Validation of the FSA nutrient profiling system - dietary index in French adults: findings from SU.VI.MAX study.

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ABSTRACT

Purpose: Population-wide nutritional recommendations give guidance on food groups' consumption, though a wide variability in nutritional quality within groups may subsist. Nutrient profiling systems may help capturing such variability. We aimed to apply and validate a dietary index based on the British Food Standards Agency-Nutrient profiling system (FSA-NPS DI) in French middle aged adults.

Methods: Dietary data were collected through repeated 24h dietary records in participants of the SU.VI.MAX (Supplémentation en Vitamines et Minéraux Antioxydants) study (N=5,882). An aggregated dietary index at the individual level was computed using the FSA-NPS for each food consumed as well as compliance to the French nutritional guidelines using the PNNS-GS. Cross-sectional associations between FSA-NPS DI and nutrient intake, PNNS-GS (*Programme National Nutrition Santé*-guideline score), sociodemographic factors, lifestyle and nutritional biomarkers were computed using ANOVAs.

Results: The FSA-NPS DI was able to characterize the quality of the diets at the individual level in terms of nutrient intake, and of adherence to nutritional recommendations: +37.6% in beta-carotene intakes between subjects with a healthier diet vs. subjects with a poorer diet, +42.8% in vitamin C intakes; +17% in PNNS-GS, all P<0.001. FSA-NPS-DI was also associated with nutritional status at the biological level: +21.4% in beta-carotene levels between subjects with a healthier diet vs. subjects with a poorer diet, +12.8% in vitamin C levels, all P<0.001.

Conclusions: the FSA-NPS DI is a useful and validated tool to discriminate individuals according to the quality of the diet, accounting for nutritional quality within food-groups. Taking into account nutritional quality of individual foods allows monitoring change in dietary patterns beyond food groups.

Introduction

In the framework of health prevention, diet and physical activity are key modifiable factors considering their role in chronic diseases development [1,2]. In a recent report, about 20% of deaths were directly or indirectly attributed to risks related to diet or physical inactivity [1].

In order to tackle the growing burden of chronic diseases attributable to nutrition, most western countries have developed public health nutrition programs [3–5]. In France, current public health nutrition recommendations provide food-based guidelines to the general population about food groups for which consumption should be encouraged or limited (e.g. ‘Five fruits and vegetables a day’) [6].

A priori dietary scores aiming at assessing the level of adherence to these food groups-based recommendations are therefore useful tool to monitor dietary pattern evolution in the population and have allowed to quantify their predictive value as regards health outcomes such as cardiovascular disease and cancer [7,8].

However, within a given food group, nutritional quality can largely vary, and individual food choices among a specific food group can impact overall diet quality [9]. Such variability within food groups cannot be grasped by dietary scores based on level of adherence to food-based recommendations. Therefore, assessing overall diet quality accounting for nutritional features of individual foods would give complementary information to currently existing dietary scores.

Nutrient profiling systems (NPS) initially aimed at positioning individual foodstuffs based on their nutritional characteristics [10–12]. Computation is based on the use of a continuous scoring system or a threshold defining ‘healthy’ and ‘less healthy’ foods. As potential applications, NPSs could be used as a support for front-of-package nutritional information and evaluation of nutritional quality, as a tool to regulate advertising of foods or as a tool to implement food taxes or subsidies [13].

Multiple NPS have been developed in the world [10,11,14,15]. They usually account for content in energy, macronutrients and micronutrients of foods, balancing between 'unhealthy' components (such as saturated fat or added sugar) and 'healthy' components (such as vitamins and minerals) [14]. Among NPS developed in Europe, some are currently in use for food labeling (the Green Keyhole [16] and Choices [17]) or for regulation of advertising to children (the FSA (Food Standard Agency) NPS [9,18,19]).

The latter is one of the most scientifically validated NPS in the European context and has been developed and validated specifically in the British food environment [18]. An individual dietary score based on FSA-NPS has been previously defined and validated in the UK [9] as regards its ability to discriminate healthy dietary patterns (compared to the Diet Quality Index (DQI), which include indicators of variety, adequacy, moderation and overall balance). However cultural disparities in dietary patterns as well as various food supply across countries lead to the need for validation of the FSA-NPS in other geographical context.

Such validation would require to ascertain that FSA-NPS correctly applies to food supply, but also that an individual FSA-NPS based dietary index adequately characterizes overall diet quality. With such validation, the FSA-NPS could be considered as an international European public health tool.

