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Original Research

Conventional foods, followed by dietary supplements and fortified foods, are the key sources of vitamin D, vitamin B6, and selenium intake in Dutch participants of the NU-AGE study

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ABSTRACT

With aging, energy needs decrease, necessitating a more nutrient-dense diet to meet nutritional needs. To bridge this gap, the use of nutrient-dense foods, fortified foods, and dietary supplements can be important. This observational study aims to describe current micronutrient intakes of Dutch elderly and to identify the contribution of nutrient-dense foods, fortified foods, and dietary supplements to the intake of micronutrients that are often inadequately consumed in Dutch elderly. Data of 245 Dutch volunteers from the NU-AGE study aged 65 to 80 years were used. Dietary intake was assessed by means of 7-day food records, and dietary supplement use was recorded with an additional questionnaire. Information on fortified foods was obtained from the Dutch Food Composition Table 2011. Nutrient density of foods was evaluated using the Nutrient Rich Food 9.3 score. The percentages of participants not meeting their average requirement were high for vitamin D (99%), selenium (41%), and vitamin B6 (54%) based on conventional foods and also when taking into account fortified foods (98%, 41%, and 27%, respectively) and vitamin and mineral supplements (87%, 36%, and 20%, respectively). Conventional foods were the main source of vitamin D, vitamin B6, and selenium intake (42%, 45%, and 82%, respectively), followed by vitamin and mineral supplements (41%, 44%, and 18%) and fortified foods (17%, 11%, and 1%). Foods with the highest nutrient density contributed most to total vitamin B6 intake only. To optimize nutrient intakes of elderly, combinations of natural food sources, fortified foods, and dietary supplements should be considered.

Abbreviations: AR, average requirement; BMI, body mass index; DNFCS, Dutch National Food Consumption Survey; ILSI Europe, European branch of the International Life Sciences Institute; LIM3, 3 nutrients to limit; MDV, maximum daily value; MVMM, multivitamin multimineral; NEVO, *Nederlands Voedingsstoffenbestand*; NR9, 9 nutrients to encourage; NRF9.3, Nutrient Rich Food 9.3; RDV, recommended daily value; UL, upper intake level.

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1. Introduction

Similar to several other developed regions of the world, the European population is aging rapidly. It is expected that approximately 30% of the European population will be 65 years or older by the year 2050 [1]. With aging, energy needs decrease while micronutrient requirements remain or increase, necessitating a more nutrient-dense diet to meet nutritional needs [2]. Inadequate nutrient intake may cause chronic metabolic disruption, including mitochondrial decay, resulting in acceleration of various degenerative diseases [3]. The prevalence of malnutrition and undernutrition is relatively high in both institutionalized (40%-65%) and noninstitutionalized elderly (5%-10%) [2]. In Europe, more than 20% of the people aged 65 years and older have inadequate intakes of vitamin D, folate, calcium, selenium, and iodine [4] and intakes of vitamin D, calcium, selenium, magnesium, thiamine, and riboflavin are of possible public health concern [5].

These findings are in line with EURRECA outcomes for priority nutrients. EURRECA was an EU 6th Framework Program–funded Network of Excellence, aimed to align the micronutrient recommendations in Europe. EURRECA identified 10 priority micronutrients for elderly (vitamin D, folate, vitamin B12, vitamin C, iron, calcium, zinc, selenium, iodine, and copper) based on heterogeneity in current recommendations, amount of new evidence, and importance for public health [4].

Sources of micronutrients include conventional foods, fortified dietary sources, and vitamin and mineral supplements. The intake of micronutrients can be limited resulting in nutrient inadequacies or deficiencies in the population. Over the last few decades, the consumption of nutrient-rich conventional foods (eg, whole grains, vegetables, and low-fat dairy products) has been partially shifted toward the consumption of nutrient-poor but, at the same time, energy-dense foods (ie, food with a high content of added sugar or solid fats) [6]. This shift in food consumption patterns could be considered as another important factor of the observed insufficient dietary intakes of micronutrients.

Widespread nutrient intake shortfalls and associated deficiencies can be prevented or improved not only by means of nutritional advice on consumption patterns but also by using fortified foods [7]. Fortification is the process of adding nutrients or nonnutrient bioactive components to foods [7]. Food fortification could be considered a public health strategy to enhance nutrient intakes of a population. In addition, dietary supplements can effectively counteract inadequate nutrient intakes and its consequences [3]. Besides estimating inadequate nutrient intakes, it is also important to take into account the possibility of excessive nutrient intakes as the availability of food fortification and dietary supplement intake increases [8].

This study aimed to describe current dietary intakes compared to nutritional requirements in Dutch elderly who were part of a cohort study and to explore which component—for example, conventional foods, fortified foods, or dietary supplements—is the main contributor to total dietary intakes of elderly. Because not much is known on how to classify conventional foods consumed by elderly based on their nutrient content, this study additionally aimed to explore if a concept of nutrient density can be used when studying the contribution of nutrient-dense foods to total dietary intakes.

