruit, nuts, and grains, combined with the nutrient content of representative SR food codes in these categories that are typically used as ingredients of RTE cereals, such as raisins, almonds, and unenriched flour, to separate the naturally occurring nutrients from fortificants.

The amounts of nutrients added as fortificants to other foods, such as vitamin C and calcium added to beverages and vitamins A or D added to margarine or milk, were directly determined by performing recipe calculations using food composition data and the SR-Link file of the FNDDS. For example, we separated the fortificants from the vitamins A or D that would be naturally occurring in milk and for all survey food recipes that included a specified amount of milk. Using the same assumptions as the USDA regarding the use of unfortified milk in food manufacturing, we performed recipe calculations to determine the proportions of the USDA survey food composition table values that were derived from the fortification of milk as opposed to the vitamins A or D naturally occurring in milk, meat, or other ingredients of the mixture.

Based on the above approaches, we were able to generate nutrients values for all foods that were either naturally occurring or added via enrichment and/or fortification.

Nutrients from dietary supplements. In conducting the NHANES 2003–2006, a dietary supplement questionnaire was administered during the household interview to assess usage of vitamins, minerals, botanicals, and other dietary supplements over the past 30 d (23). For each dietary supplement the respondent reported, he or she was asked to report the consumption frequency (i.e. number of days the product was taken in the past 30 d), the duration (i.e. for how many days, weeks, months, or years the product was taken), and the amount usually taken per day on days it was taken in the past 30 d. The interviewer also examined each dietary supplement container and recorded complete product information so that every reported dietary supplement could be matched or entered into a dietary supplements database. The NCHS maintains a dietary supplements database that contains product label information obtained from the manufacturers of dietary supplements reported in NHANES and these data include the labeled dosage or serving size, ingredients, and the amounts of ingredients per serving. The average daily intake of nutrients from dietary supplements was calculated for individuals using the number of days that supplement use was reported, the reported amount taken per day, and the serving size unit from the product label.

Estimation of usual intake. Using the food composition data described above, nutrient intakes from naturally occurring sources were quantified from each food reported during the individual's two 24-h recall interviews by multiplying the weight (in grams) of food consumed by the nutrient content (amount per 100 g). We also estimated nutrient intake from all foods (including nutrients added via enrichment and/or fortification) using the same method. To account for differential bioavailability of folate and folic acid (24), we used the dietary folate equivalent metric.

Estimates of usual intake for each nutrient were determined using the National Cancer Institute method (25) for a single dietary component, because nutrients are consumed at some level on most days. Usual intake statistics included means and percentiles of intake and probabilities of meeting or exceeding the DRI for 19 micronutrients (24,26–29). Usual intakes for nutrients with an established EAR were determined for thiamin, riboflavin, niacin, folate, calcium, phosphorus, magnesium, iron, zinc, copper, and selenium and vitamins A, B-6, B-12, C, D, and E.

TABLE 1 Usual intake from NHANES 2003–2006 compared to DRI from naturally occurring nutrients, enrichment/fortification, and dietary supplements in individuals aged ≥2 y[1]

