



**HAL**  
open science

## Sustainability analysis of the Mediterranean diet: results from the French NutriNet-Santé study

Julia Baudry, Floriane Neves, Denis Lairon, Benjamin Allès, Brigitte Langevin, Joséphine Brunin, Florine Berthy, Ina Danquah, Mathilde Touvier, Serge Hercberg, et al.

### ► To cite this version:

Julia Baudry, Floriane Neves, Denis Lairon, Benjamin Allès, Brigitte Langevin, et al.. Sustainability analysis of the Mediterranean diet: results from the French NutriNet-Santé study. *British Journal of Nutrition*, 2023, 130 (12), pp.2182-2197. 10.1017/S0007114523001411 . hal-04187644

**HAL Id: hal-04187644**

**<https://hal.inrae.fr/hal-04187644v1>**

Submitted on 17 Oct 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

## **Sustainability analysis of the Mediterranean diet: results from the French NutriNet-Santé study.**

Julia Baudry<sup>1\*†</sup>, Floriane Neves<sup>1\*</sup>, Denis Lairon<sup>2</sup>, Benjamin Allès<sup>1</sup>, Brigitte Langevin<sup>3</sup>, Joséphine Brunin<sup>1</sup>, Florine Berthy<sup>1</sup>, Ina Danquah<sup>4</sup>, Mathilde Touvier<sup>1</sup>, Serge Hercberg<sup>1,5</sup>, Marie-Josèphe Amiot<sup>6</sup>, Philippe Pointereau<sup>3</sup>, Emmanuelle Kesse-Guyot<sup>1</sup>

<sup>1</sup>Université Sorbonne Paris Nord and Université Paris Cité, Inserm, INRAE, CNAM, Centre of Research in Epidemiology and Statistics (CRESS), Nutritional Epidemiology Research Team (EREN), F-93017 Bobigny, France

<sup>2</sup>Aix Marseille Université, Inserm, INRAE, C2VN, Marseille, France

<sup>3</sup>Solagro, Voie TOEC Toulouse, France

<sup>4</sup>Heidelberg Institute of Global Health (HIGH), Medical Faculty and University Hospital, Heidelberg University, Heidelberg, Germany

<sup>5</sup>Département de Santé Publique, Hôpital Avicenne, Bobigny, France

<sup>6</sup>MOISA, INRAE, CIRAD, CIHEAM, SUPAGRO, Montpellier, France

\*Authors equally contributed

†corresponding author: [julia.baudry@inrae.fr](mailto:julia.baudry@inrae.fr)

**Short version of the title:** sustainability of the Mediterranean diet

**Keywords:** Mediterranean diet; nutritional quality; environmental impact; monetary cost; pesticide exposure

## **Abstract**

The Mediterranean diet is often proposed as a sustainable diet model. This study aimed to evaluate the associations between adherence to the Mediterranean diet and sustainability domains in a cohort of French adults, using multiple criteria including nutritional quality, environmental pressures, monetary cost, and dietary pesticide exposure. Food intakes of 29,210 NutriNet-Santé volunteers were assessed in 2014 using a semi-quantitative food frequency questionnaire. Adherence to the Mediterranean diet was evaluated using the validated literature-based adherence score (MEDI-LITE). The associations between the MEDI-LITE and various sustainability indicators were examined using analysis of covariance models, adjusted for sex, age and energy intake. Higher adherence to the MEDI-LITE was associated with higher nutritional quality scores, better overall nutrient profile as well as reduced environmental impact (land occupation: Q5 vs. Q1: -35%, greenhouse gas emissions: -15%, and cumulative energy demand: -17%). In turn, monetary cost increased with increasing adherence to the Mediterranean diet (Q5 vs. Q1: +15%) while higher adherents to the Mediterranean diet had overall higher pesticide exposure due to their high plant-based food consumption. In this large cohort of French adults, greater adherence to the Mediterranean diet was associated with nutritional and environmental benefits, but also with higher monetary cost and greater exposure to pesticides, illustrating the necessity to develop large-scale strategies for healthy, safe (pesticide- and contaminant-free), and environmentally sustainable diets for all.

## 1 **Introduction**

2 Our current food system is not sustainable and will not enable us to achieve the objectives  
3 defined by different international organisations, including the Paris agreement targets (1,2).  
4 First, Western diets, characterised by calorie-dense foods, high intakes of red and processed  
5 meat, processed food, salt and sugar and reduced intakes of complex carbohydrates, fibre,  
6 fruits and vegetables, are major risk factors for morbidity and mortality worldwide (2).  
7 Second, current food systems account for 20 to 30% of total greenhouse gas emissions  
8 (GHGE) (3), 50% of land use (4). Dominant practices of food production also contribute to  
9 biodiversity loss and degradation of natural resources (5). Third, emerging studies conducted  
10 in the general population suggest potential adverse health effects of pesticide residues  
11 contained in food (6–8). Finally, many people do not have access to, or cannot afford, a  
12 healthy and sustainable diet (1,9). These trends will likely worsen in a context of a growing  
13 world population, while many planetary boundaries have been already crossed, threatening  
14 planetary habitability (10).

15 In 2010, sustainable diets have been defined by the United Nations Food and Agriculture  
16 Organisation (FAO) as diets that bring nutritious and safe food for all, are economically  
17 equitable and affordable, do not jeopardize natural resources, and ensure food security for  
18 current and future generations (11).

19 The Mediterranean dietary pattern, which is characterised by a high consumption of fruits,  
20 vegetables, wholegrain cereals, legumes, nuts, olive and olive oil, a moderate consumption of  
21 fish and poultry, and a low consumption of meat (12), is often promoted as a healthy and  
22 environmentally sustainable diet that is socioculturally acceptable and has positive local  
23 economic benefits (13). The traditional Mediterranean “lifestyle” expands the concept to other  
24 components, such as adequate rest, physical activity, frugality, dietary diversity, or personal  
25 involvement (i.e. conviviality including culinary preparation with others and shared meals)  
26 (14). It is also recommended to favour local, seasonal, ecological and minimally processed  
27 foods that promote biodiversity (15).

28 The health benefits of the Mediterranean diet have been extensively studied, and studies  
29 showing inverse associations between adherence to a Mediterranean diet and non-  
30 communicable diseases, such as type 2 diabetes or metabolic syndrome, but also certain types  
31 of cancers, are numerous (16). In addition, a large trial demonstrated that a Mediterranean diet  
32 supplemented with extra-virgin olive oil or tree nuts reduces the incidence of major

33 cardiovascular events compared to individuals following a reduced-fat diet among high  
34 cardiovascular risk individuals (17).

35 While a large body of evidence has highlighted the health benefits of adherence to  
36 Mediterranean dietary patterns (18), fewer studies have examined the environmental impact  
37 of these diets. In general, they tended to suggest that Mediterranean diets may have lower  
38 environmental impacts than Western diets (19,20). Furthermore, according to a recent meta-  
39 analysis, the Mediterranean diet does not appear more expensive than other diets (20),  
40 although some studies have yielded divergent results (21,22).

41 In addition, few studies have evaluated other diet sustainability features (21), in particular  
42 safety aspects (such as pesticide exposure), using quantitative data (23). It is, however, of  
43 great importance to evaluate the sustainability of the Mediterranean diet in all its complexity  
44 to gain a more complete understanding of its potential as a sustainable diet (24,25).

45 In that context, the primary goal of this study was to examine the relationship between  
46 adherence to the Mediterranean diet and various sustainability features (nutritional quality,  
47 environmental pressures, monetary cost, dietary pesticide exposure), in line with the FAO  
48 definition of sustainable diets, in a large cohort of French adults. We also investigated  
49 whether higher adherence to the Mediterranean diet was related to some other Mediterranean  
50 lifestyle principles.

51

## 52 **Methods and Data**

### 53 **Study population**

54 The NutriNet-Santé study is a prospective observational cohort of French adult volunteers  
55 launched in May 2009 and based on the internet (26). Upon inclusion in the cohort,  
56 participants completed a set of self-administered questionnaires about dietary intake, health,  
57 socio-economic status, physical activity, anthropometric and lifestyle characteristics. As part  
58 of the follow-up, volunteers are regularly invited to update their sociodemographic, lifestyle,  
59 dietary and health data and also to fill in optional questionnaires regarding dietary behaviours.

60 This study was conducted according to guidelines laid down in the Declaration of Helsinki.  
61 All procedures were approved by the Institutional Review Board of the Institut National de la  
62 Santé et de la Recherche Médicale (IRB INSERM no. 0000388FWA00005831) and the  
63 Commission Nationale de l'Informatique et des Libertés (CNIL no. 908450 and no. 909216).  
64 It is registered at ClinicalTrials.gov with the number NCT03335644. Electronic informed  
65 consent was signed by all participants at inclusion.

66

67

## 68 **Dietary intake assessment**

69 Food intake was assessed using a semi-quantitative food frequency questionnaire (called Org-  
70 FFQ) administered from June to December 2014. The Org-FFQ was built upon a pre-existing  
71 validated food frequency questionnaire (27) to which statements regarding organic food  
72 consumption were added. In brief, participants had to detail their consumption of 264 items  
73 over the preceding year in order to estimate their total food intake. More specifically, they had  
74 to complete the frequency and the portion size or quantity of each food item (28). In addition  
75 to providing the latter, participants were also asked to report the consumption frequency in  
76 their organic form of each food item, by ticking one of the following frequency modalities:  
77 never, rarely, half-of-time, often or always. To obtain organic food consumption, a weight of  
78 0, 0.25, 0.5, 0.75 and 1 was applied to the respective frequencies. More detailed information  
79 about the Org-FFQ and sensitivity analyses regarding the weighting were published elsewhere  
80 (29). Nutrient values were derived from a published food composition database (30).

81

## 82 **Mediterranean diet scores**

83 Two scores were used in order to evaluate the adherence to the Mediterranean diet  
84 (**Supplemental Table 1**): the validated Literature-based adherence score to the Mediterranean  
85 diet (MEDI-LITE) (31,32), as the primary exposure, and the historical Mediterranean diet  
86 Score (MDS) (12). The MEDI-LITE is composed of six beneficial components that are  
87 typical of the Mediterranean diet (fruits, vegetables, cereals, legumes, fish and olive oil), two  
88 moderation components for which consumption is to be limited (meat and dairy products) and  
89 an alcohol component. Each food group is divided into three categories using fixed cut-offs  
90 (Supplemental Table 1). The cut-offs have been proposed by Sofi et al., based on a  
91 comprehensive meta-analysis (32). For the beneficial food groups, 2 points are given to the  
92 highest category of consumption, 1 to the middle category and 0 to the lowest category. A  
93 reverse scoring is applied for the moderation components, that is, 2 points for the lowest  
94 category, 1 for the middle category and 0 for the highest category. For the alcohol component,  
95 the scoring was as follows: 2 points if the intake was comprised between 12-24g, 1 point if  
96 <12g, 0 points if >24g. The final score ranges from 0 to 18 points (32).

97 In a sensitivity analysis, we also considered the Mediterranean Diet Scale (MDS) by  
98 Trichopoulou et al. (12) which is based on the same components as the MEDI-LITE but the

99 attribution of points for each component depends on the sex-specific median. For beneficial  
100 components, 1 point is assigned when the consumption is at or above the median and 0 point  
101 when the consumption is below the median. For moderation components, 1 point is assigned  
102 when the consumption is below the median, 0 otherwise. Regarding alcohol, 1 point is  
103 attributed if the intake is comprised between 10-50g for men and 5-25g for women, 0 points  
104 otherwise (12).

