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## Dietary patterns and sustainability according to health, environment and price: results from the SUN project

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Complete List of Authors:	Fresán, Ujué; Loma Linda University, Center for Nutrition, Healthy Lifestyles, and Disease Prevention; Universidad de Navarra, Department of Preventive Medicine and Public Health Martínez-González, Miguel; Universidad de Navarra, Preventive Medicine and Public Health; Instituto de Salud Carlos III, CIBER Physiopathology of Obesity and Nutrition (CIBERobn) Sabate, J.; Loma Linda University Adventist Health Sciences Center, Center for Nutrition, Healthy Lifestyles, and Disease Prevention BesRastrollo, Maira; University of Navarra, Preventive Medicine and Public Health; Instituto de Salud Carlos III, CIBER Physiopathology of Obesity and Nutrition (CIBERobn)
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10 Author names: Ujué Fresán, Miguel A. Martínez-Gonzalez, Joan Sabaté, and Maira Bes-  
11  
12 Rastrollo  
13

14  
15 Author affiliations:

16  
17 Center for Nutrition, Healthy Lifestyles, and Disease Prevention, Loma Linda University,  
18  
19 Loma Linda, CA 92350, USA (U.F. and J.S.)  
20

21  
22 University of Navarra, Medical School, Department of Preventive Medicine and Public  
23  
24 Health, Irunlarrea 1, 31008 Pamplona, Spain (U.F., M.A.M-G and M.B-R)  
25

26  
27 Navarra Institute for Health Research (IdisNa), 31008 Pamplona, Spain (M.A.M-G and M.B-  
28  
29 R)  
30

31  
32 CIBER Physiopathology of Obesity and Nutrition (CIBERObn), Carlos III Institute of Health,  
33  
34 28029 Madrid, Spain (M.A.M-G and M.B-R)  
35

36  
37 Department of Nutrition, Harvard TH Chan School of Public Health, Boston, USA (M.A.M-  
38  
39 G)  
40  
41

42 Corresponding author:  
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45 Ujué Fresán; Loma Linda University, School of Public Health.  
46

47 24951 Circle Dr Nichol Hall 1304 Loma Linda, California 92350-1718 United States;  
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49 Tel. +1 909 558 1000 ext 15312; [ujuefresan@gmail.com](mailto:ujuefresan@gmail.com)  
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## Abstract

**Objective:** To evaluate the sustainability of the Western, Mediterranean and Provegetarian dietary patterns, according to their effects on health and environment, and to their affordability.

**Design:** University graduates cohort study.

**Settings:** The SUN project (*Seguimiento Universidad de Navarra*, University of Navarra Follow-up). Starting from 1999, it is an Spanish ongoing cohort.

**Participants:** A total of 18429 participants

**Methods:** Information from participants is collected every two years by validated questionnaires. We assessed three dietary patterns (the Mediterranean, the Western and the Provegetarian dietary patterns). The Rate Advancement Period (RAP) was used to assess the healthiness, considering as end-point a composite of all-cause mortality, cardiovascular disease, breast cancer or type 2 diabetes. We also assessed environmental footprints and price of each dietary pattern.

**Results:** After a median follow-up of 10.1 years, we identified 469 incident cases. The Mediterranean dietary pattern was the healthiest pattern according to the RAP (Q4:-3.10 years (95%CI -4.35, -1.85)), meaning later occurrence of the first outcome, while the Western pattern was the unhealthiest pattern (Q4:+1.33 years (95%CI -0.34, +3.00)). The environmentally friendliest pattern was the Provegetarian pattern (Q4: 8.82 points (95%CI 8.75, 8.88)) whereas the Western pattern was the most environment-detrimental pattern (Q4: 10.80 points (95%CI 10.72, 10.87)) in a scale between 4 to 16. Regarding price, the Western pattern was the most affordable pattern (Q4: 5.87 €/day (95%CI 5.82, 5.93)) while the Mediterranean pattern was the most expensive pattern (Q4: 7.52 €/day (95%CI 7.47, 7.56)).

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3 The Mediterranean dietary pattern was the most overall sustainable option, closely followed  
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5 by the Provegetarian pattern. The least overall sustainable pattern was the Western dietary  
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7 pattern.  
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10 **Conclusion:** Following plant-based diets, like the Mediterranean or Provegetarian dietary  
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12 patterns, could be a good option in order to achieve an overall sustainable diet.  
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#### 15 16 17 18 19 20 21 Strengths and limitations of this study

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24 • The novelty of our study was the assessment simultaneously of 3 dimensions of an  
25  
26 overall sustainable diet (health, environment and price).  
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- 28 • We use a wide range score for food consumption of a large sample size through a  
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30 validated questionnaire.  
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- 32 • Information about food consumption is self-reported, therefore susceptible to  
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34 information bias.  
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- 36 • The generalizability of our results could be challenged because the sample, all  
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38 university graduates, is not representative of the general population.  
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## INTRODUCTION

Traditionally, nutritionists have been interested in dietary patterns regarding their health effects.[1-4] In 2010, the Food and Agriculture Organization of the United Nations (FAO) indicated that other aspects of the diet should be taken into account, as their environmental footprints and price, among other.[5]

The association between dietary patterns and ecosystems was initially studied in the 80's.[6] Environmental footprints are caused by use of resources (such as land, water and energy) or environmental degradation (such as greenhouse gasses (GHG) emission, among others). The impact on the environment differs between food items.[7]

Data on food prices in relation to food intake were for the first time assessed at the late 1990s.[8] Since then, several studies on economic aspects of the dietary patterns have been reported.

Previous investigations have assessed health, environment, and price, separately. However, studies analyzing these different aspects of a diet at the same time are necessary. For this reason, we have assessed the association between the adherence to three different dietary patterns (WDP, MeD and Provegetarian (pVD) and their repercussion on the three aspects separately, and in overall.

## SUBJECTS AND METHODS

### Study population

The SUN project (*Seguimiento Universidad de Navarra*, University of Navarra Follow-up) is an ongoing cohort composed of Spanish university graduates.[9] Starting in 1999, information from participants is collected every two years by questionnaires. Voluntary completion of the baseline questionnaire implied informed consent, as participants received detailed information

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3 about the whole study. The protocol was approved by the Research Ethics Committee of the  
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5 University of Navarra.  
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8 Up to March 2014, 22320 participants were recruited (Supplemental Figure 1). Among them,  
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10 we excluded 2031 who did not answer follow-up questionnaires (retention in the cohort:  
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12 90.90%), 404 with total energy intake beyond predefined limits (under percentile 1 or over  
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14 percentile 99), 1286 with chronic disease as cardiovascular disease (CVD), cancer or type 2  
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16 diabetes (T2DM), and 170 who failed to answer 70 or more items of the food frequency  
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18 questionnaire (FFQ), leaving a total of 18429 participants.  
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### 21 **Dietary assessment**

22  
23 Usual diet was recorded using a validated semi-quantitative FFQ completed at baseline with  
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25 136 food items.[10-12] We recoded missing FFQ values as no consumption. Daily food  
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27 intake was estimated by multiplying the frequency of consumption for each item and the  
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29 typical portion size specified in the FFQ. We used consumption data to test the adherence of  
30  
31 our population to 3 dietary patterns.  
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35 The pVD captures a preference for plant origin foods instead of animal ones. To assess it, we  
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37 followed a previously described method.[13, 14] Concisely, we adjusted for total energy  
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39 intake baseline consumption (g/day) of 12 food groups, 7 from plant origin (vegetables  
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41 (including roasted potatoes and French fries); fruits (including fruit in syrup or juice, and  
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43 dried fruits) and fruit juices; nuts; legumes; cereals (whole and refined); plant origin oils; and  
44  
45 bakery products) and 5 from animals (dairy products; eggs; meat and meat products; fish and  
46  
47 seafood; and animal fats). For that, we used the residual method, for men and women  
48  
49 separately. The residuals (energy-adjusted estimates) were ranked according to quintiles.  
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51 Quintile values of plant foods and reverse quintile values for animal were summed up in order  
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53 to evaluate the adherence. Final scores may range from 12 to 60 points (lowest and highest  
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3 adherence, respectively). At last, we divided the adherence to this dietary pattern into  
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5 quartiles (Q).

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7 The index proposed by Trichopoulou and colleagues [15] was used to measure the adherence  
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9 to the MeD. A score of 0 or 1 was given to each of these nine components of this index  
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11 (vegetables, legumes, fruits and nuts, cereals, fish, meat and meat products, fatty dairy  
12  
13 products, alcohol and fat intake (as the ratio of monounsaturated lipids to saturated ones  
14  
15 intake)), using the sex-specific median as the cut-off value. Those who consumed below the  
16  
17 median of presumed beneficial components (vegetables, legumes, fruits and nuts, cereals, fish  
18  
19 and fat ratio) were assigned a value of 0, and participants whose consumption was at or above  
20  
21 the median were assigned a value of 1. On the other way around, consumption below the  
22  
23 median was assigned 1 point assessing a priori detrimental items (meat and meat products,  
24  
25 and fatty dairy products) and the consumption at or above the median was valued as 0.  
26  
27 Consumption of ethanol between 10 to 50 g/day or 5 to 25g/day, for men and women,  
28  
29 respectively, were given one point. The total index score ranged from 0 to 9 points (minimal  
30  
31 to maximal adherence to MeD). Finally, we divided the adherence to this diet into roughly  
32  
33 quartiles.  
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36  
37 We used Principal Component Analysis in order to establish a WDP in our cohort, because  
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39 there is no specific a priori definition of the WDP. Food products were grouped into 30  
40  
41 categories, as described by Lopez et al (2009).[16] We excluded those food groups that their  
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43 measure of sampling adequacy was lower than 0.65. Food groups that loaded >0.30 were  
44  
45 considered to be making a contribution to the factor. The factor score for the diet was  
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47 constructed by summing observed consumptions of the component food items weighted by  
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49 their factor loadings. Thus, each individual received a factor score for each identified  
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51 pattern.[17] The major dietary pattern factor identified was labelled as the WDP, which  
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53 included fast food, fatty dairy products, red and processed meat, potatoes, industrial bakery,  
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3 sauces, precooked foods and sugar-sweetened soft drinks (Supplemental Table 1). Participants  
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5 were also categorized into quartiles according to their adherence to the WDP.  
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### 8 **Assessment of Other Variables**

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10 The baseline questionnaire also included sociodemographic, lifestyle and medical history  
11  
12 questions. Self-reported data, such as physical activity (total Metabolic Equivalent of Tasks  
13  
14 (MET) per hour per week), body mass index (BMI) and hypertension, have been previously  
15  
16 validated.[18-20]  
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### 19 **Outcomes assessment**

#### 20 **Health**

21  
22 We estimated the impact of each of the 3 dietary patterns on health using the metric of the  
23  
24 Rate Advancement Period (RAP).[21, 22] The RAP is a method which measures the time by  
25  
26 which a rate of a specific outcome is advanced (positive values for detrimental exposures) or  
27  
28 it is postponed (negative values for protective exposures) among exposed subjects compared  
29  
30 with unexposed individuals, conditional on being free of that outcome at the baseline age. It is  
31  
32 useful to analyze outcomes which uniformly rise with age, as it happens with total mortality  
33  
34 and with the incidence of most chronic diseases. In the current analysis, the end-point was a  
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36 composite including death, non-fatal CVD (myocardial infarction or stroke), non-fatal breast  
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38 cancer or T2DM, whichever occurred first. Time was measured in years from the entrance to  
39  
40 the cohort. In order to minimize the bias produced by comparing dietary scores measured  
41  
42 using different units, z scores were used. Each z score was calculated as the value of the diet  
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44 minus the sample mean divided by its standard deviation. Cox regression models adjusted for  
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46 sex, body mass index (BMI), including a quadratic term for BMI, physical activity, smoking,  
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48 time spend in sedentary activities, prevalent hypertension, prevalent hypercholesterolemia and  
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50 total energy intake were used to calculate point estimates of RAP for each quartile of  
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3 adherence to the three dietary patterns, by dividing the regression coefficient of the z score by  
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5 the regression coefficient of age. 95% Confidence Interval (95%CI) for RAP were calculated  
6  
7 by using variance and covariance estimates from regression coefficients.[21]

#### 8 9 Environmental footprints

10  
11 Environmental footprints index was assessed as previously described by Fresan et al.[23] In  
12  
13 brief, the impact of a serving of each food item on resource use (land, water and energy) and  
14  
15 GHG emission was estimated. The number of servings per day consumed of every item was  
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17 multiplied by the specific value of each of them. Total use of land, water and energy, and  
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19 GHG emission were calculated as the sum of all items values, obtaining the impact on these 4  
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21 footprints according to the daily food consumption of each participant. We classified  
22  
23 participants into quartiles of these total values, each of them ranking from 1 to 4 (less to high  
24  
25 resource consumption or GHG emission). A total environmental footprints index was created  
26  
27 summing the quartile values of all the four footprints: land use, water use, energy use and  
28  
29 GHG emission. Therefore, environmental footprints index ranked from 4 to 16 points (less to  
30  
31 high environmental repercussion).