Nutrient	Usual intake	Percentiles					<EAR	≥UL
		10	25	50	75	90		
	Mean ± SEM						*% ± SEM*	*% ± SEM*
Vitamin D,[2] *μg/d*								
Naturally occurring	1.9 ± 0.4	0.8	1.1	1.7	2.5	3.3	100 ± 0	0.0 ± 0.0
+ Enriched/fortified	4.9 ± 0.1	1.7	2.7	4.2	6.4	8.9	93.3 ± 0.6	0.0 ± 0.0
+ Dietary supplements	8.2 ± 0.2	2.0	3.3	6.0	11.7	16.3	69.5 ± 0.9	0.1 ± 0.1
Calcium,[2] *mg/d*								
Naturally occurring	883 ± 9	476	624	828	1084	1361	54.2 ± 0.9	0.1 ± 0.04
+ Enriched/fortified	939 ± 9	504	662	881	1152	1449	48.9 ± 0.8	0.3 ± 0.1
+ Dietary supplements	1091 ± 10	551	735	1000	1342	1740	38.0 ± 0.8	2.4 ± 0.2
Vitamin A, *μg RAE/d*								
Naturally occurring	412 ± 5	211	281	380	509	653	74.4 ± 1.0	0.1 ± 0.01
+ Enriched/fortified	601 ± 8	286	395	551	752	979	45.1 ± 1.0	1.4 ± 0.1
+ Dietary supplements	1010 ± 20	306	440	687	1316	1952	34.0 ± 1.1	4.7 ± 0.2
Vitamin C, *mg/d*								
Naturally occurring	72.5 ± 1.2	26.7	40.9	63.0	93.6	130	45.9 ± 1.1	0.0 ± 0.0
+ Enriched/fortified	85.3 ± 1.3	31.8	48.5	74.2	110	152	37.0 ± 1.1	0.0 ± 0.0
+ Dietary supplements	188 ± 7	36.7	59.2	101	172	394	25.3 ± 1.0	0.6 ± 0.1
Vitamin E, *mg AT/d*								
Naturally occurring	6.5 ± 0.1	3.7	4.7	6.1	7.9	9.8	93.3 ± 0.4	0.0 ± 0.0
+ Enriched/fortified	6.9 ± 0.1	3.8	4.9	6.4	8.4	10.5	90.7 ± 0.5	0.0 ± 0.0
+ Dietary supplements	37.7 ± 1.4	4.1	5.5	8.3	25.1	49.8	60.3 ± 0.8	0.1 ± 0.1
Thiamin, *mg/d*								
Naturally occurring	0.9 ± 0.01	0.6	0.7	0.9	1.1	1.3	50.9 ± 1.0	
+ Enriched/fortified	1.7 ± 0.01	1.0	1.2	1.6	2.0	2.4	5.9 ± 0.5	
+ Dietary supplements	4.7 ± 0.2	1.1	1.4	1.9	2.8	4.4	4.3 ± 0.4	
Riboflavin, *mg/d*								
Naturally occurring	1.7 ± 0.02	1.0	1.2	1.6	2.1	2.6	8.7 ± 0.5	
+ Enriched/fortified	2.3 ± 0.02	1.3	1.7	2.1	2.7	3.4	2.1 ± 0.2	
+ Dietary supplements	4.9 ± 0.2	1.4	1.8	2.6	3.7	5.6	1.6 ± 0.2	
Niacin,[4] *mg/d*								
Naturally occurring	17.4 ± 0.2	9.8	12.5	16.3	21.3	26.4	11.3 ± 1.2	—
+ Enriched/fortified	24.3 ± 0.2	14.3	17.9	23.0	29.4	36.1	1.7 ± 0.4	0.9 ± 0.1
+ Dietary supplements	34.4 ± 0.5	15.3	19.9	27.4	38.5	51.6	1.2 ± 0.3	10.3 ± 0.4
Vitamin B-6, *mg/d*								
Naturally occurring	1.5 ± 0.01	0.9	1.1	1.5	1.9	2.3	21.7 ± 1.1	0.0 ± 0.0
+ Enriched/fortified	1.9 ± 0.02	1.1	1.4	1.8	2.3	2.9	12.3 ± 1.0	0.0 ± 0.0
+ Dietary supplements	5.8 ± 0.2	1.2	1.6	2.2	3.6	6.4	8.2 ± 0.7	1.1 ± 0.1
Vitamin B-12, *μg/d*								
Naturally occurring	4.3 ± 0.1	2.2	3.0	4.0	5.3	6.8	6.0 ± 0.6	
+ Enriched/fortified	5.3 ± 0.1	2.6	3.6	4.9	6.6	8.5	3.2 ± 0.5	
+ Dietary supplements	24.4 ± 1.4	2.9	4.2	6.4	10.8	28.1	2.3 ± 0.3	
Folate,[3] *μg DFE/d*								
Naturally occurring	199 ± 2	112	144	189	243	302	88.0 ± 0.4	—
+ Enriched/fortified	543 ± 5	304	391	511	661	822	10.7 ± 0.6	1.0 ± 0.1
+ Dietary supplements	772 ± 11	329	440	627	1000	1328	7.6 ± 0.5	5.7 ± 0.3
Phosphorus, *mg/d*								
Naturally occurring	1295 ± 9	788	981	1240	1553	1878	5.9 ± 0.3	0.0 ± 0.0
+ Enriched/fortified	1326 ± 9	803	1004	1270	1591	1925	5.5 ± 0.3	0.0 ± 0.0
+ Dietary supplements	1343 ± 9	815	1018	1286	1608	1948	5.3 ± 0.3	0.0 ± 0.0
Magnesium,[4] *mg/d*								
Naturally occurring	266 ± 2	161	200	254	319	387	58.9 ± 0.8	–
+ Enriched/fortified	276 ± 2	164	206	263	333	406	54.5 ± 0.9	0.0 ± 0.0
+ Dietary supplements	310 ± 3	170	217	285	372	470	44.8 ± 1.0	1.7 ± 0.2
Iron,[5] *mg/d*								
Naturally occurring	9.8 ± 0.1	6.1	7.5	9.4	11.7	14.1	21.8 ± 0.3	0.0 ± 0.0
+ Enriched/fortified	15.8 ± 0.1	9.5	11.8	15.0	19.0	23.3	6.5 ± 0.2	0.0 ± 0.0