We hypothesized that, by knowing how conventional foods, fortified foods, or dietary supplements differ in their contribution to total dietary intakes, dietary advices can be targeted toward bridging the gap between dietary intakes and nutritional needs in elderly. Therefore, the objectives of this present study were (1) to estimate dietary intakes from conventional foods, fortified foods, and dietary supplements; (2) to compare these intakes to nutritional requirements of the elderly; and (3) to explore the use of a nutrient density score in this respect.

2. Methods and materials

2.1. *Study design and population*

The present study was commissioned by the Nutrient Intake Optimisation Task Force of the European branch of the International Life Sciences Institute (ILSI Europe). Baseline data from Dutch NU-AGE participants were used. The NU-AGE study is a dietary intervention study among volunteers aged 65 years and older living in the Netherlands, the United Kingdom, Italy, Poland, and France [9] that focuses on the effect of nutrition on inflammaging, that is, chronic low-grade inflammation, and its consequences on the aging process [10]. The NU-AGE dietary intervention study is a 1-year randomized, single-blind, controlled, parallel trial consisting of a control group and a diet group. The dietary intervention is specifically adapted to the nutritional needs of elderly and is described in detail elsewhere [9].

A total of 252 apparently healthy and independently living men and women, aged 65 to 80 years, were recruited from the Dutch city of Wageningen and surroundings. Exclusion criteria were overt diseases, history of severe heart disease, organ failure, insulin-dependent diabetes mellitus, chronic use of corticosteroids or recent use of antibiotics, undernourishment (body mass index [BMI], <18.5 kg/m^2), and frailty. A screening questionnaire was used to verify current health, medical history, and medication use. The presence of frailty was assessed with a test described by Fried et al [11]. The NU-AGE study has been approved by the Medical Ethical Committee from Wageningen University (NL37818.081.11), and all participants provided written informed consent. The baseline examinations started in April 2012 and continued until March 2013. Participants were visited by trained dieticians once to complete dietary and supplement intake data. Participants completed a questionnaire to collect information on lifestyle, social and economic status, food preferences, and a supplement questionnaire. In the present study, we

Table 1 – Recommended and MDVs for selected nutrients used in the NRF9.3 score

Nutrient	RDV [a, b]	MDV [a, b]
Nutrient-rich components		
Protein (g)	57 [23]	
Dietary fiber (g)	25 [22]	
Vitamin A (μg)	800 [21]	
Vitamin C (mg)	80 [21]	
Vitamin E (mg)	12 [21]	
Calcium (mg)	800 [21]	
Iron (mg)	14 [21]	
Magnesium (mg)	375 [21]	
Potassium (mg)	2000 [21]	
Nutrients to limit		
Saturated fat (g)		20 [24]
Sugar (g)		90 [24]
Sodium (mg)		2400 [24]

[a] Based on an intake of 8400 kJ/d.
[b] Recommended daily allowances as set by the European Union [21] and the labeling reference intake values as set by the European Food Safety Authority [22] were used.

excluded participants who had not completed the supplement questionnaire (n = 7), resulting in a population for analysis of 245 participants.

2.2. *Dietary intake assessment*

2.2.1. *Micronutrient intake from foods*

Usual dietary intake was assessed by means of estimated food records [12] that were kept for 7 consecutive days. Participants received both verbal and written instructions to keep prestructured food records and were trained in advance on the description of foods, portion sizes, and food preparation methods to obtain complete and accurate food records. The food record included 8 meal occasions per day: before breakfast, breakfast, morning snacks, lunch, afternoon snacks, evening meal, evening snacks, and night snacks. Portion sizes were reported in household measures, based on pictures or measured in grams or milliliters. The consumed foods were coded according to standardized coding procedures at the Department of Nutrition and Health from Wageningen University and converted to energy and micronutrient intake (mean per day) by use of the Dutch food composition table *Nederlands Voedingsstoffenbestand* (NEVO) 2011 [13]. This table was also used to create food groups and to classify foods as fortified if at least 1 micronutrient was added to the food, for example, fortified spreads, milk drinks, and juices. No distinction was made between mandatory and voluntary fortified foods. Foods without any fortification were classified as conventional foods.

2.2.2. *Micronutrient intake from dietary supplements*

Participants completed an additional questionnaire at home in which they indicated the use of predefined dietary supplements, that is, multivitamin multimineral (MVMM), iron, vitamin D, vitamin B complex, and folic acid supplements. For each supplement, the frequency was recorded in times per day, week, or month. In addition, the amount of tablets or drops, type, brand, and name were recorded for each supplement. The reported brand and name of the supplements were used to further specify the type of supplements (eg, vitamin B12 supplement vs vitamin B complex supplement). The nutrient content of the supplements was based on the product label information obtained from the manufacturer or corresponding Web site. The average daily nutrient intake from supplements was calculated per participant by multiplying the frequency by the average amount of tablets per day times the nutrient content per supplement and added to the average daily nutrient intake from foods.