#### 32 33 34 35 36 Price

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39 Food costs were derived from the Ministry of Industry, Tourism and Commerce of Spain.[24]  
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41 Annual cost of each item was calculated as the monthly reported national average costs, and it  
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43 was assessed according to the year when that participant completed their baseline  
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45 questionnaires in order to control for differences between calendar years in prices. Total daily  
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47 costs were calculated by multiplying the cost per kg (€/kg) of each food item by the reported  
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49 daily quantity consumed through the FFQ.  
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#### 52 53 Overall sustainable diet index

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3 We designed an index which gathered the impact of the daily diet on all the analyzed aspects:  
4 health, environment footprints and price. In order to all of these three aspects contribute  
5 equally for the overall index, a score from 0 to 3 points was given for each of them. We  
6 estimated the RAP, the environmental footprints index and the daily cost of the diet of each  
7 participant. Of these values, the less suitable value for health (a specific hazard is advanced  
8 more years), environment (more environmental footprints were produced) and economy (the  
9 highest daily price) was given 0 points. On the other way around, we assigned 3 points for the  
10 healthiest daily diet (a specific hazard is postponed more years), the one that produced less  
11 environmental footprints, and the cheapest one. Proportional score was given for the rest of  
12 values. Summing these three values, the overall sustainable diet index ranked from 0 to 9  
13 points, being 0 the less suitable diet and 9 the most recommendable diet.  
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### 27 **Statistical analyses**

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29 Linear Regression Models were used to assess the relationship between quartiles of adherence  
30 to each dietary pattern and overall sustainable diet index, and each of the three components  
31 separately (RAP, environmental footprints index and price). We estimated means and their  
32 95%CI using analyses of covariance for each quartile, adjusting for age, sex and total energy  
33 intake. Moreover, we analyzed differences in mean values and their 95%CI of each dietary  
34 pattern quartile *versus* the lowest quartile, as the reference. Linear trends across different  
35 quartiles were conducted by assigning the medians to each quartile; this variable was treated  
36 as continuous.  
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47 We conducted sensitivity analyses refitting the models under different assumptions to assess  
48 the robustness of our results: excluding participants who had any of the outcomes gathered in  
49 the health composite end-point in the first 2 years of follow-up; including participants with  
50 prevalent CVD, cancer or T2DM at baseline (in this case, the model was additionally  
51 adjusted for prevalent CVD, cancer and T2DM at baseline); and excluding participants with  
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3 total energy intake beyond predefined limits (<800 Kcal/day and <500 Kcal/day or >4000  
4 Kcal/day and >3500 Kcal/day in men and women, respectively).

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7 We assessed interactions, through a likelihood ratio test, between the three dietary patterns  
8 and sex, BMI, age and physical activity (assessed as continuous variables).

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11 All p-values presented are two-tailed;  $p < 0.05$  was considered statistically significant.

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13 Analyses were performed using STATA/SE V.12.1 (StataCorp, College Station, Texas,  
14 USA).

## 15 16 17 18 **RESULTS**

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21 Our analysis included a total of 18429 participants (7042 men and 11387 women). The main  
22 baseline characteristics of participants according to adherence (extreme quartiles, Q1 and Q4)  
23 to each of the three dietary patterns are presented in table 1.

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25  
26 Participants with the highest adherence to the WDP (Q4) were more likely to be men,  
27 younger, single, current smokers and having less advance studies. They tended to intake more  
28 calories. On average, they consumed more animal products, bakery products, fast food and  
29 sugared sodas; but less fish, plant products and olive oil. The opposite results were obtained  
30 for those participants in the Q4 of the MeD, whose consumption of fish and plant origin food  
31 was the highest. Dairy products, eggs and meat were less consumed for those who reported  
32 the highest pVD adherence. Fats, specially saturated fatty acids, were more popular for those  
33 in Q4 of the WDP. Fiber was highly consumed by participants of the Q4 of the pVD and  
34 MeD, and the Q4 participants of the MeD also reported higher consumption of alcohol.  
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Table 1. Distribution of baseline characteristics of participants according to quartiles of adherence to Western, Mediterranean and Provegetarian dietary patterns.

	Western dietary pattern		Mediterranean dietary pattern		Provegetarian dietary pattern	
	Q1	Q4	Q1	Q4	Q1	Q4
Frequency (n)	4608	4607	3487	1846	4672	4350
<b>Sociodemographic data</b>						
Sex (men %)	29	50	39	41	39	40
Age (years)	40 (12)	33 (10)	33 (10)	42 (13)	34 (11)	40 (12)
Civil status (%)						
Single	39	58	56	34	51	41
Married	54	39	41	60	44	54
Others	7	3	3	6	4	5
Smoking status (%)						
Current smoker	21	28	27	25	30	23
Former smoker	31	18	16	34	20	28
Studies (%)						
Technical/non graduated	4	9	9	4	7	5
Graduated	76	74	74	77	75	74
Master/doctoral	20	17	17	19	18	21
<b>Food and Nutrition</b>						
Total energy intake (Kcal/d)	2064 (639)	3184 (752)	2347 (719)	2724 (722)	2634 (786)	2539 (809)
Food items (servings/day) <sup>a</sup>						
Dairy products	3.6 (1.8)	2.9 (1.9)	3.6 (1.7)	2.6 (1.7)	3.9 (2.0)	2.5 (1.4)
Non-fat/low-fat dairy products	2.2 (1.7)	0.7 (1.1)	1.0 (1.3)	1.9 (1.6)	1.5 (1.7)	1.2 (1.2)
Fatty dairy products	1.4 (0.9)	2.2 (1.8)	2.6 (1.4)	0.8 (0.8)	2.4 (1.7)	1.3 (1.0)
Eggs	0.3 (0.2)	0.5 (0.4)	0.4 (0.3)	0.4 (0.3)	0.5 (0.4)	0.3 (0.2)
All types of meats	1.6 (0.6)	2.3 (1.1)	2.3 (0.9)	1.5 (0.7)	2.4 (1.0)	1.5 (0.7)
Red meat	0.4 (0.2)	0.7 (0.4)	0.6 (0.3)	0.4 (0.3)	0.7 (0.4)	0.4 (0.3)
White meat	0.3 (0.2)	0.3 (0.3)	0.3 (0.3)	0.3 (0.2)	0.4 (0.3)	0.3 (0.2)
Processed meat	0.8 (0.5)	1.4 (1.0)	1.3 (0.8)	0.8 (0.6)	1.4 (0.9)	0.8 (0.5)
Fish and seafood	0.9 (0.5)	0.6 (0.6)	0.5 (0.5)	1.0 (0.5)	0.8 (0.7)	0.7 (0.4)
Vegetables	3.5 (2.0)	2.2 (1.4)	1.9 (1.0)	3.9 (2.0)	2.2 (1.4)	3.5 (2.0)
Legumes	0.3 (0.2)	0.3 (0.3)	0.2 (0.2)	0.4 (0.2)	0.3 (0.2)	0.3 (0.2)
Fruits and nuts	4.1 (2.7)	1.7 (1.7)	1.7 (1.2)	4.2 (2.7)	1.9 (1.6)	3.8 (2.6)
Fresh fruit	3.7 (2.7)	1.5 (1.6)	1.5 (1.1)	3.8 (2.6)	1.8 (1.6)	3.4 (2.5)
Processed fruit	0.2 (0.3)	0.1 (0.2)	0.1 (0.2)	0.2 (0.4)	0.1 (0.2)	0.2 (0.4)
Nuts	0.2 (0.3)	0.1 (0.2)	0.1 (0.1)	0.3 (0.4)	0.1 (0.2)	0.3 (0.4)
Cereals	2.3 (1.3)	1.6 (1.4)	1.6 (1.0)	2.5 (1.3)	1.5 (1.2)	2.4 (1.3)
Oils and fats	2.3 (1.5)	1.7 (1.8)	1.6 (1.2)	2.5 (1.7)	1.6 (1.5)	2.4 (1.6)
Olive oil	2.0 (1.4)	1.1 (1.3)	1.0 (1.0)	2.2 (1.5)	1.2 (1.2)	2.0 (1.4)
Other oils	1.2 (0.5)	0.3 (0.8)	0.2 (0.6)	0.2 (0.7)	0.2 (0.6)	0.2 (0.7)

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2							
3	Margarine	0.1 (0.2)	0.1 (0.4)	0.1 (0.4)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)
4	Animal fats	0.1 (0.1)	0.2 (0.4)	0.2 (0.3)	0.1 (0.3)	0.2 (0.4)	0.1 (0.2)
5	Pastry products	1.0 (0.7)	1.3 (1.3)	1.4 (1.1)	0.8 (0.8)	1.0 (0.9)	1.2 (1.0)
6	Biscuits	0.4 (0.6)	0.2 (0.7)	0.4 (0.7)	0.2 (0.5)	0.3 (0.6)	0.4 (0.7)
7	Chocolate	0.3 (0.3)	0.4 (0.8)	0.4 (0.6)	0.2 (0.4)	0.3 (0.4)	0.4 (0.6)
8	Industrial bakery	0.2 (0.2)	0.4 (0.7)	0.4 (0.5)	0.1 (0.3)	0.3 (0.4)	0.3 (0.5)
9	Home-made bakery	0.1 (0.1)	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)
10							
11	Cakes	0.04	0.06	0.06	0.04	0.05	0.04
12		(0.05)	(0.10)	(0.08)	(0.09)	(0.07)	(0.08)
13	Fast food <sup>1</sup>	0.1 (0.1)	0.3 (0.3)	0.3 (0.2)	0.1 (0.1)	0.3 (0.2)	0.1 (0.1)
14	Beverages	7.8 (3.3)	7.1 (3)	6.8 (3.2)	8.2 (3.4)	7.4 (3.4)	7.5 (3.2)
15	Water	4.8 (2.7)	4.3 (2.6)	4.3 (2.6)	4.9 (2.7)	4.5 (2.7)	4.7 (2.6)
16	Red wine	0.3 (0.6)	0.2 (0.6)	0.2 (0.5)	0.5 (0.8)	0.2 (0.6)	0.3 (0.6)
17	Other alcoholic						
18	beverages	0.3 (0.5)	0.3 (0.6)	0.2 (0.5)	0.4 (0.5)	0.4 (0.6)	0.3 (0.5)
19	Sugared sodas	0.1 (0.2)	0.4 (0.7)	0.3 (0.6)	0.1 (0.3)	0.3 (0.6)	0.2 (0.3)
20	Regular coffee	1.2 (1.3)	1.2 (1.3)	1.1 (1.2)	1.3 (1.3)	1.3 (1.3)	1.1 (1.2)
21	Bottled juice	0.1 (0.3)	0.1 (0.4)	0.1 (0.4)	0.1 (0.4)	0.1 (0.3)	0.1 (0.4)
22							
23	Nutrient intake (% total energy						
24	intake/day)						
25	Fat	33 (7)	39 (5)	40 (6)	33 (6)	39 (6)	34 (6)
26	Saturated fatty acids	10 (3)	14 (3)	15 (3)	10 (2)	15 (3)	11 (3)
27	Monounsaturated fatty						
28	acids	15 (4)	16 (3)	16 (3)	15 (4)	16 (3)	15 (4)
29	Polyunsaturated fatty						
30	acids	5 (1)	6 (2)	5 (2)	5 (2)	5 (2)	5 (2)
31	Carbohydrates	46 (8)	42 (6)	41 (7)	47 (7)	40 (7)	47 (7)
32	Protein	19 (4)	17 (3)	18 (3)	18 (3)	19 (3)	16 (3)
33	Dietary fibre intake (g/day) <sup>a</sup>	37 (13)	23 (10)	21 (7)	40 (13)	23 (9)	37 (13)
34	Alcohol intake (g/day) <sup>a</sup>	6 (9)	7 (11)	5 (9)	10 (10)	7 (12)	6 (9)
35							
36	<b>Lifestyle data</b>						
37	Physical activity (METs-h/week)	29 (25)	27 (25)	23 (21)	33 (28)	26 (23)	29 (26)
38	Time watching TV (h/day)	1.5 (1.1)	1.6 (1.3)	1.6 (1.3)	1.6 (1.1)	1.7 (1.3)	1.5 (1.1)
39							

<sup>a</sup>Adjusted for energy intake through the residual method.<sup>1</sup>Fast food includes hamburger, pizza and

sausages. Q1=first quartile. Q4= fourth quartile.

Figure 1 shows how overall sustainable diet index, and the three elements that composed it (health as RAP, environmental footprints index and price) changed according to quartiles of adherence to the three analyzed dietary patterns (specific values for means and confidence intervals are showed in Supplemental Table 2).

[insert Figure 1]

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2  
3 Comparing people in Q4 of these dietary patterns, the most overall sustainable pattern was the  
4 MeD, followed closely by the pVD. Taking into account health repercussion, after a median  
5 follow-up of 10.1 years, and 469 incident cases of the composite end-point, the healthiest  
6  
7 dietary pattern was the MeD because the hazard of developing the end-point was postponed  
8  
9 more than 3 years. Assessing the diet of subjects on the pVD and WDP, they had a retardation  
10  
11 and advancement of the end-point respectively, although the lack of statistical significance.  
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14 Regarding environmental footprints, the pVD seemed to be the eco-friendliest option, follow  
15  
16 of those of the MeD. On average participants in Q4 of the MeD expended the highest amount  
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18 of economic resources, while the food of participants in Q4 of the WDP was the most  
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20 affordable.  
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25 Adjusted relative mean differences are shown in Figure 2, and specific values are presented in  
26  
27 Supplemental table 3. In all the analyses, there was a statistical linear trend across quartiles  
28  
29 ( $p < 0.001$ ).  
30

31  
32 [insert Figure 2]  
33  
34

35 The main results were consistent in all our sensitivity analyses (Supplemental Table 4 and  
36  
37 Supplemental Table 5). Only including those participants who reported a prevalent chronic  
38  
39 disease, the highest adherence to the pVD seemed to be better than the MeD when assessing  
40  
41 the overall sustainable diet index. However, differences between these two dietary patterns  
42  
43 were not statistically significant. Apart from that, interactions between each of the dietary  
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45 patterns with sex, BMI, age or physical activity were not statistically significant (data not  
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47 shown).  
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## 51 **DISCUSSION**