105

### 106 **Nutritional quality assessment**

107 Three *a priori* scores were used to assess overall nutritional quality of the diet. First, we  
108 employed the food-based simplified *Programme National Nutrition Santé* Guidelines Score 2  
109 (sPNNS-GS2), ranging from  $-\infty$  to 14.25, which measures adherence to the French official  
110 nutrition guidelines based on epidemiological evidence (33). Second, we constructed the  
111 nutrient-based Probability of Adequate Nutrient intake Diet score (PANDiet), ranging from 0  
112 to 100, which reflects adequacy of the diet to the current French nutrient reference values  
113 (34). Third, we computed the comprehensive diet quality index (cDQI), which allows to  
114 differentiate the consumption of healthful and unhealthful plant-based and animal food groups  
115 (35). It ranges from 0 to 85 and includes seventeen components (eleven plant-based food and  
116 six animal-based foods). Healthful plant- and animal-based foods are scored positively and  
117 reversely for unhealthful plant- and animal-based foods. More information regarding the  
118 computation of the cDQI is available elsewhere (35).

119

### 120 **Environmental impact assessment**

121 A detailed description of the development of the environmental indicators has been given  
122 elsewhere (36). Briefly, the environmental indicators were assessed per day using the life  
123 cycle assessment methodology and the system boundaries were cradle-to-farm. The following  
124 indicators were used: GHGE in kgCO<sub>2</sub>e/kg, the cumulative energy demand (CED) in MJ/kg,  
125 and land occupation (LO) in m<sup>2</sup>/kg. A database associated with the Org-FFQ items was  
126 created with the indicators, considering the food production system (conventional or organic).  
127 For this purpose, a comprehensive tool named DIALECTE, developed by the non-profit  
128 organisation Solagro, was used (37). It assesses the agro-environmental performance of  
129 French farming systems, based on approximately 2,000 farms, including organic farms. The  
130 environmental footprint of 60 agricultural items was estimated with this tool, completed by a  
131 literature review for 32 products. The GHGE, CED and LO of each food item in both their  
132 organic and conventional version were determined. The three diet-related environmental

133 outcomes were then obtained by multiplying the food quantity consumed (g/day) by each  
134 respective environmental indicator value, considering the production system. The three diet-  
135 related GHGE, CED, and LO were then obtained by multiplying the food quantity consumed  
136 (g/day) by each respective environmental indicator value, considering the production system.

137

### 138 **Monetary cost assessment**

139 Participants were asked to complete a questionnaire in 2014 concerning attitudes and  
140 motivations regarding food choices and food places of supply. The KANTAR® database  
141 2012 was used to obtain the prices for each of the 264 food items according to the place of  
142 supply and considering the method of food production (organic vs. conventional) (38).  
143 Moreover, 1,962 additional prices were collected by the Bioconsom'acteurs association  
144 between 2014 and 2015 to assess the price of each food item in short supply chains. We  
145 obtained the individual monetary cost by multiplying the price (€/g) by the quantities  
146 consumed (g/d) considering the place of supply and the food production system.

147

### 148 **Pesticide exposure assessment**

149 Data regarding pesticide residues came from the Chemisches und Veterinäruntersuchungsamt  
150 Stuttgart (CVUAS) database. The CVUAS (39) is an official regional state food control and  
151 health laboratory located in Germany, which analyses pesticides and contaminants in plant-  
152 source products, available on the German market but the products come from 88 countries.  
153 This database does not contain any animal products; however, data are available for both  
154 organically- and conventionally-grown products. Since all products are from the German  
155 market, they are subject to the European Union standards (as France) regarding organic  
156 agriculture (40). In the present work, analytical results for 4 years (2012-2015) were used,  
157 leading to a database comprising more than 6.7 million data points (including 1 million for  
158 organic plant foods). Amongst molecules available in the CVUAS database, for which a  
159 sufficient number of plant foods was covered (for instance the dithiocarbamates were not  
160 retained due to lack of data despite their frequent quantification in plant products), we  
161 selected some twenty pesticides, given their frequency of quantification exceeding the  
162 maximum residue levels and their frequency above toxicological reference values, using data  
163 from the 2015 EFSA report (41), as described elsewhere (42). Three active substances  
164 authorised in organic farming were additionally included. The estimated daily intake (EDI)  
165 (expressed in µg/kg of weight per day) under the lower-bound scenario for each pesticide and  
166 each participant was calculated using the following formula (43):



167 
$$EDI = \sum_{k=1}^{n_i} E_{i,j} = (C_{i,k} \times L_{k,j}) \div BW_i$$

168  $E_{i,j}$  estimated daily exposure to pesticide  $j$  for the individual  $i$  ( $\mu\text{g}/\text{kg}$  bw/day).

169  $n_i$  number of plant foods in the diet of individual  $i$ .

170  $C_{i,k}$  mean daily intake of plant food  $k$  by individual  $i$  (g/day).

171  $L_{k,j}$  concentration of pesticide  $j$  in food  $k$  (mg/kg).

172  $BW_i$  body weight of individual  $i$  (kg).

173

#### 174 **Assessment of practices associated with the Mediterranean lifestyle**

175 Certain specific practices are related to the Mediterranean lifestyle, beyond diet composition,  
176 therefore, we also investigated, through different sociocultural different proxy markers of the  
177 Mediterranean lifestyle, whether adherence to the Mediterranean diet was associated with  
178 physical activity, consumption frequency of ready-to-use products and consumption of  
179 organic food. Physical activity levels, as marker of recommended physical activity, were  
180 determined using the International Physical Activity Questionnaire (44,45). Three levels of  
181 physical activity were established based on the Metabolic Equivalent of Task (MET) minutes  
182 per week (MET-min/week): low ( $< 600$  MET-min/week), moderate (600 to 1500 MET-  
183 min/week) and high ( $> 1500$  MET-min/week).

184 The consumption frequency of ready-to-use products was also examined as a marker of proxy  
185 of culinary activities or sociality around food. In the aforementioned questionnaire used to  
186 retrieve food supply places, a question pertaining to the consumption frequency of canned,  
187 chilled, and frozen foods, was also asked. These consumptions were declared by each  
188 participant through 5 categories: never, rarely, half of the time, often and always and a  
189 weighting of 0, 0.25, 0.5, 0.75 and 1 point was assigned to each category. The final score is  
190 the sum of points multiplied by the weighting(46).

191 The organic food proportion in the diet was evaluated, as a marker of eco-friendly product  
192 consumption, as the ratio of total food consumed in organic (g/d) to total food consumed (g/d)  
193 without water.

194

#### 195 **Statistical analyses**

196 NutriNet-Santé participants who filled out the Org-FFQ between June and December 2014  
197 were included in the present study (N=37,685). Of these, we excluded participants with  
198 missing covariates (N=380), who were detected as under or over-reporters and who were  
199 living overseas (N=2852), and with missing data regarding the place of supply for the

200 computation of diet monetary cost (N=5243), leaving a sample of 29,210 participants  
201 **(Supplemental Figure 1)**. Participants were ranked and divided into sex-specific quintiles  
202 (Qi), according to the MEDI-LITE distribution. Baseline participants characteristics across  
203 levels of adherence to the Mediterranean diet were presented as mean  $\pm$  standard deviation  
204 (SD). P-values refer to tests for linear contrast across quintiles for continuous variables, and  
205 Mantel-Haenszel chi-square trend tests or chi-square test, for ordinal and categorial variables,  
206 respectively.

207 Normality was assessed using graphical methods (histograms and Q-Q plots). To identify the  
208 associations between each sustainability indicator and adherence to the Mediterranean diet,  
209 analyses of covariance (ANCOVA) models, with Tukey adjustment, according to the  
210 observed margins, were used, providing adjusted means and 95% confidence intervals (CI).  
211 Two different models were computed: a model which was unadjusted (model 1) and a model  
212 adjusted for age, sex and total daily energy intake (main model, model 2). The latter model  
213 enabled us to study diet composition *per se*, beyond energy intake. P-values across quintiles  
214 were estimated using linear contrast tests.

215 The relationships between the various indicators and adherence to Mediterranean diet were  
216 also examined using the MEDI-LITE as a continuous variable, and results were expressed as  
217 beta-coefficient ( $\beta$ ) per 1 SD and 95%CI.

218 Sensitivity analyses were also performed to assess the robustness of our results by computing  
219 the MDS. Thus, the same analyses were performed to evaluate the associations between each  
220 sustainability indicator and adherence to the Mediterranean diet, using the MDS.

221 To allow comparability, the two Mediterranean scores were standardised in models with the  
222 main exposure modelled as a continuous variable. Two-sided tests were used and a P-value  
223  $<0.05$  was set for statistical significance. SAS (version 9.4; SAS Institute, Inc.) was used to  
224 perform data management and statistical analyses.

225

## 226 **Results**

### 227 **Sample characteristics**

228 The MEDI-LITE in the study sample ranged from 1 to 18 (32). **Table 1** shows the  
229 characteristics of the study sample across quintiles of adherence to the MEDI-LITE. By  
230 construction, participants in Q1 were the least adherent (6.05 (SD=1.13)) to the  
231 Mediterranean diet, and those in Q5 were the most adherent (13.94 (SD=1.06)). Participants  
232 with the highest adherence to the Mediterranean diet were the oldest. Postgraduate

233 participants represented 63.62% of Q1 and 67.16% of Q5. The lowest proportion of  
234 employees and manual workers was found in Q5 and the highest proportions of participants  
235 with high-level incomes were found in the highest quintiles.

236 Participants in Q5 were more often never-smokers and less often current smokers than other  
237 quintiles. Regarding the body mass index, participants in Q1 had a mean of 24.63 kg.m<sup>-2</sup>  
238 (SD=5) and those in Q5 had a mean of 23.45 kg.m<sup>-2</sup> (SD=4.07).

239

#### 240 **Adherence to the Mediterranean diet and diet sustainability**

241 **Supplemental Table 2** shows the intake for the different MEDI-LITE components.  
242 Adherence to the Mediterranean diet, modelled as quintiles, and the different diet  
243 sustainability features are presented in **Figure 1** (multivariable models). A positive  
244 association was observed between adherence to the MEDI-LITE score and the sPNNS-GS2  
245 (Q5 vs. Q1: +470%), the PANDiet (Q5 vs. Q1: +15%), and the cDQI (Q5 vs. Q1: +22%). LO  
246 (Q5 vs. Q1: -35%), GHGE (Q5 vs. Q1: -15%) and CED (Q5 vs. Q1: -17%) decreased across  
247 quintiles. Diet monetary cost gradually increased across quintiles, the differences between Q5  
248 compared with Q1 were 1.05€/day for the total diet monetary cost (Q5 vs. Q1: +15%), -  
249 1.72€/day for the cost dedicated to conventional foods (Q5 vs. Q1: -29%) and 2.76€/day for  
250 the cost dedicated to organic foods (Q5 vs. Q1: +204%).

251 Unadjusted models pertaining to the associations between the various sustainability indicators  
252 and the MEDI-LITE are shown in **Supplemental Table 3**. Overall, the same trends were  
253 observed, apart from CED, for which the unadjusted models yielded opposite results.

254 Regarding nutrients (adjusted models), total energy intake gradually increased across MEDI-  
255 LITE quintiles while intake of ethanol decreased (**Table 2**). Higher adherents to the MEDI-  
256 LITE had lower contribution to energy-intake of saturated fatty acids, and added sugars and  
257 higher contribution of mono-unsaturated fatty acids, poly-unsaturated fatty acids and  
258 carbohydrates. The intake of proteins from plant origin, fibre, vitamins C and E were the  
259 highest in Q5 and the lowest in Q1. Adherence to the MEDI-LITE was negatively associated  
260 with the intake of vitamin B12.

261 **Table 3** presents the dietary exposure to different pesticides using the lower-bound scenario.  
262 In adjusted models, in line with the greater intakes of plant-based products in Q5 participants  
263 compared to Q1 participants (Supplemental Table 2), higher levels of adherence to the MEDI-  
264 LITE were overall associated with higher pesticide exposure (higher values observed in the  
265 highest quintiles), except for chlorpropham for which the association was inverse and  
266 imidacloprid for which no association was observed.