2.2.3. *Micronutrient intake from nutrient-dense foods*

Another way to look at sources of micronutrients is to study foods with a high nutrient density [14]. Nutrient density can be defined as the ratio of the nutrient composition of a food to the nutrient requirements [15], although at the moment, there is no consensus on how best to define nutrient density [16]. One of the possible indices to define nutrient density is the Nutrient Rich Food 9.3 (NRF9.3) score as proposed by Drewnowski et al [15]. This score is able to distinguish between foods and diets that are lower energy dense and more nutrient rich [17], and it can provide a clear measure of the nutrient density of overall diets [18]. Furthermore, it has been shown to explain the highest percentage of variation in the Healthy Eating Index [19], and it has been shown to correlate very well with the Dutch Healthy Diet Indicator [20], a diet score to rank individuals according to their adherence to the Dutch dietary guidelines for a healthy diet. These features make the NRF9.3 a suitable tool to study the contribution of naturally nutrient-dense foods to adequate nutrient intake levels. The NRF9.3 score contains 9 nutrients to encourage (NR9; protein, dietary fiber, vitamin A, vitamin C, vitamin E, calcium, magnesium, iron, and potassium) and 3 nutrients to limit (LIM3; saturated fat, added sugar, and sodium). Because only limited data on added sugar were available, total sugar was used instead. To calculate the nutrient density of foods, firstly for each food item, the nutrient contents were calculated per 420 kJ resulting in a nutrient content per food item in 420-kJ edible portion. Second, for each participant, the nutrient content of all consumed food items was divided by the corresponding recommended daily values (RDVs) [21–23] or maximum daily values (MDVs) [24] (Table 1) and multiplied by 100, resulting in a nutrient score for each nutrient included in the algorithms below. These nutrient scores were capped at 100% avoiding the possibility of a food item with high amounts of a single nutrient to contain more than 100% of the RDV. Third, the NRF9.3 scores were calculated by subtracting the LIM3 scores from the NRF9 scores. Table 2 lists the mean NR9, LIM3, and NRF9.3 scores per food group of 1107 consumed food items. Foods with a higher NRF9.3 score have a higher nutrient density per 420 kJ and were considered more nutrient dense than foods with a low NRF9.3 score. To distinguish between conventional foods with a low, middle, and high nutrient density, food items were ranked upon their NRF9.3 score and divided into tertiles of nutrient density: (1) low (NRF9.3 scores −116.7 [eg, bouillon, gravy] to 9.3 [eg, nougat, gingerbread]), (2) middle (NRF9.3 scores 9.4 [eg, rusk, refined bread] to 42.5 [eg, medium-fat cheese, soup with vegetables]), and (3) high (NRF9.3 scores 42.5 [eg, low-fat chocolate milk, low-fat minced meat] to 574.8 [eg, canned or fresh spinach, turnip greens]).

1. $NR9_{420kJ}$	$\sum_{I=1\text{-}9}$ $(\text{Nutrient}_i/\text{RDV}_i) * 100$	Nutrient_i: content of beneficial nutrients protein, dietary fiber, vitamin A, vitamin C, vitamin E, calcium, magnesium, iron, and potassium in 420-kJ edible portion; RDV_i: RDVs for nutrient_i
2. $LIM3_{420kJ}$	$\sum_{I=1\text{-}9}$ $(\text{Nutrient}_i/\text{MDV}_i) * 100$	Nutrient_i: content of limiting nutrients saturated fat, total sugar, and sodium in 420-kJ edible portion; MDV_i: MDVs for nutrient_i
3. $NRF9.3_{420kJ}$	$NR9_{420kJ} - LIM3_{420kJ}$	Difference between sums

2.2.4. *Contribution of conventional foods, fortified foods, and dietary supplements*

The relative contribution of nutrient-dense conventional foods, fortified foods, and dietary supplements to the total nutrient intake was calculated as the proportion of intakes from the different components at the group level and was expressed as percentages. For those micronutrients for which intake was inadequate in more than 20% of the study population, we also calculated the contribution of specific food groups to total intake. This was done by taking the ratio of the nutrient content per food group to the total nutrient intake.

2.2.5. *Comparison to dietary reference values*

Intakes of nutrients identified to require special attention in elderly according to EURRECA [25] and a recent systematic review on inadequate intakes among community-dwelling elderly in Western countries [5], that is, vitamin D, folate, vitamin B6, vitamin B12, selenium, iron, calcium, magnesium, zinc, iodine, and copper, were compared to their dietary reference values. The average requirement (AR) from the European Food Safety Authority [25] was used as reference value for the comparison of most nutrients, as these were also the basis for calculating the NRF9.3 score. The AR represents the average daily nutrient intake level that meets the requirement of half of healthy individuals within a group. For vitamin D, we used the AR from the Health Council of the Netherlands [27], as it was the most up to date at the moment of the study [28]. To assess adequacy of individual nutrient intakes, the mean individual intakes were compared with the AR. The prevalence of inadequate intakes was calculated using the AR cut-point method by taking the proportion of participants with a mean intake below the AR. For magnesium, for which no European AR was set, a quantitative approach was used to estimate the prevalence of inadequacy, that is, a low estimated prevalence if mean population intake was well above the adequate intake. The prevalence of usual intakes above the tolerable upper intake level (UL) was based on comparisons of mean population intakes with European ULs [29]. For all comparisons, European sex- and age-specific ARs and ULs were used.