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54 The current study showed that the Mediterranean dietary pattern was the healthiest option,  
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56 with relatively low environmental footprints. However, its price was the highest. The  
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3 Provegetarian dietary pattern was the eco-friendliest pattern, at the same time that relatively  
4 healthy and affordable. The Western dietary pattern was the less recommended pattern  
5 according to health and ecosystems consequences, but it was the most affordable food pattern.  
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7 Taking into account health, environment and price as a whole, MeD and pVD would be  
8  
9 sustainable dietary patterns. Adherence to a WDP seemed to have the opposite result.  
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14 Healthy diets have protective effects against diseases like cardiovascular, cancer, T2DM or  
15 even all-cause mortality.[25] We observed that the conformity to the MeD was the healthiest  
16 option, followed closely by the pVD. The high quality of the MeD and other pVD has been  
17 numerous times reported.[13, 26] Their benefits have been attributed to the high consumption  
18 of plant-origin foods and the low consumption of animal-based foods [25].In fact, the MeD  
19 could be considered as a special case of a pVD. MeD specifically suggests the consumption of  
20 nuts, olive oil or fish, which have reported health benefits.[1, 27] We have not assessed a  
21 “pure” Vegetarian/Vegan diet because the proportion of participants who followed these  
22 patterns was very low in our cohort. pVD is only a gentle and moderate approach. On the  
23 other hand, our results related to the WDP and its detrimental health repercussion are in  
24 agreement with previous publications.[28]  
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39 Previous research supports that a population shift to a more plant and less animal-rich diet,  
40 like the pVD or the MeD, may be positive for the environment.[7, 29-31] Conformity to the  
41 MeD, and especially to the pVD, implicated a reduction on environment footprints. The  
42 higher impact of the MeD than the pVD could be due to fish consumption, because of the  
43 great amount of energy used for fish production. It is necessary to reinforce fish consumption  
44 from sustainable sources, and in the case of wild caught fish to prevent overfishing.  
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52 It has been suggested a direct linear relationship between diet adequacy and cost of a dietary  
53 pattern.[32-34] A recent meta-analysis reported an average increment of 1.48\$/day if a  
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3 healthy diet is followed.[33] In our cohort, those with the highest *versus* the lowest adherence  
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5 to the healthiest pattern, the MeD, spent a mean of 1.42€/day more in their daily diet. Again,  
6  
7 fish consumption could be the main reason of the increasing price in parallel with the MeD  
8  
9 adherence.[16, 34]

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12 Limitations of our study include self-reported information, and difficulty of generalizability of  
13  
14 our results as the sample is not representative of the general Spanish population. We assumed  
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16 that foods were prepared and eaten at home, and this approximation may underestimate the  
17  
18 effect of the diet. The three dietary patterns were assessed by 3 different methods. The  
19  
20 environmental footprints index does not contemplate other phases of food chain apart from  
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22 production and processing. However, production is the most contributive one by far.[35, 36]

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25 Some of the strengths of the current study include the assessment simultaneously of 3  
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27 dimensions of an overall sustainable diet (health, environment and price) and this represent a  
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29 novelty of our study. We use a wide range score for food consumption of a large sample size  
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31 through a validated questionnaire. We focused on GHG emission and efficiency in using  
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33 natural resources when assessing the environment footprint, which is a more holistic approx.  
34  
35 The way we assessed price controls variation between regions, seasons and types of shop.  
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## 38 39 **CONCLUSION**

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41 Following plant-based diets, like the Mediterranean or another Provegetarian dietary pattern,  
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43 could be a good option to achieve an overall sustainable diet, according to a concordant high  
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45 score in three dimensions of an ideal healthy, environmental-friendly and affordable diet.  
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47 Mediterranean dietary pattern was the healthiest pattern and relatively high eco-friendly.  
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49 However, nowadays, it cannot be presented as an affordable model. Some price policies  
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51 (subsidizing healthy Mediterranean foods) may contribute to achieve that a diet with highly  
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53 recognized health benefits could be more affordable.  
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6  
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8  
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10

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25 analysis and interpretation of data: U.F., M.-A.M.-G. and M.B.-R. Drafting of the manuscript:  
26 U.F. Critical revision of the manuscript for important intellectual content: J.S., M.-A.M.-G.  
27 and M.B.-R. Statistical analysis: U.F. Supervision: M.B.-R.  
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33 **Data sharing statement:** No additional data are available.  
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36 **Ethics approval:** The protocol was approved by the Research Ethics Committee of the  
37 University of Navarra.  
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## LEGENDS FOR FIGURES

Figure 1. Adjusted means and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Price, according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence. Adjusted for age, sex and total energy intake.

Red line, cross: adherence to the Western dietary pattern. Blue line, diamond: adherence to the Mediterranean dietary pattern. Green line, square: adherence to the Provegetarian dietary pattern.

Figure 2. Adjusted relative means differences and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Price, according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence, taking as the reference category the first quartile. Adjusted for age, sex and total energy intake.

Red line, cross: adherence to the Western dietary pattern. Blue line, diamond: adherence to the Mediterranean dietary pattern. Green line, square: adherence to the Provegetarian dietary pattern.



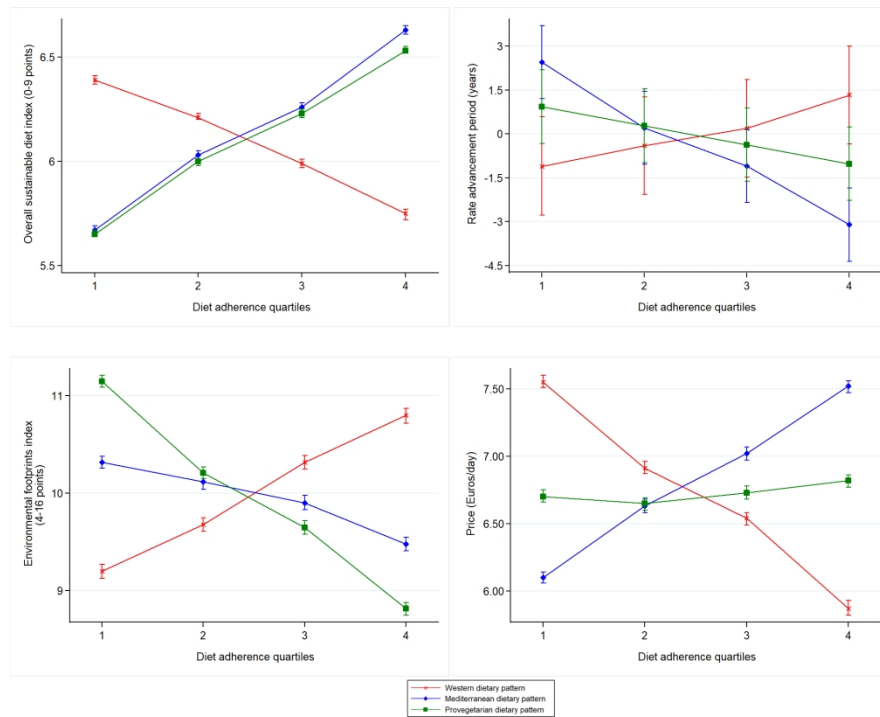


Figure 1. Adjusted means and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Price, according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence. Adjusted for age, sex and total energy intake. Red line, cross: adherence to the Western dietary pattern. Blue line, diamond: adherence to the Mediterranean dietary pattern. Green line, square: adherence to the Provegetarian dietary pattern.

199x150mm (300 x 300 DPI)

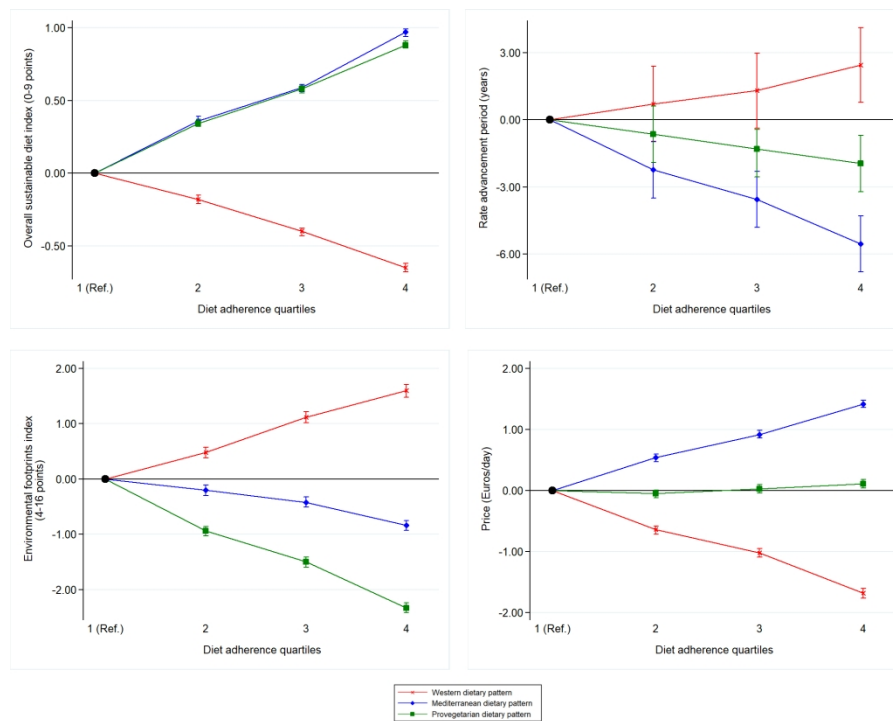
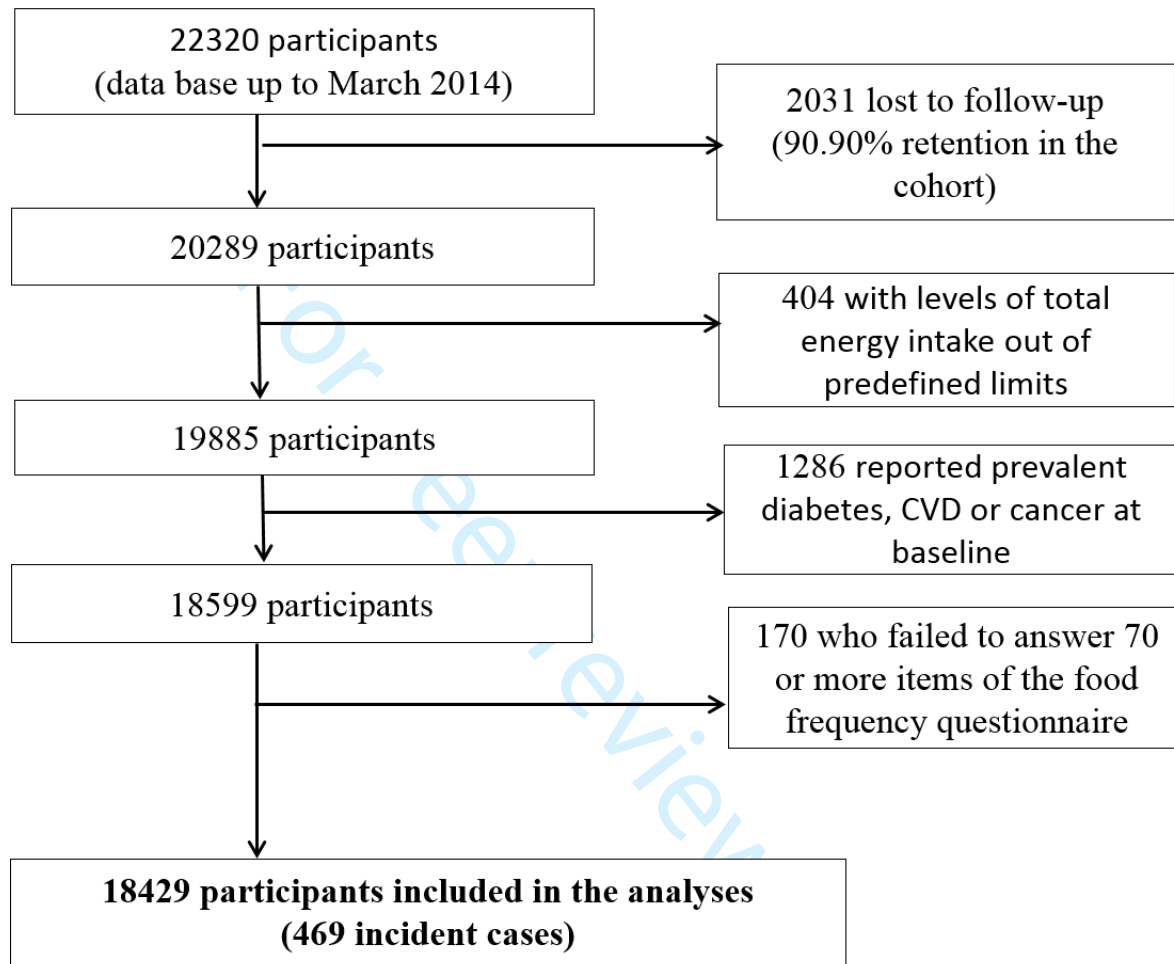


Figure 2. Adjusted relative means differences and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Price, according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence, taking as the reference category the first quartile. Adjusted for age, sex and total energy intake.

Red line, cross: adherence to the Western dietary pattern. Blue line, diamond: adherence to the Mediterranean dietary pattern. Green line, square: adherence to the Provegetarian dietary pattern.

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Supplemental Figure 1. Flow chart of the study participants in the Seguimiento Universidad de Navarra (SUN) Project 1999–2016.



CVD: cardiovascular disease

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3 Supplemental Table 1. Principal Component Analysis loadings >0.3 for Western dietary  
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5 pattern.  
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Food products	Loading factors
Fast food	0.5172
Fatty dairy products	0.4871
Red meat	0.4841
Potatoes	0.4538
Industrial bakery	0.4535
Processed meat	0.4477
Sauces	0.4385
Precooked food	0.3954
Caloric soft drinks	0.3862

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Supplemental Table 2. Adjusted mean values and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Price according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence.

