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Florine Berthy, Joséphine Brunin, Benjamin Allès, Anouk Reuzé, Serge Hercberg, et al.. Higher adherence to the EAT-Lancet reference diet is associated with higher nutrient adequacy in the NutriNet-Santé cohort: a cross-sectional study. *The American Journal of Clinical Nutrition*, 2023, 117 (6), pp.1174-1185. 10.1016/j.ajcnut.2023.03.029 . hal-04079271

HAL Id: hal-04079271

<https://hal.science/hal-04079271v1>

Submitted on 24 Apr 2023

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Higher adherence to the EAT-Lancet reference diet is associated with higher nutrient adequacy in the NutriNet-Santé cohort : a cross-sectional study

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Running Head: Nutritional quality assessment of the EAT-Lancet reference diet

Abbreviations:

AI: Adequate Intake

ANSES: Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail

BMI: Body Mass Index

CU: consumption unit

EAR: Estimated Average Requirements

EI: Energy Intake

EIWA: Energy Intake Without Alcohol

ELD-I: EAT-Lancet Diet Index

IPAQ: International Physical Activity Questionnaire

NCI: National Cancer Institute

PANDiet: diet quality index based on the probability of adequacy of nutrient intake

PNNS : Programme National Nutrition Santé

PNNS-GS2: PNNS Guidelines Score 2

Q: Quintile

Number of tables: 5

Number of figures: 1

Supplementary Material: 9

Word count: abstract = 305, text= 4,572

1 **Abstract**

2 **Background:** In 2019, the EAT-Lancet Commission proposed a planetary and healthy
3 reference diet; however, its nutritional quality has been rarely evaluated.

4 **Objective:** Across different adherence levels to the EAT-Lancet reference diet, the following
5 were our objectives: 1) describe the food and nutritional intakes of the French population, 2) to
6 evaluate the nutrient quality and, 3) investigate the consistency between the French national
7 recommendations and the EAT-Lancet reference diet.

8 **Design:** This cross-sectional study was conducted among participants of the NutriNet-Santé
9 cohort and the sample was weighted on the characteristics of the general French population.
10 Adherence to the EAT-Lancet reference diet was estimated using the EAT-Lancet Diet Index
11 (ELD-I). Usual nutrient intakes were obtained using the variance reduction method. We used
12 the estimated average requirements cut-point method to estimate the proportion of participants
13 who meet their respective nutritional requirements. Furthermore, the adequacy of the French
14 food-based dietary recommendations (*Programme National Nutrition Santé [PNNS]*)
15 according to adherence to the EAT-Lancet reference diet was studied.

16 **Results:** The weighted sample was composed of 98,465 participants. Except for bioavailable
17 zinc and vitamin B12, we observed a decrease in the nutrient inadequacy prevalence when the
18 adherence to the EAT-Lancet reference diet increased, particularly for vitamin B9 (Q1=37.8%
19 vs. Q5=5.5%, $p < 0.0001$) and vitamin C (Q1=59.0% vs. Q5=10.8%, $p < 0.0001$). However,
20 inadequacy prevalence remained high in all ELD-I quintiles, particularly for fiber (95.9%),
21 vitamin B1 (70.8%), iodine (48.4%), and magnesium (76.8%). Higher ELD-I score was
22 associated with higher adherence for most components of the PNNS, except for food groups
23 that are not specifically included in the EAT-Lancet reference diet and are typical of the
24 French diet, including alcohol, processed meat, and salt.

25 **Conclusion:** In the French context, although issues with the intake of certain nutrients may
26 occur, a diet that remains within the planetary limits as the EAT-Lancet reference diet allows
27 a favorable nutritional quality.

28 **Keywords:** sustainable diet, nutritional quality assessment, healthy eating, food system.

Trial registration number: NCT03335644

29

30 **Introduction**

31 Currently, the greatest challenge facing food systems is providing an affordable and
32 nutritionally adequate diet for a growing population while preserving the integrity of the
33 planet (1–3). The current food production is one of the main factors of environmental
34 degradation, whereas, in 2022, numerous planetary boundaries have already been
35 transgressed, threatening humanity’s viability on Earth (4–6). Several studies have shown that
36 diets based on high intakes of plant-based products, and low intakes of meat and dairy
37 products have lower environmental impacts (7–9).

38 Moreover, it is now established that modern diets, low in fiber and based on unhealthy
39 energy-dense foods, animal and processed foods, that is, rich in salt, sugars and saturated fats
40 (10), have harmful effects on health (2). Suboptimal diets, including Western diets, are
41 therefore the third leading risk factor for mortality among adults worldwide (11) and
42 contribute to the development of morbidity (12–14). In contrast, diets containing low to
43 moderate amounts of animal products and rich in plant-based foods can help lower the
44 prevalence of these chronic diseases (2,15–17). However, these diets cover various eating
45 practices, both healthy and unhealthy (18–21). Despite not being well planned, vegetarian
46 diets may be associated with nutritional inadequacy and an increased risk of micronutrient
47 deficiencies (22–25).

48 In 2019, the EAT-Lancet Commission developed a universal planetary healthy reference diet,
49 which is an evidence-based diet considering the multiple links between nutrition, health and
50 the environment (2). Overall, the EAT-Lancet reference diet is a 2,500 kcal per day-diet,
51 mainly characterized by vegetables, fruits, whole grain products, legumes, oleaginous, dairy
52 products, and unsaturated oils. It consists of very moderate amounts of seafood, eggs, and
53 poultry and considerably low amounts of products rich in added fats and sugars as well as
54 animal-based products, including beef, pork and lamb.

55 Whether the EAT-Lancet reference diet, which is developed for global targets and setting
56 very low or no intake values for several nutrient-rich food groups, is adequate to satisfy the
57 nutritional needs of different populations remains debated. The EAT-Lancet reference diet has
58 been applied, compared with various dietary guidelines, and studied in different
59 socioeconomic and nutritional contexts; the results are inconsistent (26–33). For example,
60 Blackstone and Conrad observed marked differences between the EAT-Lancet reference diet
61 and the dietary guidelines for Americans for whole grains, fruits, starches, red meat, nuts, and
62 discretionary foods, which are mostly key components of the EAT-Lancet reference diet (28).
63 Overall, these studies documented that, depending on the country and culture, compliance
64 with the EAT-Lancet reference diet may require strong changes in an individual's dietary
65 habits and that the nutritional quality does not frequently seem to be guaranteed.

66 However, the nutritional adequacy of the EAT-Lancet reference diet, favoring plant-based
67 products and greatly limiting the consumption of animal products, has not yet been studied in
68 the French context.

69 Therefore, this study aimed to investigate the nutritional quality of the diets of participants of
70 the NutriNet-Santé cohort according to the level of adherence to the EAT-Lancet reference
71 diet. Across various levels of adherence to the EAT-Lancet reference diet, the following were
72 the specific objectives: 1) describe the food and nutritional intakes of the French population,
73 2) evaluate the nutrient quality, and 3) study the consistency between the French national
74 recommendations and the EAT-Lancet reference diet.