2.3. *Statistical analyses*

Total nutrient intakes from foods and dietary supplements were calculated as means and SDs. Baseline characteristics of participants were compared between men and women using analysis of variance for continuous variables and the χ^2 statistics for

Table 2 – Nutrient-rich scores, limited nutrient scores, and NRF9.3 per 420 kJ on food group level of consumed foods (n = 1107 foods)

Food group [a]	No. of food items	NR9 [b]	LIM3 [b]	NRF9.3 [b]
Vegetables	130	249.8	17.2	232.6
Legumes	8	83.0	4.7	78.3
Fruits	74	88.7	23.4	65.3
Eggs	7	79.7	15.5	64.2
Alcoholic and nonalcoholic drinks	69	52.3	6.7	50.8
Potatoes	19	53.1	3.6	49.5
Fish	57	60.5	18.6	41.9
Soups	21	97.3	58.8	38.5
Milk and milk products	87	59.7	24.8	34.9
Mixed dishes	36	49.4	16.3	33.1
Meat, meat products, and poultry	157	55.7	23.4	32.3
Nuts, seeds, and snacks	60	37.4	13.1	24.3
Cereal products and binding agents	38	25.7	2.8	22.9
Savory sandwich filling	6	33.8	11.5	22.3
Cheese	48	55.8	36.1	19.7
Bread	73	31.2	11.4	19.8
Fats, oils, savory sauces	61	29.7	22.8	6.9
Pastry, cake, and biscuits	83	19.0	19.9	−0.9
Sugar, confectionary, sweets	65	17.8	25.5	−7.7
Soy and vegetarian products	8	46.7	91.4	−44.7

For Dutch elderly participants in NU-AGE study (n = 245).
[a] Food groups are based on the Dutch food composition table NEVO 2011 [13].
[b] Values are expressed as means per 420 kJ of a food group of consumed foods (n = 1107 foods).

Table 3 – Baseline characteristics

Characteristic	Total population (n = 245)	Men (n = 111)	Women (n = 134)
Age (y)	70.9 ± 4.0	70.9 ± 4.3	71.0 ± 3.9
BMI (kg/m^2) *	26.0 ± 3.6	26.7 ± 3.6	25.5 ± 3.6
Education (y) *	12.2 ± 3.8	12.7 ± 3.8	11.7 ± 3.6
Smoking status, n (% of total) *			
Never	126 (50)	44 (39)	82 (59)
Former	118 (47)	65 (57)	53 (38)
Current	8 (3)	4 (4)	4 (3)
Macronutrient intakes			
Energy (kJ) *	8030.4 ± 1755.6	8820 ± 1999.2	7375.2 ± 1176
Protein (g)	76.3 ± 16.0	82.5 ± 17.0	71.2 ± 13.1
Protein (EN%)	16.1 ± 2.4	15.9 ± 2.2	16.3 ± 2.5
Fat (g) *	73.1 ± 19.9	78.7 ± 23.0	68.4 ± 15.5
Fat (EN%) *	34.3 ± 5.0	33.5 ± 4.5	35.0 ± 5.3
Carbohydrates (g) *	202 ± 54.4	222 ± 61.8	185 ± 40.2
Carbohydrates (EN%)	42.1 ± 5.9	42.2 ± 5.8	42.0 ± 6.0
Micronutrient intakes			
Iron (mg) *	10.9 ± 2.48	11.6 ± 2.80	10.31 ± 2.00
Magnesium (mg) *	335 ± 78.1	354 ± 93.5	320 ± 58.7
Zinc (mg) *	9.91 ± 2.32	10.7 ± 2.55	9.29 ± 1.91
Iodine (mg) *	164 ± 58.6	179 ± 49.9	151 ± 62.4
Calcium (mg)	969 ± 310	980 ± 361	960 ± 261
Copper (mg) *	1.18 ± 0.32	1.24 ± 0.38	1.14 ± 0.26
Selenium (μg) *	44.5 ± 12.8	47.29 ± 12.63	42.11 ± 12.47
Vitamin B6 (μg) *	1.63 ± 0.52	1.77 ± 0.62	1.51 ± 0.38
Vitamin B12 (mg) *	5.00 ± 2.68	5.39 ± 3.06	4.68 ± 2.27
Folate (μg)	256 ± 71.5	259 ± 78.11	253 ± 65.65
Vitamin D (μg) *	3.56 ± 2.09	4.09 ± 2.51	3.12 ± 1.55
Use of dietary supplements			
Any supplements, n (% of total) *	106 (43)	29 (26)	77 (57)
MVMM, n (% of total)	59 (24)	22 (20)	37 (28)
Vitamin D, n (% of total)	24 (10)	2 (2)	22 (16)
Calcium, n (% of total) *	6 (2)	0 (0)	8 (6)
Calcium/vitamin D complex, n (% of total)	13 (5)	3 (3)	10 (8)
Vitamin B12, n (% of total)	1 (<1)	0 (0)	1 (1)
Vitamin B complex, n (% of total)	7 (3)	0 (0)	7 (5)
Folic acid, n (% of total)	6 (2)	0 (0)	6 (5)
Iron, n (% of total) *	1 (<1)	1 (1)	0 (0)

For Dutch elderly participants in NU-AGE study (n = 245).
Values are presented as means ± SD per day, number (percentage for EN% per day), and amount of people (% of total).
Abbreviation: EN%, energy percentage.
* Statistical significant differences between men and women ($P < .05$).

categorical variables. All statistical analyses were performed using SAS software version 9.2 (SAS Institute, Inc, Cary, NC, USA).