	<b>Western dietary pattern</b>			
	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
N (frequency)	4608	4607	4607	4607
Cases/person-years	151/43804	117/45688	104/46749	97/49219
Overall sustainable diet index (0-9 points) <sup>a</sup>	6.39 (6.37, 6.41)	6.21 (6.20, 6.23)	5.99 (5.97, 6.01)	5.75 (5.72, 5.77)
Rate advancement period (years) <sup>a</sup>	-1.11 (-2.78, 0.59)	-0.40 (-2.07, 1.27)	0.19 (-1.48, 1.86)	1.33 (-0.34, 3.00)
Environmental footprints index (4-16 points) <sup>a</sup>	9.20 (9.13, 9.27)	9.68 (9.61, 9.75)	10.32 (10.25, 10.39)	10.80 (10.72, 10.87)
Price (€/day) <sup>a</sup>	7.55 (7.51, 7.60)	6.91 (6.87, 6.96)	6.54 (6.49, 6.58)	5.87 (5.82, 5.93)
	<b>Mediterranean dietary pattern</b>			
	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
N (frequency)	6802	3796	3400	4431
Cases/person-years	149/70310	100/38942	99/33695	121/42512

Overall sustainable diet index (0-9 points) <sup>a</sup>	5.67 (5.66, 5.69)	6.03 (6.01, 6.05)	6.26 (6.24, 6.28)	6.64 (6.62, 6.66)
Rate advancement period (years) <sup>a</sup>	2.45 (1.21, 3.70)	0.21 (-1.04, 1.45)	-1.10 (-2.34, 0.15)	-3.10 (-4.35, -1.85)
Environmental footprints index (4-16 points) <sup>a</sup>	10.32 (10.26, 10.38)	10.12 (10.04, 10.19)	9.90 (9.83, 9.98)	9.48 (9.41, 9.55)
Price (€/day) <sup>a</sup>	6.10 (6.06, 6.14)	6.63 (6.58, 6.68)	7.02 (6.97, 7.07)	7.52 (7.47, 7.56)

#### Provegetarian dietary pattern

	Q1	Q2	Q3	Q4
N (frequency)	4672	5450	3957	4350
Cases/person-years	108/47626	129/55222	92/39808	140/42802
Overall sustainable diet index (0-9 points) <sup>a</sup>	5.65 (5.64, 5.67)	6.00 (5.98, 6.01)	6.23 (6.21, 6.25)	6.53 (6.52, 6.55)
Rate advancement period (years) <sup>a</sup>	0.93 (-0.33, 2.19)	0.28 (-0.98, 1.54)	-0.37 (-1.62, 0.89)	-1.02 (-2.27, 0.24)
Environmental footprints index (4-16 points) <sup>a</sup>	11.15 (11.09, 11.21)	10.21 (10.15, 10.27)	9.65 (9.58, 9.72)	8.82 (8.75, 8.88)
Price (€/day) <sup>a</sup>	6.70 (6.66, 6.75)	6.65 (6.60, 6.69)	6.73 (6.68, 6.78)	6.82 (6.77, 6.86)

Adjusted for age, sex and total energy intake. <sup>a</sup>p for trend<0.001. Qn= nth quartile of diet adherence.

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Supplemental Table 3. Adjusted relative differences of mean values and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Price according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence.

	<b>Western dietary pattern</b>			
	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
N (frequency)	4608	4607	4607	4607
Cases/person-years	151/43804	117/45688	104/46749	97/49219
Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	-0.18 (-0.21, -0.15)	-0.40 (-0.43, -0.38)	-0.65 (-0.68, -0.62)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	0.71 (-0.96, 2.38)	1.30 (-0.37, 2.97)	2.44 (0.77, 4.11)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	0.48 (0.38, 0.57)	1.12 (1.02, 1.22)	1.60 (1.48, 1.71)
Price (€/day) <sup>a</sup>	0 (Ref)	-0.64 (-0.71, -0.58)	-1.02 (-1.09, -0.95)	-1.68 (-1.76, -1.60)
	<b>Mediterranean dietary pattern</b>			
	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
N (frequency)	6802	3796	3400	4431
Cases/person-years	149/70310	100/38942	99/33695	121/42512

Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	0.36 (0.34, 0.39)	0.59 (0.56, 0.61)	0.97 (0.94, 0.99)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	-2.24 (-3.49, -0.99)	-3.55 (-4.80, -2.30)	-5.55 (-6.80, -4.30)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	-0.20 (-0.30, -0.11)	-0.42 (-0.51, -0.32)	-0.84 (-0.93, -0.75)
Price (€/day) <sup>a</sup>	0 (Ref)	0.54 (0.47, 0.60)	0.92 (0.86, 0.99)	1.42 (1.36, 1.48)

#### Provegetarian dietary pattern

	Q1	Q2	Q3	Q4
N (frequency)	4672	5450	3957	4350
Cases/person-years	108/47626	129/55222	92/39808	140/42802
Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	0.34 (0.32, 0.37)	0.58 (0.55, 0.60)	0.88 (0.86, 0.91)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	-0.65 (-1.91, 0.61)	-1.30 (-2.56, -0.44)	-1.95 (-3.21 -0.69)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	-0.94 (-1.03, -0.86)	-1.50 (-1.60, -1.41)	-2.33 (-2.42, -2.24)
Price (€/day) <sup>a</sup>	0 (Ref)	-0.05 (-0.12, 0.01)	0.03 (-0.04, 0.10)	0.11 (0.04, 0.18)

Adjusted for age, sex and total energy intake. <sup>a</sup>p for trend<0.001. Qn= nth quartile of diet adherence.



Supplemental Table 4. Sensitivity analyses. Adjusted mean values and 95% Confidence Intervals of first and fourth quartile of adherence to Western, Mediterranean and Provegetarian dietary patterns.

	Western dietary pattern		Mediterranean dietary pattern		Provegetarian dietary pattern	
	Q1	Q4	Q1	Q4	Q1	Q4
<b>Overall</b>						
N (frequency)	4608	4607	6802	4431	4672	4350
Cases/person-years	151/43804	97/49219	149/70310	121/42512	108/47626	140/42802
Overall sustainable diet index (0-9 points) <sup>a</sup>	6.39 (6.37, 6.41)	5.75 (5.72, 5.77)	5.67 (5.66, 5.69)	6.64 (6.62, 6.66)	5.65 (5.64, 5.67)	6.53 (6.52, 6.55)
Rate advancement period (years) <sup>a</sup>	-1.11 (-2.78, 0.59)	1.33 (-0.34, 3.00)	2.45 (1.21, 3.70)	-3.10 (-4.35, -1.85)	0.93 (-0.33, 2.19)	-1.02 (-2.27, 0.24)
Environmental footprints index (4-16 points) <sup>a</sup>	9.20 (9.13, 9.27)	10.80 (10.72, 10.87)	10.32 (10.26, 10.38)	9.48 (9.41, 9.55)	11.15 (11.09, 11.21)	8.82 (8.75, 8.88)
Price (€/day) <sup>a</sup>	7.55 (7.51, 7.60)	5.87 (5.82, 5.93)	6.10 (6.06, 6.14)	7.52 (7.47, 7.56)	6.70 (6.66, 6.75)	6.82 (6.77, 6.86)
<b>Excluding participants who had the health composite end-point<sup>1</sup> in the first 2 years</b>						
N (frequency)	4560	4568	6732	4396	4625	4310
Cases/person-years	130/43734	85/49157	126/70200	106/42458	96/47553	123/42743
Overall sustainable diet index (0-9 points) <sup>a</sup>	6.28 (6.26, 6.30)	5.65 (5.63, 5.67)	5.52 (5.51, 5.54)	6.59 (6.57, 6.61)	5.55 (5.53, 5.57)	6.43 (6.41, 6.45)
Rate advancement period (years) <sup>a</sup>	-0.94 (-2.76, 0.88)	1.12 (-0.70, 2.94)	2.42 (1.06, 3.78)	-3.06 (-4.42, -1.70)	0.83 (0.54, 2.20)	-0.91 (-2.28, 0.47)
Environmental footprints index (4-16 points) <sup>a</sup>	9.20 (9.13, 9.28)	10.80 (10.72, 10.88)	10.32 (10.26, 10.38)	9.48 (9.41, 9.55)	11.15 (11.09, 11.21)	8.82 (8.75, 8.89)
Price (€/day) <sup>a</sup>	7.56 (7.51, 7.61)	5.88 (5.82, 5.93)	6.10 (6.06, 6.14)	7.52 (7.47, 7.57)	6.71 (6.66, 6.76)	6.82 (6.77, 6.87)
<b>Including people with prevalent CVD, cancer and T2DM<sup>b</sup></b>						
N (frequency)	4920	4919	7140	4844	5276	3963
Cases/person-years	189/46513	121/52449	177/73585	173/46176	115/53972	132/38890

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Overall sustainable diet index (0-9 points) <sup>a</sup>	6.77 (6.75, 6.79)	6.06 (6.04, 6.08)	6.13 (6.12, 6.15)	6.83 (6.81, 6.85)	6.08 (6.06, 6.09)	6.84 (6.82, 6.86)
Rate advancement period (years) <sup>a</sup>	-1.42 (-2.87, 0.03)	1.69 (0.24, 3.14)	1.86 (0.73, 2.99)	-2.30 (-3.43, -1.17)	0.71 (-0.41, 1.84)	-0.84 (-1.96, 0.29)
Environmental footprints index (4-16 points) <sup>a</sup>	9.21 (9.14, 9.28)	10.80 (10.72, 10.87)	10.33 (10.28, 10.39)	9.47 (9.41, 9.54)	11.02 (10.97, 11.08)	8.81 (8.75, 8.88)
Price (€/day) <sup>a</sup>	7.57 (7.53, 7.62)	5.89 (5.84, 5.94)	6.11 (6.07, 6.14)	7.52 (7.47, 7.56)	6.69 (6.65, 6.73)	6.82 (6.77, 6.87)
<b>Excluding participants with total energy intake beyond predefined limits (&lt;800 Kcal/day and &lt;500 Kcal/day or &gt;4000 Kcal/day and &gt;3500 Kcal/day in men and women, respectively )</b>						
N (frequency)	4241	4241	6469	3938	6117	4703
Cases/person-years	135/40016	87/45713	147/66733	113/37707	153/62305	182/46046
Overall sustainable diet index (0-9 points) <sup>a</sup>	5.57 (5.55, 5.59)	4.98 (4.96, 5.00)	4.71 (4.70, 4.73)	6.13 (6.11, 6.15)	4.92 (4.90, 4.94)	5.77 (5.75, 5.79)
Rate advancement period (years) <sup>a</sup>	-1.23 (-2.72, 0.26)	1.33 (1.59, 2.83)	2.44 (1.15, 3.72)	-3.22 (-4.5, -1.94)	0.53 (-0.76, 1.81)	-0.62 (-1.91, 0.66)
Environmental footprints index (4-16 points) <sup>a</sup>	9.62 (9.54, 9.69)	10.54 (10.62)	10.42 (10.37, 10.48)	9.32 (9.24, 9.39)	11.11 (11.05, 11.16)	8.71 (8.64, 8.77)
Price (€/day) <sup>a</sup>	7.34 (7.29, 7.38)	5.51 (5.47, 5.56)	5.80 (5.76, 5.83)	7.17 (7.13, 7.22)	6.33 (6.29, 6.37)	6.47 (6.43, 6.52)

Adjusted for age, sex and total energy intake. <sup>a</sup>p for trend<0.001. <sup>1</sup>Composite end-point: all-cause mortality, non-fatal cardiovascular disease, non-fatal breast cancer or type 2 diabetes. <sup>b</sup>Additionally adjusted for prevalent CVD, cancer and T2DM. CVD: Cardiovascular Disease. Qn= nth quartile of diet adherence. T2DM: Type 2 Diabetes Mellitus.

Supplemental Table 5. Sensitivity analyses. Relative differences and 95% Confidence Intervals of the fourth compared to the first quartile of adherence to Western, Mediterranean and Provegetarian dietary patterns.

	Western dietary pattern		Mediterranean dietary pattern		Provegetarian dietary pattern	
	Q1	Q4	Q1	Q4	Q1	Q4
<b>Overall</b>						
N (frequency)	4608	4607	6802	4431	4672	4350
Cases/person-years	151/43804	97/49219	149/70310	121/42512	108/47626	140/42802
Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	-0.65 (-0.68, -0.62)	0 (Ref)	0.97 (0.94, 0.99)	0 (Ref)	0.88 (0.86, 0.91)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	2.44 (0.77, 4.11)	0 (Ref)	-5.55 (-6.80, -4.30)	0 (Ref)	-1.95 (-3.21, -0.69)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	1.60 (1.48, 1.71)	0 (Ref)	-0.84 (-0.93, -0.75)	0 (Ref)	-2.33 (-2.42, -2.24)
Price (€/day) <sup>a</sup>	0 (Ref)	-1.68 (-1.76, -1.60)	0 (Ref)	1.42 (1.36, 1.48)	0 (Ref)	0.11 (0.04, 0.18)
<b>Excluding participants who have the health composite end-point<sup>1</sup> in the first 2 years</b>						
N (frequency)	4560	4568	6732	4396	4625	4310
Cases/person-years	130/43734	85/49157	126/70200	106/42458	96/47553	123/42743
Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	-0.63 (-0.66, -0.60)	0 (Ref)	1.06 (1.04, 1.09)	0 (Ref)	0.88 (0.85, 0.90)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	2.06 (0.24, 3.88)	0 (Ref)	-5.48 (-6.84, -4.12)	0 (Ref)	-1.73 (-3.10, -0.36)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	1.60 (1.48, 1.71)	0 (Ref)	-0.84 (-0.93, -0.75)	0 (Ref)	-2.33 (-2.42, -2.24)
Price (€/day) <sup>a</sup>	0 (Ref)	-1.69 (-1.77, -1.61)	0 (Ref)	1.42 (1.36, 1.48)	0 (Ref)	0.11 (0.04, 0.18)
<b>Including people with prevalent CVD, cancer and T2DM<sup>b</sup></b>						
N (frequency)	4920	4919	7140	4844	5276	3963
Cases/person-years	189/46513	121/52449	177/73585	173/46176	115/53972	132/38890

