Original Communication

Dietary patterns according to vitamin supplement use. A cross-sectional study in Switzerland

Editor's Choice

Pollyanna Patriota[1], Idris Guessous[2], and Pedro Marques-Vidal[3]

[1] Department of Nutrition, Institute of Health Sciences, Federal University of Triangulo Mineiro, Brazil
[2] Division of Primary Care Medicine, Department of Primary Care Medicine, Geneva University Hospitals, Geneva, Switzerland
[3] Department of Medicine, Internal Medicine, Lausanne University Hospital (CHUV), Lausanne, Switzerland

Abstract: *Background*: consumers of dietary supplements (DS) or vitamin-mineral supplements (VMS) have a better health profile than nonconsumers; whether this also applies to healthier dietary patterns has seldom been assessed. We aimed to assess the dietary intake of subjects according to their consumption of DS or VMS. *Methods*: Cross-sectional, population-based studies conducted in 2009–2012 (3773 participants, 52.4% women, 57.0 ± 10.0 years) and 2014–2017 (2536 participants, 52.4% women, 60.0 ± 10 years) in Lausanne, Switzerland. Dietary intake was assessed via a 97-item food frequency questionnaire. Nutrients, consumption of specific food groups, dietary scores, and compliance with the Swiss nutritional guidelines were compared between VMS/DS consumers and nonconsumers. *Results*: In 2009–2012, after multivariable adjustment for gender, age, body mass index, education, smoking, country of birth, sedentariness, diet and total energy intake, VMS/DS consumers had a higher score for the "Fruits & vegetables"(−0.09 ± 0.02 vs. 0.15 ± 0.05) dietary pattern and a lower score for the "Fatty & sugary" dietary pattern (0.02 ± 0.02 vs. −0.14 ± 0.04) and had a lower likelihood to comply with the guideline on total fat [odds ratio and 95 %CI: 0.72 (0.57–0.89)] than nonconsumers. In 2014–2017, after multivariable adjustment, no differences (at $p < 0.005$) were found between VMS/DS consumers and nonconsumers. *Conclusion*: VMS/DS consumers tend to have healthier dietary choices than nonconsumers. The beneficial effect of VMS and/or DS consumption is decreased, as it does not target subjects who really need them.

Keywords: dietary intake, vitamin supplements, epidemiology, dietary patterns, Switzerland

Background

Dietary supplements (DS) and vitamin-mineral supplements (VMS) are widely consumed by the general population [1, 2]. The main argument for the marketing of VMS and DS is that they complement the current diet by providing adequate amounts of the necessary nutrients [3, 4]. Further, available studies conducted in Europe [5–7] and the USA [8, 9] have suggested that subjects who consume VMS or DS have a healthier diet than subjects who do not consume VMS or DS, although the associations might be more complex [10]. Hence, the beneficial effect of VMS and/or DS consumption would be decreased, as it does not target subjects who really need them [11].

VMS or DS consumption is frequent in the Swiss population, and many DS users have misguided health beliefs regarding their positive features [12]. Subjects consuming VMS or DS have a better health profile than subjects who do not consume VMS or DS [13], but whether this finding also applies to dietary intake has not been assessed.

Hence, we aimed to verify if the people consuming supplements have healthier diets than those who do not. The hypothesis was that subjects consuming VMS or DS had a healthier dietary intake than subjects not consuming them.

Materials and methods

Participants

The CoLaus study is a population-based study assessing the clinical, biological and genetic determinants of cardiovascular disease in the city of Lausanne, Switzerland. Its aims and sampling strategy have been reported previously [14]. Briefly, all subjects living in the city of Lausanne and aged between 35 and 75 years were eligible for the study and were included in the main study if they were willing to participate and provide blood samples. Participants were excluded from this study if they 1) reported no dietary data; 2) reported extreme energy intakes (<500 and > 3500 kcal for women and < 800 and > 4000 kcal for men) [15]; 3) had missing data for any covariate, and 4) were prescribed VMS for medical reasons (i.e. calcium supplements for osteoporosis).

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Three waves of examinations were performed: the first in 2003–2006, the second in 2009–2012, and the third in 2014–2017. Each examination included an interview, a physical exam, and a blood analysis. As dietary assessment was performed only in 2009–2012 and 2014–2017, data from those two waves was used.

Ethical approval

The institutional Ethics Committee of the University of Lausanne, which afterwards became the Ethics Commission of Canton Vaud (www.cer-vd.ch) approved the baseline CoLaus study (reference 16/03, decisions of 13th January and 10th February 2003). The approval was renewed for the first (reference 33/09, decision of 23th February 2009), the second (reference 26/14, decision of 11th March 2014) and the third (reference PB_2018-00040, decision of 20th March 2018) follow-ups. The full decisions of the CER-VD can be obtained from the authors upon request. The study was performed in agreement with the Helsinki declaration and its former amendments, and in accordance with the applicable Swiss legislation (LRH 810.30, approved by the Swiss Federal Parliament on 30th of September 2011). All participants gave their signed informed consent before entering the study.

Vitamin and dietary supplements

Participants were asked to report all prescribed and over the counter medications and supplements taken during the last six months. Vitamin and mineral supplements were defined according to the Swiss compendium (https://compendium.ch/home/fr, assessed June 2017). When the supplements were not listed in the Swiss compendium, further searches on the internet were conducted. Due to the wide differences in the composition of the Swiss VMS [16] and to inaccurate reporting (i.e. reporting "multivitamins" from a producer that manufactures 6 different types of multivitamins), it was not possible to assess the amounts of vitamins and minerals consumed by the participants.