267

268 **Adherence to the Mediterranean diet and practices associated with the Mediterranean**  
269 **lifestyle**

270 The highest proportion of individuals with elevated physical activity was observed in Q5  
271 (**Table 4**). Higher adherence to the MEDI-LITE was also related to higher organic food  
272 consumption (Q5 vs. Q1: +171%). Positive associations were also observed between  
273 adherence to the MEDI-LITE while consumption of ready-to-use products decreased with  
274 adherence to the MEDI-LITE.

275

276 The results pertaining to the MDS are shown in **Supplemental Tables 4, 5, 6, and 7**.  
277 Associations between diet sustainability and the MEDI-LITTE and the MDS per 1 SD are  
278 shown in Supplemental Figure 2. Overall, the same findings were observed. Further  
279 adjustment for education level did not substantially change the results (data not shown).

280

281 **Discussion**

282 Using a multi-criteria analysis, the present study evaluated diet sustainability according to  
283 various levels of adherence to the Mediterranean diet, as reflected by the MEDI-LITE score,  
284 using a large adult sample from the NutriNet-Santé cohort.

285 Our evaluation encompassed various indicators including nutrient intakes, dietary scores,  
286 environmental pressures, monetary cost, and dietary pesticide exposure. In this French adult  
287 population, following a Mediterranean dietary pattern was associated with nutritional and  
288 environmental benefits, although higher adherence was also accompanied by overall higher  
289 pesticide exposure and additional monetary costs.

290 To our knowledge, this is the first study which simultaneously considers all these indicators,  
291 in particular pesticide exposure, thus allowing a thorough evaluation of the sustainability of  
292 this dietary pattern.

293

294 The nutritional benefits of the Mediterranean diet have been extensively described. With  
295 regard to overall nutritional quality scores (reflecting both food- and nutrient-based  
296 recommendations) and nutrient intakes, our results are thus in line with those of previous  
297 studies (20), indicating a high nutritional quality associated with the adherence to the  
298 Mediterranean diet. These results are also in accordance with a work by Aboussaleh et al.  
299 which also reported that individuals following a Mediterranean diet more often met

300 recommended nutrient and micronutrient intakes (47,48). It should be noted that the  
301 recommended intake for alcohol in the Mediterranean diet is much higher than the official  
302 French national guideline (33).

303

304 In accordance with the literature, we observed that, in energy-adjusted models, higher  
305 adherence to the Mediterranean diet, as expressed by the MEDI-LITE, was associated with  
306 lower overall environmental impact (Q5 vs. Q1: -15%, -35, -17%, for GHGE, LO and CED,  
307 respectively) (20). Several studies conducted in other Mediterranean countries (Italy, Spain  
308 and Lebanon) have thus produced comparable findings (21,49–51). This is explained by the  
309 fact that the Mediterranean diet encourages the consumption of plant-based foods, including  
310 fruit and vegetables, whole grains, legumes and nuts, which exhibit lower overall  
311 environmental impacts than animal-based foods (19,36,52). The carbon footprint of the  
312 Mediterranean diet has been extensively studied (20). In adjusted models, total GHGE were  
313 2.93 kgCO<sub>2</sub>eq/day among high-adherent participants. In a study conducted in Spain, the  
314 Mediterranean diet was found to have GHGE levels in line with our findings (2.79  
315 kgCO<sub>2</sub>eq/day) (22). Of note, the system boundaries considered in the Spanish study were not  
316 the same as ours. The value for GHGE for strong adherents to the Mediterranean diet in the  
317 present study is lower than that of omnivores (4.16 kgCO<sub>2</sub>eq/day) but more than twice as high  
318 than that of vegans (1.17 kgCO<sub>2</sub>eq/day) observed in a previous work that we carried out in the  
319 NutriNet-Santé cohort (53). Our findings are partially in line with a simulation study  
320 performed on a global level (19). Interestingly, energy-adjustment appeared to reverse the  
321 relationships in the case of CED, emphasising that excessive energy intake is a strong  
322 contributor to overall environmental impact. In addition, the reduction in emissions is in line  
323 with the frugality aspect promoted by the Mediterranean lifestyle.

324

325 Regarding the economic dimension, we observed that participants reporting higher adherence  
326 to the Mediterranean diet exhibited slightly higher monetary costs than other groups (in  
327 energy-adjusted models). This is in line with some previous studies showing extra-cost  
328 associated with adherence to the Mediterranean diet pattern (21,54). A study showed that  
329 following a Western diet was less expensive than following a Mediterranean diet (21). In our  
330 study, participants who adhered the most to the Mediterranean diet spent 1.05€ extra per day.  
331 According to a recent systematic review, the Mediterranean diet is not more expensive than  
332 other diets, but varies greatly (3.33 and 14.42€/ d per capita) according to the region, food  
333 brand, season, and stores. In some cases, the costs can be the same as for other diets (20). In

334 the present work, individuals who adhered the most to the Mediterranean diet were also those  
335 who had higher intake of organic food, explaining the higher monetary cost. In our study,  
336 adjustment for energy intake tended to lower the cost difference, which is consistent with the  
337 findings of a work conducted in Spain comparing various dietary patterns (22). In our  
338 analysis, we distinguished the prices of organic from conventional foods, this may have led to  
339 higher diet monetary cost compared with other studies, in addition to methodological  
340 differences. The increase in monetary cost of 15% for the highest adherence level raises a  
341 concern about affordability for the fraction of the population with limited incomes. Following  
342 the Mediterranean diet was approximately 1€/d more expensive. Although this value is an  
343 estimate and does not represent the actual cost difference, this difference still reflects food  
344 inequality. One euro per day may constitute a substantial burden for disadvantaged  
345 households. For instance, in an intervention study carried out in a socially deprived districts of  
346 Marseille (France), individuals spent on average 3.65€/d per person for food consumed at  
347 home (55). This should encourage national authorities to subsidise environmentally  
348 sustainable and healthy diets such as the Mediterranean diet to allow as many people as  
349 possible to access this diet and benefit from the reduced environmental and health impacts  
350 associated with it. The Mediterranean diet has been described as a sustainable diet by several  
351 conceptual studies (56–58). However, safety aspects are rarely considered and few studies  
352 have investigated pesticide exposure associated with adherence to the Mediterranean diet. It is  
353 known that plant foods are the most contaminated food groups by pesticide residues while  
354 organic plant foods are less contaminated than their conventional counterparts (59). In the  
355 present work, due to their greater consumption of cereals, fruits, vegetables, participants in  
356 highest quintiles were more exposed to pesticide residues than individuals in lowest quintiles  
357 (Q1 and Q2). Thus, intakes of less pesticide-contaminated organically grown foods did not  
358 appear to fully compensate for the higher exposure from high intake of conventional foods of  
359 plant origin among these participants. In contrast, another study based on the NutriNet-Santé  
360 cohort showed that individuals with a very high contribution of organic food in their diet (on  
361 average 70% of food coming from organic sources) had a reduced exposure to food pesticide  
362 residues compared to individuals with null or low contribution of organic food in the diet  
363 (42). The higher discrimination between the two extreme quintiles in terms of share of  
364 organic in the diet (71% (Q5) vs. 0% (Q1)) in the latter study as compared in the present  
365 study (46% vs. 17%) also explains the differences regarding pesticide exposure between the  
366 two studies. It was also observed during a controlled trial that a Mediterranean diet combined  
367 with full organic food intake reduced total pesticides exposure by >90%, while increasing

368 conventional fruit and vegetable consumption led to higher levels of pesticide exposure (60).  
369 In a recent study carried out in the US, consumption of certain foods, such as legumes and  
370 grains, was the primary contributor to total dietary glyphosate body burden rather than diet  
371 style (Mediterranean-style and Vegetarian eating pattern) (61). Pesticide exposure through  
372 diet in the general population has been associated with adverse health outcomes (7,8). In a  
373 recent US study based on three large adult cohorts, a diet rich in low-pesticide contaminated  
374 fruit and vegetables reduced mortality whereas a comparable diet with high-pesticide  
375 contaminated fruit and vegetables had no longer a significant protective effect (6). However,  
376 the healthiness of the Mediterranean diet probably outweighs the potential deleterious effect  
377 of the exposure to pesticides, given the very large literature showing its possible health  
378 benefits (16), although, more data are needed to quantify this precisely. Particular attention  
379 should also be paid to seafood since these products are source of contamination of persistent  
380 organic pollutants, furans or polychlorinated biphenyls (62). This is of importance and needs  
381 further consideration since sustainable diets, as defined by the FAO, are supposed to provide  
382 “safe foods” (11). This indicates the need to generalise production methods limiting  
383 agricultural inputs to maximise the health benefits of plant-rich diets such as the  
384 Mediterranean diet. A recent study conducted in Australia somewhat supports this idea (63).  
385 In this study, a dietary shift towards recommended dietary patterns was associated with a  
386 higher environmental pesticide toxicity footprint, leading the authors to conclude that actions  
387 in the agricultural sector might the best approach to reduce the environmental burden  
388 associated with pesticides.

389 We also examined the associations between adherence to the Mediterranean diet and other  
390 components of the Mediterranean lifestyle (apart from the diet composition *per se*). We  
391 observed that individuals who adhered to the Mediterranean diet were more often physically  
392 active and less often prone to eat ready-to-use products and therefore more likely to have  
393 varied culinary and cooking practices. Furthermore, the Mediterranean diet now also  
394 emphasises the importance of eco-friendly products (15). We observed here a strong positive  
395 association between organic food consumption and adherence to the Mediterranean diet,  
396 which is of interest since organic food consumption has been associated with biodiversity  
397 benefits (64). Therefore, individuals who followed Mediterranean dietary patterns appeared to  
398 be more likely to also follow the principles of a Mediterranean lifestyle, thereby increasing  
399 possible health benefit.

400

401 Some limitations should be noted. First, the NutriNet-Santé cohort study includes volunteers,  
402 who are probably more interested in nutrition and health issues than the general population,  
403 leading to a health-conscious sample with healthier eating habits and probably higher  
404 adherence to the Mediterranean diet than the French adult population (65). It has also been  
405 shown that NutriNet-Santé participants tend to exhibit a higher socioeconomic status than the  
406 general population (66). It is likely that some population subgroups, such as deprived  
407 individuals or individuals who are not-Internet users (e.g. computer illiteracy) are not  
408 included or underrepresented in the cohort. **Therefore, caution is needed before generalising**  
409 **the results to the French population.** Moreover, food consumption data were self-reported  
410 using a food frequency questionnaire, making some degree of measurement error inevitable.  
411 Total food intake may have thus been overestimated (67), and possibly a desirability bias may  
412 have occurred. Furthermore, the questions used to estimate the share of organic food in the  
413 diet had not been validated. Nonetheless, the original FFQ used to develop the Org-FFQ has  
414 been validated against dietary records (27), and all lifestyle and anthropometric questionnaires  
415 have been validated against traditional methods (68,69). In addition, fish is one of the most  
416 important beneficial components of the Mediterranean diet but while we did not have the  
417 most relevant indicators to assess its environmental impact, we do know that 60% of fish  
418 stocks are fully exploited and 30% overexploited (2). Regarding environmental indicators,  
419 biodiversity and water use should be also accounted for in future studies, in particular due to  
420 the high water footprint of some products such as nuts (70), for which we had very limited  
421 data. Furthermore, we only assessed pesticide exposure through foods of plant origin since  
422 they are the primary contributors. However, we may have underestimated the overall pesticide  
423 impact, in particular among participants eating more animal-based foods. In addition, we did  
424 not consider potential nutritional differences between organic and conventional products due  
425 to lack of data. Lastly, dietary data and related sustainability outcomes were collected in  
426 2014, almost ten years ago, and the food system has been through and is still going through  
427 multiple crises (including Covid-19 pandemic, the massive acceleration of climate change,  
428 invasion of Ukraine and inflation). As a result – more than dietary patterns themselves which  
429 are relatively constant over time – diet-related costs observed in the current study do not  
430 reflect the current situation (e.g. inflation and reduction of organic purchase among low-  
431 income households). Similarly, pesticide exposure patterns may have changed since 2014  
432 (e.g. ban of certain molecules and introduction of new ones). However, overall, the extent of  
433 food sample contaminations did not noticeably changed during this time period (41,59). Our  
434 study has also several strengths. This is the first study to concomitantly consider multiple



435 criteria (using a wide range of indicators related to sustainability) and describe the pesticide  
436 exposure in relation to Mediterranean diet sustainability. In addition, we were able to  
437 distinguish organic from conventional food intakes. We also attempted to account for the  
438 other principles of the Mediterranean lifestyle. Finally, our study was based on a large sample  
439 allowing an important diversity of dietary patterns and profiles.