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Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	-0.71 (-0.74, -0.68)	0 (Ref)	0.70 (0.68, 0.72)	0 (Ref)	0.76 (0.74, 0.79)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	3.11 (1.66, 4.56)	0 (Ref)	-4.17 (-5.30, -3.04)	0 (Ref)	-1.55 (-2.67, -0.43)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	1.59 (1.47, 1.70)	0 (Ref)	-0.86 (-0.95, -0.77)	0 (Ref)	-2.21 (-2.30, -2.13)
Price (€/day) <sup>a</sup>	0 (Ref)	-1.68 (-1.76, -1.61)	0 (Ref)	1.41 (1.35, 1.47)	0 (Ref)	0.13 (0.06, 0.19)
<b>Excluding participants with total energy intake beyond predefined limits (&lt;800 Kcal/day and &lt;500 Kcal/day or &gt;4000 Kcal/day and &gt;3500 Kcal/day in men and women, respectively )</b>						
N (frequency)	4241	4241	6469	3938	6117	4703
Cases/person-years	135/40016	87/45713	147/66733	113/37707	153/62305	182/46046
Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	-0.59 (-0.63, -0.56)	0 (Ref)	1.41 (1.39, 1.44)	0 (Ref)	0.85 (0.82, 0.88)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	2.57 (1.08, 4.06)	0 (Ref)	-5.65 (-6.93, -4.37)	0 (Ref)	-1.15 (-2.43, 0.13)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	0.92 (0.81, 1.03)	0 (Ref)	-1.11 (-1.20, -1.01)	0 (Ref)	-2.40 (-2.49, -2.31)
Price (€/day) <sup>a</sup>	0 (Ref)	-1.82 (-1.89, -1.76)	0 (Ref)	1.37 (1.31, 1.43)	0 (Ref)	0.14 (0.08, 0.21)

Adjusted for age, sex and total energy intake. <sup>a</sup>p for trend<0.001. <sup>1</sup>Composite end-point: all-cause mortality, non-fatal cardiovascular disease, non-fatal breast cancer or type 2 diabetes. <sup>b</sup>Additionally adjusted for prevalent CVD, cancer and T2DM. CVD: Cardiovascular Disease. Q<sub>n</sub>= nth quartile of diet adherence. T2DM: Type 2 Diabetes Mellitus.

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**STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology\***  
**Checklist for cohort, case-control, and cross-sectional studies (combined)**

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any pre-specified hypotheses	4
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	4-5
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4-9
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5-9
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	9-10
		(b) Describe any methods used to examine subgroups and interactions	9-10
		(c) Explain how missing data were addressed	5
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed	

		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	9-10
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	Online Supplemental material
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	13
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	13
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	13
		(b) Report category boundaries when continuous variables were categorized	10-13
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	13
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	13-14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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4 **Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE  
5 checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at  
6 <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).  
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# BMJ Open

## Global sustainability (health, environment, and monetary costs) of three dietary patterns: results from a Spanish cohort (the SUN project).

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2018-021541.R1
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Complete List of Authors:	Fresán, Ujué; Loma Linda University, Center for Nutrition, Healthy Lifestyles, and Disease Prevention; Universidad de Navarra, Department of Preventive Medicine and Public Health Martínez-González, Miguel; Universidad de Navarra, Preventive Medicine and Public Health; Instituto de Salud Carlos III, CIBER Physiopathology of Obesity and Nutrition (CIBERObn) Sabate, J.; Loma Linda University Adventist Health Sciences Center, Center for Nutrition, Healthy Lifestyles, and Disease Prevention BesRastrollo, Maira; University of Navarra, Preventive Medicine and Public Health; Instituto de Salud Carlos III, CIBER Physiopathology of Obesity and Nutrition (CIBERObn)
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5 patterns: results from a Spanish cohort (the SUN project).  
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8 Author names: Ujué Fresán, Miguel A. Martínez-González, Joan Sabaté, and Maira Bes-  
9  
10 Rastrollo

11  
12  
13 Author affiliations:

14  
15 Center for Nutrition, Healthy Lifestyles, and Disease Prevention, Loma Linda University,  
16  
17 Loma Linda, CA 92350, USA (U.F. and J.S.)

18  
19 University of Navarra, Medical School, Department of Preventive Medicine and Public  
20  
21 Health, Irunlarrea 1, 31008 Pamplona, Spain (U.F., M.A.M-G and M.B-R)

22  
23 Navarra Institute for Health Research (IdisNa), 31008 Pamplona, Spain (M.A.M-G and M.B-  
24  
25 R)

26  
27  
28 CIBER Physiopathology of Obesity and Nutrition (CIBERObn), Carlos III Institute of Health,  
29  
30 28029 Madrid, Spain (M.A.M-G and M.B-R)

31  
32 Department of Nutrition, Harvard TH Chan School of Public Health, Boston, USA (M.A.M-  
33  
34 G)

35  
36  
37  
38  
39 Corresponding author:

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41  
42 Ujué Fresán; Loma Linda University, School of Public Health.

43  
44 24951 Circle Dr Nichol Hall 1304 Loma Linda, California 92350-1718 United States;

45  
46  
47 Tel. +1 909 558 1000 ext 15312; [ujuefresan@gmail.com](mailto:ujuefresan@gmail.com)  
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## Abstract

**Objective:** To evaluate the sustainability of the dietary patterns, according to their effects on health and environment, and their affordability.

**Design:** Prospective, ongoing cohort study of university graduates.

**Settings:** The Spanish SUN project (*Seguimiento Universidad de Navarra*, University of Navarra Follow-up), starting from 1999.

**Participants:** A total of 18429 participants.

**Methods:** Information from participants is collected every two years by validated questionnaires. We assessed three dietary patterns (the Mediterranean, the Western and the Provegetarian dietary patterns). The Rate Advancement Period (RAP) was used to assess the healthiness of each pattern (considering the composite end-point of all-cause mortality, cardiovascular disease, breast cancer or type 2 diabetes). We also assessed environmental footprints and monetary costs of each dietary pattern.

**Results:** After a median follow-up of 10.1 years, we identified 469 incident cases of the composite end-point. The Mediterranean dietary pattern exhibited the best RAP (3.10 years gained (95% confidence interval [CI] 4.35, 1.85) for the highest versus the lowest quartile), while the Western pattern was the unhealthiest pattern (1.33 years lost when comparing extreme quartiles). In a scale between 4 to 16 of harmful environmental effects (the lower, the more environmentally friendly) the Provegetarian pattern scored best (8.82 (95%CI 8.75, 8.88) when comparing extreme quartiles) whereas the Western pattern was the most detrimental pattern (10.80 (95%CI 10.72, 10.87)). Regarding monetary costs, the Western pattern was the most affordable pattern (5.87 €/day (95%CI 5.82, 5.93), for the upper quartile) while the Mediterranean pattern was the most expensive pattern (7.52 €/day (95%CI 7.47,

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3 7.56)). The Mediterranean dietary pattern was the most overall sustainable option, closely  
4 followed by the Provegetarian pattern. The least overall sustainable pattern was the Western  
5 dietary pattern.  
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10 **Conclusion:** Following plant-based diets, like the Mediterranean or Provegetarian dietary  
11 patterns, could be a good option in order to achieve an overall sustainable diet.  
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#### 21 Strengths and limitations of this study

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- 24 • The novelty of our study was in the assessment simultaneously of 3 dimensions of an  
25 overall sustainable diet (health, environment and monetary cost).  
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- 28 • We use a wide range score for food consumption of a large sample size, through a  
29 validated questionnaire.  
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- 33 • Information about food consumption is self-reported, therefore susceptible to  
34 information bias.  
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- 37 • The generalizability of our results could be challenged because the sample, all  
38 university graduates, is not representative of the general population.  
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## INTRODUCTION

Traditionally, nutritionists have been interested in the relationship between food and health outcomes. This association should be preferentially conducted according to complete dietary patterns, not solely by assessing specific food items or their nutrient compositions. [1] In general, plant-based diets such as the Mediterranean (MeD) or any other pattern which emphasizes the consumption of plant-origin food commodities against foods produced from animals, are reportedly healthy options. [2-4] On the other hand, nutrient-poor energy dense diets, such as the Western dietary pattern (WDP), rich in highly-processed and animal-based foods, have a detrimental health impact. [5]

In 2010, the Food and Agriculture Organization of the United Nations (FAO) indicated that other aspects of the diet should be taken into account, such as their environmental footprints and affordability, among others.[6] The association between dietary patterns and ecosystems was initially studied in the 80's.[7] Environmental footprints (the harmful effects of any activity on the ecosystems) are caused by the use of resources (such as land, water and energy) or environmental degradation (such as greenhouse gas (GHG) emissions, among others). The impact on the environment differs between food items, [8] with plant foods being the most eco-friendly and animal products the most adverse for the environment. [9-11] It seems plausible that those food patterns mainly based on plant-derived products are more environmentally friendly than others like the WDP, which includes larger amounts of animal commodities.[12-14]

Data on monetary costs of food products in relation to their consumption were assessed for the first time in the late 1990s.[15] Since then, several studies on economic aspects of the dietary patterns have been reported. Mainly, energy-dense elements provide calories at lower monetary costs than other foods like fish, vegetables and fruits - which are healthier. [16]

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3 Taste and retail prices are important factors for food choices. [16, 17] However, following a  
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5 cheaper diet could result in health problems for the consumer due to the decrease in  
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7 nutritional quality. This may finally lead to an increment in the global societal cost. [16, 18]  
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10 Previous investigations have assessed health, environment, and monetary cost, separately.

11 However, few studies have focused on these different dietary aspects at the same time. [19]

12 For this reason, we have assessed the association between the adherence to three different

13 dietary patterns (WDP, MeD and provegetarian dietary pattern –pVD-) and their

14 repercussions on the three aspects separately and all together.  
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## 21 **SUBJECTS AND METHODS**

### 22 **Study population**

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25 The SUN project (*Seguimiento Universidad de Navarra*, University of Navarra Follow-up) is

26 an ongoing cohort composed of Spanish university graduates.[20] Starting in 1999,

27 information from participants is collected every two years by questionnaires. Voluntary

28 completion of the baseline questionnaire implied informed consent, as participants received

29 detailed information about the whole study. The protocol was approved by the Research

30 Ethics Committee of the University of Navarra. The SUN cohort is registered at

31 clinicaltrials.gov as the number NCT02669602.  
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43 Up to March 2014, 22320 participants were recruited (Supplemental Figure 1). Among them,

44 we excluded 2031 who did not answer any follow-up questionnaires (retention in the cohort:

45 90.90%), 404 with total energy intake beyond predefined limits (under percentile 1 or over

46 percentile 99), 1286 with chronic disease as cardiovascular disease (CVD), cancer or type 2

47 diabetes (T2DM), and 170 who failed to answer 70 or more items of the food frequency

48 questionnaire (FFQ), leaving a total of 18429 participants.  
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## Dietary assessment

Usual diet was recorded using a validated semi-quantitative FFQ completed at baseline with 136 food items.[21-23] We recoded missing FFQ values as no consumption. Daily food intake was estimated by multiplying the frequency of consumption for each item and the typical portion size specified in the FFQ. We used consumption data to test the adherence of our population to 3 dietary patterns.

The pVD captures a preference for plant origin foods instead of animal ones. To assess it, we followed a previously described method.[4, 24] Concisely, we adjusted for total energy intake, using the residual method separately for men and women. We also adjusted for the baseline consumption (g/day) of 12 food groups - 7 from plant origin (vegetables (including roasted potatoes and French fries); fruits (including fruit in syrup or juice, and dried fruits) and fruit juices; nuts; legumes; cereals (whole and refined); plant origin oils; and bakery products) and 5 from animals (dairy products; eggs; meat and meat products; fish and seafood; and animal fats). The residuals (energy-adjusted estimates) were ranked according to quintiles. Quintile values of plant foods and reverse quintile values for animal were summed up in order to evaluate the adherence. Final scores may range from 12 to 60 points (lowest and highest adherence, respectively). Lastly, we categorized the adherence to this dietary pattern into quartiles (Q).