75 **Methods**

76 Data were collected from the NutriNet-Santé study, a French web-based prospective cohort
77 launched in 2009. Adult volunteers aged 18 years old or older were recruited from the general
78 population through a large multimedia campaign. Registration and follow-up are made online

79 on a dedicated website (www.etude-nutrinet-sante.fr). The NutriNet-Santé study's design and
80 methods are described elsewhere (34). The NutriNet-Santé study is conducted in accordance
81 with the Declaration of Helsinki and was approved by the Ethics Committee of the French
82 Institute of Health and Medical Research (IRB Inserm Research n° 0000388FWA00005831)
83 and by the National Commission on Informatics and Liberty (CNIL n° 908450 and
84 n°909216). This cohort is registered in ClinicalTrials.gov (NCT03335644). At inclusion, all
85 participants signed an electronic informed consent via the online platform. This procedure is
86 appropriate for web-based cohorts and has been validated by the abovementioned ethical and
87 regulatory authorities.

88 ***Data collection***

89 *Sociodemographic and lifestyle factors*

90 Participants completed a set of validated self-administered questionnaires (34) at baseline, in
91 the same period during which they completed the first 24-h dietary records, and their
92 sociodemographic and lifestyle characteristics as well as health status information were
93 collected. Data collected included sex, age, education level, monthly household income,
94 occupation, and marital status. Monthly household income was calculated per consumption
95 unit (c.u.) according to a weighting system, where 1, 0.5, and 0.3 are attributed to the first
96 adult in the household, each person aged 14 years or older, and all children under 14 years
97 old, respectively (35). Lifestyle and anthropometric characteristics were self-reported using
98 validated questionnaires (36,37) and body mass index (BMI) was calculated from the formula
99 weight (kg)/height in meter squared (m^2). Three levels of physical activity were defined based
100 on the metabolic equivalent of task (MET) minutes per week (MET-min/week): low (<600
101 MET-min/week), moderate (600-1500 MET-min/week), and high (>1,500 MET-min/week).
102 For females, menopausal status was also collected.

103 *Dietary data*

104 Dietary intakes were assessed at enrollment and twice a year thereafter using a series of three
 105 non-consecutive 24-h dietary records, randomized over a 2-week period (two weekdays and
 106 one weekend day). Participants reported all food and beverages (type and quantity) consumed
 107 during a 24-h period: three main meals (breakfast, lunch, and dinner) and all other eating
 108 occasions. Supplements were not considered in nutrition intakes. Portion sizes were estimated
 109 according to standard measurements or using photographs from a previously validated photo
 110 booklet (38). Collection methods were validated against biomarkers of nutritional status and
 111 conventional data collection methods (39–41). Daily energy, macronutrient and micronutrient
 112 intakes were calculated using a published food composition table (42). Intake from composite
 113 dishes was calculated using reference recipes validated by nutrition professionals. Energy
 114 under-reporters were identified following Black’s method (43) using Goldberg’s cut-offs (44),
 115 and the basal metabolic rate was determined based on Schofield’s equations (45) according to
 116 sex, weight, and height collected upon study enrollment.

117 *Computation of nutritional scores*

118 *EAT-Lancet Diet Index (ELD-I)*

119 Adherence to the EAT-Lancet reference diet was estimated using the ELD-I. This dietary
 120 score has been described elsewhere (46).

121 The ELD-I for an individual j can be written as follows, equation (1):

122

$$123 \quad (1) \text{ ELD-I } j = \frac{100 \times \left\{ \sum_{\text{component } i=1}^{14} \frac{a_i \times \left(\text{cut-off } i - \frac{\text{consumption}_{ij} \times 2500}{\text{Energy intake } j} \right)}{\text{cut-off } i} \right\}}{14}$$

124

125

126 where i refers to the 14 EAT-Lancet food groups and j is the individual. $a_i = 1$ for component
127 to limit and $a_i = -1$ for component to promote.

128 Computing of the ELD-I leads to a continuous variable (positive or negative). The higher the
129 score, the higher the adherence to the EAT-Lancet reference diet. In the present study, the
130 ELD-I was estimated for each participant using the average of all 24-h dietary records during
131 the first 2 years following inclusion in the NutriNet-Santé cohort. All mixed dishes have been
132 decomposed into ingredients, which were subsequently allocated to the ELD-I food groups.
133 Cut-offs values are presented in **Supplementary Table 1**.

134 *French nutritional recommendation scores*

135 As complementary approaches in the study of the quality of the EAT-Lancet scheme in the
136 French context, we calculated the following two scores: the *Programme National Nutrition*
137 *Santé* -Guidelines Score 2 (PNNS-GS2) and the PANDiet score.

138 The PNNS-GS2, which reflects adherence to current French food-based dietary guidelines
139 (47), includes 13 dietary components, which are divided into six adequacy components and
140 seven moderation components.

141 The PANDiet is a diet quality whose objective is to estimate the probability of adequacy of
142 nutrient intakes (48). This score is decomposed into the following two sub-scores: an
143 adequacy score based on the probabilities of the adequacy of 27 nutrients and a sub-score
144 including 6 nutrients and 12 penalty values referring to the probabilities of exceeding the
145 upper limits of intakes. We presented the complement to 100 of the PANDiet score ($100 -$
146 $[\text{PANDiet} \times 100]$) to be consistent with estimates of the prevalence of nutritional inadequacy.

147 *Statistical analyses*

148 This study included participants registered in the NutriNet-Santé cohort between 2009 and
149 2015, and who validated at least three 24-h dietary records during the first 2 years following

150 enrollment into the cohort. Owing to dietary intakes potentially not representative of the usual
151 diet, female participants who were pregnant during the dietary data collection period were
152 excluded as well as those who had missing sociodemographic or socioeconomic data and
153 resided in overseas territories (**Supplementary Figure 1**).

154 Our sample was weighted to improve its representativeness in relation to the French
155 population. Individual weights were calculated, by sex, according to the 2009 national census
156 on age, presence of children aged <18 years in the household, education level, occupation
157 status, marital status, and area of residence using the iterative proportional fitting procedure,
158 to adjust the percentage of individuals in each stratum to the actual percentage in the French
159 population (49). In case of rare presence of certain socio-demographic profiles, this method
160 can lead to very high weights. Participants with extreme weights were excluded from the
161 analyses.

162 Baseline characteristics were described across weighted sex-specific quintiles (Q) of the ELD-
163 I using mean and standard deviation or percentage. Food intakes were adjusted for total
164 energy intake (EI) and usual nutrient intakes for usual EI without alcohol (EIWA) using the
165 residual method (50). Food and nutrients data were presented as means with their standard
166 errors (SEM). P-values were estimated using the Mantel–Haenszel χ^2 test for dichotomized or
167 ordinal variables, χ^2 for other categorical variables, and generalized linear models with linear
168 contrast for continuous variables.

169 To estimate the proportion of participants meeting each specific item of the EAT-Lancet
170 reference diet in our sample, we estimated the mean intakes for each food group considered in
171 the EAT-Lancet reference diet for the total sample and by ELD-I quintiles and subsequently
172 calculated the proportion of participants reaching these recommendations. For this, we used
173 the reference values proposed by Willett et al (2).