Dietary supplements were defined as any other supplement that could not be considered as a VMS, such as plant extracts not considered as phytotherapy by the Swiss compendium, cod liver oil, shark cartilage or amino acids [13, 17].

Dietary intake

Dietary intake was assessed using a self-administered, semi-quantitative FFQ which also included an estimation of the consumed portion size. This FFQ has been validated in 1995 in the Geneva population [18, 19], which is similar to our study population. Briefly, this FFQ assesses the dietary intake of the previous 4 weeks and consists of 97 different food items that account for more than 90% of the intake of calories, proteins, fat, carbohydrates, alcohol, cholesterol, vitamin D and retinol, and 85% of fiber, carotene, and iron. To our knowledge, there is no FFQ (validated or not) assessing dietary intake for the whole year in Switzerland; the other available and validated FFQ assesses the dietary intake of the previous month [20]. Hence, this FFQ provides the best dietary assessment currently available. For each item, consumption frequencies ranging from "less than once during the last 4 weeks" to "2 or more times per day" were provided, and participants indicated the average serving size (smaller, equal or bigger) compared to a reference size. The questionnaire is provided in Electronic Supplementary Material 2.

Two dietary scores were computed based on the Mediterranean diet. The first Mediterranean dietary score (designated as "Mediterranean score 1") was derived from Trichopoulou et al. [21]. The score uses consumption frequencies instead of amounts. Briefly, a value of 0 or 1 is assigned to each of seven foods using their sex-specific medians as cut-off. Participants whose consumption frequencies for "healthy" foods (vegetables, fruits, fish, cereal) were above the median were given the value of 1, while for "unhealthy" foods (meat, dairy products), consumption frequencies below the median were given the value of 1. Two other items were considered: ratio of monounsaturated to saturated fats and moderate alcohol consumption (between 5 and 25 g/day for women and 10 and 50 g/day for men). The score ranges between 0 and 8. The second Mediterranean dietary score (designated as "Mediterranean score 2") adapted to the Swiss population was computed according to Vormund et al. [22]. It used the same scoring system but considered nine types of "healthy" foods: fruits, vegetables, fish, cereal, salads, poultry, dairy products and wine. The score ranges between 0 and 9. For both scores, higher values represented a healthier diet.

In the first survey, data-driven dietary patterns were used. Contrary to dietary scores that rely on specific foods and/or nutrients, data-driven dietary patterns rely on all dietary intake information available. In this study, we used three dietary patterns as detailed in a previous publication [23]. The patterns were based on daily consumption frequencies. The 97 items were then grouped into 40 food groups, which were then assessed by principal components analysis (PCA) with varimax rotation as described [24]. The three dietary patterns were retained based on established criteria [25] such as: 1) an eigenvalue

> 1, 2) the analysis of the scree plot, and 3) the interpretability of the dietary pattern. The three dietary patterns were named based on the items with absolute factor loadings ≥ 0.300: "Meat & fries", "Fruits & Vegetables" and "Fatty & sugary".

Participants were dichotomized according to whether they followed the dietary recommendations for fruits, vegetables, meat, fish and dairy products from the Swiss Society of Nutrition [26, 27]. The recommendations were ≥ 2 fruit portions/day; ≥ 3 vegetable portions/day; ≤ 5 meat portions/week; ≥ 1 fish portion/week and ≥ 3 dairy products portions/day. In this study, we did not use portion size to compute compliance, but relied on consumption frequencies. This was done as the portion sizes recommended by the Swiss Society of Nutrition do not take into account a subject's corpulence and caloric needs [27]. As the FFQ queried about fresh and fried fish, two categories of compliance to fish consumption were considered: one included and one excluded fried fish.

For each participant, the number of guidelines complied to was computed. Two sums were computed: one used compliance to fish consumption using all types of fish preparation (i.e. including fried fish); the other used compliance to fish consumption using fresh fish only. A similar procedure was adopted regarding nutrient intake [26]. Finally, participants were categorized according to the (non)compliance to at least three guidelines (i.e. if the sum was ≥ 3).

Covariates

Smoking status (never, former, current) was self-reported. Marital status was categorized as living alone (i.e. being single, divorced and widowed) or in a couple (i.e. married or cohabiting). Educational level was categorized into four groups: university, high school, apprenticeship and mandatory. Country of birth was categorized as Switzerland, France, Portugal, Spain, Italy, Germany, and others. Physical activity was assessed by questionnaire [28] and sedentary status was defined as spending more than 90% of the daily energy in activities below moderate- and high-intensity (defined as requiring at least 4 times the basal metabolic rate) [29]. Presence of an on-going diet was assessed by a questionnaire. Diets a) to reduce weight; b) low in fat; c) low in sugar/for diabetes, and d) low in salt were considered and grouped as any diet yes/no.

Body weight and height were measured with participants barefoot and in light indoor clothes. Body weight was measured in kilograms to the nearest 100 g using a Seca® scale (Hamburg, Germany). Height was measured to the nearest 5 mm using a Seca® (Hamburg, Germany) height gauge. Body mass index (BMI) was computed and categorized into normal (<25 kg/m^2), overweight (25–29.9 kg/m^2) and obese (≥30 kg/m^2).