(Continued)

TABLE 1 *Continued*

Nutrient	Usual intake	Percentiles 10	25	50	75	90	<EAR	≥UL
+ Dietary supplements	19.3 ± 0.2	9.8	12.5	16.5	22.9	32.0	5.0 ± 0.2	2.0 ± 0.1
Zinc, *mg/d*								
Naturally occurring	10.9 ± 0.1	6.5	8.1	10.3	13.1	16.2	15.2 ± 0.8	2.5 ± 0.2
+ Enriched/fortified	12.1 ± 0.1	7.1	8.9	11.4	14.6	18.1	10.5 ± 0.7	4.5 ± 0.2
+ Dietary supplements	16.8 ± 0.2	7.6	9.8	13.5	21.2	28.9	8.0 ± 0.6	8.4 ± 0.4
Copper, *μg/d*								
Naturally occurring	1.2 ± 0.01	0.7	0.9	1.2	1.5	1.8	4.8 ± 0.6	0.6 ± 0.1
+ Enriched/fortified	1.3 ± 0.01	0.8	0.9	1.2	1.5	1.9	4.3 ± 0.5	0.7 ± 0.1
+ Dietary supplements	1.7 ± 0.02	0.8	1.0	1.3	2.1	3.3	3.7 ± 0.4	1.5 ± 0.1
Selenium, *mg/d*								
Naturally occurring	106 ± 1	64	80	101	128	155	0.9 ± 0.2	0.7 ± 0.1
+ Enriched/fortified	107 ± 1	64	80	102	129	156	0.9 ± 0.2	0.7 ± 0.1
+ Dietary supplements	118 ± 1	66	84	108	140	180	0.7 ± 0.2	0.8 ± 0.1
Nutrients with an AI							*>AI % ± SEM*	
Potassium,[2] *mg/d*								
Naturally occurring	2591 ± 19	1582	1975	2493	3103	3731	2.2 ± 0.2	
+ Enriched/fortified	2615 ± 18	1593	1993	2516	3133	3770	2.4 ± 0.2	
+ Dietary supplements	2631 ± 19	1600	2001	2529	3153	3799	2.5 ± 0.2	
Vitamin K, *μg/d*								
Naturally occurring	79.0 ± 1.1	34.9	48.6	69.7	99.0	135	30.1 ± 1.0	
+ Enriched/fortified	80.3 ± 1.2	35.0	49.0	70.6	101	137	31.1 ± 1.0	
+ Dietary supplements	85.5 ± 1.3	35.8	50.7	74.4	108	149	35.3 ± 1.1	

[1] Data source: NHANES 2003–2006; *n* = 16,110. Usual intake determined using the National Cancer Institute method; covariates included recall number, weekday/weekend day, and dietary supplement use (yes/no). AI, adequate intake; AT, α-tocopherol; DFE, dietary folate equivalents; DRI, dietary reference intake; EAR, estimated average requirement; RAE, retinol activity equivalents; UL, tolerable upper intake level.
[2] Nutrient identified by 2010 Dietary Guidelines Advisory Committee as being a nutrient of public health concern.
[3] Total DFE (folate from supplements multiplied by 1.7 and folic acid added from fortification and enrichment multiplied by 1.7 summed with naturally occurring food folate); UL values are for folic acid.
[4] UL values are for added/supplemental sources only (naturally occurring food sources not included).
[5] EAR values determined by probability method. AT, α-tocopherol; DFE, dietary folate equivalents; RAE, retinol activity equivalents.