The index proposed by Trichopoulou and colleagues [25] was used to measure the adherence to the MeD. A score of 0 or 1 was given to each of these nine components of this index (vegetables, legumes, fruits and nuts, cereals, fish, meat and meat products, fatty dairy products, alcohol and fat intake (as the ratio of monounsaturated lipid to saturated lipid intake)), using the sex-specific median as the cut-off value. Those who consumed below the median of presumed beneficial components (vegetables, legumes, fruits and nuts, cereals, fish and fat ratio) were assigned a value of 0, and participants whose consumption was at or above

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3 the median were assigned a value of 1. The other way around, consumption below the  
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5 median was assigned 1 point assessing a priori detrimental items (meat and meat products,  
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7 and fatty dairy products) and the consumption at or above the median was valued as 0.  
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9 Consumption of ethanol between 10 to 50 g/day or 5 to 25g/day, for men and women,  
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11 respectively, was given one point. The total index score ranged from 0 to 9 points (minimal to  
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13 maximal adherence to MeD). Finally, we roughly divided the adherence to this diet into  
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15 quartiles.  
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18 We used Principal Component Analysis in order to establish a WDP in our cohort, because  
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20 there is no specific a priori definition of the WDP. Food products were grouped into 30  
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22 categories, as described by Lopez et al (2009).[26] We excluded those food groups whose  
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24 measure of sampling adequacy was lower than 0.65. Food groups that loaded >0.30 were  
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26 considered to be making a contribution to the factor. The factor score for the diet was  
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28 constructed by summing observed consumptions of the component food items weighted by  
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30 their factor loadings. Thus, each individual received a factor score for each identified  
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32 pattern.[27] The major dietary pattern factor identified was labelled as the WDP, which  
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34 included fast food, fatty dairy products, red and processed meat, potatoes, industrial bakery,  
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36 sauces, precooked foods and sugar-sweetened soft drinks (Supplemental Table 1). Participants  
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38 were also categorized into quartiles according to their adherence to the WDP.  
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#### 41 42 **Assessment of Other Variables**

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45 The baseline questionnaire also included sociodemographic, lifestyle and medical history  
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47 questions. Self-reported data such as physical activity (total Metabolic Equivalent of Tasks  
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49 (MET) per hour per week), body mass index (BMI) and hypertension - had been previously  
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51 validated.[28-30]  
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#### 53 54 55 **Outcomes assessment**



## Health

We estimated the impact of each of the 3 dietary patterns on health using the metric of the Rate Advancement Period (RAP).[31, 32] The RAP is a method which measures the time by which a rate of a specific outcome is advanced (positive values for detrimental exposures) or it is postponed (negative values for protective exposures) among exposed subjects compared with unexposed individuals, conditional on being free of that outcome at the baseline age. It is useful to analyze outcomes which uniformly rise with age, as it happens with total mortality and with the incidence of most chronic diseases. In the current analysis, the end-point was a composite including death, non-fatal CVD (myocardial infarction or stroke), non-fatal breast cancer or T2DM, whichever occurred first (detailed data of the rates (cases/frequency; percentage) assessing specifically each individual health outcome that compose the overall health effect was reported in supplemental Table 2). Time was measured in years from the entrance to the cohort. In order to minimize the bias produced by comparing dietary scores measured using different units, z scores were used. Each z score was calculated as the value of the diet minus the sample mean divided by its standard deviation. Cox regression models adjusted for sex, body mass index (BMI) (including a quadratic term for BMI), physical activity, smoking, time spent in sedentary activities, prevalent hypertension, prevalent hypercholesterolemia and total energy intake. These Cox models were used to estimate the RAP for each quartile of adherence to the three dietary patterns, by dividing the regression coefficient of the z score by the regression coefficient of age; the 95% confidence intervals (95%CI) for the RAP were calculated by using the variance and covariance estimates from the regression coefficients.[31]

## Environmental footprints

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3 Environmental footprints index was assessed as previously described by Fresan et al.[33] In  
4 brief, the impact of the production of 1kg of each food product reported in the FFQ on  
5 resource use (land, water and energy) and GHG emission was assessed using secondary data.  
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7 The impact on the environment of each participant was estimated considering the amount of  
8 every item consumed per day, and the specific value of each of them. Total use of land, water  
9 and energy, and GHG emission were calculated as the sum of all items values, obtaining the  
10 impact on these 4 footprints according to the daily food consumption of each participant. We  
11 classified participants into quartiles of these total values, each of them ranking from 1 to 4  
12 (less to high resource consumption or GHG emission). A total environmental footprints index  
13 was created summing the quartile values of all the four footprints: land use, water use, energy  
14 use and GHG emission. Therefore, environmental footprints index ranked from 4 to 16 points  
15 (from low to high environmental repercussion).

#### 26 27 28 29 Monetary cost

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32 Monetary cost of food was derived from the Ministry of Industry, Tourism and Commerce of  
33 Spain.[34] Annual cost of each item was calculated as the monthly reported national average  
34 costs, and it was assessed according to the year in which that participant completed their  
35 baseline questionnaires in order to control for differences between calendar years in retail  
36 prices. Total daily monetary costs were calculated by multiplying the cost per kg (€/kg) of  
37 each food item by the reported daily quantity consumed through the FFQ.  
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#### 46 Overall sustainable diet index

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49 We designed an index which gathered the impact of the daily diet on all the analyzed aspects:  
50 health, environmental footprints and monetary costs. In order for all of these three aspects to  
51 contribute equally for the overall index, a score from 0 to 3 points was given for each of them.  
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55 We estimated the RAP, the environmental footprints index and the daily monetary cost of the  
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3 diet of each participant. Of these values, the less suitable value for health (a specific hazard is  
4 advanced more years), environment (more environmental footprints were produced) and  
5 economy (the highest daily monetary cost) was given 0 points. On the other hand, we  
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7 assigned 3 points for the healthiest daily diet (a specific hazard is postponed more years), the  
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9 one that produced less environmental footprints, and the cheapest one. Proportional score was  
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11 given for the rest of values. Summing these three values, the overall sustainable diet index  
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13 ranked from 0 to 9 points, with 0 being the less suitable diet and 9 the most appropriate diet.  
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### 18 **Statistical analyses**

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20 Linear Regression Models were used to assess the relationship between quartiles of adherence  
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22 to each dietary pattern and overall sustainable diet index, and each of the three components  
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24 separately (RAP, environmental footprints index and monetary costs). We estimated means  
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26 and their 95%CI using analyses of covariance for each quartile, adjusting for age, sex and  
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28 total energy intake. Moreover, we analyzed differences in mean values and their 95% CI for  
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30 each of the three upper quartiles of the respective dietary pattern using the lowest quartile as  
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32 the reference category. Linear trends across different quartiles were conducted by assigning  
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34 the medians to each quartile; this variable was treated as continuous.  
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39 We conducted sensitivity analyses refitting the models under different assumptions to assess  
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41 the robustness of our results: excluding participants who had any of the outcomes gathered in  
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43 the health composite end-point in the first 2 years of follow-up; including participants with  
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45 prevalent CVD, cancer or T2DM at baseline (in this case, the model was additionally  
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47 adjusted for prevalent CVD, cancer and T2DM at baseline); and excluding participants with  
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49 total energy intake beyond predefined limits (<800 Kcal/day and <500 Kcal/day or >4000  
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51 Kcal/day and >3500 Kcal/day in men and women, respectively).  
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54 We assessed interactions, through a likelihood ratio test, between the respective dietary  
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56 pattern and sex, BMI, age and physical activity (assessed as continuous variables).  
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All p-values presented are two-tailed;  $p < 0.05$  was considered statistically significant.

Analyses were performed using STATA/SE V.12.1 (StataCorp, College Station, Texas, USA).

### Patient and public involvement

Neither patients nor public were involved in the study.

### RESULTS

Our analysis included a total of 18429 participants (7042 men and 11387 women). The main baseline characteristics of participants according to adherence (extreme quartiles, Q1 and Q4) to each of the three dietary patterns are presented in table 1.

Participants with the highest adherence to the WDP (Q4) were more likely to be men, younger, single, current smokers with less advanced studies. They tended to intake more calories. On average, they consumed more animal products, bakery products, fast food and sugared sodas; but less fish, plant products and olive oil. The opposite results were obtained for those participants in the Q4 of the MeD, whose consumption of fish and plant origin food was the highest. Dairy products, eggs and meat were consumed less frequently for those who reported the highest pVD adherence. Intake of fats, specifically saturated fatty acids, were higher in the Q4 of the WDP. Fiber was highly consumed by participants of the Q4 of the pVD and MeD, and the Q4 participants of the MeD also reported higher consumption of alcohol.

Table 1. Distribution of baseline characteristics of participants according to quartiles of adherence to Western, Mediterranean and Provegetarian dietary patterns.

	Western dietary pattern		Mediterranean dietary pattern		Provegetarian dietary pattern	
	Q1	Q4	Q1	Q4	Q1	Q4
Frequency (n)	4608	4607	3487	1846	4672	4350

**Sociodemographic data**

Sex (men %)	29	50	39	41	39	40
Age (years)	40 (12)	33 (10)	33 (10)	42 (13)	34 (11)	40 (12)
Civil status (%)						
Single	39	58	56	34	51	41
Married	54	39	41	60	44	54
Others	7	3	3	6	4	5
Smoking status (%)						
Current smoker	21	28	27	25	30	23
Former smoker	31	18	16	34	20	28
Studies (%)						
Technical/non graduated	4	9	9	4	7	5
Graduated	76	74	74	77	75	74
Master/doctoral	20	17	17	19	18	21

**Food and Nutrition**

Total energy intake (Kcal/d)	2064 (639)	3184 (752)	2347 (719)	2724 (722)	2634 (786)	2539 (809)
Food items (servings/day) <sup>a</sup>						
Dairy products	3.6 (1.8)	2.9 (1.9)	3.6 (1.7)	2.6 (1.7)	3.9 (2.0)	2.5 (1.4)
Non-fat/low-fat dairy products	2.2 (1.7)	0.7 (1.1)	1.0 (1.3)	1.9 (1.6)	1.5 (1.7)	1.2 (1.2)
Fatty dairy products	1.4 (0.9)	2.2 (1.8)	2.6 (1.4)	0.8 (0.8)	2.4 (1.7)	1.3 (1.0)
Eggs	0.3 (0.2)	0.5 (0.4)	0.4 (0.3)	0.4 (0.3)	0.5 (0.4)	0.3 (0.2)
All types of meats	1.6 (0.6)	2.3 (1.1)	2.3 (0.9)	1.5 (0.7)	2.4 (1.0)	1.5 (0.7)
Red meat	0.4 (0.2)	0.7 (0.4)	0.6 (0.3)	0.4 (0.3)	0.7 (0.4)	0.4 (0.3)
White meat	0.3 (0.2)	0.3 (0.3)	0.3 (0.3)	0.3 (0.2)	0.4 (0.3)	0.3 (0.2)
Processed meat	0.8 (0.5)	1.4 (1.0)	1.3 (0.8)	0.8 (0.6)	1.4 (0.9)	0.8 (0.5)
Fish and seafood	0.9 (0.5)	0.6 (0.6)	0.5 (0.5)	1.0 (0.5)	0.8 (0.7)	0.7 (0.4)
Vegetables	3.5 (2.0)	2.2 (1.4)	1.9 (1.0)	3.9 (2.0)	2.2 (1.4)	3.5 (2.0)
Legumes	0.3 (0.2)	0.3 (0.3)	0.2 (0.2)	0.4 (0.2)	0.3 (0.2)	0.3 (0.2)
Fruits and nuts	4.1 (2.7)	1.7 (1.7)	1.7 (1.2)	4.2 (2.7)	1.9 (1.6)	3.8 (2.6)
Fresh fruit	3.7 (2.7)	1.5 (1.6)	1.5 (1.1)	3.8 (2.6)	1.8 (1.6)	3.4 (2.5)
Processed fruit	0.2 (0.3)	0.1 (0.2)	0.1 (0.2)	0.2 (0.4)	0.1 (0.2)	0.2 (0.4)
Nuts	0.2 (0.3)	0.1 (0.2)	0.1 (0.1)	0.3 (0.4)	0.1 (0.2)	0.3 (0.4)
Cereals	2.3 (1.3)	1.6 (1.4)	1.6 (1.0)	2.5 (1.3)	1.5 (1.2)	2.4 (1.3)
Oils and fats	2.3 (1.5)	1.7 (1.8)	1.6 (1.2)	2.5 (1.7)	1.6 (1.5)	2.4 (1.6)
Olive oil	2.0 (1.4)	1.1 (1.3)	1.0 (1.0)	2.2 (1.5)	1.2 (1.2)	2.0 (1.4)
Other oils	1.2 (0.5)	0.3 (0.8)	0.2 (0.6)	0.2 (0.7)	0.2 (0.6)	0.2 (0.7)
Margarine	0.1 (0.2)	0.1 (0.4)	0.1 (0.4)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)
Animal fats	0.1 (0.1)	0.2 (0.4)	0.2 (0.3)	0.1 (0.3)	0.2 (0.4)	0.1 (0.2)
Pastry products	1.0 (0.7)	1.3 (1.3)	1.4 (1.1)	0.8 (0.8)	1.0 (0.9)	1.2 (1.0)
Biscuits	0.4 (0.6)	0.2 (0.7)	0.4 (0.7)	0.2 (0.5)	0.3 (0.6)	0.4 (0.7)
Chocolate	0.3 (0.3)	0.4 (0.8)	0.4 (0.6)	0.2 (0.4)	0.3 (0.4)	0.4 (0.6)
Industrial bakery	0.2 (0.2)	0.4 (0.7)	0.4 (0.5)	0.1 (0.3)	0.3 (0.4)	0.3 (0.5)
Home-made bakery	0.1 (0.1)	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)
Cakes	0.04 (0.05)	0.06 (0.10)	0.06 (0.08)	0.04 (0.09)	0.05 (0.07)	0.04 (0.08)

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3	Fast food <sup>1</sup>	0.1 (0.1)	0.3 (0.3)	0.3 (0.2)	0.1 (0.1)	0.3 (0.2)	0.1 (0.1)
4	Beverages	7.8 (3.3)	7.1 (3)	6.8 (3.2)	8.2 (3.4)	7.4 (3.4)	7.5 (3.2)
5	Water	4.8 (2.7)	4.3 (2.6)	4.3 (2.6)	4.9 (2.7)	4.5 (2.7)	4.7 (2.6)
6	Red wine	0.3 (0.6)	0.2 (0.6)	0.2 (0.5)	0.5 (0.8)	0.2 (0.6)	0.3 (0.6)
7	Other alcoholic						
8	beverages	0.3 (0.5)	0.3 (0.6)	0.2 (0.5)	0.4 (0.5)	0.4 (0.6)	0.3 (0.5)
9	Sugared sodas	0.1 (0.2)	0.4 (0.7)	0.3 (0.6)	0.1 (0.3)	0.3 (0.6)	0.2 (0.3)
10	Regular coffee	1.2 (1.3)	1.2 (1.3)	1.1 (1.2)	1.3 (1.3)	1.3 (1.3)	1.1 (1.2)
11	Bottled juice	0.1 (0.3)	0.1 (0.4)	0.1 (0.4)	0.1 (0.4)	0.1 (0.3)	0.1 (0.4)
12							
13	Nutrient intake (% total energy						
14	intake/day)						
15	Fat	33 (7)	39 (5)	40 (6)	33 (6)	39 (6)	34 (6)
16	Saturated fatty acids	10 (3)	14 (3)	15 (3)	10 (2)	15 (3)	11 (3)
17	Monounsaturated fatty						
18	acids	15 (4)	16 (3)	16 (3)	15 (4)	16 (3)	15 (4)
19	Polyunsaturated fatty						
20	acids	5 (1)	6 (2)	5 (2)	5 (2)	5 (2)	5 (2)
21	Carbohydrates	46 (8)	42 (6)	41 (7)	47 (7)	40 (7)	47 (7)
22	Protein	19 (4)	17 (3)	18 (3)	18 (3)	19 (3)	16 (3)
23	Dietary fibre intake (g/day) <sup>a</sup>	37 (13)	23 (10)	21 (7)	40 (13)	23 (9)	37 (13)
24	Alcohol intake (g/day) <sup>a</sup>	6 (9)	7 (11)	5 (9)	10 (10)	7 (12)	6 (9)
25							
26	<b>Lifestyle data</b>						
27	Physical activity (METs-h/week)	29 (25)	27 (25)	23 (21)	33 (28)	26 (23)	29 (26)
28	Time watching TV (h/day)	1.5 (1.1)	1.6 (1.3)	1.6 (1.3)	1.6 (1.1)	1.7 (1.3)	1.5 (1.1)
29							

<sup>a</sup>Adjusted for energy intake through the residual method. <sup>1</sup>Fast food includes hamburger, pizza and sausages. Q1=first quartile. Q4= fourth quartile.