Statistical analysis

Statistical analyses were performed separately for each study period (2009–2012 and 2014–2017) using Stata version 15.1 for Windows (Stata Corp, College Station, Texas, USA). Descriptive results were expressed as a number of participants (percentage) for categorical variables or as the average ± standard deviation for continuous variables. Normality of the variables was tested using the "sixplot" option of Stata and by visually checking the resulting graphs. Bivariate analyses were performed using chi-square or Fisher's exact test for categorical variables and Student's t-test, analysis of variance or Kruskal-Wallis test for continuous variables.

For categorical variables, multivariate analysis was performed using logistic regression and the results were expressed as Odds ratio and 95% confidence interval. For continuous variables, multivariable analysis was conducted using analysis of variance and the results were expressed as average ± standard error. For binary outcomes, multivariate analysis was performed using logistic regression and the results were expressed as Odds ratio (95% confidence interval). For continuous variables, multivariable analysis was conducted using analysis of variance and the results were expressed as average ± standard error.

Multivariable models were adjusted on gender (male/female), age (continuous), BMI categories (normal, overweight and obese), educational level (university, high school, apprenticeship and mandatory), smoking status (never, former, current), country of birth (Switzerland, France, Portugal, Spain, Italy, Germany, other), sedentariness (yes/no), being on a diet (yes/no), total energy intake (except for macronutrients, which were expressed as % of total energy intake, and dietary guidelines, where the models did not converge) and conditions such as diabetes, hypertension and dyslipidemia.

Sensitivity analyses were conducted by 1) using inverse probability weighting to take into account excluded participants for categorical outcomes [30]; 2) testing a possible dose effect of DS and VMS and 3) using income as a confounder. For the first sensitivity analysis, a logistic regression modeling the probability of being included was performed using gender, age, BMI categories, educational levels, smoking status, country of birth, sedentariness and being on a diet as independent variables; the posterior probability of inclusion for each participant was computed and the inverse of the probability was then used as a weight in the multivariable analyses. For the second sensitivity analyses, three categories were used: nonconsumers, consumers of VMS or DS (but not both) and consumers of both VMS and DS. As no information regarding income was collected in the first follow-up, the third sensitivity

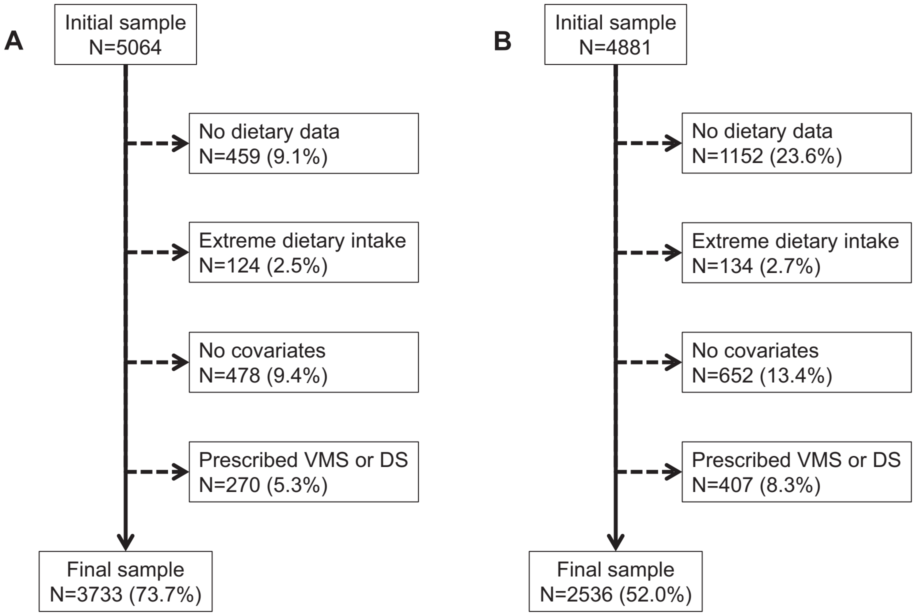

Figure 1. Selection procedure, CoLaus study, Lausanne, Switzerland, 2009–2012 (panel A) and 2014–2017 (panel B).

analysis was conducted in the second follow-up, where income data was available for 76% of the participants.

As suggested by others [31], a more conservative cut-off was used for statistical significance, which was assessed for a two-sided test with $p < 0.005$.

Results

Characteristics of participants

Of the initial 5064 participants in the first study period, 3733 (73.7%) were retained for analysis. The selection procedure is summarized in Figure 1A and the characteristics of the excluded and included participants are summarized in Electronic Supplementary Material 1, Table E1. Excluded participants were older, with a lower educational level, more frequently non-Swiss, living alone, current smokers, sedentary and obese. The characteristics of included participants according to (non)consumption of VMS/DS are summarized in ESM 1, Table E2. VMS/DS consumers were older, more frequently women, born in Switzerland, living alone, with a normal BMI or on a diet than nonconsumers.

Of the initial 4881 participants in the second study period, 2536 (52.0%) were retained for analysis. The selection procedure is summarized in Figure 1B and the characteristics of the excluded and included participants are summarized in ESM 1, Table E2. Excluded participants were older, with a lower educational level, more frequently women, non-Swiss, living alone, sedentary and overweight/obese. The characteristics of included participants according to (non)consumption of VMS/DS are summarized in ESM 1, Table E2. VMS/DS consumers were older, more frequently women, living alone and with a normal BMI than nonconsumers.