Additionally, usual intake was determined for 2 nutrients with AI: vitamin K and potassium. Because the distribution of requirements is skewed for iron (28), we used the probability method to determine the prevalence of the population below the EAR. We also determined the percentages of the population exceeding the UL for nutrients for which an UL was established, including vitamin A, vitamin C, vitamin E, niacin, vitamin B-6, folate, phosphorus, magnesium, iron, zinc, copper, selenium, vitamin D, and calcium. Because the UL for niacin and magnesium were established only for supplemental sources (24,26) and the UL for vitamin A and folate were based on retinol and added folic acid, respectively (24,28), these were considered when determining estimates of usual intakes greater than the UL for these nutrients.

Intakes from naturally occurring nutrients and from all foods (including those enriched and fortified) were determined separately from total intakes. To determine total nutrient intake, we added nutrient intake from dietary supplements to the usual intake from all foods similar to that previously reported (13). Intake data from both 24-h recalls were used to estimate usual intake from foods. Covariates in the usual intake models included age groups, day of the week of dietary recall (weekend/weekday), interview sequence of the dietary recall (in person vs. via telephone), and dietary supplement use. Thus, we generated 3 sets of data on micronutrient intakes: *1*) naturally occurring in foods only; *2*) from all food sources (including nutrients added via enrichment and/or fortification); and *3*) from all sources (including all foods and dietary supplements).

Results

Total usual micronutrient intake from all food and supplement sources. The percentage of individuals aged ≥2 y with total usual nutrient intake, including that from foods and dietary supplements, falling below the EAR was considerable for vitamin D (70%), vitamin E (60%), calcium (38%), vitamin A (34%), vitamin C (25%), and magnesium (45%) (**Table 1**). In contrast, smaller proportions of the population had total usual intakes below the EAR (in decreasing prevalence) for vitamin B-6, zinc, folate, iron, thiamin, copper, vitamin B-12, riboflavin, niacin, and selenium. Less than 3% of the population had total usual intakes that exceeded the AI for potassium and ~35% of the population had total usual intake greater than the AI for vitamin K.

The percentage of the population that exceeded the UL (Table 1) was low for most nutrients (<3% for calcium, iron, and vitamins D, C, and E; and ~5% and 8% for vitamin A and zinc, respectively). The sole exception was niacin, in which ~10% of the population had total usual intakes that exceeded UL.

Comparisons of usual micronutrient intake from various sources. The percentage of micronutrient intake from foods, including that from naturally occurring micronutrients and micronutrients added via enrichment, varied considerably by micronutrient for individuals aged ≥2 y (**Table 2**). Large percentages of vitamins A, B-6, B-12, C, and D as well as thiamin, riboflavin, niacin, folate, and iron were from fortification and/or enrichment.

The percentage of the population with usual intakes below the EAR for many micronutrients was much higher when only naturally occurring nutrients were considered (**Fig. 1**; Table 1).

When the contribution of micronutrients added to food via enrichment and/or fortification was also considered, the percentage of the population with usual intakes below the EAR was dramatically reduced for vitamin A (74 to 45%), thiamin (51 to 6%), folate (88 to 11%), and iron (22 to 7%) compared with usual intakes from only naturally occurring nutrients. In addition, smaller reductions in the percentage of the population with usual intakes below the EAR due to enrichment and/or fortification were noted for vitamin C (46 to 37%), vitamin B-6 (22 to 12%), and zinc (15 to 11%). When the contribution of dietary supplements was also considered, the percentage of the total population (Fig. 1*A*,*B*; Table 1) with usual intakes below the EAR was further reduced for vitamin A (45 to 34%), vitamin C (37 to 25%), vitamin E (91 to 60%), and magnesium (55 to 45%).