3. Results

General characteristics of the study population are presented in Table 3. The population's mean age was 70.9 ± 4.0 years. Compared to women, men tended to have a higher BMI; were slightly higher educated; were more likely to have ever smoked; and had higher absolute energy, protein, fat, carbohydrate, and micronutrient intakes. Macronutrient intakes expressed as percentage of total energy intake were similar between men and women. Of the total population, 43% used dietary supplements, of which MVMMs were most frequently used (24%), followed by vitamin D supplements (10%). Compared to men, the percentage of supplement users was higher in women (57% vs 26%), particularly for vitamin D supplements (16% vs 2%).

Based on the intake of conventional foods only, 99% of participants did not meet their AR of vitamin D. Based on the intake of conventional foods plus fortified foods, still 98% did not meet their AR. Taking into account foods plus the intake from vitamin and mineral supplements, 87% did not meet their AR, as shown in Table 4. For selenium and vitamin B6, based on the intake conventional foods, 41% and 54% did not meet their AR. These percentages of inadequate intakes decreased to 36% and 20% when taking into account the intake from fortified foods and vitamin and mineral supplements. Other nutrients studied showed no or smaller percentages of inadequate intakes when including conventional foods, fortified foods, and dietary supplements (folate 17%, copper 8%, iodine 7%, calcium 6%, zinc 5%, vitamin B12 2%, and 0% for iron and magnesium). No nutrient intakes reached levels above the UL.

The contributions of dietary supplements, fortified foods, and conventional foods to total nutrient intakes are presented in Fig. 1. Almost half of the total vitamin D and vitamin B6 and more than half of total selenium intake came from

Table 4 – Usual nutrient intakes from conventional foods, fortified foods, and dietary supplements compared to dietary reference values

Nutrient	Nutrient intake [a]	AR	Percentages of participants with intakes below AR	UL	Percentages of participants with intakes above UL
Vitamin D (μg/d)		10 μg [27]		100 μg [29]	
Conventional foods	2.49 ± 1.91		99.2%		
Fortified foods	1.06 ± 0.95				
All foods	3.56 ± 3.09		98.4%		0%
Supplements	2.47 ± 6.19				
Foods + supplements	6.04 ± 6.59		86.5%		0%
Selenium (μg/d)		40 μg [26]		300 μg [29]	
Conventional foods	44.2 ± 12.8		41.2%		
Fortified foods	0.22 ± 0.53				
All foods	44.5 ± 12.8		41.2%		0%
Supplements	9.47 ± 31.38				
Foods + supplements	53.9 ± 33.8		35.9%		0.4%
Vitamin B6 (μg/d)		1.3 mg [26]		25 mg [29]	
Conventional foods	1.34 ± 0.32		53.5%		
Fortified foods	0.29 ± 0.39				
All foods	1.63 ± 0.52		26.5%		0%
Supplements	1.21 ± 5.71				
Foods + supplements	2.83 ± 5.73		20.0%		0.8%
Folate (μg/d)		200 μg [26]		1000 μg [29]	
Conventional foods	252.7 ± 70.7		24.1%		
Fortified foods	3.29 ± 9.32				
All foods	256.0 ± 71.5		22.9%		0%
Supplements	60.38 ± 155.78				
Foods + supplements	316.7 ± 170.5		16.7%		1.2%
Copper (mg/d)		0.8 mg [26]		5 mg [29]	
Conventional foods	1.17 ± 0.32		8.9%		
Fortified foods	0.01 ± 0.03				
All foods	1.18 ± 0.32		7.8%		0%
Supplements	0.18 ± 0.65				
Foods + supplements	1.36 ± 0.72		7.8%		0.8%
Iodine (mg/d)		100 μg [26]		600 μg [29]	
Conventional foods	162.7 ± 58.5		8.6%		0.4%
Fortified foods	0.97 ± 3.04				
All foods	163.7 ± 58.6		7.8%		0%
Supplements	15.06 ± 55.96				
Foods + supplements	178.7 ± 81.2		6.5%		0.8%
Calcium (mg/d)		550 mg [26]		2500 mg [29]	
Conventional foods	936.4 ± 304.4		7.8%		
Fortified foods	32.7 ± 69.9				
All foods	969.2 ± 309.9		6.1%		0%
Supplements	56.54 ± 196.24				
Foods + supplements	1026.3 ± 370.8		5.7%		0.4%
Zinc (mg/d)		7.55 mg men, 5.5 mg women [26]		45 mg [29]	
Conventional foods	9.84 ± 2.34		5.3%		
Fortified foods	0.07 ± 0.16				
All foods	9.91 ± 2.32		4.9%		0%
Supplements	1.74 ± 5.96				
Foods + supplements	11.7 ± 6.2		4.5%		0.4%
Vitamin B12 (mg/d)		2.0 μg [26]		N/A [b]	
Conventional foods	4.75 ± 2.67		4.1%		
Fortified foods	0.25 ± 0.32				
All foods	5.00 ± 2.68		3.3%		0%
Supplements	4.53 ± 19.92				
Foods + supplements	9.53 ± 20.1		2.0%		N/A
Iron (mg/d)		7 μg men, 6 μg women [26]		75 mg [40]	
Conventional foods	10.7 ± 2.4		1.2%		
Fortified foods	0.21 ± 0.89				
All foods	10.9 ± 2.5		1.2%		0%
Supplements	1.50 ± 5.79				
Foods + supplements	12.4 ± 6.1		0%		0.4%