The aim of the present study was to assess the validity of a dietary index (DI) based on the FSA NPS in a French population. Specifically, our objective is to validate the FSA NPS DI against nutrient intake, and the Programme National Nutrition Santé-guideline score (PNNS-GS), an a priori dietary score previously developed and validated and reflecting the level of adherence to current national food-based recommendations in France as well as against nutritional status using objective diet-related biomarkers that have not previously investigated.

Materials and methods

Population and data collection

Study population

The SU.VI.MAX (Supplémentation en Vitamines et Minéraux Antioxydants) study (1994-2002) was initially designed as a randomized double-blind, placebo-controlled primary prevention trial which included a total of 12,741 volunteer individuals from the general population (women aged 35–60 years and men aged 45–60 years) for a planned follow-up of 8 years to test the potential efficacy of a daily supplementation with antioxidant vitamins and minerals at nutritional doses on the incidence of cancers, ischemic heart diseases and overall mortality [20,21].

The SU.VI.MAX study was conducted according to the guidelines laid down in the Declaration of Helsinki and was approved by the Ethical Committee for Studies with Human Subjects of Paris-Cochin Hospital (CCPPRB n° 706) and the Commission Nationale de l'Informatique et des Libertés (CNIL n° 334641). Written informed consent was obtained from all subjects.

Data collection

Dietary data

During the SU.VI.MAX study, subjects were invited to complete a 24 hr dietary record every 2 months for a total of 6 records per year so that all days of the week and all seasons were covered to account for individual variability in intake. Data were collected through computerized questionnaires using the Minitel, a small terminal used in France as an adjunct to the telephone.

Participants were assisted by an instruction manual for coding food portions which included validated photographs of more than 250 foods represented in three different portion sizes. Subjects could also choose from two intermediate or two extreme portions, for a total of seven different possible portion sizes [22]. Alcohol intake was estimated using a short validated semi-quantitative dietary questionnaire [23] and weekly consumption of seafood was collected using a specific question.

Covariates

Information on gender, date of birth, smoking status, physical activity, marital status, education level and occupational categories was collected through self-administered questionnaires.

Specifically, physical activity was assessed in 1998 through a French validated self-administered version of the Modifiable Activity Questionnaire (MAQ) as previously described [24] to assess average MET (metabolic equivalent*)*-h per week of leisure time physical activity.

At the inclusion visit, blood samples were obtained after a 12-h fast in vacutainer tubes that do not interfere with the concentration of trace elements (Becton Dickinson) and all biochemical measurements were centralized. Nutritional biomarkers were centrally measured. Biochemical methods have been previously presented in detail elsewhere [21].

Anthropometric measurements were assessed at the first (1995-1996) clinical examination of the cohort follow-up; weight was measured using an electronic scale, with subjects wearing indoor clothing and no shoes. Height was measured under the same conditions with a wall-mounted stadiometer.

Data computation and statistical analysis

FSA-NPS based score computation

The FSA score for foods and beverages was computed taking into account nutrient content for 100g. Scores for foods and beverages are based on a discrete continuous scale from -15 (most healthy) to +40 (less healthy) (see **Supplemental table 1**). FSA score allocates points (0-10) for content in energy (KJ), total sugar (g), saturated fatty acids (g) and sodium (mg). Points (0-5) are subtracted from the previous sum according to content in fruits, vegetables and nuts, fibers and proteins. Increasing FSA-NPS therefore reflects decreasing quality of foods.

FSA-NPS DI was computed using arithmetic energy-weighted means with the following equation:

$$\mathrm{FSA-NPS\ DI} = \frac{\sum_{i=1}^{n} \mathrm{FSA-NPS_i E_i}}{\sum_{i=1}^{n} \mathrm{E_i}}$$

With FSA-NPS DI: Food Standards Agency-Nutrient Profiling System Dietary Index, FSA-NPSi: Food (or beverage) score, Ei: Energy intake from food or beverage

PNNS-GS computation

PNNS-GS (namely, the "*Programme National Nutrition Santé"*-guideline score) development, including food groupings, serving sizes, scoring, cut-off and penalties, was previously described in detail [24]. Briefly, the 15-point score was based on French national guidelines and included 13 components. Eight components referred to food serving recommendations and four components referred to moderation in consumption. The last component focused on adherence to physical activity recommendations. Scoring and cut-off values are presented in **supplemental table 2**.