For most micronutrients, only small changes were evident in the percentage of the total population exceeding the UL when intakes from enrichment and/or fortification were considered (Table 1). With the addition of intakes from dietary supplements, the percentage of the total population that exceeded the UL for vitamin A (2–5%), niacin (1–10%), folate (1–6%), and zinc (5–8%) further increased (Table 1).

Comparison of age groups. We also examined differences between children (2–18 y) and adults (≥19 y). Large percentages of children (**Supplemental Table 1**) with total usual intakes below the EAR were observed for vitamin D (73%), vitamin E (66%), calcium (45%), magnesium (34%), vitamin A (25%), and vitamin C (16%). Similarly, the percentage of adults with total usual intakes below the EAR (**Supplemental Table 2**) was considerable for vitamin D (68%), vitamin E (58%), magnesium (48%), vitamin A (37%), calcium (36%), and vitamin C (28%).

In children, the percentages of the population with total usual intake above the UL (Supplemental Table 1) were notable for zinc (24%), niacin (16%), vitamin A (15%), and folate (15%). Comparable data in adults were zinc (3%), niacin (94%), vitamin A (1%), and folate (3%) (Supplemental Table 2). Among children (Supplemental Table 1; **Fig. 2**) and adults (Supplemental Table 2; **Fig. 3**), substantial percentages of both populations had intakes less than the EAR when only naturally occurring sources were considered, but these percentages fell dramatically with the addition of micronutrients from enriched and/or fortified foods.

In children, the increase in the percentage of the population that exceeded the UL when including intakes from enrichment and/or fortification increased for vitamin A (0–6%), niacin (0–4%), folate (0–4%), and zinc (10–18%) (Supplemental Table 1). The addition of nutrients from dietary supplements increased the percentage of children exceeding the UL to even higher levels for vitamin A (6–15%), niacin (4–16%), folate (4–15%), and zinc (18–24%).

Discussion

Current dietary guidance recommends that individuals achieve recommended nutrient intakes from food sources while not exceeding their energy requirements (1,2). Although all foods contain some naturally occurring nutrients, naturally nutrient-dense foods such as fruits and vegetables, whole grains, milk, and lean meats are more likely to help individuals meet their nutrient needs. Other foods contain both naturally occurring nutrients and nutrients added through fortification and/or enrichment. In evaluating total usual intake, most Americans met their recommended nutrient target for the majority of vitamins and minerals evaluated; however, far fewer individuals would have done so without fortification and enrichment. Nevertheless, even after accounting for the contributions of fortification and/or enrichment and dietary supplements, considerable

TABLE 2 Mean total, naturally occurring, fortified, and enriched nutrients and percentages of daily naturally occurring, fortified, and enriched nutrients in all individuals aged ≥2 y[1]