Table 4 (*continued*)

Nutrient	Nutrient intake [a]	AR	Percentages of participants with intakes below AR	UL	Percentages of participants with intakes above UL
Magnesium (mg/d)		150-500 mg [26]		250 mg [26] [c]	
Conventional foods	329.8 ± 76.3		0.4%		
Fortified foods	5.40 ± 14.38				
All foods	335.2 ± 78.1		0%		0.0%
Supplements	39.55 ± 55.96				
Foods + supplements	375.5 ± 251.8		0%		0.0%

For Dutch elderly participants in NU-AGE study (n = 245).
Recommended daily allowances as set by European Union [21], the labeling reference intakes values as set by the European Food Safety Authority [22–24], and ARs and tolerable ULs as set by the Health Council of the Netherlands [27,40] and the European Union were used [26,29,41].
[a] Values are expressed as means ± SD.
[b] For vitamin B12, no UL of safe intakes was established.
[c] The UL for magnesium does not include magnesium normally present in foods and beverages.

conventional foods (42%, 45%, and 82%, respectively), followed by dietary supplements (41%, 44%, and 18%, respectively) and fortified foods (17%, 11%, and 1%, respectively).

When comparing the contribution of low, middle and high nutrient dense foods to total nutrient intakes, high nutrient-dense foods contributed most to the total vitamin B6 intake (23%), followed by the middle nutrient-dense group (19%) (Fig. 1). For vitamin D and selenium, the middle NRF9.3 group contributed most to total vitamin D and selenium intake (18% and 39%). When comparing the contribution of the different nutrient density groups to the nutrient intake from conventional foods only, half of this intake came from the highest NRF9.3 group for vitamin B6 (50%), whereas half of the intakes from vitamin D and selenium came from the middle NRF9.3 group (44% and 47%). For all nutrients, the lowest NRF9.3 group contributed least to both total nutrient intake as well as the nutrient intake from conventional foods only.

Of the food groups, fish contributed most to vitamin D intake, followed by eggs, meat (products), and poultry (Fig. 2). Fish, meat (products), and poultry and bread contributed most to the intake of selenium. For vitamin B6, meat (products) and poultry, followed by potatoes, and (non)alcoholic drinks contributed most to the intake.

4. Discussion

In this cross-sectional analysis of 245 Dutch elderly persons based on the consumption of conventional foods, the percentage of inadequate intake was high for vitamin D and moderate for vitamin B6 and selenium. Including the consumption of fortified foods and dietary supplements substantially lowered the percentage of nutrient inadequacy for vitamin B6, but not for

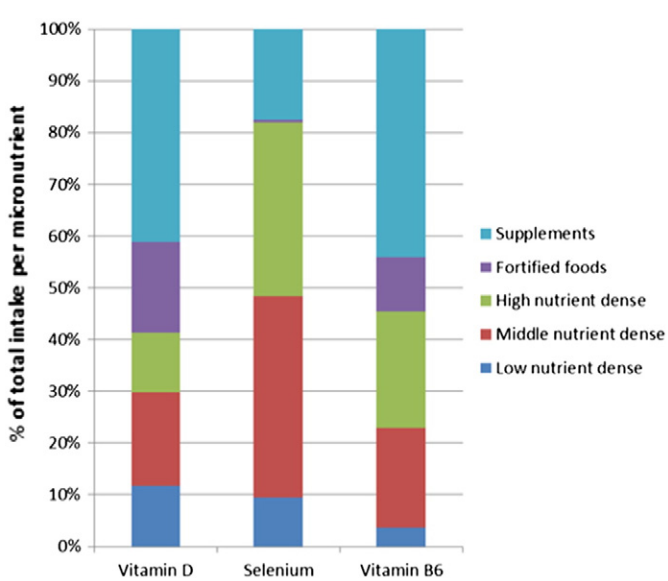

Fig. 1 – Contribution of dietary supplements, fortified foods, and conventional foods categorized into nutrient density scores to the total nutrient intake, for Dutch elderly participants in NU-AGE study (n = 245). Values are presented as percentage of total intake per micronutrient.