A penalty for overconsumption was assigned to individuals with energy intakes higher than estimated energy expenditure [24]. For instance, a subject with a crude score of 8 with energy intake 10% higher than need will have a penalized score of 8- 8*0.10 = 7.2. Age, weight and height at the first clinical exam were used to estimate Schofield's basal metabolic rate (BMR)[25]. Energy expenditures were estimated using BMR and physical activity level. In case of energy intake greater than 5% over the estimated energy expenditure, an identical part was subtracted from the score.

Statistical analysis

All data collected from eligible 24-h records (with a mean of 9.7 (SD=3.3)) were averaged to obtain a proxy for usual dietary intake consumption and nutrient per person. Descriptive characteristics are reported as mean ± standard deviation or % by sex. Reported P-values referred to the Kruskal-Wallis test, chi² test or Mantel-Haenszel chi² test as appropriate.

ANCOVA was used to estimate adjusted mean (95% confidence interval) of nutrient intake and biomarkers concentration across quartile of FSA-NPS DI (<6.6, 6.6-7.6, 7.6-8.6, >8.6). Nutrient intakes were energy adjusted using the residual method [26]. P for linear trend was calculated using a linear contrast. All biomarkers concentrations were log-transformed to improve normality. Adherence to French nutritional guidelines (PNNS-GS as well as adherence to each individual recommendation) is reported across quartiles of FSA-NPS DI.

Univariate and multivariable logistic regression models were used to estimate the lifestyle and sociodemographic factors associated with FSA-NPS DI. We modeled the probability to obtain a lower score of FSA-NPS DI (first quartile versus the others) reflecting a better quality of the diet.

All tests of statistical significance were 2-sided and the type I error was set at 5%. Statistical analyses were performed using SAS software (version 9.3, SAS Institute Inc, Cary, NC, USA).

Results

We selected for the present analysis the data from participants providing at least three 24-h dietary records collected during the first 2 years of the study (1994-1996) as a measurement of baseline dietary habits (N=8,111), with available PNNS-GS (N=6,150). Participants with at least one missing covariate for lifestyle and demographic factors were removed leaving a sample of 5,588 subjects (44.3 % male).

Compared to participants from the SU.VI.MAX study excluded, those included in the present analysis exhibited higher number of 24-h records, higher energy intake but lower body mass index. They were also more often men, highly educated and less often current smokers (data not tabulated).

Sample description

Characteristics of the studied sample are presented in **Table 1**. The mean age (SD) was 52.1 (4.6) years in men and 51.9 (4.7) years in women. Participants were highly educated, frequently non-smokers, mostly cohabiting, and reported often a low level of physical activity.

FSA-NPS DI was 7.7 (1.5) and 7.6 (1.7) in men and women respectively ranging from -0.89 (most favorable) to 13.7 (least favorable).

FSA-NPS DI and nutrient intakes

A healthier diet, as expressed by a lower FSA-NPS DI was associated with lower energy and lipids intakes (total and subtypes of FA as well as dietary cholesterol) (**Table 2)**. In addition, a healthier diet was associated with higher simple sugars intake (e.g. mono- and disaccharides glucose, saccharose, fructose etc.).

Besides, an increase in contribution of carbohydrates and proteins to energy intake, minerals (except sodium), beta-carotene, vitamins and fibers intake was observed with healthier FSA-NPS DI.

FSA-NPS DI and adherence to nutritional guidelines

Healthier FSA-NPS DI was associated with healthier PNNS-GS (**Table 3**). Healthier FSA-NPS DI was correlated with increase in meeting each nutritional recommendation except for dairy products, meat, fish and eggs, and vegetable added fats. A strong difference in percentage of meeting the recommendations across quartiles of FSA-NPS DI was specifically observed for fruits and vegetables, whole grains, seafood and alcohol consumption.

FSA-NPS DI and biomarkers of nutritional status

Associations of nutritional biomarkers concentration with FSA-NPS DI are presented in **Table 4**. Healthier FSA-NPS DI weas associated with biomarkers of antioxidant status including vitamin C, beta-carotene and selenium serum concentrations. In addition, healthier FSA-NPS DI was associated with higher plasma level of LDL-cholesterol. No significant association was found between the FSA-NPS DI and other nutritional biomarkers.