	Total	Naturally occurring		Fortified + enriched		Enriched		Fortified	
Nutrient	*Mean ± SEM*	*Mean ± SEM*	*%*	*Mean ± SEM*	*%*	*Mean ± SEM*	*%*	*Mean ± SEM*	*%*
Thiamin, *mg/d*	1.7 ± 0.02	0.9 ± 0.01	54.9	0.7 ± 0.01	45.1	0.5 ± 0.01	31.0	0.2 ± 0.01	14.1
Riboflavin, *mg/d*	2.3 ± 0.03	1.7 ± 0.02	75.5	0.6 ± 0.01	24.5	0.3 ± 0.004	12.9	0.3 ± 0.01	11.6
Niacin, *mg/d*	24.3 ± 0.3	17.4 ± 0.2	71.6	6.9 ± 0.2	28.4	3.8 ± 0.05	15.5	3.1 ± 0.1	12.8
Folate, *μg DFE/d*	401 ± 4	200 ± 2	50.0	200 ± 3	50.0	130 ± 2	32.5	70.4 ± 2.6	17.6
Iron, *mg/d*	15.8 ± 0.1	9.8 ± 0.1	62.3	5.9 ± 0.1	37.7	3.0 ± 0.04	19.1	2.9 ± 0.1	18.6
Vitamin D, *μg/d*	4.9 ± 0.1	2.0 ± 0.1	40.8					2.9 ± 0.1	59.2
Vitamin A, *μg RAE/d*	602 ± 10	418 ± 6	69.3					185 ± 6	30.7
Vitamin E, *mg AT/d*	6.9 ± 0.1	6.5 ± 0.1	94.1					0.4 ± 0.05	5.9
Vitamin K, *μg/d*	85.4 ± 1.8	84.3 ± 1.7	98.7					1.1 ± 0.2	1.3
Vitamin C, *mg/d*	86.6 ± 1.7	73.1 ± 1.5	84.4					13.5 ± 0.6	15.6
Vitamin B-6, *mg/d*	1.9 ± 0.03	1.5 ± 0.01	81.0					0.4 ± 0.02	19.0
Vitamin B-12, *μg/d*	5.3 ± 0.1	4.4 ± 0.1	82.1					1.0 ± 0.03	17.9
Calcium, *mg/d*	940 ± 12	885 ± 12	94.1					55.3 ± 2.5	5.9
Phosphorus, *mg/d*	1327 ± 13	1296 ± 12	97.7					30.9 ± 1.5	2.3
Magnesium, *mg/d*	277 ± 3	266 ± 3	96.2					10.5 ± 0.6	3.8
Zinc, *mg/d*	12.1 ± 0.1	10.9 ± 0.1	90.2					1.2 ± 0.04	9.8
Copper, *mg/d*	1.3 ± 0.01	1.2 ± 0.01	97.0					0.04 ± 0.004	3.0
Potassium, *mg/d*	2616 ± 25	2597 ± 24	99.2					19.7 ± 1.4	0.8
Selenium, *μg/d*	107 ± 1	106 ± 1	99.3					0.7 ± 0.1	0.7

[1] Data source: NHANES 2003–2006; *n* = 16,110 using the first 24-h recall. Nutrients in foods consumed as reported in NHANES were separated into nutrients naturally occurring and those that were added; when possible, added nutrients were further separated into nutrients added via enrichment and those added via fortification. AT, α-tocopherol; DFE, dietary folate equivalents; RAE, retinol activity equivalents.