174 Nutrient inadequacy was defined as the prevalence of individuals whose usual intakes were
175 below their individual nutrient requirements. For the estimation of inadequacy prevalence, the
176 effects of day-to-day intake variability were removed to estimate a long-term mean nutrients
177 intake, that is, the usual nutrient intake. We performed variance reduction using the National
178 Cancer Institute method (51–53). The usual intake modeling was performed from MIXTRAN
179 macro followed by INDIVINT macro, using a one-part model, with age at inclusion and sex
180 as variable parameters. Nutrient inadequacy was assessed using the estimated average
181 requirement (EAR) cut-point method (54); for each nutrient, the threshold value considered
182 was the estimated average requirement declined according to age and sex. The proportion of
183 participants whose usual intake was below the EAR was estimated for each nutrient across
184 sex and ELD-I quintiles. At the population level, this proportion represents an unbiased
185 estimate of the proportion of participants with inadequate intakes relative to their individual
186 requirements (54). When the EAR was not available for a nutrient, we considered the
187 proportion of participants with a low intake, using the adequate intake (AI). For zinc and iron,
188 the threshold values considered were those of the estimated average physiological
189 requirements. Therefore for each participant the bioavailable zinc and iron were computed
190 using the published formula (55,56). Of note, because the nutritional requirement for iron in
191 menstruating females is not symmetrical around the population mean (57,58), the EAR-cut
192 point method could not be used for this subgroup (54). Therefore, for menstruating females
193 we performed out the probabilistic approach based on the distribution of the physiological
194 requirement for iron, as modelled for females of reproductive age (59) . The EAR and AI used
195 were those proposed by the French Agency for Food, Environmental and Occupational Health
196 Safety (ANSES) (60) (**Supplementary Table 2**). Furthermore, we calculated the PANDiet
197 complementary across the ELD-I quintiles.

198 Finally, sensitivity analyses were performed. First analyses were performed after removing
199 prevalent cancer, cardiovascular diseases, and types 1 and 2 diabetes. Subsequently, we
200 estimated the proportion of participants meeting the recommendation for each component of
201 the PNNS-GS2, by the adherence level to the ELD-I to investigate the coherence between the
202 EAT-Lancet reference diet and the official French dietary guidelines.

203 All tests were two-sided, and $P < 0.05$ was considered statistically significant. Statistical
204 analyses were performed using SAS[®] version 8.3 (SAS Institute) and R[®] version 4.0.4 (R
205 Foundation).

206 **Results**

207 *Sociodemographic and lifestyle characteristics*

208 The final study sample included 98,465 participants followed between 2009 and 2015.
209 (Flowchart in **Supplementary Figure 1**). Participant characteristics in the overall sample and
210 across quintiles of the ELD-I are presented in **Table 1**. The sample was 78% female, and the
211 average ELD-I score was 41.2 (range, -161.5 to 428.6) points (**Supplementary Table 3**).
212 Better adherence to the EAT-Lancet reference diet was more frequently associated with older
213 age and lower physical activity.

214 *Food consumption and usual nutrient intakes according to the ELD-I*

215 By construction, higher consumption of fruits, vegetables, legumes, nuts, and seafood was
216 associated with higher ELD-I scores. Conversely, a higher score was associated with lower
217 consumption of meat, eggs, tubers, fat, fatty and/or sweetened products, and sweetened soft
218 drinks (**Table 2**).

219 Participants with high adherence to the EAT-Lancet reference diet had, on average, lower EI
220 than those with low adherence (**Table 3**). We observed a minimal decrease in the overall

221 protein intake as the ELD-I increases; however, across ELD-I sex-specific quintiles, the
222 percentage of animal protein decreased in favor of plant proteins. Compared with the
223 participants with the lowest ELD-I, those with the highest had slightly increased carbohydrate
224 consumption, whereas fat intake decreased. Moreover, as the score increased, so did the fiber
225 intake. Across ELD-I quintiles, an increase in the intake of beta-carotene, calcium, copper,
226 total iron, iodine, potassium, magnesium, manganese, phosphorus, vitamin A and vitamin B9
227 and vitamin C was observed while intake of cholesterol, vitamin B12 and heme-iron intake
228 decreased. The polyunsaturated fatty-acid, zinc, retinol, sodium, selenium, vitamins B1, B2,
229 B3, B5, B6 and vitamin E intake was similar across quintiles.

230 The proportion of individuals meeting the different EAT-Lancet reference diet components
231 widely varied across food groups (**Figure 1 and Supplementary Table 4**). The components
232 for which the proportions of participants meeting the recommendations varied the most across
233 quintiles were fruits, vegetables, and red meat. However, it was observed that for legumes,
234 nuts, and whole grains as well as unsaturated oils, the recommendations were overall very
235 poorly met regardless of the ELD-I.

236 *Nutrient quality*

237 The complement to 100 of the PANDiet score and mean values of prevalence inadequacy for
238 main macronutrients and micronutrients are shown in **Table 4**.

239 PANDiet complement gradually decreased across the ELD-I. Inadequacy prevalence for
240 vitamins B9 and C gradually decreased across the ELD-I quintiles. This was also the case for
241 vitamin A and calcium; however, this decrease stagnates between the fourth and fifth
242 quintiles. Conversely, zinc was the only nutrient for which the inadequacy prevalence was the
243 highest in quintile 5 (42.9 %) and the lowest in quintile 1 (38.6 %). In our sample, inadequacy
244 intakes for protein (1.8 %), copper (1.9 %), vitamin B3 (3.6 %) and iron in males and

245 menopausal females (1.4 %) were small. In non-menopausal females, the prevalence of
246 bioavailable iron inadequacy of approximately 35% equal in all quintiles. Regarding fiber
247 intake, although the inadequacy prevalence decreased with increasing ELD-I, the intake was
248 by far insufficient whatever the quintile. The results of the sensitivity analysis after removing
249 participants with prevalent chronic diseases were unchanged (**Supplementary Table 5**).

250 Sex differences in the prevalence of nutrient inadequacy are presented in **Supplementary**
251 **Table 6**

252 As shown in **supplementary table 7**, the average proportion of participants with an intake is
253 considered low (i.g. below the AI for the French population); however, in some cases, these
254 intakes may potentially meet their individual micronutrient requirements. For vitamins B1,
255 B6, E, magnesium, and manganese, this proportion gradually decreased across the ELD-I
256 quintiles. Moreover, for selenium, vitamin B1 and magnesium a high prevalence of
257 participants had intakes that were considered low. Regarding phosphorus, < 1% of our sample
258 had intakes that were considered low.

259 *Consistency between the EAT-Lancet reference diet and the French dietary*
260 *recommendations*

261 The PNNS-GS diet quality score gradually increased across ELD-I quintiles (**Table 5**).
262 Regarding adherence to individual components of the PNNS-GS2 across ELD-I quintiles
263 (**Supplementary Figure 2 and Table 5**), we observed similar trends for the components
264 common to the EAT-Lancet reference diet. That is, across ELD-I quintiles, we observed a
265 marked increase in the proportion of participants following the recommendations for fruits,
266 vegetables and red meat as well as moderate-to-low proportions in whatever quintiles for nuts,
267 legumes, fish, and dairy products. Regarding the groups of foods specific to the PNNS,
268 including processed meats, alcohol, and salt, the proportion of participants respecting the

269 recommendations decreased in the first quintile and subsequently increased in the other
270 quintiles. The proportion of participants following the recommendations for salt was equal in
271 quintiles 1 and 5 and lower in the fifth quintile for alcohol consumption.