Dietary intake according to vitamin-mineral or dietary supplements

For the first period, the bivariate and multivariable analyses of dietary intake according to (non)consumption of VMS/DS are summarized in Tables 1 and 2, respectively. On bivariate analysis, VMS/DS consumers had a lower intake of total energy, polysaccharides, red and processed meat and ultra-processed foods; VMS/DS consumers also scored lower on the "Meat & fries" and the "Fatty & sugary" dietary patterns than nonconsumers and complied less to the guidelines on total fat and iron. Conversely, VMS/DS consumers had a higher intake of monosaccharides, MUFA, wholegrain, vegetables and fruits than nonconsumers; VMS/DS consumers also scored higher in the "Fruits & vegetables" dietary pattern and complied more frequently to the guidelines on fish (excluding fried) and fresh fruits & any fruit juice ≥ 2/day, and with at least three food guidelines than nonconsumers (Table 1). Most differences became non-significant (at $p < 0.005$) after multivariable adjustment, except that VMS/DS consumers scored higher for the "Fruits & vegetables" and lower for the "Fatty & sugary" dietary patterns and had a lower likelihood to comply with the guideline on total fat than nonconsumers (Table 2).

Table 1. Bivariate analysis of the dietary intake according to (non)consumption of vitamin-mineral and/or dietary supplements, CoLaus study, Lausanne, Switzerland, 2009–2012 and 2014–2017

	2009–2012			2014–2017		
	Non consumers[§]	Consumers[‡]	P-value	Non consumers §	Consumers ‡	P-value
Number of participants	3120	613		2536	2345	
Total energy intake (kcal/day)	1756 [1376–2215]	1665 [1308–2094]	0.002	1768 [1362–2201]	1667 [1309–2069]	<0.001
Macronutrients (% TEI)						
Protein						
Total	15.0 [13.4–17.1]	15.0 [13.3–17]	0.778	15.5 [13.6–17.7]	15.2 [13.4–17.1]	0.012
Vegetable	4.6 [3.9–5.4]	4.6 [3.9–5.4]	0.663	4.5 [3.8–5.2]	4.6 [3.9–5.5]	0.004
Animal	10.3 [8.4–12.7]	10.2 [8.3–12.6]	0.896	10.9 [8.7–13.3]	10.4 [8.4–12.7]	0.001
Carbohydrates						
Total	46.5 [40.5–52.4]	46.4 [40–51.6]	0.397	44.4 [38.6–50.2]	45.0 [40.1–50.9]	0.034
Monosaccharides	21.4 [16.7–27.3]	23.2 [17.8–28.1]	<0.001	20.3 [15.9–25.8]	22.3 [17.8–27.0]	<0.001
Polysaccharides	23.1 [18.5–28.3]	21.5 [17.3–26.5]	<0.001	22.2 [17.8–27.6]	21.7 [17.2–26.9]	0.066
Fat						
Total	34.2 [29.7–38.6]	34.7 [31.0–38.7]	0.008	35.8 [31.3–40.0]	35.6 [31.4–40.1]	0.931
Saturated	12.6 [10.4–14.8]	12.5 [10.6–14.8]	0.706	13.0 [10.8–15.3]	12.5 [10.6–14.9]	0.004
Monounsaturated	13.3 [11.3–15.7]	13.7 [11.8–16.4]	0.002	14.3 [12.2–16.7]	14.6 [12.3–17.0]	0.093
Polyunsaturated	4.6 [3.8–5.6]	4.7 [3.9–5.7]	0.115	4.7 [3.9–5.7]	4.8 [4.0–5.8]	0.098
Alcohol	2.1 [0.5–5.5]	1.7 [0.4–5.1]	0.024	2.4 [0.7–5.6]	1.8 [0.5–4.5]	0.003
Fibre (g/day)	13.9 [9.8–19.7]	14.2 [10.1–20.1]	0.290	13.2 [9.4–18.6]	14.4 [10.2–19.7]	0.007
Cholesterol (mg/day)	280 [205–368]	264 [198–349]	0.008	296 [217–388]	283 [206–373]	0.013
Micronutrients						
Calcium (mg/day)	925 [655–1298]	909 [669–1253]	0.619	915 [648–1271]	905 [616–1211]	0.091
Iron (mg/day)	10 [7.8–12.8]	9.7 [7.7–12.3]	0.096	10.0 [7.7–12.6]	9.7 [7.6–12.4]	0.071
Retinol (μg/day)	347 [218–592]	340 [223–618]	0.983	345 [218–587]	330 [205–511]	0.008
Carotene (μg/day)	3184 [2090–4722]	3357 [2270–5055]	0.015	3156 [2094–4781]	3330 [2196–5297]	0.118
Vitamin D (μg/day)	2.1 [1.3–3.1]	2.2 [1.4–3.3]	0.168	2.4 [1.4–3.6]	2.4 [1.5–3.6]	0.845
Food Items (g/day)						
Dairy	174 [92–270]	182 [95–274]	0.411	157 [90–260]	161 [79–257]	0.479
Red meat	40 [21–64]	34 [19–57]	<0.001	41 [23–70]	33 [17–55]	<0.001
Processed meats	9.4 [4.1–17.5]	7.1 [2.9–14.3]	<0.001	10.7 [4.5–19.3]	7.1 [2.3–16.1]	<0.001
Fish, excluding fried	23 [11–39]	24 [13–42]	0.030	27 [13–46]	28 [15–46]	0.241
Fish, all	30 [17–48]	31 [18–51]	0.272	33 [19–53]	34 [21–54]	0.521
Wholegrain	25 [4–63]	38 [12–75]	<0.001	23 [5–60]	39 [11–75]	<0.001
Vegetables	144 [96–212]	155 [108–224]	0.004	151 [101–216]	155 [107–225]	0.078
Fresh fruits	159 [75–300]	184 [92–347]	0.005	151 [73–280]	185 [98–325]	<0.001
Fresh fruits + fresh juice	194 [91–360]	217 [112–403]	0.005	185 [94–334]	226 [123–388]	<0.001
Any fruit and fruit juice	260 [130–443]	292 [161–489]	0.002	248 [134–408]	285 [158–455]	<0.001
Ultraprocessed foods	54 [16–139]	31 [9–80]	<0.001	50 [14–107]	29 [7–82]	<0.001
Ingredients	12.3 [7.0–22.2]	10.7 [7.0 – 20.0]	0.006	12.0 [7.0–20.5]	11.5 [6.8–18.6]	0.057
Dietary patterns						
Meat & fries	−0.01 ± 1.11	−0.26 ± 1.06	0.001	NA	NA	
Fruits & vegetables	−0.13 ± 1.49	0.35 ± 1.50	<0.001	NA	NA	
Fatty & sugary	0.03 ± 1.35	−0.18 ± 1.30	<0.001	NA	NA	
Dietary scores						
Mediterranean[a]	4.0 ± 1.5	4.0 ± 1.5	0.513	3.9 ± 1.6	4.0 ± 1.5	0.135
Mediterranean[b]	4.6 ± 1.9	4.7 ± 1.9	0.182	4.6 ± 2.0	4.8 ± 2	0.084
Compliance to food guidelines (%)						
Dairy ≥ 3/day	222 (7.1)	54 (8.8)	0.143	134 (7.4)	36 (5.4)	0.078
Meat ≤ 5/week	1892 (60.6)	408 (66.6)	0.006	995 (54.5)	429 (63.6)	<0.001