Socio-demographic factors and lifestyles associated with FSA-NPS DI

In univariate models, women older and physically active individuals were more likely to have a healthier FSA-NPS DI (OR 1.3, 95% CI (1.15-1.47) for women vs; men; OR 1.52 (1.27-1.82) for ≥55y-o vs. < 45 y-o; OR 1.20 (1.04-1.39 for ≥ 60min/day vs. [0-30min[, respectively; all P<0.001) (**Table 5**). Besides, heavy alcohol consumers and smokers were less likely to have a healthier FSA-NPS DI.

In the fully-adjusted model, most of these associations remained statistically significant except education, occupational position and marital status. Moreover, women exhibited a lower probability to have a healthier FSA-NPS DI (after adjustment for energy intake).

Discussion

Our findings based on a wide range of accurate data provide evidence of the ability of the FSA-NPS DI to discriminate the quality of the diets at the individual level in terms of nutrient intake, adherence to nutritional recommendations and nutritional status. FSA-NPS DI was previously considered as a validated tool to assess the quality of individual diet in the UK [9] but our study provides 1) information as regards validity in another geographical context with specific cultural dietary practices – namely France, 2) additional arguments as regards validity using a wide range of markers of dietary exposure.

The fact that healthier FSA-NPS DI was associated with decreasing intake in energy and fat was expected, given that both energy and saturated fat are directly accounted for in the FSA-NPS computation at the food level. Regarding sugar intake, results are somewhat unexpected, as simple sugars are also considered in the FSA-NPS. However, one explanation relies on the fact that simple sugars intake encompasses natural sugars (notably in fruits), i.e. not added, as well as added sugar in manufactured foodstuffs. In turn, when computing the FSA-NPS DI, less healthy food containing simple added sugars could be balanced by the healthier food containing fruit which have more favorable scores given that content in fruit balances the FSA-NPS at the food level.

Healthier FSA-NPS DI was correlated to PNNS-GS globally. This result is concordant with prior research reporting that dietary scores based on NPS are correlated with the overall quality of the diet [9,27]. Specifically, healthier FSA-NPS DI was associated with the probability of meeting each nutritional recommendation, except for 'Milk and Dairy' and vegetable added fat. Thus, the FSA-NPS DI confirms its complementarity with dietary recommendations which are based on food groups as it accounts for nutritional quality of foods within food groups. Indeed, if no difference is observed in terms of meeting the 'Milk and Dairy' recommendation overall across quartiles of FSA-NPS DI, choice of foods within this group is however very different: subjects with a healthier FSA-NPS DI chose preferentially yogurts (which have a better FSA-NPS) while subjects with poorer diets chose preferentially cheese (data not shown). This result emphasizes the valuable add-on of considering the variability in nutritional composition within food groups to the food groups approach. Another example illustrating this strength is the level of adherence to the "meat, fish and eggs" recommendation: it was lower among participants with healthier FSA-NPS DI because of over-elevated consumption (beyond the recommendation). However, these subjects exhibited mainly higher consumption of fish and poultry.

Moreover, FSA-NPS DI was associated with meeting the recommendation on alcoholic beverages and physical activity. Yet the FSA NPS excludes alcoholic beverages from its computations, and, by definition, does not apply to physical activity. Therefore the observed associations here support the validity of the FSA-NPS DI as a measure of the healthiness of the diet and more broadly to a healthy lifestyle providing some support for its face validity.

Healthier FSA-NPS DI was associated with antioxidant status, and more specifically to β-carotene, vitamin C and selenium serum concentrations. Biological antioxidant status has been found to be associated to reduced mortality and incidence of major chronic diseases in observational studies [28]. However, numerous randomized trials (including the SU.VI.MAX study) have at least partly failed to show an impact of a supplementation, especially at high doses, in antioxidant nutrients on mortality, CVD or cancer [29–35]. These results suggest that biological antioxidant status could be viewed as a surrogate marker of fruit and vegetable consumption, and more broadly of an overall better diet quality. However, the effects of such a healthy diet would depend on a broader number of indicators then merely antioxidant status [36].

FSA-NPS DI was not associated with plasma concentrations of cholesterol, HDL-cholesterol, triglycerides but was negatively associated with LDL-cholesterol concentration. Total cholesterol and LDL-cholesterol levels have been shown to be positively associated with cholesterol and saturated fat intake, but negatively associated with polyunsaturated fatty acids intake [37]. Moreover, carbohydrate intake, and more specifically simple sugars intake has been shown to be positively associated to LDL-cholesterol levels [38]. We may therefore hypothesize that the overall association between FSA-NPS DI and LDL-cholesterol is driven by associations with increasing dietary intake in all types of fatty acids, and decreasing intake in simple sugars. However, the associations observed at the cross-sectional level with these intermediate biomarkers of cardiovascular risk question the potential predictive performance of the FSA-NPS DI as regards cardiovascular diseases risk which need future investigations.