272 **Discussion**

273 In the present study, we investigated the dietary and usual nutrient quality of French adults
274 across adherence levels to the EAT-Lancet reference diet. Attention is needed regarding fiber,
275 calcium, vitamin C, bioavailable zinc, and bioavailable iron (in non-menopausal females)
276 intakes. Nutrient inadequacy regarding macronutrient as protein and fiber decreased across
277 ELD-I. For micronutrients, the lowest prevalence of inadequacy was observed for the
278 participants with the highest adherence to the EAT-Lancet reference diet. Differences in food
279 consumption according to ELD-I levels were substantial for only a few foods, with plant-
280 based consumption being too low for any adherence level to the EAT-Lancet reference diet.
281 Therefore, participants in the highest ELD-I score quintile remain far from meeting the
282 recommendations of the EAT-Lancet reference diet. Additionally, the specific components of
283 the French PNNS recommendations (salt, alcohol, and processed meat) were not better
284 followed for higher adherence to the EAT-Lancet reference diet.

285 First, as noted in other studies (29,32), animal protein intake decreased across ELD-I
286 quintiles. Although this decrease was largely offset by an increase in plant protein intake, as
287 Hanley–Cook and Vallejo (30,32), we observed, a decrease in the proportion of energy
288 provided by protein with increasing adherence to the EAT-Lancet reference diet.

289 Nevertheless, current evidence shows that, in high-income countries, plant-based diets can
290 provide sufficient protein and essential amino acid intakes (25,61); therefore, more attention
291 should be focused on fiber-related issues. The increase in plant-based foods promoted by the
292 EAT-Lancet reference diet unequivocally allowed for an increase in fiber intake whatever the
293 context (26,29,32). In our sample, the participants, whatever their ELD-I quintile, were very

294 far from the cut-off point provided by the PNNS. Higher adherence to plant-based
295 components, including fruits, vegetables, legumes, and whole grains, would also lead to better
296 adherence to the French reference values (30 g/day). Contrary to other studies (26,29,32), in
297 the French context, we noted a decrease in the total fat intake across ELD-I quintiles. This
298 should be ascribed to the fact that higher scores are mainly related to higher fruit and
299 vegetable consumption and the decrease in meat, with lower increases in other products, such
300 as nuts, which therefore cannot contribute to limiting the decrease in fat intake.

301 In our study, except for bioavailable zinc, the prevalence of nutrient inadequacy decreased
302 with increasing adherence to the EAT-Lancet reference diet, particularly for vitamins C and
303 B9, wherein the inadequacy prevalence was greatly reduced between the least and most
304 adherent to the reference diet. In the study by Tucci et al. (29), zinc and vitamin B12 intakes
305 were lower in participants who followed the EAT-Lancet reference diet; however, in these
306 participants, intakes of these nutrients both met the national reference values, whereas
307 calcium intakes were inadequate. A study conducted in the Danish population reported similar
308 results for vitamin B12 and calcium (26). In these two populations, the insufficient intakes
309 among participants who followed better the EAT-Lancet reference diet were explained by the
310 low consumption of animal-based foods and more particularly of dairy products for calcium;
311 however, dairy products are encouraged in the EAT-Lancet reference diet. However, in our
312 study, the participants with higher adherence to the EAT-Lancet reference diet showed some
313 intakes of these products, and in particular a higher consumption of dairy products than those
314 in the first quintiles, which may explain that a high prevalence of inadequate intakes of
315 calcium, zinc and vitamin B12 was not observed. Our results were consistent with the results
316 of an observational study conducted on a sample of French adults, simulating a total or partial
317 replacement of meat by plant-based substitutes, resulting in a decrease in the adequacy of
318 vitamin B12 and bioavailable zinc and iron (62). Nutritional references for bioavailable iron

319 and zinc often appear to be the primary limiting factors in a transition to a plant-based diet;
320 however, official thresholds lower than current values, not jeopardizing overall health, would
321 allow for the identification of healthier diets (63,64). Furthermore, among non-menopausal
322 females, although the prevalence of inadequacy was high, they were not reduced in the
323 quintiles where meat consumption was the highest.

324 Overall, nutritional quality was better in the highest ELD-I quintiles. However, a study by
325 Hanley–Cook (30) showed that in some populations, it is essential that the diet still include
326 some nutrient-dense foods for nutritional adequacy to be improved by the EAT-Lancet
327 reference diet. In our study the participants with the highest adherence to the EAT-Lancet
328 reference diet did not attain the consumption target for all 14 components. In our study,
329 participants with high adherence to the EAT-Lancet reference diet had a suboptimal and
330 improvable diet. For example, on average they had a very high tuber and starchy vegetable
331 consumption and a very low legume, whole grain, and nut consumption. However, dietary
332 intakes remained sufficiently varied to cover most nutritional needs. However, other studies
333 that have developed a plant-based diet that meets the EAT-Lancet targets adapted to Italian
334 (29) and Danish (26) intakes showed that these highly strict targets can be challenging in
335 achieving certain national references values.

336 Dietary recommendations varied from country to country and were nearly consistent with the
337 EAT-Lancet reference diet. The PNNS-GS2 was consistent with the EAT-Lancet reference
338 diet for fruits and vegetables, dairy products, and unsaturated fats (65); components for which
339 (except for fruits) the Dietary Guidelines for Americans recommendations were also
340 consistent with those of the EAT-Lancet Commission (28). However, the two national
341 recommendations differed from the EAT-Lancet reference diet in several aspects, including
342 the recommended serving sizes of whole grains, red meat and poultry, nuts, and legumes,
343 which were essential components of this reference diet. These facts show the significance of

344 adapting dietary recommendations to the habits and cultures of each country, to account for
345 the variability in the food offered and cultural specificities (66). Processed meat, alcohol, or
346 salt, which are typical components of the French diet and therefore are to be limited according
347 to the PNNS (65), are not specifically considered in the EAT-Lancet reference diet and that
348 higher adherence to this reference diet tended to result in lower compliance with
349 recommendations related to these components. These disparities in components between the
350 EAT-Lancet reference diet and the French PNNS recommendations partly explain the lower
351 associations previously observed between the ELD-I score and the occurrence of cancers and
352 the nonsignificant associations with cardiovascular diseases (67) compared with those with
353 the PNNS-GS2 score (68), wherein the inverse associations were highly significant. These
354 two studies focused on existing dietary recommendations, defined differently (EAT-Lancet
355 and Official French dietary guidelines), and the risk of chronic diseases. Additionally, it is
356 observed that intakes were similar between quintiles, for some food groups and nutrients,
357 suggesting that the differences observed in terms of health impact were more related to those
358 components for which large differences were observed such as fruits, vegetables, red meat,
359 sweet products, and whole grains for foods, and vitamins C, B9, and magnesium for nutrients.