(Continued on next page)

Table 1. (Continued)

	2009–2012			2014–2017		
	Non consumers§	Consumers‡	P-value	Non consumers §	Consumers ‡	P-value
Fish (excluding fried) ≥ 1/week	1186 (38.0)	275 (44.9)	0.001	818 (44.7)	328 (48.4)	0.103
Fish, all ≥ 1/week	2034 (65.2)	417 (68)	0.177	1273 (69.6)	497 (73.7)	0.046
Vegetables ≥ 3/day	219 (7)	47 (7.7)	0.569	124 (6.8)	56 (8.3)	0.189
Fresh fruits & any fruit juice ≥ 2/day	1229 (39.4)	281 (45.8)	0.003	725 (39.7)	325 (48.2)	<0.001
At least three guidelines[c]	487 (15.6)	123 (20.1)	0.006	283 (15.6)	147 (21.9)	<0.001
At least three guidelines[d]	670 (21.5)	174 (28.4)	<0.001	378 (20.9)	186 (27.8)	<0.001
Compliance, nutrient guidelines (%)						
Carbohydrates ≥ 50% TEI	1074 (34.4)	200 (32.6)	0.341	486 (26.2)	197 (28.8)	0.197
Protein 10–20% TEI	3036 (97.3)	596 (97.2)	0.910	1817 (98.1)	662 (96.8)	0.045
Fat						
Total < 30% TEI	812 (26.0)	126 (20.6)	0.004	353 (19.1)	124 (18.1)	0.594
Saturated < 10% TEI	644 (20.6)	113 (18.4)	0.214	309 (16.7)	132 (19.3)	0.123
Monounsaturated ≥ 10% TEI	2708 (86.8)	543 (88.6)	0.228	1689 (91.2)	629 (92.0)	0.544
Polyunsaturated ≥ 7% TEI	259 (8.3)	51 (8.3)	0.988	162 (8.8)	65 (9.5)	0.554
Cholesterol < 300 mg/day	1764 (56.5)	380 (62.0)	0.013	945 (51)	379 (55.4)	0.050
Fibre ≥ 30 g/day	235 (7.5)	54 (8.8)	0.279	118 (6.4)	46 (6.7)	0.748
Calcium ≥ 1 g/day	1372 (44.0)	256 (41.8)	0.313	805 (43.5)	267 (39.0)	0.045
Iron ≥ 10[e] or 15[f] mg/day	1072 (34.4)	146 (23.8)	<0.001	709 (38.3)	162 (23.7)	<0.001
Vitamin D ≥ 5 μg/day	280 (9)	59 (9.6)	0.608	226 (12.2)	92 (13.5)	0.400

TEI, total energy intake. §, participants who did not report the consumption of prescribed or over the counter vitamin/mineral supplements or dietary supplements. Consumers are participants who reported any consumption of vitamin/mineral supplements or dietary supplements. [a], according to Trichopoulou et al.; [b], according to Vormund et al.; [c], excluding fried fish; [d], including fried fish; [e], for men; [f], for women. TEI, total energy intake. Results are expressed as number of participants (column percentage) for categorical variables and as average ± standard deviation or as median [interquartile range] for continuous variables. Between-group comparisons were performed using chi-square for categorical variables and student's t-test or Kruskal-Wallis test as appropriate for continuous variables. Compliance to nutrient guidelines was assessed without considering DS or VMS-derived nutrient consumption.