FSA-NPS DI was inversely associated with age in agreement with the fact that older subjects tend to be more health conscious and therefore to have healthier diet. Such an observation has been documented in numerous studies in Western countries [24,39–44]. Consistent with other reports, diet quality index were lower in smokers [24,40,44] who indeed tend to display clustered associations of risk factors, cumulating low fruit and vegetable intakes, low leisure time physical activity and high alcohol consumption [45–47].

In multivariate analyses, FSA-NPS DI was not associated to either educational level or occupational category. This is consistent with prior French research reporting a lack of association between diet quality (measured using the PNNS-GS) and educational level [24,41,48]. In the context of the SU.VI.MAX cohort, we hypothesize that socioeconomic factors are mainly grasped by other demographic characteristics. In turn, associations between FSA-NPS DI and markers of economic status should be further explored in other settings

Strengths of our study include the use of highly accurate dietary data, using an elevated number of 24h records taking into account for seasonal and day-to day variation in dietary intake at the individual level, and a wide range of nutritional biomarkers in a population-based study.

Of note, some limitations of our study should be underlined. First, dietary scores computation is relatively limited by current knowledge about diet-disease relationship and is prone to some shortcomings that have been extensively discussed including selection of components, lack of account for energy confounding, as well as subjectivity as regards choice in cut-off values and scoring criteria [7,8]. In the case of the FSA-NPS DI, all food consumptions – except alcoholic beverages – are enclosed in the computation and the score is further weighted by energy contribution limiting some of these issues. Besides, the wide scoring scale leads probably to a foremost sensitiveness of the index allowing to capture extremes dietary pattern and to improve power as a risk factor for health outcomes. Finally, beyond specific nutritional quality related to food groups, the FSA-NPS DI also reflects intrinsic characteristics of foods within a food group.

Second, caution is needed when generalizing the present findings, as participants were relatively healthy volunteers involved in a long-term nutrition-focused study. In turn these participants are therefore more likely to be health conscious and to have globally better food choices.

Conclusion

The FSA-NPS DI appears to be a validated discriminator of dietary quality, allowing for the accounting of disparities in nutritional quality within food groups. In turn, it could be useful for monitoring nutritional behavior changes.

Further ultimate validation work is now required to determine whether this index exhibits prognostic value with respect to health outcomes in large-scale longitudinal studies.

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Table 1: Characteristics of the participants, SU.VI.MAX study (1994-1996), N=5,882[1]

	Men	Women	P[2]
N	2478	3404	
Age, y	51.89 (4.69)	46.99 (6.52)	<.0001
FSA-NPS DI	7.67 (1.53)	7.47 (1.67)	<.0001
BMI, kg/m²	25.40 (3.11)	23.11 (3.78)	<.0001
Energy intake, Kcal/d	2479.90 (579.58)	1845.56 (458.39)	<.0001
Alcohol intake, g/d	25.11 (19.41)	7.69 (9.54)	<.0001
Lipids[3],%	40.04 (5.24)	40.53 (5.13)	<.0001
Carbohydrates[3], %	41.98 (6.33)	41.68 (5.99)	0.02
Protein[3], %	17.96 (2.77)	17.78 (2.90)	0.003
PNNS-GS	7.53 (1.91)	7.89 (1.85)	<.0001
Educational level (years of schooling), %			<.0001
Primary (<6 y)	23.3	17.9	
Secondary (6-11 y)	36.6	40.3	
Post-secondary (≥12 y)	40.1	41.8	
Occupation,%			<.0001
Self-employed, artisans	40.1	43.4	
Farmers	1.5	1.0	
Managerial staff/intellectual professions	42.3	17.5	
Employees	8.9	21.7	
Homemakers	0.5	14.4	
Manual workers	6.7	1.9	
Marital status, %			<.0001
Living alone	9.7	19.1	
Cohabiting	90.3	80.9	
Smoking status,%			<.0001
Non-smokers	34.7	56.9	
Former smokers	52.2	29.5	
Current smokers	13.1	13.5	
Physical activity[4],%			<.0001
[0 – 30[min/d	48.6	63.8	
[30 – 60[min/d	23.7	18.9	
≥ 60 min/d	27.7	17.3	