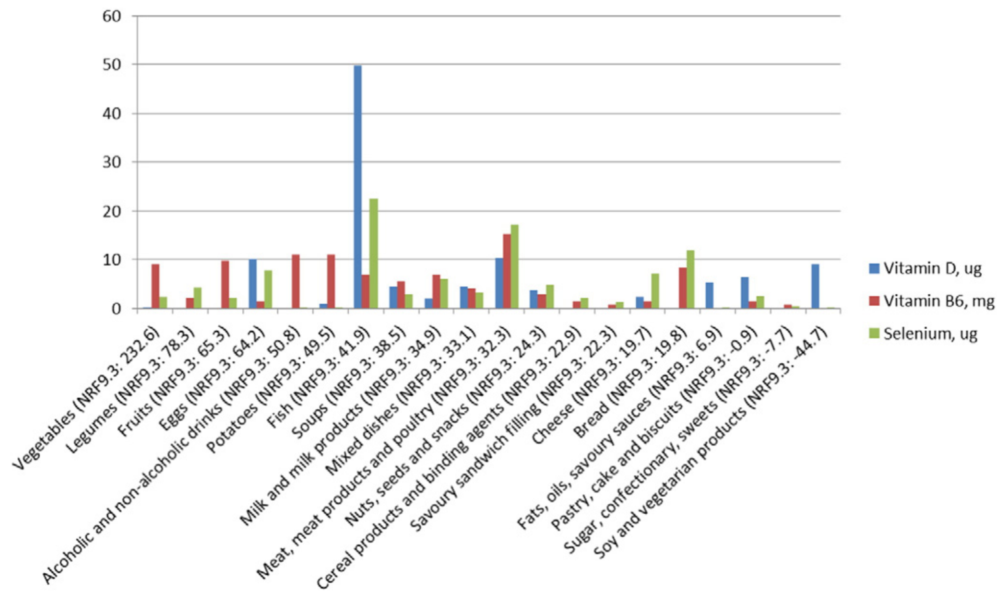

Fig. 2 – Food groups sorted by their NRF9.3 score (high NRF9.3 on the left to low NRF9.3 on the right) and their relative contribution to nutrient intakes (vitamin D, vitamin B6 and selenium), for Dutch elderly participants in NU-AGE study (n = 245). Values are presented as percentage of total intake of each micronutrient.

vitamin D and selenium without affecting risk of excessive intakes. High nutrient-dense foods contributed most to total vitamin B6 intake, whereas middle nutrient-dense foods contributed most to total vitamin D and selenium intake.

Our finding of a high percentage of inadequate vitamin D intake is in line with other dietary intake surveys among Dutch (the Dutch National Food Consumption Survey [DNFCS] 2010-2012) and Irish elderly, showing percentages of inadequate vitamin D intake ranging from 81% to 100% [30,31] also when including fortified foods and dietary supplements. For selenium, the mean prevalence of inadequate intake in European elderly was greater than 20%, which mirrored our study (36%) [4]. The low prevalence of inadequate intakes observed for zinc, vitamin B12, and iron is in line with previous Dutch [31] and European findings [4,31], showing a mean prevalence of inadequacy less than 11% for these nutrients. In contrast, the proportion of elderly with inadequate vitamin B6 intakes was reported as being less than 15% in the Netherlands in a previous study [31], compared to 20% in the present study. In addition, a higher prevalence of inadequate intakes in European elderly was observed for copper (11%-20%), folate, calcium, and iodine (all > 20%) [4]. As in the present study, the European survey did not find substantial percentages of excessive intakes of vitamin D, selenium, and vitamin B6 [32]. The observed natural main sources of vitamin D (eg, fish, eggs, and meat) and fortified foods are in line with other studies in Europe [33] as well as the main sources of selenium (eg, fish, meat and cereals) [31,32] and vitamin B6 (eg, meat, potatoes) [31].

The difference in the prevalence of inadequate intakes between the present study and previous European studies could be explained by differences in study populations and methodological differences.

First, the NU-AGE study aimed to recruit independently living, apparently healthy elderly, which resulted in a generally healthy (50% never smoked) and highly educated (12.2 years of education) study population. This could have resulted in better dietary intakes and lower percentages of inadequate intakes compared to other community-dwelling Dutch [31] and European populations [4]. Second, supplement intake or food fortification was not taken into account in the European study [4], possibly overestimating the true percentages of inadequate intakes compared to the present study population. Third, different dietary requirements have been used as cutoff values to define nutrient adequacy. For example, for calcium, the European study used guidelines from the Institute of Medicine for North American populations (Estimated Average Requirement (EAR) 800 mg) [28], compared to the EAR from the European Commission for European populations used in the present study (EAR 550 mg) [26]. If we would have used the Institute of Medicine guidelines, the prevalence of inadequacy for calcium would have been higher, namely, 64% instead of 8% in the current study.