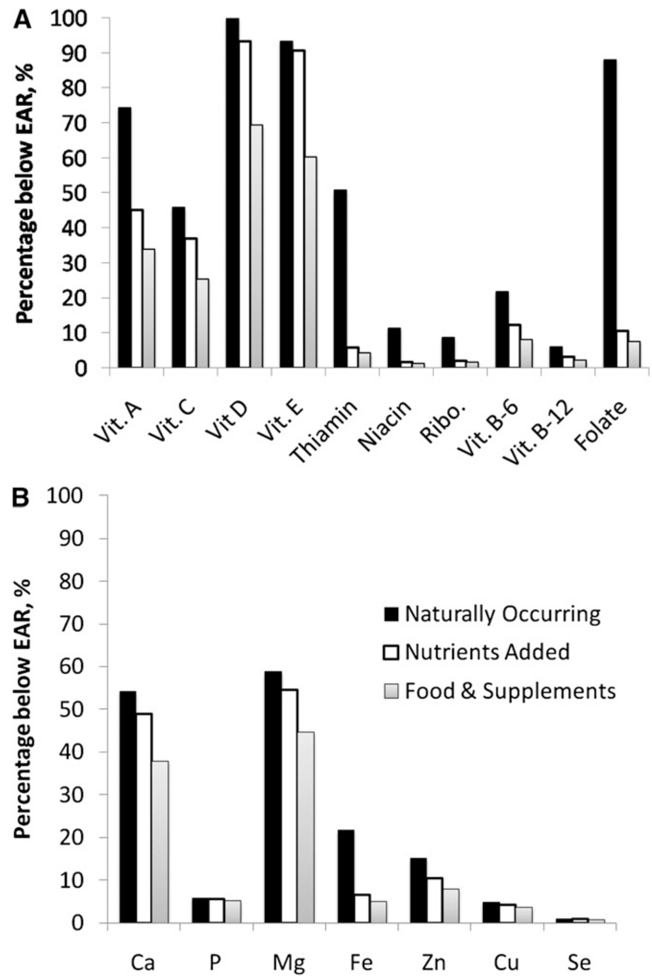

FIGURE 1 Percentage of the population with vitamin (*A*) and mineral (*B*) intakes below the EAR for individuals aged ≥2 y (data from NHANES 2003–2006; *n* = 16,110). Usual intakes from foods (naturally occurring and that from naturally occurring plus added via enrichment and/or fortification) and dietary supplements were estimated by using the National Cancer Institute method with 2 d of reported intake. EAR, estimated average requirement; Vit, vitamin; Ribo, riboflavin.

percentages of individuals aged ≥2 y had intakes that were below the EAR for calcium and vitamin D and very few consumed the recommended amount of potassium (all nutrients that the *2010 Dietary Guidelines for Americans* singled out as being of public health concern). Intakes of magnesium and vitamins A, C, E, and K were also low for a considerable percentage of the population. Our data suggest that enrichment/fortification makes a greater contribution in the U.S. compared to Europe. Flynn et al. (14) reported that nutrients naturally occurring in foods were the major source of nutrients in most European countries. This may be because the U.S. fortifies and enriches foods to a greater extent than most European countries.

In addition to a sizeable percentage of the population who appeared to have intakes below recommended levels for some micronutrients, children were also likely to exceed the UL for certain vitamins and minerals. Children were also more likely to exceed the UL in Europe as well, with retinol, zinc, and magnesium specifically mentioned (14). However, the proper application of UL values for children has been the topic of considerable debate (30). The UL is the highest level of daily intake that is likely to pose no risk of adverse health (24). As intake increases above the UL, the risk of adverse effects may increase. However, the UL is based on a risk assessment approach and it is not recommended to be used as a rigid standard or cutoff point; other factors must be considered to assess any possible adverse health effects of intakes exceeding UL values (24). More research is needed on the adverse health effects, if any, from intake levels exceeding the UL, especially because the UL for children for several nutrients, including folate, zinc, and vitamin A, were based on data with considerable limitations, including insufficient dose-response and toxicity data (31–34).

The separation of added nutrients allowed for correct assessment of certain nutrient intakes above the UL, namely magnesium and niacin, which without doing so would overestimate the percentage of the population with intakes greater than the UL. In our data, using total niacin intake for UL purposes (not eliminating the naturally occurring niacin), the estimate of the population that exceeds the UL was ~50% as compared to 10% when conducted with only added niacin intakes.

A major strength of our study is the use of a large nationally representative population-based sample of children and adults to assess the source of total usual intake of nutrients with the National Cancer Institute method. For the first time, to our knowledge, intakes of micronutrients naturally occurring in foods and intakes of nutrients contributed by enrichment and/or fortification were separately determined. One of the limitations to our study was that both dietary intake and dietary supplement intake estimates were self-reported and as such were subject to bias. Additionally, our estimates of naturally occurring nutrients and nutrients added to foods were approximate given the assumptions needed to determine these intakes.