For the second period, the bivariate and multivariable analyses of dietary intake according to VMS/DS (non)consumption are summarized in Tables 1 and 2, respectively. On bivariate analysis, VMS/DS consumers had a lower intake of total energy, animal-derived protein, SFA, alcohol, red or processed meat and ultra-processed foods; VMS/DS consumers also complied less to the guideline on iron than nonconsumers. Conversely, VMS/DS consumers had a higher intake of vegetable protein, monosaccharides, wholegrain and fruits than nonconsumers; VMS/DS consumers also complied more frequently with the guidelines on meat and fruit, and with at least three food guidelines guideline than nonconsumers (Table 1). All those differences became non-significant (at $p < 0.005$) after multivariable adjustment (Table 2).

Sensitivity analyses

The results of the sensitivity analyses are summarized in ESM 1, Tables E3 to E6. For the first period, when inverse probability weighting was applied, VMS/DS consumers had a lower likelihood of complying to the guideline on total fat than nonconsumers (ESM 1, Table E3). When VMS/DS consumers were split into VMS or DS consumers and VMS + DS consumers, an increasing trend was found for vitamin D and vegetable intake, and for higher compliance to at least three guidelines than nonconsumers (ESM 1, Table E4).

For the second period, when inverse probability weighting was applied, no differences were found between VMS/DS consumers and nonconsumers (ESM 1, Table E3). When VMS/DS consumers were split into VMS or DS consumers and VMS + DS consumers, a trend for a higher cholesterol intake and for a lower compliance regarding the guideline on cholesterol were found (ESM 1, Table E5). When the analysis was conducted with further adjustment on income, no differences were found between VMS/DS consumers and nonconsumers (ESM 1, Table E6).

Discussion

Our results show that VMS/DS consumers tend to have a better dietary intake than nonconsumers. The beneficial effect of VMS and/or DS consumption might be decreased, as it does not target subjects who really need them.

Table 2. Multivariable analysis of the dietary intake according to (non)consumption of vitamin-mineral or dietary supplements, CoLaus study, Lausanne, Switzerland, 2009–2012 and 2014–2017

	2009–2012			2014–2017		
	Non consumers§	Consumers‡	P-value	Non consumers§	Consumers‡	P-value
Number of participants	3120	613		2536	2345	
Macronutrients (% TEI)						
Protein						
Total	15.4 ± 0.1	15.6 ± 0.1	0.117	15.8 ± 0.1	15.6 ± 0.1	0.138
Vegetable	4.7 ± 0	4.7 ± 0.1	0.365	4.6 ± 0.1	4.7 ± 0.1	0.029
Animal	10.7 ± 0.1	10.9 ± 0.1	0.090	11.2 ± 0.1	10.9 ± 0.1	0.045
Carbohydrates						
Total	46.4 ± 0.2	45.5 ± 0.4	0.021	44.4 ± 0.2	44.9 ± 0.3	0.212
Monosaccharides	22.7 ± 0.1	22.6 ± 0.3	0.801	21.6 ± 0.2	22.0 ± 0.3	0.217
Polysaccharides	23.6 ± 0.1	22.8 ± 0.3	0.018	22.7 ± 0.2	22.7 ± 0.3	0.834
Fat						
Total	34.2 ± 0.1	35.0 ± 0.3	0.009	35.9 ± 0.2	35.5 ± 0.3	0.291
Saturated	12.7 ± 0.1	12.9 ± 0.1	0.099	13.1 ± 0.1	12.9 ± 0.1	0.073
Monounsaturated	13.7 ± 0.1	14.1 ± 0.1	0.009	14.7 ± 0.1	14.6 ± 0.2	0.685
Polyunsaturated	4.9 ± 0.1	4.9 ± 0.1	0.281	5.0 ± 0.1	5.0 ± 0.1	0.926
Alcohol	4.0 ± 0.1	3.9 ± 0.2	0.632	4.0 ± 0.1	4.0 ± 0.2	0.805
Fibre (g/day)	15.9 ± 0.1	15.9 ± 0.3	0.813	15.2 ± 0.1	15.7 ± 0.2	0.103
Cholesterol (mg/day)	297 ± 2	303 ± 4	0.196	312 ± 3	318 ± 4	0.235
Micronutrients						
Calcium (mg/day)	1035 ± 7	1058 ± 17	0.227	1016 ± 9	990 ± 15	0.152
Iron (mg/day)	10.5 ± 0	10.5 ± 0.1	0.259	10.3 ± 0.1	10.5 ± 0.1	0.101
Retinol (μg/day)	498 ± 9	522 ± 22	0.310	487 ± 10	444 ± 17	0.038
Carotene (μg/day)	3938 ± 51	4025 ± 119	0.508	3990 ± 70	3981 ± 117	0.951
Vitamin D (μg/day)	2.49 ± 0.03	2.67 ± 0.07	0.018	2.81 ± 0.05	2.94 ± 0.08	0.164
Food items (g/day)						
Dairy	212 ± 3	221 ± 7	0.277	203 ± 4	191 ± 6	0.101
Red meat	48 ± 1	49 ± 2	0.572	51 ± 1	47 ± 2	0.066
Processed meats	12.9 ± 0.2	13.1 ± 0.6	0.766	13.8 ± 0.3	13.1 ± 0.6	0.329
Fish, excluding fried	28 ± 0	31 ± 1	0.046	33 ± 1	34 ± 1	0.436
Fish, all	36 ± 1	38 ± 1	0.104	40 ± 1	41 ± 1	0.517
Wholegrain	47 ± 1	50 ± 2	0.133	45 ± 1	50 ± 2	0.016
Vegetables	171 ± 2	177 ± 5	0.250	175 ± 3	179 ± 4	0.474
Fresh fruits	233 ± 4	232 ± 9	0.875	218 ± 4	228 ± 8	0.283
Fresh fruits + fresh juice	271 ± 4	268 ± 9	0.766	260 ± 5	266 ± 8	0.566
Any fruit and fruit juice	333 ± 4	334 ± 10	0.915	319 ± 6	327 ± 9	0.473
Ultraprocessed foods	103 ± 2	92 ± 6	0.098	87 ± 3	87 ± 5	0.946
Ingredients	16.1 ± 0.2	15.4 ± 0.5	0.182	15.3 ± 0.3	15.4 ± 0.5	0.798
Dietary patterns						
Meat & fries	−0.04 ± 0.02	−0.08 ± 0.04	0.387	NA	NA	
Fruits & vegetables	−0.09 ± 0.02	0.15 ± 0.05	<0.001	NA	NA	
Fatty & sugary	0.02 ± 0.02	−0.14 ± 0.04	<0.001	NA	NA	
Dietary scores						
Mediterranean[a]	3.98 ± 0.03	4.00 ± 0.06	0.833	3.90 ± 0.04	4.02 ± 0.06	0.115
Mediterranean[b]	4.64 ± 0.03	4.69 ± 0.07	0.472	4.62 ± 0.04	4.64 ± 0.07	0.851
Compliance to food guidelines (%)						
Dairy ≥ 3/day	1 (ref.)	1.22 (0.88–1.69)	0.225	1 (ref.)	0.71 (0.48–1.06)	0.091
Meat ≤ 5/week	1 (ref.)	0.98 (0.81–1.19)	0.826	1 (ref.)	1.08 (0.89–1.31)	0.449
Fish (excluding fried) ≥ 1/week	1 (ref.)	1.18 (0.99–1.42)	0.070	1 (ref.)	1.07 (0.89–1.29)	0.480