440

441

## 442 **Conclusions**

443 In this population of French adults, adherence to the Mediterranean diet was associated with  
444 higher nutritional quality and overall lower environmental impact. However, adherence to the  
445 Mediterranean diet (based on high intake of foods from plant origin) was overall positively  
446 associated with pesticide residue exposure which was not fully counterbalanced by the higher  
447 consumption of organic food. This underscores the importance of implementing political  
448 strategies aiming to generalise production methods limiting pesticide residue exposure. The  
449 higher monetary cost may also be a barrier for acceptance and highlights the urgent need for  
450 strategies aiming to promote affordable, nutritious but also safe and environmentally  
451 sustainable diets for all.

452

## 453 **Acknowledgements**

454 The authors warmly thank all the NutriNet-Santé participants. We also thank Cédric Agaësse  
455 (dietitian manager), Alexandre De-Sa, and Rebecca Lutchia (dietitians); Younes Esseddik and  
456 Selim Aloui (IT managers); Nathalie Druesne-Pecollo (operational coordinator); Thi Hong  
457 Van Duong, Régis Gatibelza, Jagatjit Mohinder, and Aladi Timera (computer scientists);  
458 Fabien Szabo de Edelenyi (data-manager supervisor), Julien Allègre, Nathalie Arnault,  
459 Laurent Bourhis, and Nicolas Dechamp (data-manager/statisticians); and Maria Gomes and  
460 Mirette Foham (NutriNet-Santé participant support) for their technical contribution to the  
461 NutriNet-Santé study.

462

## 463 **Funding**

464 The NutriNet-Santé study is supported by the following public institutions: French Ministry  
465 of Health (DGS), Santé Publique France, the National Institute for Health and Medical  
466 Research (Inserm), the French National Research Institute for Agriculture (INRAE), Food and  
467 Environment, the National Conservatory of Arts and Crafts (CNAM) and Sorbonne Paris

468 Nord University. The BioNutriNet project was supported by the French National Research  
469 Agency (ANR) in the context of the 2013 Programme de Recherche Systèmes Alimentaires  
470 Durables (ANR-13-ALID-0001). FB is supported by a doctoral scholarship from Sorbonne  
471 Paris Nord University and JBr by a doctoral scholarship from INRAE and the French  
472 Environment and Energy Management Agency (ADEME).

473

#### 474 **Author contributions**

475 The authors' responsibilities were as follows: JBau, DL, BA, BL, SH, PP, and EK-G: led the  
476 BioNutriNet project from which the data used came; DL, BA, BL, JBr, FB, ID, MT, SH, M-  
477 JA, PP and EK-G: contributed to interpretation of results and provided critical revisions to the  
478 manuscript; JBau and FN: performed statistical analysis, wrote the paper and had full access  
479 to all the data in the study; JBau: had primary responsibility for the final content and takes  
480 responsibility for the integrity of the data and the accuracy of the data analysis as guarantor;  
481 and all authors: read and approved the final manuscript.

482

#### 483 **Conflict of Interest**

484 None.

485

486

#### **References:**

- 487 1. FAO I. The State of Food Security and Nutrition in the World 2021: Transforming food  
488 systems for food security, improved nutrition and affordable healthy diets for all  
489 [Internet]. Rome, Italy: FAO; 2021 [cited 2022 Aug 17]. 240 p. (The State of Food  
490 Security and Nutrition in the World (SOFI)). Available from:  
491 <https://www.fao.org/documents/card/en/c/cb4474en>
- 492 2. Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S, et al. Food in  
493 the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food  
494 systems. *The Lancet*. 2019 Feb;393(10170):447–92.
- 495 3. Vermeulen SJ, Campbell BM, Ingram JSI. Climate Change and Food Systems. *Annual*  
496 *Review of Environment and Resources*. 2012;37(1):195–222.
- 497 4. Poore J, Nemecek T. Reducing food's environmental impacts through producers and  
498 consumers. *Science*. 2018 Jun 1;360(6392):987–92.
- 499 5. Dudley N, Alexander S. Agriculture and biodiversity: a review. *Biodiversity*. 2017 Jul  
500 3;18(2–3):45–9.
- 501 6. Sandoval-Insausti H, Chiu YH, Wang YX, Hart JE, Bhupathiraju SN, Mínguez-Alarcón  
502 L, et al. Intake of fruits and vegetables according to pesticide residue status in relation to

- 503 all-cause and disease-specific mortality: Results from three prospective cohort studies.  
504 *Environ Int.* 2022 Jan 15;159:107024.
- 505 7. Rebouillat P, Vidal R, Cravedi JP, Taupier-Letage B, Debrauwer L, Gamet-Payrastre L, et  
506 al. Prospective association between dietary pesticide exposure profiles and  
507 postmenopausal breast-cancer risk in the NutriNet-Santé cohort. *International Journal of*  
508 *Epidemiology* [Internet]. 2021 Mar 15 [cited 2021 Mar 15];(dyab015). Available from:  
509 <https://doi.org/10.1093/ije/dyab015>
- 510 8. Rebouillat P, Vidal R, Cravedi JP, Taupier-Letage B, Debrauwer L, Gamet-Payrastre L, et  
511 al. Prospective association between dietary pesticide exposure profiles and type 2 diabetes  
512 risk in the NutriNet-Santé cohort. *Environ Health.* 2022 Dec;21(1):1–15.
- 513 9. Fanzo J, Rudie C, Sigman I, Grinspoon S, Benton TG, Brown ME, et al. Sustainable food  
514 systems and nutrition in the 21st century: a report from the 22nd annual Harvard Nutrition  
515 Obesity Symposium. :16.
- 516 10. Wang-Erlandsson L, Tobian A, van der Ent RJ, Fetzer I, te Wierik S, Porkka M, et al. A  
517 planetary boundary for green water. *Nat Rev Earth Environ.* 2022 Jun;3(6):380–92.
- 518 11. Systèmes alimentaires | Organisation des Nations Unies pour l'alimentation et  
519 l'agriculture [Internet]. [cited 2022 May 19]. Available from: [https://www.fao.org/food-](https://www.fao.org/food-systems/fr/)  
520 [systems/fr/](https://www.fao.org/food-systems/fr/)
- 521 12. Trichopoulou A, Costacou T, Bamia C, Trichopoulos D. Adherence to a Mediterranean  
522 diet and survival in a Greek population. *N Engl J Med.* 2003 Jun 26;348(26):2599–608.
- 523 13. Dernini S, Berry EM. Mediterranean Diet: From a Healthy Diet to a Sustainable Dietary  
524 Pattern. *Front Nutr.* 2015 May 7;2:15.
- 525 14. Bach-Faig A, Berry EM, Lairon D, Reguant J, Trichopoulou A, Dernini S, et al.  
526 Mediterranean diet pyramid today. Science and cultural updates. *Public Health Nutrition.*  
527 2011 Dec;14(12A):2274–84.
- 528 15. Serra-Majem L, Tomaino L, Dernini S, Berry EM, Lairon D, Ngo de la Cruz J, et al.  
529 Updating the Mediterranean Diet Pyramid towards Sustainability: Focus on  
530 Environmental Concerns. *Int J Environ Res Public Health.* 2020 Dec;17(23):8758.
- 531 16. Guasch-Ferré M, Willett WC. The Mediterranean diet and health: a comprehensive  
532 overview. *Journal of Internal Medicine.* 2021;290(3):549–66.
- 533 17. Estruch R, Ros E, Salas-Salvado J, Covas MI. Primary Prevention of Cardiovascular  
534 Disease with a Mediterranean Diet | *NEJM* [Internet]. [cited 2022 May 19]. Available  
535 from: [https://www.nejm.org/doi/10.1056/NEJMoa1200303?url\\_ver=Z39.88-](https://www.nejm.org/doi/10.1056/NEJMoa1200303?url_ver=Z39.88-2003&rfr_id=ori:rid:crossref.org&rfr_dat=cr_pub%20%200www.ncbi.nlm.nih.gov)  
536 [2003&rfr\\_id=ori:rid:crossref.org&rfr\\_dat=cr\\_pub%20%200www.ncbi.nlm.nih.gov](https://www.nejm.org/doi/10.1056/NEJMoa1200303?url_ver=Z39.88-2003&rfr_id=ori:rid:crossref.org&rfr_dat=cr_pub%20%200www.ncbi.nlm.nih.gov)
- 537 18. Lotfi K, Saneei P, Hajhashemy Z, Esmailzadeh A. Adherence to the Mediterranean Diet,  
538 Five-Year Weight Change, and Risk of Overweight and Obesity: A Systematic Review  
539 and Dose–Response Meta-Analysis of Prospective Cohort Studies. *Adv Nutr.* 2022 Feb  
540 1;13(1):152–66.

- 541 19. Tilman D, Clark M. Global diets link environmental sustainability and human health.  
542 Nature. 2014 Nov;515(7528):518–22.
- 543 20. Bôto JM, Rocha A, Miguéis V, Meireles M, Neto B. Sustainability Dimensions of the  
544 Mediterranean Diet: A Systematic Review of the Indicators used and Its Results.  
545 Advances in Nutrition. 2022 Jun 9;nmac066.
- 546 21. Fresán U, Martínez-González MA, Sabaté J, Bes-Rastrollo M. Global sustainability  
547 (health, environment and monetary costs) of three dietary patterns: results from a Spanish  
548 cohort (the SUN project). BMJ Open. 2019 Feb 21;9(2):e021541.
- 549 22. González-García S, Green RF, Scheelbeek PF, Harris F, Dangour AD. Dietary  
550 recommendations in Spain –affordability and environmental sustainability? Journal of  
551 Cleaner Production. 2020 May 1;254:120125.
- 552 23. Seconda L, Baudry J, Allès B, Hamza O, Boizot-Szantai C, Soler LG, et al. Assessment  
553 of the Sustainability of the Mediterranean Diet Combined with Organic Food  
554 Consumption: An Individual Behaviour Approach. Nutrients. 2017 Jan 12;9(1):61.
- 555 24. Donini LM, Dernini S, Lairon D, Serra-Majem L, Amiot MJ, Del Balzo V, et al. A  
556 Consensus Proposal for Nutritional Indicators to Assess the Sustainability of a Healthy  
557 Diet: The Mediterranean Diet as a Case Study. Front Nutr. 2016;3:37.
- 558 25. Portugal-Nunes C, Nunes FM, Fraga I, Saraiva C, Gonçalves C. Assessment of the  
559 Methodology That Is Used to Determine the Nutritional Sustainability of the  
560 Mediterranean Diet-A Scoping Review. Front Nutr. 2021;8:772133.
- 561 26. Hercberg S, Castetbon K, Czernichow S, Malon A, Mejean C, Kesse E, et al. The  
562 Nutrinet-Santé Study: a web-based prospective study on the relationship between  
563 nutrition and health and determinants of dietary patterns and nutritional status. BMC  
564 Public Health. 2010 May 11;10:242.
- 565 27. Kesse-Guyot E, Castetbon K, Touvier M, Hercberg S, Galan P. Relative validity and  
566 reproducibility of a food frequency questionnaire designed for French adults. Ann Nutr  
567 Metab. 2010;57(3–4):153–62.
- 568 28. Validation du manuel-photos utilisé pour l'enquête alimentaire de l'étude SU.VI.MAX |  
569 Semantic Scholar [Internet]. [cited 2022 Jun 9]. Available from:  
570 [https://www.semanticscholar.org/paper/Validation-du-manuel-photos-utilis%C3%A9-  
571 pour-l%27enqu%C3%AAta-Moullec-  
572 Deheeger/3e18905fb9584e0766662ae6a052cac245eb1807](https://www.semanticscholar.org/paper/Validation-du-manuel-photos-utilis%C3%A9-pour-l%27enqu%C3%AAta-Moullec-Deheeger/3e18905fb9584e0766662ae6a052cac245eb1807)
- 573 29. Baudry J, Méjean C, Allès B, Péneau S, Touvier M, Hercberg S, et al. Contribution of  
574 Organic Food to the Diet in a Large Sample of French Adults (the NutriNet-Santé Cohort  
575 Study). Nutrients. 2015 Oct 21;7(10):8615–32.
- 576 30. #. Publication de la Table de composition nutritionnelle des aliments [Internet]. Salle de  
577 presse | Inserm. 2013 [cited 2022 Jun 9]. Available from:  
578 [https://presse.inserm.fr/publication-de-la-table-de-composition-nutritionnelle-des-  
aliments-utilisee-dans-letude-nutrinet-sante/7519/](https://presse.inserm.fr/publication-de-la-table-de-composition-nutritionnelle-des-<br/>579 aliments-utilisee-dans-letude-nutrinet-sante/7519/)