360 Moreover, adherence to the EAT-Lancet reference diet has been studied in other settings,
361 particularly in Gambia (69). In this population, as in our study, the intake of unhealthy plant-
362 based foods, including sugars and refined cereals, was excessively high and that of healthy
363 plant-based foods was excessively low. However, in the Gambian context, the consumption of
364 red and white meat and dairy products was below the EAT-Lancet reference diet range in
365 most households. In this country, beyond the financial barrier, the production and supply of
366 these food groups are challenging. Furthermore, consistent with our study, Bäck et al (31)
367 estimated the proportion of participants meeting each of the EAT-Lancet reference diet target
368 in Finnish children. In both populations, very low proportions (<10%) of participants met the

369 EAT-Lancet reference diet target for whole grains, legumes, nuts, saturated oils, and sugars,
370 which are key components of the reference diet. These different comparisons confirm the
371 need for not only adapting dietary recommendations to cultural habits (70,71) and the
372 capacities of each country in terms of production and provisioning but also for specifically
373 adapting them to individual preferences since a remarkable change from their usual food
374 consumption could make several individuals reluctant to adhere to these new reference diet
375 (72). In our study, we observe that the recommendations were followed differently according
376 to participants profiles and that the EAT-Lancet reference diet was more followed by older
377 and higher income participants. Therefore, it is also significant to adapt the messages related
378 to the dietary recommendations to less-adherent individuals.

379 This study had some limitations. First, there is a lack of official values for the EAR of certain
380 nutrients. When these values were unavailable although the AI was, we used the AI, which
381 provides an indication of the proportion of participants with low intakes compared with an
382 arbitrary threshold; however, for some participants, this intake may be sufficient as regards
383 their individual physiology. Furthermore, some limitations inherent to the NutriNet-Santé
384 cohort should be acknowledged. Indeed, owing to the voluntary-basis recruitment, the
385 participants of the NutriNet-Santé cohort may be more health conscious and therefore exhibit
386 healthier dietary habits (73,74) that may differ from those of the general population in
387 particular regarding health and risk factors including diet. However, the large sample includes
388 usually inaccessible individuals, including young adults, older or jobless population (73).
389 However, this limited representativeness is minimized herein by weighting on a number of
390 socioeconomic characteristics to best mimic the national population. Moreover, the small
391 number of studies on the topic and the disparities in dietary habits between countries make
392 comparisons challenging.

393 However, our study also exhibited significant strengths. First, we have used very detailed and
394 high-quality nutritional data, with an average number of 5.9 24-h dietary records per
395 participant. Additionally, the dietary assessment method used in the NutriNet-Santé cohort
396 was validated by comparing with urinary and blood biomarkers (39,40) as well as supervised
397 assessment performed by dietitians (41). Furthermore, the nutritional adequacy study was
398 performed on usual consumption data, which allows limiting the intra-individual variation.
399 Additionally, to better consider the ingredients of different foods, complex recipes were
400 disaggregated into individual ingredients. Lastly, the very large sample of participants allows
401 assessing a wide range of dietary profiles.

402 **Conclusion**

403 In French context, overall, although some key nutrient intakes remain challenging, including
404 fibers, calcium, bioavailable zinc and vitamin C, a higher adherence to the global EAT-Lancet
405 reference diet is associated with higher nutritional adequacy. In the context of environmental
406 emergency, the inadequacy prevalence in certain nutrients should not be a barrier to a
407 transition to a higher proportion of plant-based foods in the diet, especially since, overall,
408 these diets present better nutritional profiles. However, the acceptability of this type of
409 recommendation is a major issue of this diet as well as accessibility and cost, which must be
410 studied to determine if they are fully compatible with a sustainable diet.

Acknowledgements

We thank Thi Hong Van Duong, Régis Gatibelza, Jagatjit Mohinder and Aladi Timera (computer scientists); Fabien Szabo de Edelenyi, Ph.D. (data management supervisor); Julien Allegre, Nathalie Arnault, Laurent Bourhis, Nicolas Dechamp (data-manager/statisticians); Paola Ivroud (health event validator); Maria Gomes, Mirette Foham (Nutrinautes support), Cédric Agaesse, Rébecca Lutchia, Alexandre De Sa (dietitians); Younes Esseddik (IT supervisor); and Nathalie Druesne-Pecollo, Ph.D. (operational coordinator) for their technical contribution to the NutriNet-Santé study.

We thank all the volunteers of the NutriNet-Santé cohort.

Authors' contributions:

The authors' contributions were as follows: EKG and FB designed the study. FB performed statistical analyses and wrote the manuscript; EKG supervised statistical analysis and paper writing. All authors: contributed to the data interpretation and revised each draft for important intellectual content. All authors read and approved the final manuscript. FB and EKG had full access to all the data in the study, EKG takes responsibility for the integrity of the data and the accuracy of the data analysis, she is the guarantor. The corresponding author (FB) attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

Transparency statement

Dr Emmanuelle Kesse-Guyot (the guarantor) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Conflict of Interest

The authors declare no conflict of interest.

Data sharing statement

Analytic code will be made available upon request pending. Researchers from public institutions can submit a collaboration request including information on the institution and a brief description of the project to collaboration@etude-nutrinet-sante.fr. All requests will be reviewed by the steering committee of the NutriNet-Santé study. If the collaboration is accepted, a data access agreement will be necessary and appropriate authorizations from the competent administrative authorities may be needed. In accordance with existing regulations, no personal data will be accessible.

Funding

Funding statement and statement of the independence of researchers from funders. The NutriNet-Santé study was supported by the following public institutions: Ministère de la Santé, Santé Publique France, Institut National de la Santé et de la Recherche Médicale (Inserm), Institut national de recherche pour l'agriculture, l'alimentation et l'environnement (INRAE), Conservatoire National des Arts et Métiers (CNAM) and Université Sorbonne Paris Nord. FB was supported by a Doctoral Fellowship from Université Sorbonne Paris Nord – Galilée Doctoral School.

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Table 1. Description of socio-demographic and lifestyle characteristics at inclusion, by weighted sex-specific quintiles of EAT-Lancet Diet Index. NutriNet-Santé study, 2009-2015, France (n=98,465)