Abbreviations: BMI: body mass index, FSA-NPS DI: Food Standards Agency- nutrient profiling system dietary index, PNNS-GS: Programme national nutrition santé-guideline score

[1] Values are means (sd) or % as appropriate

[2] P values referred to non-parametric Kruskal-Wallis test, Chi^2 or Mantel-Heanzel Chi^2 test

[3] Percentage of total daily energy intake (without alcohol)

[4] time equivalent brisk walking per day

Table 2: Mean nutrient intake across quartiles of FSA-NPS DI, SU.VI.MAX study, N=5,882[1]

	Q1 healthiest	Q2	Q3	Q4 Least healthy	P for trend
Energy intake[2], kcal/d	1841.66 (1817.0-1866.3)	2017.48 (1993.1-2041.9)	2099.92 (2075.6-2124.2)	2137.40 (2113.0-2161.8)	<.0001
Lipids[3],%	36.27 (36.04-36.49)	39.40 (39.17-39.62)	41.18 (40.96-41.40)	44.17 (43.95-44.39)	<0.0001
Carbohydrates[3], %	44.45 (44.15-44.75)	42.75 (42.45-43.05)	41.38 (41.08-41.67)	38.85 (38.55-39.15)	<.0001
Protein[3], %	19.27 (19.13-19.41)	17.84 (17.70-17.98)	17.43 (17.29-17.56)	16.96 (16.82-17.10)	<.0001
SFA, g/d	12.61 (12.44-12.78)	13.22 (13.05-13.39)	13.34 (13.17-13.51)	13.87 (13.70-14.05)	<0.0001
MUFA, g/d	30.36 (30.11-30.61)	32.79 (32.55-33.04)	34.15 (33.91-34.40)	36.95 (36.70-37.20)	<0.0001
PUFA, g/d	12.61 (12.44-12.78)	13.22 (13.05-13.39)	13.34 (13.17-13.51)	13.87 (13.70-14.05)	<0.0001
Cholesterol, mg/d	377.51 (371.82-383.20)	384.77 (379.19-390.34)	397.67 (392.08-403.26)	416.03 (410.39-421.67)	<0.0001
Simple sugars, g/d	102.61 (101.33-103.88)	95.45 (94.19-96.70)	91.85 (90.59-93.10)	86.47 (85.21-87.74)	<0.0001
Calcium, mg/d	1019.33 (1005.7-1033.0)	942.70 (929.35-956.05)	933.44 (920.06-946.81)	920.71 (907.21-934.20)	<0.0001
Potassium, mg/d	3359.27 (3336.7-3381.8)	3064.69 (3042.6-3086.8)	2931.29 (2909.1-2953.4)	2733.21 (2710.9-2755.6)	<0.0001
Magnesium, mg/d	322.98 (320.42-325.55)	299.43 (296.91-301.94)	290.63 (288.11-293.15)	280.17 (277.63-282.71)	<0.0001
Phosphorus, mg/d	1377.14 (1367.3-1387.0)	1292.03 (1282.4-1301.7)	1272.05 (1262.4-1281.7)	1244.19 (1234.4-1253.9)	<0.0001
Sodium, mg/d	3448.85 (3405.0-3492.7)	3490.66 (3447.7-3533.6)	3495.26 (3452.2-3538.3)	3517.36 (3474.0-3560.8)	<0.0001
Iron, mg/d	13.33 (13.19-13.47)	12.85 (12.72-12.99)	12.69 (12.55-12.82)	12.46 (12.32-12.60)	<0.0001
β-carotene, µg/d	4616.01 (4491.6-4740.5)	4075.35 (3953.4-4197.3)	3745.10 (3622.9-3867.3)	3354.57 (3231.3-3477.8)	<0.0001
Folate, µg/d	337.28 (333.54-341.01)	311.96 (308.29-315.62)	301.03 (297.36-304.70)	294.01 (290.31-297.72)	<0.0001
Vitamin C, mg/d	112.48 (110.32-114.64)	96.17 (94.05-98.29)	88.84 (86.72-90.96)	79.01 (76.87-81.15)	<0.0001
Vitamin D, µg/d	2.87 (2.77-2.96)	2.77 (2.67-2.86)	2.76 (2.66-2.85)	2.72 (2.62-2.81)	0.04
Vitamine E, mg/d	12.51 (12.32-12.71)	12.56 (12.37-12.76)	12.31 (12.12-12.50)	12.35 (12.15-12.54)	0.09
Fiber, g/d	22.36 (22.13-22.59)	19.49 (19.27-19.72)	18.05 (17.83-18.28)	16.39 (16.17-16.62)	<0.0001