- 580 31. Sofi F, Dinu M, Pagliai G, Marcucci R, Casini A. Validation of a literature-based  
581 adherence score to Mediterranean diet: the MEDI-LITE score. *Int J Food Sci Nutr*. 2017  
582 Sep;68(6):757–62.
- 583 32. Sofi F, Macchi C, Abbate R, Gensini GF, Casini A. Mediterranean diet and health status:  
584 an updated meta-analysis and a proposal for a literature-based adherence score. *Public*  
585 *Health Nutrition*. 2014 Dec;17(12):2769–82.
- 586 33. Chaltiel D, Adjibade M, Deschamps V, Touvier M, Hercberg S, Julia C, et al. Programme  
587 National Nutrition Santé - guidelines score 2 (PNNS-GS2): development and validation of  
588 a diet quality score reflecting the 2017 French dietary guidelines. *Br J Nutr*. 2019 Aug  
589 14;122(3):331–42.
- 590 34. Gavelle E de, Huneau JF, Mariotti F. Patterns of Protein Food Intake Are Associated with  
591 Nutrient Adequacy in the General French Adult Population. *Nutrients*. 2018 Feb  
592 17;10(2):E226.
- 593 35. Keaver L, Ruan M, Chen F, Du M, Ding C, Wang J, et al. Plant- and animal-based diet  
594 quality and mortality among US adults: a cohort study. *British Journal of Nutrition*. 2021  
595 Jun;125(12):1405–15.
- 596 36. Seconda L, Baudry J, Allès B, Boizot-Szantai C, Soler LG, Galan P, et al. Comparing  
597 nutritional, economic, and environmental performances of diets according to their levels  
598 of greenhouse gas emissions. *Climatic Change*. 2018 Apr 13;148.
- 599 37. Pointereau P, Langevin B, Gimaret M. DIALECTE, a comprehensive and quick tool to  
600 assess the agro-environmental performance of farms. undefined [Internet]. 2012 [cited  
601 2022 Jun 9]; Available from: <https://www.semanticscholar.org/paper/DIALECTE%2C-a-comprehensive-and-quick-tool-to-assess-Pointereau-Langevin/33db4cdf6eef55ee53c52c020e68793aedeb7456>
- 604 38. Kantar | Consumer Panel | Consumer behaviour insights | Consumer panels - Kantar  
605 Worldpanel [Internet]. [cited 2022 Jun 9]. Available from:  
606 <https://www.kantarworldpanel.com/global>
- 607 39. UA-BW | CVUA Stuttgart (Startseite) [Internet]. [cited 2022 Jun 8]. Available from:  
608 <https://www.ua-bw.de/pub/default.asp?subid=1&Lang=DE>
- 609 40. Regulation (EU) 2018/848 of the European Parliament and of the Council of 30 May  
610 2018 on organic production and labelling of organic products and repealing Council  
611 Regulation (EC) No 834/2007 [Internet]. [https://webarchive.nationalarchives.gov.uk/eu-exit/https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02018R0848-](https://webarchive.nationalarchives.gov.uk/eu-exit/https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02018R0848-20201114)  
612 [20201114](https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02018R0848-20201114). Queen’s Printer of Acts of Parliament; [cited 2022 Jun 9]. Available from:  
613 <https://www.legislation.gov.uk/eur/2018/848/contents>  
614
- 615 41. EFSA. The 2015 European Union Report on Pesticide Residues in Food. *EFSA Journal*,  
616 11(3), 3130. 2017.
- 617 42. Baudry J, Pointereau P, Seconda L, Vidal R, Taupier-Letage B, Langevin B, et al.  
618 Improvement of diet sustainability with increased level of organic food in the diet:  
619 findings from the BioNutriNet cohort. *The American Journal of Clinical Nutrition*. 2019  
620 Apr 1;109(4):1173–88.

- 621 43. Chronic dietary risk characterization for pesticide residues: a ranking and scoring method  
622 integrating agricultural uses and food contamination data - PubMed [Internet]. [cited 2022  
623 Jun 9]. Available from: <https://pubmed.ncbi.nlm.nih.gov/21421018/>
- 624 44. Hagströmer M, Oja P, Sjöström M. The International Physical Activity Questionnaire  
625 (IPAQ): a study of concurrent and construct validity. *Public Health Nutr.* 2006  
626 Sep;9(6):755–62.
- 627 45. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, et al.  
628 International physical activity questionnaire: 12-country reliability and validity. *Med Sci  
629 Sports Exerc.* 2003 Aug;35(8):1381–95.
- 630 46. Seconda L, Baudry J, Pointereau P, Lacour C, Langevin B, Hercberg S, et al.  
631 Development and validation of an individual sustainable diet index in the NutriNet-Santé  
632 study cohort. *Br J Nutr.* 2019 May;121(10):1166–77.
- 633 47. Aboussaleh Y, Capone R, Bilali HE. Mediterranean food consumption patterns: low  
634 environmental impacts and significant health-nutrition benefits. *Proc Nutr Soc.* 2017  
635 Nov;76(4):543–8.
- 636 48. Serra-Majem L, Bes-Rastrollo M, Román-Viñas B, Pfrimer K, Sánchez-Villegas A,  
637 Martínez-González MA. Dietary patterns and nutritional adequacy in a Mediterranean  
638 country. *Br J Nutr.* 2009 Jul;101 Suppl 2:S21-28.
- 639 49. Fresán U, Martínez-Gonzalez MA, Sabaté J, Bes-Rastrollo M. The Mediterranean diet, an  
640 environmentally friendly option: evidence from the Seguimiento Universidad de Navarra  
641 (SUN) cohort. *Public Health Nutr.* 2018 Jun;21(8):1573–82.
- 642 50. Grosso G, Fresán U, Bes-Rastrollo M, Marventano S, Galvano F. Environmental Impact  
643 of Dietary Choices: Role of the Mediterranean and Other Dietary Patterns in an Italian  
644 Cohort. *Int J Environ Res Public Health.* 2020 Feb 25;17(5):E1468.
- 645 51. Naja F, Jomaa L, Itani L, Zidek J, El Labban S, Sibai AM, et al. Environmental footprints  
646 of food consumption and dietary patterns among Lebanese adults: a cross-sectional study.  
647 *Nutr J.* 2018 Sep 12;17(1):85.
- 648 52. Clark MA, Springmann M, Hill J, Tilman D. Multiple health and environmental impacts  
649 of foods. *Proc Natl Acad Sci USA.* 2019 Nov 12;116(46):23357–62.
- 650 53. Rabès A, Seconda L, Langevin B, Allès B, Touvier M, Hercberg S, et al. Greenhouse gas  
651 emissions, energy demand and land use associated with omnivorous, pescovegetarian,  
652 vegetarian, and vegan diets accounting for farming practices. *Sustainable Production and  
653 Consumption* [Internet]. 2020 Mar 5 [cited 2020 Mar 6]; Available from:  
654 <http://www.sciencedirect.com/science/article/pii/S2352550919304920>
- 655 54. Lopez CN, Martinez-Gonzalez MA, Sanchez-Villegas A, Alonso A, Pimenta AM, Bes-  
656 Rastrollo M. Costs of Mediterranean and western dietary patterns in a Spanish cohort and  
657 their relationship with prospective weight change. *J Epidemiol Community Health.* 2009  
658 Nov;63(11):920–7.

- 659 55. Marty L, Dubois C, Gaubard MS, Maidon A, Lesturgeon A, Gaigi H, et al. Higher  
660 nutritional quality at no additional cost among low-income households: insights from food  
661 purchases of “positive deviants.” *Am J Clin Nutr.* 2015 Jul;102(1):190–8.
- 662 56. Lacirignola C, Dernini S, Capone R, Meybeck A, Burlingame B, Gitz V, et al. Towards  
663 the development of guidelines for improving the sustainability of diets and food  
664 consumption patterns: the Mediterranean Diet as a pilot study. *Options Méditerranéennes*  
665 *Série B, Études et Recherches* [Internet]. 2012 [cited 2022 Jun 21];(No.70). Available  
666 from: <https://www.cabdirect.org/cabdirect/abstract/20193219933>
- 667 57. Burlingame B, Dernini S. Sustainable diets: the Mediterranean diet as an example. *Public*  
668 *Health Nutr.* 2011 Dec;14(12A):2285–7.
- 669 58. Dernini S, Berry EM, Serra-Majem L, La Vecchia C, Capone R, Medina FX, et al. *Med*  
670 *Diet 4.0: the Mediterranean diet with four sustainable benefits.* *Public Health Nutr.* 2017  
671 May;20(7):1322–30.
- 672 59. Cabrera LC, Pastor PM. The 2019 European Union report on pesticide residues in food.  
673 *EFSA Journal.* 2021;19(4):e06491.
- 674 60. Rempelos L, Wang J, Barański M, Watson A, Volakakis N, Hoppe HW, et al. Diet and  
675 food type affect urinary pesticide residue excretion profiles in healthy individuals: results  
676 of a randomized controlled dietary intervention trial. *Am J Clin Nutr.* 2022 Feb  
677 9;115(2):364–77.
- 678 61. Louie F, Jacobs NFB, Yang LGL, Park C, Monnot AD, Bandara SB. A comparative  
679 evaluation of dietary exposure to glyphosate resulting from recommended U.S. diets.  
680 *Food Chem Toxicol.* 2021 Dec;158:112670.
- 681 62. Prache S, Sante-Lhoutellier V, Adamiec C, Astruc T, Baéza E, Bouillot PE, et al. La  
682 qualité des aliments d’origine animale selon les conditions de production et de  
683 transformation. Synthèse de l’Expertise scientifique collective [Internet] [report]. INRAE;  
684 2020 [cited 2022 Sep 30]. p. 112 p. Available from: <https://hal.inrae.fr/hal-02934505>
- 685 63. Ridoutt B, Baird D, Navarro J, Hendrie GA. Pesticide Toxicity Footprints of Australian  
686 Dietary Choices. *Nutrients.* 2021 Nov 29;13(12):4314.
- 687 64. Gomiero T, Pimentel D, Paoletti MG. Environmental Impact of Different Agricultural  
688 Management Practices: Conventional vs. Organic Agriculture. *Critical Reviews in Plant*  
689 *Sciences.* 2011 Jan 1;30(1–2):95–124.
- 690 65. Andreeva VA, Deschamps V, Salanave B, Castetbon K, Verdot C, Kesse-Guyot E, et al.  
691 Comparison of Dietary Intakes Between a Large Online Cohort Study (Etude NutriNet-  
692 Santé) and a Nationally Representative Cross-Sectional Study (Etude Nationale Nutrition  
693 Santé) in France: Addressing the Issue of Generalizability in E-Epidemiology. *American*  
694 *Journal of Epidemiology.* 2016 Nov 1;184(9):660–9.
- 695 66. Andreeva V, Salanave B, Castetbon K, Deschamps V, Vernay M, Kesse-Guyot E, et al.  
696 Comparison of the sociodemographic characteristics of the large NutriNet-Santé e-cohort  
697 with French Census data: the issue of volunteer bias revisited. *J Epidemiol Community*  
698 *Health.* 2015 Apr 1;

- 699 67. Thompson FE, Byers T. Dietary assessment resource manual. *J Nutr.* 1994 Nov;124(11  
700 Suppl):2245S-2317S.
- 701 68. Touvier M, Méjean C, Kesse-Guyot E, Pollet C, Malon A, Castetbon K, et al. Comparison  
702 between web-based and paper versions of a self-administered anthropometric  
703 questionnaire. *Eur J Epidemiol.* 2010 May;25(5):287–96.
- 704 69. Lassale C, Péneau S, Touvier M, Julia C, Galan P, Hercberg S, et al. Validity of web-  
705 based self-reported weight and height: results of the Nutrinet-Santé study. *J Med Internet*  
706 *Res.* 2013;15(8):e152.
- 707 70. Gerbens-Leenes PW, Mekonnen MM, Hoekstra AY. The water footprint of poultry, pork  
708 and beef: A comparative study in different countries and production systems. *Water*  
709 *Resources and Industry.* 2013 Mar 1;1–2:25–36.
- 710 71. Willett W, Stampfer MJ. Total energy intake: implications for epidemiologic analyses.  
711 *Am J Epidemiol.* 1986 Jul;124(1):17–27.