	Weighted sex-specific quintiles of ELD-I ¹						p-value ²
	All	Q1	Q2	Q3	Q4	Q5	
n	98,465	16,758	19,805	20,609	20,704	20,589	
Weighted n	98,465	19,673.1	19,696.7	19,704.6	19,692.7	19,698.9	
ELD-I	41.2 (27.5)	4.3 (18.6)	28.8 (4.4)	41.1 (3.8)	53.3 (4.6)	78.4 (14.4)	<0.0001
Sex %							1.00
Females	78.0	78.0	78.0	78.0	78.0	78.0	
Age (y)	47.4 (16.1)	40.8 (15.8)	44.1 (15.4)	47.7 (15.7)	51.2 (15.2)	53.3 (15.0)	<0.0001
Age category (y)							<0.0001
< 25	11.1	17.5	14.3	10.6	7.2	6.1	
25 - 40	25.2	34.9	29.5	25.3	20.0	16.5	
40 - 55	27.2	28.9	28.5	27.5	25.8	25.0	
55- 65	17.1	10.8	14.9	16.7	21.4	21.9	
≥ 65	19.4	7.9	12.8	19.9	25.6	30.5	
Education level, %							<0.0001
< High-school degree	53.8	58.4	52.4	52.1	53.6	52.9	
≥ High-school degree to < 2 y after high-school degree	17.4	19.2	18.5	17.2	15.6	16.3	
≥ 2 y after high-school degree	28.8	22.5	29.1	30.7	30.8	30.8	
Occupational category, %							<0.0001
Unemployed	4.3	6.0	5.1	4.0	3.4	3.0	
Farmer. merchant. artisan. company director	6.0	5.6	6.1	5.7	5.9	6.8	
Employees, manual workers	49.0	59.1	50.8	46.5	43.4	40.1	
Intermediate profession	25.1	19.4	24.1	26.3	27.6	28.3	
Managerial staff	16.6	9.9	13.9	17.5	19.7	21.8	
Monthly household income³, %							<0.0001
No communicated	13.0	14.4	12.7	12.9	12.2	13.0	
<1.200 €	22.6	34.3	26.1	20.5	17.7	14.3	
1.200 – 1.800 €	27.8	27.8	29.0	29.0	27.7	25.7	
1.800 – 2.700 €	21.6	14.7	20.0	22.3	24.6	26.3	
≥ 2.700 €	15.0	8.8	12.2	15.3	17.8	20.7	
Marital status, %							<0.0001
Single	9.9	9.5	9.4	9.3	10.0	11.5	
Married. civil union. cohabiting	75.9	76.7	77.9	77.5	75.3	72.2	
Separated. divorced. widowed	14.2	13.8	12.7	13.2	14.7	16.3	
Smoking status, %							<0.0001
Never smoker	47.8	42.9	48.1	48.6	50.2	49.4	
Former smoker	35.3	30.5	32.6	35.7	37.5	40.4	
Current smoker	16.8	26.5	19.4	15.7	12.4	10.2	
Level of physical activity⁴, %							<0.0001
Missing	17.2	21.1	18.3	16.0	16.0	14.7	
Low	32.5	28.6	29.6	31.7	33.6	39.0	
Moderate	31.2	28.3	30.1	31.8	33.7	32.0	
High	19.1	22.0	22.0	20.5	16.7	14.3	
Body Mass Index (kg/m²)	24.7 (5.1)	25.3 (6.3)	24.9 (5.2)	24.7 (4.8)	24.6 (4.6)	24.0 (4.0)	
Prevalent chronic disease⁵, %	10.3	7.7	9.0	10.5	11.9	12.4	<0.0001
Food supplementation⁶, %	35.4	26.4	30.6	35.0	38.6	44.3	<0.0001

Abbreviations: Q: quintiles; ELD-I: EAT-Lancet Diet Index.

Mean (standard deviation) for quantitative variables and percentages for qualitative variables.

¹ Sex-specific cut-offs for quintiles of ELD-I were -140.1/23.8/36.3/46.5/59.2/332.2 for females and -161.5/27.8/40.7/51.7/65.2/323.9 for males.

² P-value for comparison across weighted quintiles of ELD-I estimated by test from Mantel-Haenszel χ^2 for binary or ordinals variables, χ^2 for others categorical variables and generalized linear models with linear contrast for numeric variables.

³ Per consumption unit.

⁴ Physical activity: low (< 600 MET-min/week), moderate (600-1,500 MET-min/week) and high (> 1,500 MET-min/week).

⁵ The following are considered: prevalent cases of type 1 and type 2 diabetes, cancers excluding basal cell cancer and cardiovascular diseases.

⁶ Among 75,890 participants.

Table 2. Daily food consumption¹ according to weighted sex-specific quintiles of the EAT-Lancet Diet Index. NutriNet-Santéstudy, 2009 – 2015, France
(n=98,465)

	Target ¹ (g/day)	All	Weighted sex-specific quintiles ³					P-trend ⁴
			Q1	Q2	Q3	Q4	Q5	
Whole grains	≥ 232	45.4 (60.1)	26.2 (47.7)	35.2 (50.7)	42.8 (54.3)	52.3 (59.2)	70.3 (73.2)	<.0001
Tubers and starchy vegetables	≤ 50	65.0 (60.4)	82.0 (80.4)	68.5 (58.9)	63.7 (54.7)	59.8 (51.5)	51.2 (51.8)	<.0001
Vegetables	≥ 300	309.6 (185.3)	212.1 (152.0)	249.7 (142.9)	291.2 (140.8)	342.9 (148.5)	452.0 (224.4)	<.0001
Fruits	≥ 200	263.8 (211.5)	107.6 (116.1)	160.4 (112.7)	221.0 (121.9)	308.4 (132.7)	521.3 (240.0)	<.0001
Dairy foods	≤ 250	225.9 (210.3)	238.0 (219.4)	229.1 (205.7)	227.4 (196.0)	239.1 (201.5)	258.0 (232.2)	<.0001
Protein sources								<.0001
Beef and lamb	≤ 7	30.6 (46.7)	70.3 (78.2)	32.0 (36.6)	22.0 (29.5)	16.9 (25.5)	11.9 (23.5)	<.0001
Pork	≤ 7	17.5 (30.0)	32.6 (50.7)	19.1 (26.9)	15.4 (22.9)	12.4 (19.7)	8.1 (16.4)	<.0001
Poultry	≤ 29	37.8 (45.3)	48.6 (64.8)	40.8 (43.1)	35.4 (38.4)	33.9 (38.5)	30.3 (38.2)	<.0001
Eggs	≤ 13	20.5 (27.9)	31.4 (44.4)	21.3 (25.6)	18.3 (22.6)	16.7 (19.9)	14.8 (20.2)	<.0001
Fish	≥ 28	43.8 (49.9)	37.9 (59.0)	40.7 (48.3)	42.4 (44.8)	45.8 (44.2)	51.9 (52.6)	<.0001
Legumes	≥ 75	15.8 (32.1)	12.8 (30.4)	14.2 (29.2)	15.9 (31.9)	16.3 (29.2)	19.7 (38.3)	<.0001
<i>Dry beans, lentils and peas</i>	≥ 50	14.3 (32.3)	12.6 (30.5)	13.7 (29.4)	15.0 (31.3)	14.6 (29.9)	15.5 (39.1)	<.0001
<i>Soy foods</i>	≥ 25	1.5 (13.8)	0.2 (5.2)	0.5 (7.2)	0.9 (8.9)	1.7 (13.7)	4.2 (23.8)	<.0001
All nuts	≥ 50	5.7 (17.7)	1.4 (7.0)	2.6 (9.5)	4.2 (11.4)	6.9 (16.1)	13.4 (29.9)	<.0001
<i>Peanuts</i>	≥ 25	1.8 (7.4)	0.3 (2.7)	0.7 (3.8)	1.2 (4.4)	2.2 (6.7)	4.6 (13.0)	<.0001
<i>Tree nuts</i>	≥ 25	3.9 (11.3)	1.1 (5.1)	1.9 (6.6)	3.0 (8.2)	4.7 (10.5)	8.8 (18.4)	<.0001
Added fats								<.0001
Unsaturated oils	≤ 40	7.0 (9.4)	5.3 (9.1)	6.1 (8.4)	6.9 (8.7)	7.9 (9.5)	9.0 (10.5)	<.0001
Saturated oils	≤ 11.8	0.0 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.2)	0.0 (0.0)	0.0 (0.1)	0.13
Added sugars	≤ 31	44.5 (25.8)	54.7 (35.7)	50.5 (25.8)	45.1 (21.7)	39.9 (19.4)	32.1 (18.7)	<.0001

¹ Food consumption (g/d) standardized about 2,500 kcal/day.² Dietary targets of the EAT-Lancet reference diet.³ Sex-specific cut-offs for quintiles of EAT-Lancet Diet Index (ELD-I) were -161.5/22.2/36.5/48.1/62.4/428.6 for females and -148.7/18.2/31.8/42.5/55.7/332.2 for males.⁴ P-value for comparison across quintiles of ELD-I estimated by linear contrast models.