(Continued on next page)

Table 2. (Continued)

	2009–2012			2014–2017		
	Non consumers§	Consumers‡	P-value	Non consumers §	Consumers ‡	P-value
Fish, all ≥ 1/week	1 (ref.)	1.15 (0.95–1.40)	0.146	1 (ref.)	1.32 (1.07–1.63)	0.010
Vegetables ≥ 3/day	1 (ref.)	0.95 (0.67–1.34)	0.762	1 (ref.)	1.10 (0.78–1.56)	0.576
Fresh fruits & any fruit juice ≥ 2/day	1 (ref.)	1.07 (0.89–1.28)	0.490	1 (ref.)	1.20 (0.99–1.45)	0.063
At least three guidelines [c]	1 (ref.)	1.02 (0.81–1.29)	0.846	1 (ref.)	1.19 (0.93–1.50)	0.160
At least three guidelines [d]	1 (ref.)	1.15 (0.94–1.41)	0.180	1 (ref.)	1.17 (0.94–1.46)	0.150
Compliance, nutrient guidelines (%)						
Carbohydrates ≥ 50% TEI	1 (ref.)	0.82 (0.67–0.99)	0.041	1 (ref.)	0.99 (0.8–1.22)	0.928
Protein 10–20% TEI	1 (ref.)	1.09 (0.63–1.88)	0.766	1 (ref.)	0.72 (0.41–1.27)	0.255
Fat						
Total < 30% TEI	1 (ref.)	0.72 (0.57–0.89)	0.003	1 (ref.)	0.96 (0.75–1.22)	0.739
Saturated < 10% TEI	1 (ref.)	0.78 (0.62–0.99)	0.037	1 (ref.)	1.07 (0.84–1.36)	0.582
Monounsaturated ≥ 10% TEI	1 (ref.)	1.23 (0.93–1.63)	0.150	1 (ref.)	1.18 (0.85–1.66)	0.322
Polyunsaturated ≥ 7% TEI	1 (ref.)	0.96 (0.69–1.33)	0.809	1 (ref.)	1.02 (0.75–1.41)	0.882
Cholesterol < 300 mg/day	1 (ref.)	0.94 (0.75–1.17)	0.571	1 (ref.)	0.90 (0.72–1.13)	0.375
Fibre ≥ 30 g/day	1 (ref.)	1.17 (0.82–1.68)	0.392	1 (ref.)	1.00 (0.66–1.52)	0.997
Calcium ≥ 1 g/day	1 (ref.)	1.00 (0.81–1.23)	0.979	1 (ref.)	0.86 (0.69–1.07)	0.182
Iron ≥ 10[e] or 15[f] mg/day	1 (ref.)	1.29 (0.90–1.84)	0.167	1 (ref.)	0.89 (0.60–1.33)	0.580
Vitamin D ≥ 5 μg/day	1 (ref.)	1.10 (0.80–1.50)	0.571	1 (ref.)	1.16 (0.87–1.53)	0.317

TEI, total energy intake. §, participants who did not report the consumption of prescribed or over the counter vitamin/mineral supplements or dietary supplements. Consumers are participants who reported any consumption of vitamin/mineral supplements or dietary supplements. [a], according to Trichopoulou et al.; [b], according to Vormund et al.; [c], excluding fried fish; [d], including fried fish; [e], for men; [f], for women. Results are expressed as odds ratio (95% confidence interval) for categorical variables and as adjusted average ± standard error for continuous variables. Between-group comparisons were performed using logistic regression for categorical variables and analysis of variance for continuous variables. Multivariable models were adjusted on gender (male/female), age (continuous), BMI categories (normal, overweight and obese), educational level (university, high school, apprenticeship and mandatory), smoking status (never, former, current), country of birth (Switzerland, France, Portugal, Spain, Italy, Germany, other), sedentariness (yes/no), being on a diet (yes/no) and total energy intake (except for macronutrients and compliance to food guidelines). Compliance to nutrient guidelines was assessed without considering DS or VMS-derived nutrient consumption.