**Table 1:** General characteristics according to sex-specific quintiles of adherence to the Mediterranean diet (MEDI-LITE), n=29,210, 2014, NutriNet-Santé study<sup>1</sup>

	Quintiles of level of adherence to the Mediterranean diet					P <sup>2</sup>
	Q1	Q2	Q3	Q4	Q5	
<b>MEDI-LITE</b>	6.05 (1.13)	8.54 (0.50)	10.00 (0.00)	11.45 (0.50)	13.94 (1.06)	<.0001
<b>Age, years</b>	49.69 (14.88)	53.20 (14.13)	54.27 (13.73)	55.24 (13.23)	55.18 (13.21)	<.0001
<b>Women, %</b>	75.14	75.21	75.15	74.29	73.97	0.39
<b>Education level, %</b>						0.0001
Less than high-school diploma	20.95	22.36	22.83	21.02	19.40	
High school diploma	15.43	14.92	14.59	14.73	13.44	
Postgraduate	63.62	62.72	62.58	64.25	67.16	
<b>Occupation status, %</b>						<.0001
Unemployed	4.30	3.65	3.86	3.98	4.66	
Never employed	7.24	6.63	5.97	6.43	8.14	
Self-employed, Farmer	1.77	1.74	1.45	1.78	1.93	
Employee, Manual worker	18.60	15.33	13.57	12.95	10.91	
Intermediate professionals	16.52	14.91	14.71	13.94	13.53	
Managerial staff	22.59	20.76	21.00	20.70	20.18	
Retired	28.98	36.98	39.44	40.23	40.66	
<b>Monthly income per unit household unit, %</b>						<.0001
Unwilling to answer	5.87	5.83	6.21	6.04	6.40	
< €1,200	13.34	11.45	10.50	10.72	11.87	
€1,200-1,800	26.01	22.98	22.61	21.98	22.22	
€1,800-2,700	27.24	28.26	28.30	27.22	26.44	
> €2,700	27.54	31.48	32.37	34.04	33.07	
<b>Region, %</b>						<.0001
Parisian basin	17.57	14.98	14.28	13.77	12.19	
East Center	13.73	14.49	14.35	14.37	14.61	
East	8.97	8.91	8.09	7.86	7.06	
Mediterranean	10.13	11.70	13.33	14.39	16.55	
North	4.87	4.15	3.28	2.96	2.76	
West	14.34	14.29	14.90	15.58	15.48	
Parisian area	19.90	20.21	19.69	19.69	19.29	
South West	10.48	11.27	12.07	11.39	12.06	
<b>Smoking habits, %</b>						
Never smoker	50.22	48.75	48.89	48.61	47.51	
Former smoker	36.43	39.79	40.73	41.76	43.60	
Current smoker	13.34	11.46	10.38	9.62	8.89	
<b>Body mass index, kg.m<sup>2</sup></b>	24.63 (5.00)	24.48 (4.77)	24.30 (4.69)	24.10 (4.47)	23.45 (4.07)	<.0001

95%CI: 95% confidence interval; MEDI-LITE: Literature-based adherence score to the Mediterranean diet; Q: quintiles.

<sup>1</sup>Values are means (standard deviation) or %, as appropriate.

<sup>2</sup>P-values are based on linear contrast tests for continuous variables, and Mantel-Haenszel chi-square and chi-square tests for ordinal or categorical variables, respectively.

**Figure 1:** Associations between adherence to the Mediterranean diet (MEDI-LITE) and diet sustainability indicators (mean and 95%CI), n=29,210, 2014, NutriNet-Santé study<sup>1,2</sup>

95%CI: 95% confidence interval; cDQI: Comprehensive Diet Quality Index; CED: Cumulative Energy Demand; GHGE: Greenhouse gas emissions; LO: Land Occupation; MEDI-LITE: Literature-based adherence score to the Mediterranean diet; PANDiet: Diet Quality Index Based on the Probability of Adequate Nutrient Intake; Q: quintiles; sPNNS-GS2: simplified Programme National Nutrition Santé-Guideline Score. cDQI, PANDiet, and sPNNS-GS range from 0 to 85, 0 to 100, and  $-\infty$  to 14.25, respectively. CED, GHGE, and LO are expressed in MJ/d, kgCO<sub>2</sub>eq/d, m<sup>2</sup>/d, respectively. Costs are expressed in €/d.

<sup>1</sup>P-values are based on linear contrast tests. All P-values <.0001

<sup>2</sup>Model 2: adjusted for age, sex, and daily energy intake.

**Table 2:** Associations between adherence to the Mediterranean diet (MEDI-LITE) and nutrient intakes, n=29,210, 2014, NutriNet-Santé study

	Quintiles of level of adherence to the Mediterranean diet										Per SD			
	Q1		Q2		Q3		Q4		Q5		P <sup>1</sup>	β	95%CI	P <sup>2</sup>
	mean	95%CI	mean	95%CI	mean	95%CI	mean	95%CI	mean	95%CI				
<b>Total energy intake, kcal/day</b>														
<i>Model 1<sup>3</sup></i>	1759	1743; 1776	1891	1877; 1905	2002	1984; 2021	2111	2097; 2125	2250	2234; 2267	<.0001	169.65	162.7; 176.6	<.0001
<i>Model 2<sup>4</sup></i>	1765	1749; 1781	1893	1879; 1907	2003	1985; 2021	2108	2094; 2121	2246	2230; 2262	<.0001	166.58	159.8; 173.4	<.0001
<b>%Total fat</b>														
<i>Model 1<sup>3</sup></i>	41.11	40.93; 41.30	41.09	40.92; 41.25	40.98	40.76; 41.19	41.27	41.11; 41.44	41.63	41.44; 41.82	<.0001	0.18	0.10; 0.27	<.0001
<i>Model 2<sup>4</sup></i>	41.29	41.10; 41.48	41.10	40.94; 41.26	40.94	40.72; 41.15	41.20	41.04; 41.37	41.57	41.38; 41.76	<.0001	0.1	0.02; 0.18	0.01
<b>%Saturated fatty acids</b>														
<i>Model 1<sup>3</sup></i>	16.62	16.53; 16.71	15.59	15.51; 15.67	14.95	14.85; 15.06	14.35	14.27; 14.43	13.01	12.92; 13.10	<.0001	-1.23	-1.26; -1.19	<.0001
<i>Model 2<sup>4</sup></i>	16.64	16.55; 16.73	15.59	15.51; 15.67	14.95	14.85; 15.06	14.34	14.26; 14.42	13.00	12.91; 13.09	<.0001	-1.24	-1.28; -1.20	<.0001
<b>%Mono-unsaturated fatty acids</b>														
<i>Model 1<sup>3</sup></i>	15.40	15.30; 15.51	15.98	15.89; 16.07	16.28	16.16; 16.40	16.76	16.67; 16.86	17.58	17.47; 17.69	<.0001	0.75	0.70; 0.79	<.0001
<i>Model 2<sup>4</sup></i>	15.48	15.38; 15.59	15.98	15.89; 16.08	16.26	16.14; 16.38	16.73	16.64; 16.83	17.56	17.45; 17.66	<.0001	0.71	0.67; 0.76	<.0001
<b>%Poly-unsaturated fatty acids</b>														
<i>Model 1<sup>3</sup></i>	6.02	5.96; 6.09	6.44	6.39; 6.50	6.69	6.62; 6.76	7.09	7.04; 7.15	8	7.93; 8.07	<.0001	0.67	0.64; 0.70	<.0001
<i>Model 2<sup>4</sup></i>	6.08	6.01; 6.14	6.45	6.39; 6.50	6.68	6.60; 6.75	7.07	7.01; 7.13	7.98	7.91; 8.05	<.0001	0.65	0.62; 0.68	<.0001
<b>%Carbohydrates</b>														
<i>Model 1<sup>3</sup></i>	38.28	38.08; 38.48	39.09	38.92; 39.26	39.8	39.58; 40.03	40.06	39.88; 40.23	41	40.80; 41.20	<.0001	0.93	0.85; 1.02	<.0001
<i>Model 2<sup>4</sup></i>	38.00	37.80; 38.20	39.07	38.90; 39.24	39.86	39.64; 40.08	40.18	40.01; 40.35	41.12	40.92; 41.32	<.0001	1.07	0.99; 1.16	<.0001
<b>%Added sugars</b>														
<i>Model 1<sup>3</sup></i>	6.46	6.38; 6.54	5.58	5.51; 5.65	5.26	5.17; 5.36	4.89	4.82; 4.96	4.33	4.25; 4.42	<.0001	-0.73	-0.76; -0.69	<.0001
<i>Model 2<sup>4</sup></i>	6.32	6.24; 6.40	5.58	5.51; 5.64	5.29	5.20; 5.38	4.95	4.88; 5.02	4.39	4.30; 4.47	<.0001	-0.66	-0.70; -0.63	<.0001
<b>%Proteins</b>														
<i>Model 1<sup>3</sup></i>	20.2	20.11; 20.30	19.42	19.34; 19.50	18.82	18.72; 18.93	18.29	18.21; 18.37	17.01	16.91; 17.11	<.0001	-1.1	-1.14; -1.06	<.0001
<i>Model 2<sup>4</sup></i>	20.32	20.22; 20.41	19.43	19.35; 19.51	18.80	18.70; 18.91	18.24	18.16; 18.32	16.96	16.87; 17.06	<.0001	-1.16	-1.20; -1.12	<.0001
<b>Protein from plant origin, g/day</b>														
<i>Model 1<sup>3</sup></i>	20.75	20.46; 21.03	24.68	24.43; 24.93	27.78	27.45; 28.10	31.4	31.14; 31.65	39.19	38.90; 39.48	<.0001	6.29	6.17; 6.42	<.0001
<i>Model 2<sup>5</sup></i>	23.67	23.44; 23.90	26.07	25.87; 26.26	26.07	27.53; 28.04	30.06	29.86; 30.26	36.06	35.83; 36.29	<.0001	4.22	4.13; 4.32	<.0001
<b>Fibre, g/day</b>														
<i>Model 1<sup>3</sup></i>	15.47	15.23; 15.72	19.97	19.76; 20.19	23.03	22.75; 23.30	26.23	26.02; 26.45	32.48	32.23; 32.73	<.0001	5.8	5.69; 5.90	<.0001
<i>Model 2<sup>5</sup></i>	18.15	17.95; 18.36	21.10	20.92; 21.27	22.96	22.73; 23.19	25.02	24.84; 25.20	29.86	29.66; 30.07	<.0001	3.98	3.89; 4.07	<.0001
<b>Poly-unsaturated fatty acids, g/day</b>														
<i>Model 1<sup>3</sup></i>	11.37	11.18; 11.57	13.12	12.95; 13.28	14.46	14.24; 14.68	16.13	15.96; 16.30	19.57	19.37; 19.76	<.0001	2.79	2.71; 2.87	<.0001
<i>Model 2<sup>5</sup></i>	13.38	13.23; 13.53	13.99	13.86; 14.12	14.42	14.26; 14.59	15.22	15.09; 15.35	17.56	17.41; 17.71	<.0001	1.41	1.35; 1.48	<.0001
<b>Omega-3 fatty acids, g/day</b>														
<i>Model 1<sup>3</sup></i>	1.38	1.35; 1.42	1.8	1.76; 1.83	2.04	2.00; 2.08	2.39	2.35; 2.42	3.03	3.00; 3.07	<.0001	0.56	0.55; 0.58	<.0001
<i>Model 2<sup>5</sup></i>	1.69	1.66; 1.72	1.91	1.89; 1.94	2.03	1.99; 2.07	2.25	2.22; 2.28	2.75	2.72; 2.78	<.0001	0.36	0.35; 0.37	<.0001
<b>EPA, g/day</b>														
<i>Model 1<sup>3</sup></i>	0.12	0.11; 0.12	0.17	0.17; 0.17	0.19	0.19; 0.20	0.23	0.22; 0.23	0.26	0.25; 0.26	<.0001	0.05	0.05; 0.05	<.0001
<i>Model 2<sup>5</sup></i>	0.14	0.14; 0.15	0.18	0.18; 0.19	0.19	0.19; 0.20	0.21	0.21; 0.22	0.24	0.23; 0.24	<.0001	0.0322	0.030; 0.034	<.0001