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Table 3. Daily usual nutrient intakes according to weighted sex-specific quintiles of the EAT-Lancet Diet Index¹. NutriNet-Santé study, 2009 – 2015, France (n=98,465)

	Weighted sex-specific quintiles of ELD-I ²				
	Q1	Q2	Q3	Q4	Q5
Energy intake (kcal)³	1,829.2 (424.9)	1,897.9 (385.1)	1,888.7 (366.5)	1,865.5 (357.2)	1,791.7 (357.1)
Energy intake without alcohol (kcal)²	1,766.5 (403.1)	1,820.2 (358.4)	1,808.2 (338.3)	1,786.0 (330.2)	1,724.2 (331.1)
Macronutrients					
Proteins (% of EIWA)	18.6 (3.6)	17.7 (2.7)	17.5 (2.4)	17.5 (2.4)	17.5 (2.7)
<i>Animal protein (g)</i>	60.3 (14.1)	56.2 (11.1)	54.1 (10.8)	52.8 (11.2)	49.8 (13.3)
<i>Plant protein (g)</i>	22.0 (3.9)	23.3 (3.7)	24.3 (3.8)	25.6 (4.1)	27.6 (5.3)
Carbohydrates (% of EIWA)	40.8 (5.6)	42.0 (4.7)	42.3 (4.4)	42.9 (4.5)	44.3 (5.1)
<i>Simple carbohydrates (g)</i>	84.8 (21.1)	86.7 (18.0)	88.1 (16.5)	91.3 (15.8)	99.8 (18.2)
<i>Added simple sugars (g)</i>	42.1 (18.5)	39.9 (14.9)	37.2 (13.1)	34.4 (12.2)	30.4 (12.2)
Lipids (% of EIWA)	40.6 (4.6)	40.3 (4.1)	40.2 (4.0)	39.5 (4.1)	38.2 (4.8)
<i>MUFA (g)</i>	30.6 (4.1)	30.3 (3.9)	30.3 (3.9)	30.0 (4.1)	29.2 (4.8)
<i>PUFA (g)</i>	11.2 (2.0)	11.1 (1.9)	11.2 (1.9)	11.4 (2.1)	11.7 (2.6)
PUFA n3 (g)	0.8 (0.2)	0.9 (0.2)	0.9 (0.2)	1.0 (0.3)	1.1 (0.3)
PUFA n6 (g)	0.2 (0.0)	0.2 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)
<i>SFA (g)</i>	33.5 (5.0)	33.6 (4.8)	33.3 (4.6)	32.3 (4.8)	30.0 (5.2)
<i>Cholesterol (mg)</i>	340.5 (63.9)	326.0 (51.7)	315.8 (49.8)	305.2 (50.1)	280.6 (58.5)
Fibers	15.6 (3.6)	17.0 (3.4)	18.6 (3.5)	20.4 (3.7)	24.1 (5.1)
Alcohol (g)	9.0 (13.0)	11.1 (13.9)	11.5 (13.6)	11.4 (13.2)	9.7 (11.6)
Micronutrients⁴					
Calcium (mg)	857.4 (189.2)	889.3 (168.3)	910.3 (164.4)	930.7 (160.3)	954.5 (178.9)
Copper (mg)	1.4 (0.3)	1.5 (0.3)	1.5 (0.3)	1.6 (0.3)	1.8 (0.4)
Iron (mg)	12.5 (2.4)	12.6 (2.3)	13.0 (2.3)	13.4 (2.4)	14.1 (2.6)
Non-heme iron (mg)	1.5 (0.5)	1.3 (0.5)	1.2 (0.5)	1.2 (0.5)	1.0 (0.5)
Iodine (µg)	151.3 (36.6)	154.7 (33.5)	159.9 (37.0)	164.5 (40.4)	166.5 (44.9)
Zinc (mg)	10.8 (2.1)	10.6 (2.0)	10.6 (2.0)	10.6 (2.0)	10.4 (2.0)
Magnesium (mg)	297.1 (65.5)	308.8 (62.2)	321.7 (61.5)	341.5 (66.7)	372.9 (78.2)
Manganese (mg)	3.2 (1.1)	3.5 (1.2)	3.9 (1.2)	4.2 (1.3)	4.9 (1.6)
Phosphorus (mg)	1,249.7 (200.9)	1,240.7 (166.8)	1,244.0 (162.5)	1,262.0 (168.0)	1,290.6 (182.1)
Potassium (mg)	2,724.6 (462.6)	2,786.1 (420.9)	2,888.3 (411.3)	3,051.2 (426.4)	3,348.8 (536.0)
Selenium (µg)	68.5 (13.5)	67.5 (11.9)	67.6 (11.4)	68.6 (12.0)	69.1 (12.4)
Sodium (mg)	2,643.0 (463.8)	2,692.0 (417.8)	2,748.1 (419.4)	2,751.7 (413.5)	2,692.7 (452.8)
Retinol (µg)	445.1 (114.4)	458.3 (109.1)	459.0 (108.0)	454.2 (112.3)	415.9 (117.6)
Beta-carotene (µg)	2,599.1 (1,012.4)	2,925.1 (948.3)	3,234.6 (976.7)	3,629.8 (1,083.7)	4,180.0 (1,419.8)
Vitamin A (µg)	914.6 (198.1)	971.8 (183.7)	1,015.7 (189.5)	1,070.6 (202.9)	1,122.5 (240.6)
Vitamin B1 (mg)	1.1 (0.2)	1.1 (0.2)	1.1 (0.2)	1.2 (0.2)	1.2 (0.3)
Vitamin B2 (mg)	1.7 (0.4)	1.7 (0.3)	1.7 (0.3)	1.7 (0.3)	1.8 (0.4)
Vitamin B3 (mg)	18.6 (4.0)	18.3 (3.5)	18.2 (3.3)	18.6 (3.4)	19.1 (3.6)
Vitamin B5 (mg)	5.2 (0.9)	5.1 (0.8)	5.2 (0.8)	5.3 (0.8)	5.4 (0.8)
Vitamin B6 (mg)	1.7 (0.3)	1.6 (0.3)	1.7 (0.3)	1.7 (0.3)	1.9 (0.4)
Vitamin B9 (µg)	278.5 (57.9)	295.5 (52.9)	313.7 (53.5)	337.8 (55.2)	376.0 (70.8)
Vitamin B12 (µg)	5.1 (1.2)	5.0 (1.1)	4.9 (1.1)	4.9 (1.2)	4.8 (1.4)
Vitamin C (mg)	89.4 (37.0)	98.8 (34.9)	107.4 (33.5)	120.8 (35.5)	143.6 (44.1)
Vitamin E (mg)	10.8 (2.2)	11.1 (2.0)	11.3 (2.0)	11.8 (2.1)	12.5 (2.3)

Abbreviations: Q: Quintile; ELD-I: EAT-Lancet Diet Index; EIWA: Energy intake without alcohol; PUFA: Poly unsaturated fatty acids; MUFA: mono unsaturated fatty acids; SFS: saturated fatty acids.

¹ P-value for comparison between quintiles of ELD-I estimated by linear contrast models. All p-values were significant, except added carbohydrates (p=0.1087).