Abbreviations: FSA-NPS DI, Food Standards Agency- nutrient profiling system dietary index MUFA: monounsaturated fatty acides, PUFA: polyunsaturated fatty acids, Q: quartile, SFA: saturated fatty acids

[1] Values are means (95% confidence interval) intake/d adjusted for total energy intake (unless otherwise specified), sex and age

[2] Values are means (95% confidence interval) intake/d (without alcohol) adjusted for sex and age

[3] Values are percentage (95% confidence interval) of total daily energy intake (without alcohol) adjusted for sex and age

Table 3: PNNS guidelines (PNNS-GS and adherence to individual recommendations) across quartiles of FSA-NPS DI, SU.VI.MAX study, N=5,882[1,2]

	Q1	Q2	Q3	Q4	P
PNNS-GS[3]	8.42 (8.33-8.51)	7.86 (7.77-7.95)	7.50 (7.41-7.58)	7.17 (7.08-7.26)	<.0001
Fruits and vegetables	73 (71-75)	60 (57-62)	52 (50-55)	43 (40-45)	<0.0001
Bread, cereals, potatoes and legumes	55 (52-57)	53 (51-56)	54 (52-57)	48 (45-50)	0.001
Whole grain food	19 (17-21)	13 (12-15)	09 (08-11)	09 (07-11)	<0.0001
Milk and dairy products	33 (30-35)	32 (30-35)	34 (31-36)	32 (30-35)	0.87
Meat and poultry, seafood and eggs	59 (56-61)	62 (60-65)	62 (59-64)	63 (61-66)	0.03
Seafood	48 (45-50)	39 (37-42)	37 (34-39)	33 (30-35)	<0.0001
Sweetened foods	93 (91-94)	86 (85-88)	82 (80-83)	78 (76-80)	<0.0001
Added fats	83 (80-85)	73 (70-75)	72 (70-75)	70 (67-72)	<0.0001
Vegetable added fats	66 (64-69)	65 (62-67)	64 (61-66)	65 (63-68)	0.45
Beverages (Water and soda)	58 (55-60)	53 (50-55)	50 (48-53)	44 (41-46)	<0.0001
Alcohol	41 (39-44)	33 (31-36)	30 (28-33)	26 (24-29)	<0.0001
Salt	27 (25-28)	21 (19-23)	20 (18-21)	20 (18-22)	<0.0001
Physical activity	48 (45-51)	45 (42-47)	41 (39-44)	39 (36-42)	<0.0001

Abbreviations: FSA-NPS DI: Food Standards Agency- nutrient profiling system dietary index, PNNS-GS: Programme national nutrition santé-guideline score, Q: quartile

[1] Values are percentage (95% confidence interval) adjusted for energy intake, sex and age (except otherwise is noted)

[2] Subjects meeting individual recommendations were those with attributed at least 1 point

[3] Values are means (95% confidence interval) adjusted for energy intake sex and age

Table 4: Mean serum biomarkers across quartiles of FSA-NPS DI, SU.VI.MAX study, N=5,882[1,2]

	Q1	Q2	Q3	Q4	P for trend
Cholesterol, mmol/L	5.96 (5.91-6.01)	5.94 (5.89-5.99)	5.94 (5.89-5.99)	5.90 (5.85-5.95)	0.11
HDL-cholesterol mmol/L	1.76 (1.74-1.77)	1.76 (1.75-1.78)	1.78 (1.76-1.80)	1.76 (1.75-1.78)	0.31
LDL-cholesterol mmol/L	3.68 (3.64-3.72)	3.66 (3.63-3.70)	3.65 (3.61-3.69)	3.62 (3.58-3.66)	0.04
Blood glucose, mol/L	5.68 (5.64-5.71)	5.66 (5.63-5.69)	5.68 (5.65-5.71)	5.69 (5.66-5.73)	0.40
Triglycerides, mmol/L	0.96 (0.94-0.99)	0.96 (0.93-0.98)	0.94 (0.91-0.96)	0.94 (0.91-0.96)	0.08
Ferritin, µg/L	67.08 (63.64-70.70)	68.61 (65.14-72.26)	65.27 (61.98-68.74)	70.06 (66.51-73.80)	0.49
Transferrin, g/L	2.50 (2.47-2.53)	2.49 (2.47-2.52)	2.51 (2.48-2.53)	2.48 (2.45-2.51)	0.41
Selenium, µmol/L	1.11 (1.10-1.12)	1.10 (1.09-1.11)	1.09 (1.08-1.10)	1.08 (1.07-1.09)	<0.0001
Zinc, µmol/L	13.04 (12.95-13.14)	13.07 (12.97-13.16)	13.06 (12.97-13.16)	13.01 (12.92-13.11)	0.67
Retinol, µmol/L	2.19 (2.15-2.22)	2.16 (2.13-2.19)	2.18 (2.15-2.21)	2.17 (2.13-2.20)	0.56
Tocopherol, µmol/L	30.72 (30.30-31.14)	30.49 (30.08-30.90)	30.26 (29.86-30.67)	30.29 (29.89-30.71)	0.12
β-Carotene, µmol/L	0.51 (0.50-0.53)	0.49 (0.47-0.51)	0.45 (0.44-0.47)	0.42 (0.41-0.44)	<0.0001
Vitamin C, µmol/L	9.31 (9.07-9.56)	8.93 (8.70-9.17)	8.69 (8.46-8.92)	8.25 (8.03-8.46)	<0.0001