Figure 1 shows how the overall sustainable diet index, and the three elements that composed it (health as captured by the RAP, environmental footprints index and monetary costs) changed across successive quartiles of adherence to each of the three analyzed dietary patterns (specific values for means and confidence intervals are shown in Supplemental Table 3).

[insert Figure 1]

Comparing the dietary patterns of participants in the upper quartile of each dietary pattern, the most overall sustainable pattern was the MeD, followed closely by the pVD. Taking health repercussions into account, after a median follow-up of 10.1 years, and after observing 469 incident cases of the composite end-point, the healthiest dietary pattern was the MeD because

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2  
3 the hazard of developing the end-point was postponed for more than 3 years when comparing  
4 the upper versus the lowest quartile. Assessing the diet of subjects on the pVD and WDP, we  
5 noticed a retardation and an advancement of the end-point, respectively, although both lacked  
6 statistical significance. Regarding environmental footprints, the pVD seemed to be the most  
7 eco-friendliest option, followed by the MeD. On average participants in the upper quartile of  
8 the MeD spent the highest amount of economic resources, while the upper quartile of the  
9 WDP included the most relatively affordable foods.  
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18 Adjusted relative mean differences are shown in Figure 2, and specific values are presented in  
19 Supplemental table 4. In all analyses, there was a statistical linear trend across quartiles  
20 (p<0.001).  
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26 [insert Figure 2]  
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29 The main results were consistent in all our sensitivity analyses (Supplemental Table 5 and  
30 Supplemental Table 6). Only including those participants who reported a prevalent chronic  
31 disease, a higher adherence to the pVD presented a higher overall sustainable diet index than  
32 higher adherence to the MeD. However, differences between these two dietary patterns were  
33 not statistically significant. We did not observe any statistically significant interaction  
34 between the dietary patterns and sex, BMI, age or physical activity (data not shown).  
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## 45 **DISCUSSION**

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48 The current study showed the Mediterranean dietary pattern as the healthiest option, with  
49 relatively low environmental footprints. However, its monetary costs were the highest. The  
50 Provegetarian dietary pattern was the most eco-friendliest pattern, relatively healthy and  
51 affordable. The Western dietary pattern was the least recommended pattern according to  
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2 health criteria and ecosystems consequences, but it was the most affordable food pattern.

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4 Considering in conjunction health, environment and monetary costs, the MeD and the pVD  
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6 would be sustainable dietary patterns, while the WDP would not be a sustainable dietary  
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8 pattern.  
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12 Healthy diets are inversely associated with the risk of diseases like CVD, cancer, T2DM and  
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14 also all-cause mortality.[35] We observed that better conformity to the MeD was the  
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16 healthiest option, followed closely by the pVD. The high quality of the MeD and other pVD  
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18 has been reported previously.[3, 4] Their benefits have been attributed to the high  
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20 consumption of plant-origin foods and the low consumption of animal-based foods. [35] In  
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22 fact, the MeD could be considered as a special case of a pVD. The similarity of these two  
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24 patterns can be appreciated in the recommendations of high intakes of fruit, vegetables, beans,  
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26 cereals, nuts, and seeds. Olive oil as the main source of fat, moderate to high consumption of  
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28 fish and other seafood, moderate amounts of red wine with meals as the main source of  
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30 alcohol, and a low intake of meat and dairy products is what specifically defines MeD  
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32 compared to a general pVD. Indeed, the specific suggestion in the MeD of the consumption  
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34 of olive oil or fish, could be one of the reasons why this diet achieved more health benefits.[2,  
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36 36] We have not assessed a “pure” Vegetarian/Vegan diet because the proportion of  
37  
38 participants who followed these patterns was very low in our cohort. pVD is only a gentle and  
39  
40 moderate approach. On the other hand, our results related to the WDP and its detrimental  
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42 health repercussion are in agreement with previous publications.[37]  
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47 Previous research supports that a population shift to a more plant and less animal-rich diet,  
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49 like the pVD or the MeD, may be positive for the environment.[8-10, 12-14, 38] Conformity  
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51 to the MeD, and especially to the pVD, implicated a reduction on environmental footprints.  
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53 The higher impact of the MeD than the pVD could be due to fish consumption, because of the  
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55 great amount of energy used for fish production that for fruits, vegetables and other plant-  
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3 derived foods. It is necessary to reinforce fish consumption from sustainable sources, and in  
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5 the case of wild caught fish to prevent overfishing.  
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8 A direct linear relationship between nutritional adequacy and the monetary costs of a  
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10 dietary pattern has been suggested.[39-41] A recent meta-analysis reported an average  
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12 increment of 1.48\$/day if a healthy diet is followed.[40] In our cohort, those participants with  
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14 the highest adherence to the healthiest pattern, the MeD, spent a mean of 1.42€/day more in  
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16 their daily diet than those with the poorest adherence to the MeD. Again, fish consumption  
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18 could be the main reason for the monotonically increasing monetary costs in parallel with  
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20 better MeD adherence.[26, 41] However, it should be noticed that we only took into account  
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22 the amount of money that people spent to buy their foods. The relevance of this item as part of  
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24 an overall sustainability index could be discussed. It has been suggested that a full societal  
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26 cost of diet (i.e. health care expenditures and loss of productivity) should be addressed when  
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28 assessing sustainability evaluation. [42] Indeed, a recent publication concluded that moving  
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30 towards plant-based dietary patterns, and specifically the MeD, could save huge amounts of  
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32 money when the assessment is done from a full societal perspective taking into account all the  
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34 costs. [43] We reran our analyses assessing the overall sustainability of the three dietary  
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36 patterns without the cost item, and the main results supported the higher benefits associated  
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38 with following plant-based diets, in particular the MeD (data non-shown).  
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43 We observed only a modest magnitude for the differences between the extreme quartiles on  
44  
45 the overall sustainable diet index (Supplemental table 2). This limitation could be due to the  
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47 method used to construct the overall index according to quartiles of the three dimensions  
48  
49 evaluated. This might explain why some of the differences according to dietary patterns were  
50  
51 not well captured. In fact, although in the overall sustainability index, the health-related and  
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53 environmental items seem to have been considered appropriately, their contribution is only  
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55 qualitative, as their differences between the first and the fourth quartiles are small. This fact  
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3 may limit the interpretability of the impacts reported here. There would potentially be much  
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5 greater differences with the inclusion of the true global costs from a societal perspective of the  
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7 food patterns. Some other limitations of our study include self-reported information, and the  
8  
9 difficulties to generalize our results to other populations, given that the sample is not  
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11 representative of the general Spanish population (young cohort composed only by university  
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13 graduates). However, the advantages of using a socially homogenous and well-educated  
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15 cohort overcome this limitation because this approach removes part of the residual  
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17 confounding and ensures a higher quality of the self-reported information. We assumed that  
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19 foods were prepared and eaten at home, and this approximation may underestimate the effect  
20  
21 of the diet. The three dietary patterns were assessed by 3 different methods. Assessing the  
22  
23 adherence to the diets using different cut-offs could give different results. The relevance of  
24  
25 the RAP metric for health outcomes in a young people cohort could be questioned. It would  
26  
27 be interesting to assess in the future the impact on health using other criteria; for instance,  
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29 quality-adjusted life-years, which is another common measure used to value health gains. The  
30  
31 environmental footprints index does not contemplate other phases of the food chain apart  
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33 from production and processing. However, production is the most contributive aspect by  
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35 far.[44, 45]  
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40 Some of the strengths of the current study include the simultaneous assessment of the three  
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42 dimensions of an overall sustainable diet (health, environment and monetary costs). This  
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44 represents a novelty of our study. We used a wide range of scores for food consumption in a  
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46 large sample size through a validated questionnaire. We focused on GHG emission and  
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48 efficiency in using natural resources when assessing the environmental footprints, which is a  
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50 more holistic approach.  
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## 56 **CONCLUSION**

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3 Following plant-based diets, like the Mediterranean or another model of Provegetarian dietary  
4 pattern, could be a good option to achieve an overall sustainable diet, according to a  
5 concordant high score in three dimensions of an ideally healthy, environmental-friendly and  
6 affordable diet. The Mediterranean dietary pattern was the healthiest pattern and relatively  
7 environmentally sustainable. However, nowadays, it cannot be presented as an affordable  
8 model. Some monetary policies, such as subsidizing healthy Mediterranean foods, may  
9 contribute to increased adherence to a diet with recognized health benefit. This translates into  
10 huge savings from a global societal perspective in terms of making healthier foods more  
11 affordable for the general population.  
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7

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9  
10

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24 analysis and interpretation of data: U.F., M.-A.M.-G. and M.B.-R. Drafting of the manuscript:  
25 U.F. Critical revision of the manuscript for important intellectual content: J.S., M.-A.M.-G.  
26 and M.B.-R. Statistical analysis: U.F. Supervision: M.B.-R.  
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33 **Data sharing statement:** No additional data are available.  
34

35 **Ethics approval:** The protocol was approved by the Research Ethics Committee of the  
36 University of Navarra.  
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3 LEGENDS FOR FIGURES  
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6 Figure 1. Adjusted means and 95% Confidence Intervals of Overall sustainable diet index,  
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8 Rate advancement period, Environmental footprints index and Monetary cost, according to  
9  
10 quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence. Adjusted  
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12 for age, sex and total energy intake.  
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15 Red line, cross: adherence to the Western dietary pattern. Blue line, diamond: adherence to  
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17 the Mediterranean dietary pattern. Green line, square: adherence to the Provegetarian dietary  
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19 pattern.  
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22 Figure 2. Adjusted relative means differences and 95% Confidence Intervals of Overall  
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24 sustainable diet index, Rate advancement period, Environmental footprints index and  
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26 Monetary cost, according to quartiles of Western, Mediterranean and Provegetarian dietary  
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28 patterns adherence, taking as the reference category the first quartile. Adjusted for age, sex  
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30 and total energy intake.  
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34 Red line, cross: adherence to the Western dietary pattern. Blue line, diamond: adherence to  
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36 the Mediterranean dietary pattern. Green line, square: adherence to the Provegetarian dietary  
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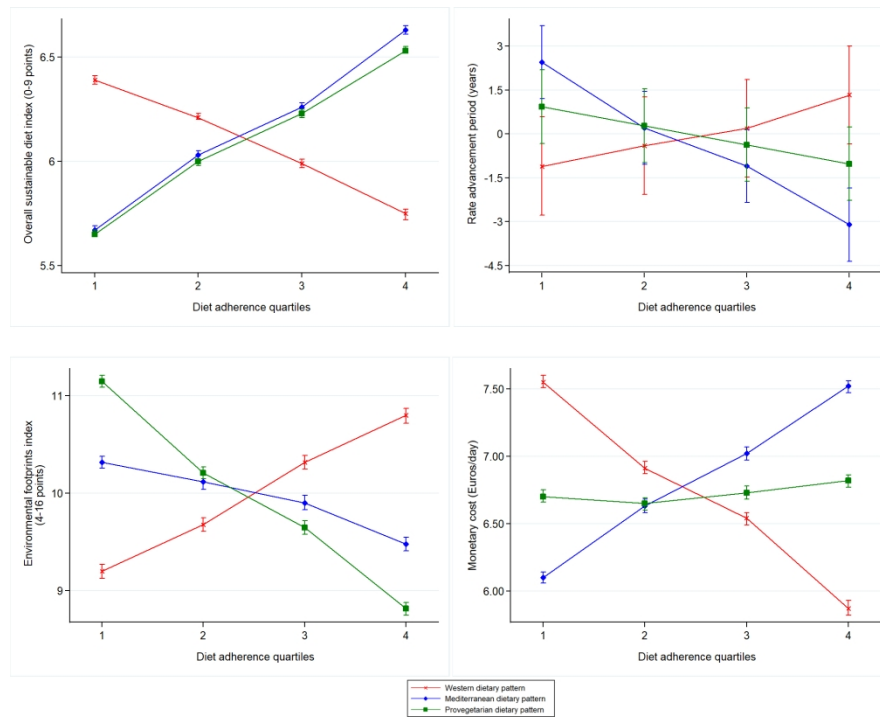


Figure 1. Adjusted means and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Monetary cost, according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence. Adjusted for age, sex and total energy intake. Red line, cross: adherence to the Western dietary pattern. Blue line, diamond: adherence to the Mediterranean dietary pattern. Green line, square: adherence to the Provegetarian dietary pattern.