² Sex-specific cut-offs for quintiles of EAT-Lancet Diet Index (ELD-I) were -161.5/22.2/36.5/48.1/62.4/428.6 for females and -148.7/18.2/31.8/42.5/55.7/332.2 for males.

³ Values are means (SD).

⁴ Means (standard errors) adjusted for energy intake without alcohol using the residual method, except for alcohol.

Table 4. Prevalence of nutrient inadequacy¹, full sample, and by weighted sex-specific quintiles of the EAT-Lancet Diet Index. NutriNet-Santé study, France, 2009 – 2015 (n=98,465)

	All	Weighted sex-specific quintiles of ELD-I					P-value ³
		Q1	Q2	Q3	Q4	Q5	
PANDiet complement to 100⁴	36.6 (8.7)	41.3 (8.2)	39.3 (7.5)	37.4 (7.5)	34.5 (7.5)	30.2 (8.1)	<.0001
Proteins	1.8	3.1	1.5	1.5	1.1	2.0	<.0001
Fibers	95.9	99.5	98.9	98.3	95.9	86.7	<.0001
Vitamin A	6.4	11.9	6.5	5.2	3.9	4.7	<.0001
Vitamin B3	3.6	4.0	3.4	3.4	3.5	3.5	0.01
Vitamin B9	18.4	37.8	23.7	15.7	9.6	5.5	<.0001
Vitamin C	34.6	59.0	45.7	34.7	22.8	10.8	<.0001
Calcium	27.9	39.0	29.4	24.6	23.2	23.3	<.0001
Copper	1.9	4.7	2.1	1.4	0.9	0.6	<.0001
Bioavailable iron							
Males and menopausal females	1.4	2.9	1.2	0.7	0.9	1.6	<.0001
Non-menopausal females ⁵	35.0 (23.7)	33.7 (26.2)	35.9 (23.6)	35.7 (22.7)	34.7 (22.5)	35.4 (23.6)	0.0026
Bioavailable zinc	40.8	38.6	40.3	40.8	41.2	42.9	<.0001

Mean (standard deviation) for quantitative variables and percentages for qualitative variables.

¹ The probability of nutrient intakes below the estimated average requirements for the French population, %. Probability estimated only for nutrients for which ANSES has proposed an EAR.

² Sex-specific cut-offs for quintiles of EAT-Lancet Diet Index (ELD-I) were -161.5/22.2/36.5/48.1/62.4/428.6 for females and -148.7/18.2/31.8/42.5/55.7/332.2 for males.

³ P-value for comparison across weighted quintiles of ELD-I estimated by test from generalized linear models with linear contrast for numeric variables and Mantel-Haenszel χ^2 for binary variables.

⁴ Complementary to 100 of the diet quality index based on probability of adequate nutrient intake (100 – [PANDiet × 100]) (n=98,120).

⁵ Due to the non-symmetry distribution around the iron requirements average in non-menopausal females, the EAR-cut method is not applicable in this sub-population. Bioavailable iron was obtained using complementary to 100 of the probability of adequate nutrient intake as calculated in the PANDiet.

Table 5. Proportion (%) of participants meeting each PNNS recommendation¹ according to weighted sex-specific quintiles of the EAT-Lancet Diet Index. NutriNet-Santé study, 2009 – 2015, France

Dietary components	Recommendation	All	Weighted sex-specific quintiles of ELD-I ²					p-value ³
			Q1	Q2	Q3	Q4	Q5	
PNNS-GS2		1.4 (3.5)	-0.5 (3.6)	0.3 (3.2)	1.1 (3.1)	2.1 (3.0)	3.7 (3.0)	<0.0001
Simplified PNNS-GS2		1.6 (3.5)	-0.4 (3.7)	0.4 (3.3)	1.2 (3.1)	2.3 (3.0)	4.0 (3.0)	<0.0001
Fruits and vegetables	≥ 5 servings/ d	51.4	11.9	27.7	47.2	73.3	93.4	<0.0001
Organic fruits and vegetables ⁴	Most of the time	11.1	5.5	8.0	10.2	12.8	17.9	<0.0001
Nuts	≥ 1 serving/ d	5.1	1.0	2.1	4.0	6.9	10.9	<0.0001
Legumes	≥ 1 servings / week	4.7	3.8	4.9	4.7	4.3	6.0	<0.0001
Organic legumes ⁴	Most of the time	10.1	3.6	6.2	9.0	12.4	18.0	<0.0001
Whole grain food	1-2 servings/ d	22.3	11.4	16.5	20.4	27.3	34.8	<0.0001

(n=92,770)

Organic legumes ⁴	Most of the time	8.6	2.8	4.6	7.3	10.5	16.5	<0.0001
Milk and dairy products	1.5-2.5 servings/ d	31.9	30.3	33.2	33.5	32.1	30.1	0.15
Red meat	< 500 g/ week	76.7	54.3	73.4	80.7	84.5	89.1	<0.0001
Processed meat	< 150 g/ week	42.3	39.0	36.9	38.6	43.3	53.1	<0.0001
White ham ⁴	> 50 %	32.2	29.1	28.3	29.6	34.1	43.8	<0.0001
Fish and seafood	1.5-2.5 servings/	16.7	14.6	17.5	18.1	17.1	16.0	0.01
Fat fish ⁴	0.5-1.5 servings/ week	24.3	19.0	23.7	25.7	26.7	25.6	<0.0001
Added fat	≤ 16 % of EIWA	81.2	80.4	82.0	81.1	80.2	82.1	0.07
ALA-rich and olive oil ⁶	≥ 50 %	37.9	23.5	30.5	38.3	44.1	50.4	<0.0001
Plant fat ⁴	>50 %	76.2	77.6	74.1	74.8	76.0	78.4	0.0003
Sugary foods	< 10 % of EIWA	78.1	63.6	69.2	77.8	85.8	92.7	<0.0001
Sweet-tasting beverages	0 ml/ d	24.8	23.3	22.5	22.2	24.2	31.5	<0.0001
Alcoholic beverages	0 g/ week	33.5	43.7	32.4	28.1	27.4	36.5	<0.0001
Salt	≤ 6 g/ d	18.1	22.9	16.1	14.0	15.3	22.4	0.17

Abbreviations: PNNS: Programme National Nutrition Santé; Q: Quintile; EIWA: Energy intake without alcohol.

Mean (standard deviation) for quantitative variables and percentages for qualitative variables.

¹ Recommendations of the fourth Programme National Nutrition Santé 2017-2021.

² Cut-offs for quintiles of ELD-I were -161.5/22.2/36.5/48.1/62.4/428.6 for females and -148.7/18.2/31.8/42.5/55.7/332.2 for males.

³ P-value for comparison across weighted quintiles of ELD-I estimated by test from generalized linear models with linear contrast for numeric variables and Mantel-Haenszel χ^2 for binary variables.

⁴ Dietary index reflecting the adherence to the 2017 French food-based dietary guidelines, penalized on energy intake (n=76,252).

⁵ Dietary index reflecting the adherence to the 2017 French food-based dietary guidelines, penalized on energy intake and simplified (n=92,770).

⁶ Among 76,252 participants.

Figure 1. Proportion of participants meeting each EAT-Lancet reference diet item according to weighted sex-specific quintiles of the EAT-Lancet Diet Index. NutriNet-Santé study, 2009 – 2015, France (n=98,465)