Abbreviations: FSA-NPS DI: Food Standards Agency- nutrient profiling system dietary index, Q: quartile

[1] Values are geometric mean (95% confidence interval) adjusted for age and sex(unless otherwise noted);

[2] Number of participants with available data: Cholesterol: 5,830; HDL-cholesterol: 5,610; LDL-cholesterol: 5,756; Blood glucose, 5,492; Triglycerides, 5,214; Ferritin, 4,928; Transferrin, 4,931;Selenium, 5,714; Zinc, 5,733; Retinol, 5,078; Tocopherol, 5,078; β-Carotene, 5,077; Vitamin C, 4,538.

Table 5: Demographics and lifestyle factors associated with healthier FSA-NPS DI (Q1 versus Q2-Q4), SU.VI.MAX study, N=5,882[1]

	OR[2] (95% CI)	p	OR[3] (95% CI)	p
Sex		<.0001		<.0001
Male	reference		reference	
female	1.30 (1.15-1.47)		0.64 (0.52-0.77)	
Age group, y		<.0001		<.0001
<45	reference		reference	
45-<55	1.16 (1.00-1.35)		1.22 (1.03-1.45)	
55	1.52 (1.27-1.82)		1.68 (1.37-2.06)	
Alcohol intake, g/d		<.0001		<.0001
≤20	reference		reference	
20-40	0.68 (0.59-0.79)		0.69 (0.57-0.83)	
≥40	0.62 (0.50-0.78)		0.59 (0.46-0.77)	
Occupational categories		0.09		0.57
Self-employed, artisans	reference		reference	
Farmers	0.84 (0.48-1.48)		1.01 (0.56-1.82)	
Managerial staff/intellectual professions	0.90 (0.78-1.04)		0.92 (0.78-1.08)	
Employees	1.00 (0.85-1.19)		0.86 (0.71-1.04)	
Homemakers	1.23 (0.99-1.52)		1.01 (0.80-1.28)	
Manual workers	0.81 (0.59-1.13)		0.85 (0.60-1.21)	
Education level		0.13		0.92
Primary school	reference		reference	
Secondary school	1.00 (0.86-1.18)		1.02 (0.86-1.22)	
University level	0.89 (0.75-1.04)		1.00 (0.82-1.21)	
Marital status		0.07		0.40
Living with a partner	reference		reference	
Living alone	1.16 (0.99-1.36)		1.08 (0.91-1.28)	
Smoking status		<.0001		0.0003
Non-smokers	reference		reference	
Former smokers	0.79 (0.69-0.90)		0.83 (0.72-0.95)	
Smokers	0.69 (0.57-0.84)		0.68 (0.56-0.84)	
Physical activity[4]		0.004		0.001
[0 – 30[min/d	reference		reference	
[30 – 60[min/d	1.25 (1.07-1.45)		1.30 (1.12-1.52)	
≥ 60 min/d	1.20 (1.04-1.39)		1.26 (1.08-1.47)	

Abbreviations: FSA-NPS DI: Food Standards Agency- nutrient profiling system dietary index, Q: quartile

[1] Values are odd-ratio and 95% confidence interval

[2] Model is crude

[3] Model is adjusted for all demographics and lifestyle factors and energy intake and number of 24h records

[4] Time equivalent brisk walking per day