<b>DHA, g/day</b>														
<i>Model 1</i> <sup>3</sup>	0.15	0.15; 0.16	0.22	0.22; 0.23	0.25	0.25; 0.26	0.29	0.29; 0.30	0.33	0.32; 0.33	<.0001	0.06	0.06; 0.06	<.0001
<i>Model 2</i> <sup>5</sup>	0.19	0.18; 0.19	0.24	0.23; 0.24	0.25	0.25; 0.26	0.28	0.27; 0.28	0.28	0.29; 0.30	<.0001	0.04	0.04; 0.04	<.0001
<b>Vitamin C, mg/day</b>														
<i>Model 1</i> <sup>3</sup>	108.3	106.0; 110.6	136.3	134.3; 138.2	156	153.4; 158.6	169.7	167.7; 171.7	194.3	192.0; 196.7	<.0001	29.47	28.48; 30.45	<.0001
<i>Model 2</i> <sup>5</sup>	123.6	121.4; 125.7	142.8	140.9; 144.6	155.6	153.2; 158.0	162.8	160.9; 164.7	179.3	177.1; 181.4	<.0001	18.99	18.07; 19.91	<.0001
<b>Vitamin E, mg/day</b>														
<i>Model 1</i> <sup>3</sup>	10.74	10.56; 10.91	12.83	12.68; 12.98	14.35	14.15; 14.54	16.01	15.85; 16.16	19.19	19.01; 19.36	<.0001	2.88	2.81; 2.96	<.0001
<i>Model 2</i> <sup>5</sup>	12.58	12.45; 12.72	13.61	13.49; 13.72	14.30	14.15; 14.45	15.17	15.06; 15.29	17.37	17.23; 17.51	<.0001	1.62	1.56; 1.68	<.0001
<b>Vitamin B12, mg/day</b>														
<i>Model 1</i> <sup>3</sup>	5.83	5.68; 5.97	6.44	6.31; 6.57	6.61	6.44; 6.78	6.94	6.81; 7.07	6.63	6.48; 6.78	<.0001	0.27	0.21; 0.33	<.0001
<i>Model 2</i> <sup>5</sup>	6.84	6.71; 6.98	6.84	6.73; 6.96	6.57	6.42; 6.73	6.48	6.36; 6.60	5.68	5.55; 5.82	<.0001	-0.42	-0.47; -0.36	<.0001
<b>Calcium, mg/day</b>														
<i>Model 1</i> <sup>3</sup>	1100	1088; 1112	1113	1102; 1123	1125	1112; 1139	1133	1123; 1144	1101	1089; 1113	0.24	0.28	-4.88; 5.45	0.91
<i>Model 2</i> <sup>5</sup>	1223	1214; 1231	1166	1159; 1173	1123	1114; 1133	1078	1071; 1085	978	970; 987	<.0001	-84.76	-88.4; -81.1	<.0001
<b>Ethanol, g/day</b>														
<i>Model 1</i> <sup>3</sup>	9	8.67; 9.34	8.54	8.25; 8.83	8.44	8.06; 8.82	8.5	8.21; 8.79	8.07	7.73; 8.41	0.0003	-0.22	-0.37; -0.08	<.0001
<i>Model 2</i> <sup>5</sup>	10.78	10.47; 11.09	9.15	8.89; 9.42	8.35	8.01; 8.70	7.68	7.42; 7.95	6.57	6.26; 6.88	<.0001	-1.36	-1.50; -1.23	<.0001

95% CI: 95% confidence interval; DHA: Docosahexaenoic acid; EPA: Eicosapentaenoic acid; MEDI-LITE: Literature-based adherence score to the Mediterranean diet; Q: quintiles.

<sup>1</sup>P values are based on linear contrast tests.

<sup>2</sup>P-values are calculated by linear regression.

<sup>3</sup>Model 1: unadjusted.

<sup>4</sup>Model 2: adjusted for age and sex.

<sup>5</sup>Model 2: adjusted for age, sex, and daily energy intake using the residual method (71).

**Table 3:** Associations between adherence to the Mediterranean diet (MEDI-LITE) and dietary exposure to pesticides from plant-based foods, n=29,210, 2014, NutriNet-Santé study

	Quintiles of level of adherence to the Mediterranean diet										Per SD			
	Q1		Q2		Q3		Q4		Q5		P <sup>1</sup>	β	95% CI	P <sup>2</sup>
	mean	95%CI	mean	95%CI	mean	95%CI	mean	95%CI	mean	95%CI				
<b>Acetamiprid</b>														
<i>Model 1<sup>3</sup></i>	0.042	0.0402; 0.0438	0.0481	0.0465; 0.0496	0.0536	0.0516; 0.0557	0.0538	0.0522; 0.0553	0.0518	0.0500; 0.0536	<.0001	0.0037	0.0030; 0.0045	<.0001
<i>Model 2<sup>4</sup></i>	0.0437	0.0419; 0.0455	0.0484	0.0469; 0.0499	0.0533	0.0513; 0.0553	0.0531	0.0515; 0.0546	0.0508	0.0490; 0.0526	<.0001	0.0028	0.0020; 0.0036	<.0001
<b>Anthraquinone</b>														
<i>Model 1<sup>3</sup></i>	0.0005	0.0005; 0.0006	0.0006	0.0005; 0.0006	0.0006	0.0005; 0.0006	0.0006	0.0006; 0.0007	0.0007	0.0006; 0.0007	<.0001	0	0.0000; 0.0001	<.0001
<i>Model 2<sup>4</sup></i>	0.0005	0.0005; 0.0006	0.0006	0.0005; 0.0006	0.0006	0.0006; 0.0006	0.0006	0.0006; 0.0006	0.0006	0.0006; 0.0007	0.003	0	0.0000; 0.0000	0.006
<b>Azadirachtin</b>														
<i>Model 1<sup>3</sup></i>	0.0002	0.0001; 0.0002	0.0003	0.0002; 0.0003	0.0003	0.0003; 0.0003	0.0004	0.0004; 0.0004	0.0006	0.0006; 0.0006	<.0001	0.0001	0.0001; 0.0002	<.0001
<i>Model 2<sup>4</sup></i>	0.0002	0.0002; 0.0002	0.0003	0.0003; 0.0003	0.0003	0.0003; 0.0003	0.0004	0.0004; 0.0004	0.0006	0.0006; 0.0006	<.0001	0.0001	0.0001; 0.0001	<.0001
<b>Azoxystrobin</b>														
<i>Model 1<sup>3</sup></i>	0.0311	0.0298; 0.0323	0.0399	0.0388; 0.0409	0.0447	0.0433; 0.0461	0.0482	0.0471; 0.0493	0.0495	0.0482; 0.0508	<.0001	0.0064	0.0058; 0.0069	<.0001
<i>Model 2<sup>4</sup></i>	0.0351	0.0338; 0.0364	0.0415	0.0404; 0.0425	0.0446	0.0432; 0.0460	0.0464	0.0453; 0.0475	0.0457	0.0444; 0.0469	<.0001	0.0036	0.0031; 0.0042	<.0001
<b>Boscalid</b>														
<i>Model 1<sup>3</sup></i>	0.0767	0.0740; 0.0795	0.1069	0.1045; 0.1093	0.1222	0.1191; 0.1254	0.1323	0.1298; 0.1347	0.1325	0.1297; 0.1353	<.0001	0.0194	0.0182; 0.0206	<.0001
<i>Model 2<sup>4</sup></i>	0.0909	0.0882; 0.0936	0.1116	0.1093; 0.1139	0.1212	0.1181; 0.1242	0.126	0.1236; 0.1283	0.1208	0.1181; 0.1235	<.0001	0.0104	0.0092; 0.0116	<.0001
<b>Carbendazim</b>														
<i>Model 1<sup>3</sup></i>	0.0397	0.0384; 0.0411	0.0459	0.0447; 0.0471	0.0508	0.0492; 0.0523	0.052	0.0508; 0.0532	0.0529	0.0515; 0.0543	<.0001	0.0047	0.0041; 0.0053	<.0001
<i>Model 2<sup>4</sup></i>	0.0413	0.0399; 0.0426	0.0463	0.0451; 0.0475	0.0506	0.0490; 0.0521	0.0513	0.0502; 0.0525	0.0517	0.0503; 0.0531	<.0001	0.0038	0.0032; 0.0044	<.0001
<b>Chlorpropham</b>														
<i>Model 1<sup>3</sup></i>	0.057	0.0553; 0.0588	0.0616	0.0601; 0.0632	0.064	0.0620; 0.0659	0.0669	0.0654; 0.0685	0.0619	0.0601; 0.0636	<.0001	0.0018	0.0011; 0.0026	<.0001
<i>Model 2<sup>4</sup></i>	0.0653	0.0636; 0.0670	0.065	0.0636; 0.0665	0.0637	0.0618; 0.0656	0.0632	0.0617; 0.0646	0.054	0.0522; 0.0557	<.0001	-0.0039	-0.005; -0.003	<.0001
<b>Chlorpyrifos</b>														
<i>Model 1<sup>3</sup></i>	0.0512	0.0497; 0.0528	0.0627	0.0614; 0.0641	0.0698	0.0680; 0.0716	0.0709	0.0695; 0.0723	0.0701	0.0685; 0.0717	<.0001	0.0066	0.0059; 0.0073	<.0001
<i>Model 2<sup>4</sup></i>	0.0552	0.0537; 0.0568	0.064	0.0627; 0.0653	0.0694	0.0677; 0.0711	0.0692	0.0678; 0.0705	0.0668	0.0652; 0.0684	<.0001	0.0041	0.0034; 0.0048	<.0001
<b>Lambda</b>														
<b>Cyhalothrin</b>														
<i>Model 1<sup>3</sup></i>	0.0065	0.0062; 0.0067	0.0092	0.0090; 0.0094	0.0105	0.0102; 0.0108	0.0112	0.0109; 0.0114	0.0113	0.0110; 0.0115	<.0001	0.0016	0.0015; 0.0017	<.0001
<i>Model 2<sup>4</sup></i>	0.0077	0.0074; 0.0079	0.0096	0.0094; 0.0098	0.0104	0.0102; 0.0107	0.0107	0.0104; 0.0109	0.0103	0.0100; 0.0105	<.0001	0.0009	0.0008; 0.0010	<.0001
<b>Cypermethrin</b>														
<i>Model 1<sup>3</sup></i>	0.0616	0.0591; 0.0642	0.0702	0.0680; 0.0724	0.078	0.0751; 0.0809	0.0793	0.0770; 0.0815	0.0804	0.0778; 0.0830	<.0001	0.0069	0.0058; 0.0080	<.0001
<i>Model 2<sup>4</sup></i>	0.0633	0.0607; 0.0659	0.0705	0.0683; 0.0726	0.0777	0.0748; 0.0805	0.0786	0.0764; 0.0809	0.0794	0.0768; 0.0820	<.0001	0.006	0.0048; 0.0071	<.0001
<b>Cyprodinil</b>														
<i>Model 1<sup>3</sup></i>	0.0467	0.0447; 0.0488	0.0663	0.0645; 0.0681	0.0747	0.0724; 0.0770	0.0799	0.0781; 0.0817	0.0789	0.0768; 0.0810	<.0001	0.0112	0.0103; 0.0120	<.0001
<i>Model 2<sup>4</sup></i>	0.0563	0.0543; 0.0583	0.0694	0.0677; 0.0711	0.0739	0.0717; 0.0762	0.0757	0.0740; 0.0774	0.0711	0.0691; 0.0731	<.0001	0.0051	0.0042; 0.0060	<.0001
<b>Difenoconazole</b>														
<i>Model 1<sup>3</sup></i>	0.0115	0.0111; 0.0120	0.0152	0.0149; 0.0156	0.0172	0.0167; 0.0177	0.0189	0.0185; 0.0193	0.0196	0.0192; 0.0201	<.0001	0.0028	0.0026; 0.0030	<.0001
<i>Model 2<sup>4</sup></i>	0.0131	0.0127; 0.0135	0.0157	0.0154; 0.0161	0.0171	0.0166; 0.0176	0.0182	0.0179; 0.0186	0.0183	0.0179; 0.0188	<.0001	0.0018	0.0016; 0.0020	<.0001
<b>Dimethoate</b>														
<b>Ometoate</b>														
<i>Model 1<sup>3</sup></i>	0.0024	0.0023; 0.0025	0.003	0.0029; 0.0031	0.0034	0.0033; 0.0035	0.0035	0.0034; 0.0036	0.0036	0.0035; 0.0037	<.0001	0.0004	0.0004; 0.0004	<.0001
<i>Model 2<sup>4</sup></i>	0.0027	0.0026; 0.0028	0.0031	0.0030; 0.0032	0.0034	0.0033; 0.0035	0.0034	0.0033; 0.0035	0.0034	0.0033; 0.0035	<.0001	0.0002	0.0002; 0.0003	<.0001