Characteristics of vitamin-mineral or dietary supplement consumers

In this study, almost a quarter of all participants consumed VMS or DS. This prevalence is similar to that found in Germany [32] but lower than in the United States [33], Denmark [34] or France [6]. VMS/DS consumers were older, more frequently women, born in Switzerland, living alone with a normal BMI or on a diet than nonconsumers, a finding also reported previously [2]. Hence, our results suggest that prevalence and characteristics of VMS/DS consumers living in Lausanne resembles that of neighbouring countries.

The reasons for VMS or DS consumption vary considerably according to each individual's motivations. The primary reason for using dietary supplements in adults might be to improve or maintain overall health, which may or may not include the prevention or treatment of disease [35]. Other reasons might be fostered by aggressive marketing strategies. For instance, the longevity and/or anti-aging treatment properties of VMS or DS, as well as claims of improvement of physical and mental health, improvement of sexual performance and, weight reduction [36] are common arguments for the marketing of VMS or DS, although those effects are controversial [37]. Further, some VMS or DS have been shown to be noncompliant with national regulations, i.e. by containing excessive amounts of vitamins or minerals [16].

Dietary intake according to vitamin-mineral or dietary supplements

In our study, VMS/DS consumers showed a trend to healthier eating practices, a finding in agreement with our initial hypothesis and also with another study [38]. Although most associations were not considered as statistically significant at the $p < 0.005$ thresholds, still they were rather consistent between studies and related to the same types of food. Hence, for a sizable fraction of VMS/DS consumers, current dietary intake could be considered as adequate and consumption of VMS or DS as unnecessary. These findings agree with an US and an Australian studies, where supplement users were more likely to achieve Estimated Average Requirements or Adequate Intake for many micronutrients only from food [39, 40]. Although supplement use might compensate for a low micronutrient intake from food [40], evidence supports that nutrients should be acquired primarily through food, not supplements.

Finally, the consumption of VMS and DS, when added to the consumption of nutrients from food, may represent a metabolic overload that presents health risks [2]. For instance, VMS/DS consumption might decrease absorption capacity and/or competition in absorption, (e.g. iron vs. calcium or iron vs. zinc). Indeed, DS has shown no preventive effect on cardiovascular disease and cancer and might even be deleterious in at-risk populations such as smokers [41].

Strengths and weaknesses

This study has also several limitations. Firstly, a sizable fraction of the participants had to be excluded, which might lead to a selection bias. Still, sensitivity analyses correcting for the selection bias led to comparable results. Secondly, the food composition table linked to the FFQ contained a limited number of micronutrients. Hence, the adequacy of intake of important micronutrients such as B-vitamins, zinc or selenium could not be established. Also, it is possible that the amount of micronutrients might have been misestimated by the FFQ; still, this misestimation would impact both groups, so we believe that the differences reported are unbiased. Further studies should use more detailed food composition databases to assess this issue. Thirdly, it was not possible to estimate the amount of micronutrients consumed from the VMS and DS because participants failed to provide enough detail regarding the VMS or DS their consumed and because of the large variations in VMS and DS content in Switzerland [16]. Fourthly, compliance to guidelines was based on consumption frequencies and not on total amounts; this strategy was preferred as the portion sizes recommended by the Swiss Society of Nutrition do not take into account a subject's corpulence and caloric needs. Hence, a small subject might consume five portions a day of fruits and vegetables but might be unable to reach the corresponding amount of 600 g [27]. Fifthly, although subjects with chronic diseases tend to take VMS or DS [42], information on chronic diseases was not systematically collected; hence, it was not possible to adjust for it. Finally, the analysis was conducted in a single, French-speaking, urban Swiss population, and the results might not be generalizable to other locations or countries. It would be of interest that this study be replicated in other settings.

This study has also several strengths. Firstly, it assessed the association between VMS/DS consumption and dietary intake using a rather large population-based sample, and at two different time points. This is important as it has been shown that, with time, a sizable fraction VMS/DS consumers tends to quit, this fraction being compensated by new consumers [17]. Secondly, it assessed different dietary markers, as recommended [43].

Conclusions

Dietary intake of VMS/DS consumers differs little from and does not appear to be healthier than non consumers.

Electronic Supplementary Material

The electronic supplementary material is available with the online version of the article https://doi.org/10.1024/0300-9831/a000679

ESM 1. Tables E1 to E6

ESM 2. Food frequency questionnaire used in the study

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Conflict of interest
The authors declare that there are no conflicts of interest.

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ORCID
Pollyanna Patriota
https://orcid.org/0000-0003-0853-1458

Pedro Marques-Vidal
Office BH10-642
Department of Medicine, Internal Medicine
Lausanne University Hospital
Rue du Bugnon 46
1011 Lausanne
Switzerland

Pedro-Manuel.Marques-Vidal@chuv.ch