With respect to the relative contribution of fortified foods to total nutrient intakes, our findings are comparable to the DNFCS 2010-2012, showing the smallest contribution for selenium and a highest contribution for vitamin D and vitamin B6 (between 15% and 8% in DNFCS 2010-2012 [31] and 19% and 12% in the current study, respectively). In contrast, the Irish ingest 3 times as much vitamin D from fortified foods compared to participants in the present study [30]. This difference in vitamin D intake from fortified foods in the present study compared to the Irish study might be due to the fact that fortification with vitamin D is mandatory in Ireland, but not in the Netherlands [33].

To the best of our knowledge, this is the first study to estimate the contribution of high, medium, and low nutrient-dense foods to total nutrient intakes. With this approach, we aimed to identify which kind of foods substantially contribute to total nutrient intakes and which foods should be encouraged in elderly people to improve their nutritional intakes to meet nutritional requirements. Using the NRF9.3 score as developed by Drewnowski et al [15], the current study has shown that the contribution of nutrient-dense foods varied between the nutrients investigated. A first explanation could be that we have divided the continuum of NRF9.3 scores in tertiles, based on the distribution of consumed foods. As the positioning of foods categories along the spectrum is arbitrary, this could have led to a ranking of food categories rather than a continuous scale [34]. A second explanation could be related to the fact the NRF9.3 does not take into account the actual frequency and amount consumption of a food. Although legumes do have a high NRF9.3 score, they do not substantially contribute to the total nutrient intake as their actual intake is relatively low. At last, the NRF9.3 algorithms include nutrients that are not specifically of interest for the elderly, resulting in poorly fitting nutrient algorithms for this study population [34]. To increase the applicability of the NRF9.3 score to diets of the elderly, it might be worthwhile to adapt the NRF9.3 score to nutrients of concern for older populations [15], such as by including vitamin D, vitamin B12, folate, and vitamin B6 and other priority micronutrients as proposed by EURRECA. In addition, more detailed nutritional information on current available fortified foods should be collected to optimize estimation of micronutrient intakes via fortified foods; in addition, the list of fortified foods should be updated regularly as new products may be fortified in the future or products may be reformulated.

A strength of the present study includes the extensive information of vitamin intakes from both foods and vitamin and mineral supplements. The food records that were used are based on actual intake. In contrast to food frequency questionnaires and 24-hour recalls, the use of food records has the advantage in older populations in that it minimizes reliance on memory, as food intake was recorded by participants at the time the foods were consumed [35]. After completion of the food records, they were extensively reviewed and checked for completeness by trained research dieticians. This method, in combination with information from the NEVO 2011 [13], allowed us to estimate comprehensively nutrient intakes from conventional foods as well as from fortified foods. Because of the detailed information solicited with the extensive supplement questionnaire (eg, name, brand, frequency, number of tablets, and label information), we were able to collect the specific nutrient contents of all the predefined dietary supplements used.

A limitation of the present study is the generalizability of our study population because the participants of the NU-AGE study had to be willing to change their dietary habits for the dietary intervention, and as such, it is very likely that particularly health-conscious people were included. In addition, our sample mainly consisted of highly educated, non-Hispanic whites, former smokers, and normal/underweight, which have all been shown to be related to a higher use of dietary supplements [36]. When extrapolating our findings, it should be taken into consideration that results of our study population probably underestimate the prevalence of inadequate micronutrient intakes in the general population and overestimate the contribution of supplements to micronutrient intake. This further highlights the importance of addressing nutrition inadequacy in the general population and of encouraging the consumption of nutrient-dense and/or fortified foods.

Another limitation of the present study concerns the estimation of nutrient adequacy based on dietary intake alone. Taking into account micronutrient bioavailability, bioaccessibility and micronutrient status would better reflect the nutrient adequacy, also capturing different changes in nutrient status for fortified foods or supplement intakes. Some supplements taken separately from food, for example, may result in a rapid increase in plasma concentrations of the supplemented nutrient, whereas consuming a food fortified with the same nutrient may have a more gradual effect on blood concentrations because of the presence of the food matrix, as has been shown for zinc [37]. For other micronutrients, such as folate, changes in serum values could be higher in food fortification than through supplementation [38].

Because the aim of food fortification is to beneficially impact population health, both the total additional intake and the quality of the nutrient or nutrients supplied must be taken into account, not just the intake of the vehicle (fortified food) alone [7]. Future studies investigating the contribution of dietary supplements, nutrient-dense foods, and fortified foods to total nutrient intakes should consider the bioavailability and bioaccessibility and include status markers indicating adequacy of intakes, as defined using the EURRECA guidelines [39].

To conclude, the intake of vitamin D was inadequate in most of this Dutch elderly population, and nutrient intakes of vitamin B6 and selenium are of concern. The inadequacy of vitamin D could be confirmed via biomarkers of vitamin D status.

Conventional foods were the main source of vitamin D, vitamin B6, and selenium intake, followed by vitamin and mineral supplements and fortified foods. Although fortified foods and vitamin and mineral supplements importantly contributed to the total intake from vitamin D and B6 intake, the use of these components did not necessarily lead to adequate intakes of nutrients that are of concern for older populations. Foods with the highest nutrient density contributed the most to total vitamin B6 intake only. To optimize nutrient intakes of elderly, combinations of conventional foods, fortified foods, and dietary supplements need to be considered.

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