<b>Fenhexamid</b>														
<i>Model 1<sup>3</sup></i>	0.0639	0.0605; 0.0673	0.0866	0.0837; 0.0895	0.0984	0.0946; 0.1023	0.1032	0.1003; 0.1062	0.0975	0.0941; 0.1009	<.0001	0.0121	0.0106; 0.0135	<.0001
<i>Model 2<sup>4</sup></i>	0.0764	0.0730; 0.0797	0.0905	0.0876; 0.0934	0.0974	0.0936; 0.1011	0.0977	0.0948; 0.1006	0.0876	0.0842; 0.0910	<.0001	0.0043	0.0028; 0.0058	<.0001
<b>Glyphosate</b>														
<i>Model 1<sup>3</sup></i>	0.0019	0.0017; 0.0020	0.0026	0.0025; 0.0027	0.0034	0.0032; 0.0035	0.0042	0.0041; 0.0043	0.0057	0.0056; 0.0058	<.0001	0.0013	0.0012; 0.0013	<.0001
<i>Model 2<sup>4</sup></i>	0.0021	0.0020; 0.0022	0.0027	0.0026; 0.0028	0.0034	0.0032; 0.0035	0.0041	0.0040; 0.0042	0.0054	0.0053; 0.0056	<.0001	0.0011	0.0011; 0.0012	<.0001
<b>Imazalil</b>														
<i>Model 1<sup>3</sup></i>	0.5605	0.5361; 0.5848	0.7209	0.6999; 0.7419	0.8143	0.7867; 0.8420	0.8317	0.8104; 0.8531	0.8039	0.7793; 0.8285	<.0001	0.0846	0.0741; 0.0951	<.0001
<i>Model 2<sup>4</sup></i>	0.6315	0.6070; 0.6560	0.7454	0.7246; 0.7662	0.8094	0.7821; 0.8366	0.8003	0.7792; 0.8215	0.7433	0.7186; 0.7679	<.0001	0.0386	0.0278; 0.0495	<.0001
<b>Imidacloprid</b>														
<i>Model 1<sup>3</sup></i>	0.0741	0.0721; 0.0760	0.0768	0.0751; 0.0785	0.0822	0.0800; 0.0845	0.0802	0.0785; 0.0819	0.0791	0.0772; 0.0811	<.0001	0.002	0.0012; 0.0029	<.0001
<i>Model 2<sup>4</sup></i>	0.0773	0.0753; 0.0792	0.0787	0.0771; 0.0804	0.0824	0.0802; 0.0846	0.0788	0.0771; 0.0805	0.075	0.0730; 0.0770	0.15	-0.0005	-0.001; 0.0004	0.25
<b>Iprodione</b>														
<i>Model 1<sup>3</sup></i>	0.081	0.0768; 0.0851	0.1227	0.1191; 0.1263	0.143	0.1383; 0.1477	0.152	0.1483; 0.1556	0.1516	0.1474; 0.1558	<.0001	0.0241	0.0223; 0.0259	<.0001
<i>Model 2<sup>4</sup></i>	0.1008	0.0967; 0.1049	0.1287	0.1252; 0.1322	0.1412	0.1367; 0.1458	0.1432	0.1397; 0.1468	0.136	0.1319; 0.1401	<.0001	0.0117	0.0099; 0.0135	<.0001
<b>Pyrethrins</b>														
<i>Model 1<sup>3</sup></i>	0.0017	0.0016; 0.0017	0.0019	0.0018; 0.0019	0.0021	0.0020; 0.0021	0.0023	0.0023; 0.0024	0.0026	0.0026; 0.0027	<.0001	0.0003	0.0003; 0.0004	<.0001
<i>Model 2<sup>4</sup></i>	0.0018	0.0017; 0.0018	0.0019	0.0019; 0.0020	0.0021	0.0020; 0.0022	0.0023	0.0022; 0.0023	0.0025	0.0025; 0.0026	<.0001	0.0003	0.0003; 0.0003	<.0001
<b>Spinosad</b>														
<i>Model 1<sup>3</sup></i>	0.0736	0.0692; 0.0779	0.1105	0.1068; 0.1143	0.1377	0.1328; 0.1426	0.1612	0.1574; 0.1650	0.2214	0.2171; 0.2258	<.0001	0.0507	0.0489; 0.0526	<.0001
<i>Model 2<sup>4</sup></i>	0.0818	0.0774; 0.0861	0.1124	0.1087; 0.1161	0.1365	0.1317; 0.1414	0.1577	0.1540; 0.1615	0.216	0.2117; 0.2204	<.0001	0.0464	0.0445; 0.0483	<.0001
<b>Tebuconazole</b>														
<i>Model 1<sup>3</sup></i>	0.0206	0.0196; 0.0217	0.0302	0.0293; 0.0311	0.0354	0.0342; 0.0366	0.0368	0.0359; 0.0378	0.0365	0.0355; 0.0376	<.0001	0.0054	0.0050; 0.0059	<.0001
<i>Model 2<sup>4</sup></i>	0.0257	0.0247; 0.0268	0.0318	0.0309; 0.0327	0.035	0.0338; 0.0361	0.0346	0.0337; 0.0355	0.0324	0.0314; 0.0335	<.0001	0.0022	0.0017; 0.0027	<.0001
<b>Thiabendazole</b>														
<i>Model 1<sup>3</sup></i>	0.219	0.2112; 0.2268	0.2604	0.2537; 0.2672	0.289	0.2801; 0.2979	0.2912	0.2843; 0.2981	0.2802	0.2723; 0.2881	<.0001	0.0216	0.0182; 0.0250	<.0001
<i>Model 2<sup>4</sup></i>	0.2412	0.2333; 0.2491	0.2693	0.2626; 0.2760	0.2881	0.2794; 0.2969	0.2813	0.2745; 0.2881	0.2591	0.2512; 0.2670	0.0002	0.0065	0.0030; 0.0100	0.0003

95%CI: 95% confidence interval; MEDI-LITE: Literature-based adherence score to the Mediterranean diet; Q: quintiles.

<sup>1</sup>P-values are based on linear contrast tests.

<sup>2</sup>P-values are calculated by linear regression.

<sup>3</sup>Model 1: unadjusted.

<sup>4</sup>Model 2: adjusted for age, sex, and daily energy intake.

**Table 4:** Associations between adherence to the Mediterranean diet (MEDI-LITE) and lifestyle and eating practices associated with the Mediterranean lifestyle, n=29,210, 2014, NutriNet-Santé study<sup>1</sup>

	Quintiles of level of adherence to the Mediterranean diet					P <sup>2</sup>	β	Per SD	
	Q1	Q2	Q3	Q4	Q5			95% CI	P <sup>3</sup>
<b>Physical activity, %</b>									
<i>Model 1</i> <sup>4</sup>						<.0001			
Missing data	11.90	10.68	11.09	10.83	9.44				
Low	26.12	21.71	18.52	16.28	13.12				
Moderate	35.62	35.67	35.73	37.21	37.54				
High	26.36	31.94	34.66	35.68	39.90				
<i>Model 2</i> <sup>5</sup>						<.0001			
Missing data	11.66	10.29	10.61	10.31	8.91				
Low	24.74	21.21	18.31	16.33	13.17				
Moderate	34.17	35.04	35.59	37.65	38.29				
High	29.43	33.46	35.49	35.71	39.63				
<b>Organic food consumption</b>									
<i>Model 1</i> <sup>4</sup>	0.18 (0.17; 0.18)	0.24 (0.24; 0.25)	0.28 (0.27; 0.29)	0.33 (0.33; 0.34)	0.45 (0.45; 0.46)	<.0001	0.09	0.09; 0.10	<.0001
<i>Model 2</i> <sup>5</sup>	0.17 (0.16; 0.17)	0.24 (0.23; 0.24)	0.28 (0.27; 0.29)	0.34 (0.33; 0.34)	0.46 (0.46; 0.47)	<.0001	0.10	0.10; 0.10	<.0001
<b>Consumption of ready-to-use products<sup>6</sup></b>									
<i>Model 1</i> <sup>4</sup>	1.27 (1.25; 1.28)	1.21 (1.20; 1.22)	1.19 (1.18; 1.21)	1.17 (1.16; 1.18)	1.09 (1.08; 1.10)	<.0001	-0.06	-0.06; -0.05	<.0001
<i>Model 2</i> <sup>5</sup>	1.28 (1.27; 1.29)	1.22 (1.21; 1.23)	1.19 (1.18; 1.21)	1.16 (1.15; 1.17)	1.07 (1.06; 1.08)	<.0001	-0.07	-0.08; -0.07	<.0001

95%CI: 95% confidence interval; MEDI-LITE: Literature-based adherence score to the Mediterranean diet; Q: quintiles.

<sup>1</sup>Values are means (95%CI) or %, as appropriate.

<sup>2</sup>P-values are based on Mantel-Haenszel chi-square tests or linear contrast tests, as appropriate.

<sup>3</sup>P-values are calculated by linear regression.

<sup>4</sup>Model 1: unadjusted.

<sup>5</sup>Model 2: adjusted for age, sex, and daily energy intake.

<sup>6</sup>For consumption of ready-to-use products: N=29,177.