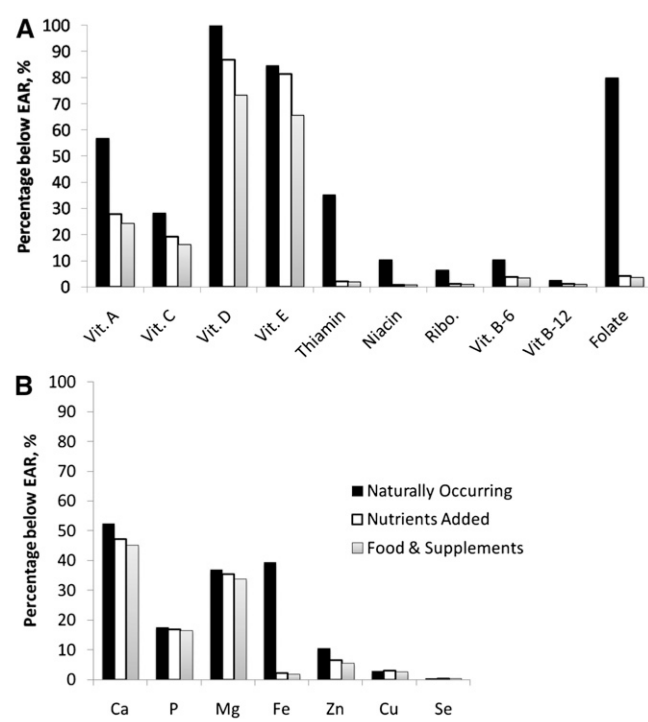

FIGURE 2 Percentage of the population with vitamin (*A*) and mineral (*B*) intakes below the EAR for individuals aged 2–18 y (data from NHANES 2003–2006; *n* = 7250). Usual intakes from foods (naturally occurring and that from naturally occurring plus added via enrichment and/or fortification) and dietary supplements were estimated by using the National Cancer Institute method with 2 d of reported intake. EAR, estimated average requirement; Vit, vitamin; Ribo, riboflavin.

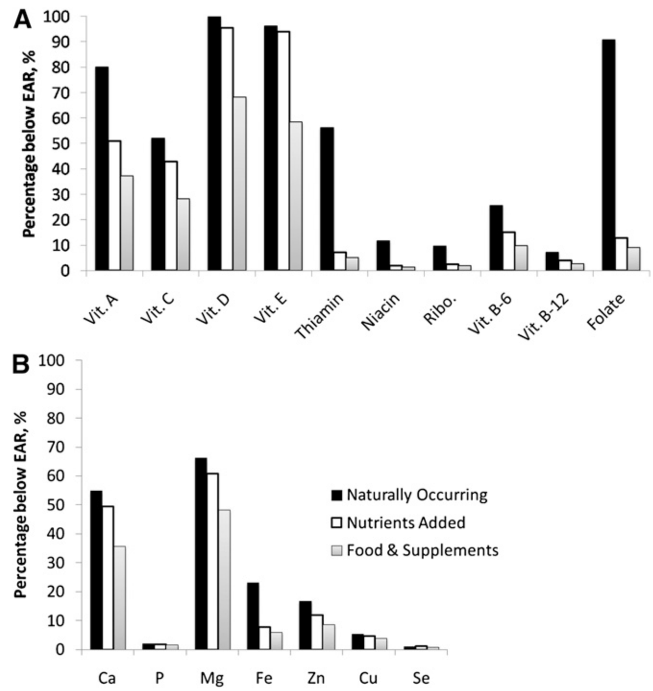

FIGURE 3 Percentage of the population with vitamin (*A*) and mineral (*B*) intakes below the below the EAR for individuals aged ≥19 y (data from NHANES 2003–2006; *n* = 8860). Usual intakes from foods (naturally occurring and that from naturally occurring plus added via enrichment and/or fortification) and dietary supplements were estimated by using the National Cancer Institute method with 2 d of reported intake. EAR, estimated average requirement; Vit, vitamin; Ribo, riboflavin.

In conclusion, most Americans met their needs for many of the micronutrients examined. However, large percentages of the population had intakes below the EAR for magnesium and vitamins A, C, D, and E, and very few individuals obtained the recommended level of potassium. Compared with intakes from naturally occurring nutrients, enrichment and/or fortification dramatically improved intakes of several key nutrients, including folate, thiamin, iron, and vitamins A and D. Dietary supplements added to the intakes of those who used them and further reduced the percentage of the population below the EAR for magnesium and vitamins A, C, and E. Intakes from enrichment and/or fortification and from dietary supplements also increased the percentage of participants whose intakes exceeded the UL for niacin, vitamin A, folate, and zinc. The percentage of individuals exceeding UL for most nutrients was relatively small. Health professionals must be aware of the contribution that enrichment and/or fortification and dietary supplements make to the nutritional status of Americans.

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V.L.F. and D.R.K. designed and analyzed data; R.L.B. and J.D. provided scientific oversight; V.L.F., D.R.K., R.L.B., and J.D. contributed to writing the manuscript. All authors read and approved the final manuscript.

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