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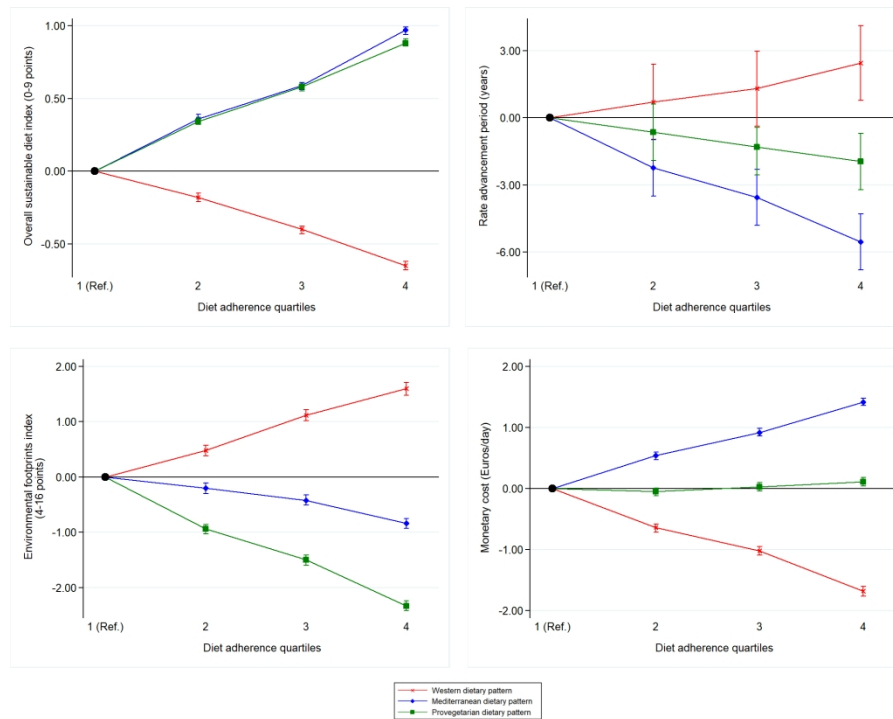
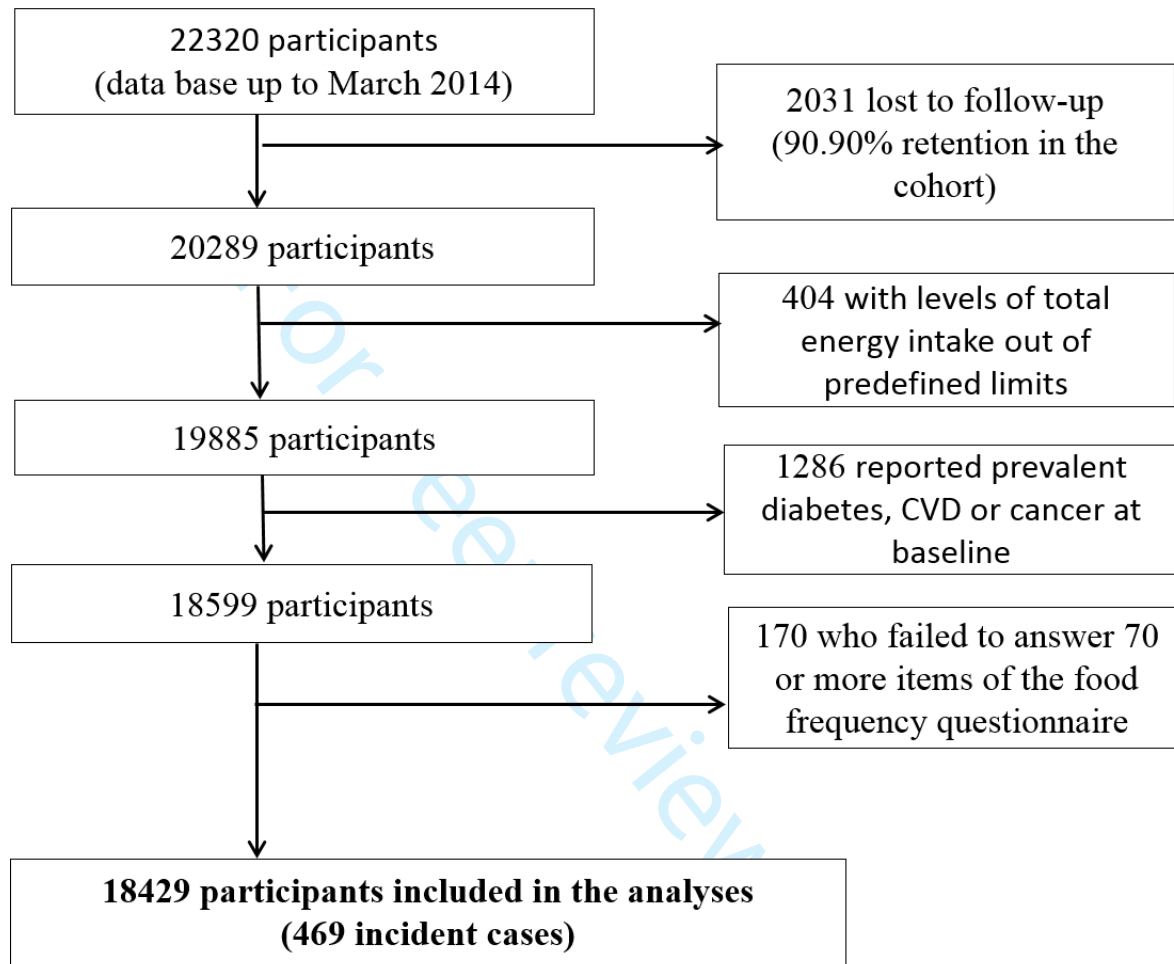


Figure 2. Adjusted relative means differences and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Monetary cost, according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence, taking as the reference category the first quartile. Adjusted for age, sex and total energy intake.

Red line, cross: adherence to the Western dietary pattern. Blue line, diamond: adherence to the Mediterranean dietary pattern. Green line, square: adherence to the Provegetarian dietary pattern.

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Supplemental Figure 1. Flow chart of the study participants in the Seguimiento Universidad de Navarra (SUN) Project 1999–2016.



CVD: cardiovascular disease

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3 Supplemental Table 1. Principal Component Analysis loadings >0.3 for Western dietary  
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Food products	Loading factors
Fast food	0.5172
Fatty dairy products	0.4871
Red meat	0.4841
Potatoes	0.4538
Industrial bakery	0.4535
Processed meat	0.4477
Sauces	0.4385
Precooked food	0.3954
Caloric soft drinks	0.3862

Supplemental Table 2. Rates (cases/frequency; percentage) assessing total mortality, non-fatal cardiovascular disease, non-fatal breast cancer and incidence of type 2 diabetes, according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence.

	<b>Western diet</b>			
	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
Cases/N (frequency) <sup>a</sup>	72/4608	49/4607	52/4607	44/4607
% <sup>a</sup>	1.56	1.06	1.13	0.96
Cases/N (frequency) <sup>b</sup>	41/4608	31/4607	24/4607	19/4607
% <sup>b</sup>	0.89	0.67	0.52	0.41
Cases/N (frequency) <sup>c</sup>	16/4608	11/4607	17/4607	19/4607
% <sup>c</sup>	0.35	0.24	0.37	0.41
Cases/N (frequency) <sup>d</sup>	40/4608	38/4607	22/4607	24/4607
% <sup>d</sup>	0.87	0.82	0.48	0.52
	<b>Mediterranean diet</b>			
	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
Cases/N (frequency) <sup>a</sup>	62/6802	56/3796	44/3400	55/4431
% <sup>a</sup>	0.91	1.48	1.29	1.24
Cases/N (frequency) <sup>b</sup>	47/6802	20/3796	25/3400	23/4431
% <sup>b</sup>	0.69	0.53	0.74	0.52
Cases/N (frequency) <sup>c</sup>	27/6802	9/3796	16/3400	11/4431
% <sup>c</sup>	0.40	0.24	0.47	0.25
Cases/N (frequency) <sup>d</sup>	35/6802	23/3796	25/3400	41/4431
% <sup>d</sup>	0.51	0.61	0.74	0.93
	<b>Provegetarian diet</b>			
	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
Cases/N (frequency) <sup>a</sup>	43/4672	64/5450	44/3957	66/4350
% <sup>a</sup>	0.92	1.17	1.11	1.52
Cases/N (frequency) <sup>b</sup>	29/4672	35/5450	27/3957	24/4350
% <sup>b</sup>	0.62	0.64	0.68	0.55
Cases/N (frequency) <sup>c</sup>	21/4672	12/5450	11/3957	19/4350
% <sup>c</sup>	0.45	0.22	0.28	0.44
Cases/N (frequency) <sup>d</sup>	26/4672	35/5450	23/3957	40/4350
% <sup>d</sup>	0.56	0.64	0.58	0.92

Adjusted for age, sex and total energy intake. Qn= nth quartile of diet adherence



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3     <sup>a</sup>The endpoint is total mortality  
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5     <sup>b</sup>The endpoint is non-fatal cardiovascular disease  
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9     <sup>a</sup>The endpoint is type 2 diabetes  
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Supplemental Table 3. Adjusted mean values and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Monetary cost according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence.

	<b>Western dietary pattern</b>			
	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
N (frequency)	4608	4607	4607	4607
Cases/person-years	151/43804	117/45688	104/46749	97/49219
Overall sustainable diet index (0-9 points) <sup>a</sup>	6.39 (6.37, 6.41)	6.21 (6.20, 6.23)	5.99 (5.97, 6.01)	5.75 (5.72, 5.77)
Rate advancement period (years) <sup>a</sup>	-1.11 (-2.78, 0.59)	-0.40 (-2.07, 1.27)	0.19 (-1.48, 1.86)	1.33 (-0.34, 3.00)
Environmental footprints index (4-16 points) <sup>a</sup>	9.20 (9.13, 9.27)	9.68 (9.61, 9.75)	10.32 (10.25, 10.39)	10.80 (10.72, 10.87)
Monetary cost (€/day) <sup>a</sup>	7.55 (7.51, 7.60)	6.91 (6.87, 6.96)	6.54 (6.49, 6.58)	5.87 (5.82, 5.93)
	<b>Mediterranean dietary pattern</b>			
	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
N (frequency)	6802	3796	3400	4431
Cases/person-years	149/70310	100/38942	99/33695	121/42512
Overall sustainable diet index (0-9 points) <sup>a</sup>	5.67 (5.66, 5.69)	6.03 (6.01, 6.05)	6.26 (6.24, 6.28)	6.64 (6.62, 6.66)

Rate advancement period (years) <sup>a</sup>	2.45 (1.21, 3.70)	0.21 (-1.04, 1.45)	-1.10 (-2.34, 0.15)	-3.10 (-4.35, -1.85)
Environmental footprints index (4-16 points) <sup>a</sup>	10.32 (10.26, 10.38)	10.12 (10.04, 10.19)	9.90 (9.83, 9.98)	9.48 (9.41, 9.55)
Monetary cost (€/day) <sup>a</sup>	6.10 (6.06, 6.14)	6.63 (6.58, 6.68)	7.02 (6.97, 7.07)	7.52 (7.47, 7.56)

### Provegetarian dietary pattern

	Q1	Q2	Q3	Q4
N (frequency)	4672	5450	3957	4350
Cases/person-years	108/47626	129/55222	92/39808	140/42802
Overall sustainable diet index (0-9 points) <sup>a</sup>	5.65 (5.64, 5.67)	6.00 (5.98, 6.01)	6.23 (6.21, 6.25)	6.53 (6.52, 6.55)
Rate advancement period (years) <sup>a</sup>	0.93 (-0.33, 2.19)	0.28 (-0.98, 1.54)	-0.37 (-1.62, 0.89)	-1.02 (-2.27, 0.24)
Environmental footprints index (4-16 points) <sup>a</sup>	11.15 (11.09, 11.21)	10.21 (10.15, 10.27)	9.65 (9.58, 9.72)	8.82 (8.75, 8.88)
Monetary cost (€/day) <sup>a</sup>	6.70 (6.66, 6.75)	6.65 (6.60, 6.69)	6.73 (6.68, 6.78)	6.82 (6.77, 6.86)

Adjusted for age, sex and total energy intake. <sup>a</sup>p for trend<0.001. Qn= nth quartile of diet adherence.

Supplemental Table 4. Adjusted relative differences of mean values and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Monetary cost according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence.

	<b>Western dietary pattern</b>			
	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
N (frequency)	4608	4607	4607	4607
Cases/person-years	151/43804	117/45688	104/46749	97/49219
Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	-0.18 (-0.21, -0.15)	-0.40 (-0.43, -0.38)	-0.65 (-0.68, -0.62)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	0.71 (-0.96, 2.38)	1.30 (-0.37, 2.97)	2.44 (0.77, 4.11)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	0.48 (0.38, 0.57)	1.12 (1.02, 1.22)	1.60 (1.48, 1.71)
Monetary cost (€/day) <sup>a</sup>	0 (Ref)	-0.64 (-0.71, -0.58)	-1.02 (-1.09, -0.95)	-1.68 (-1.76, -1.60)
	<b>Mediterranean dietary pattern</b>			
	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
N (frequency)	6802	3796	3400	4431
Cases/person-years	149/70310	100/38942	99/33695	121/42512

Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	0.36 (0.34, 0.39)	0.59 (0.56, 0.61)	0.97 (0.94, 0.99)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	-2.24 (-3.49, -0.99)	-3.55 (-4.80, -2.30)	-5.55 (-6.80, -4.30)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	-0.20 (-0.30, -0.11)	-0.42 (-0.51, -0.32)	-0.84 (-0.93, -0.75)
Monetary cost (€/day) <sup>a</sup>	0 (Ref)	0.54 (0.47, 0.60)	0.92 (0.86, 0.99)	1.42 (1.36, 1.48)
<b>Provegetarian dietary pattern</b>				
	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
N (frequency)	4672	5450	3957	4350
Cases/person-years	108/47626	129/55222	92/39808	140/42802
Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	0.34 (0.32, 0.37)	0.58 (0.55, 0.60)	0.88 (0.86, 0.91)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	-0.65 (-1.91, 0.61)	-1.30 (-2.56, -0.44)	-1.95 (-3.21 -0.69)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	-0.94 (-1.03, -0.86)	-1.50 (-1.60, -1.41)	-2.33 (-2.42, -2.24)
Monetary cost (€/day) <sup>a</sup>	0 (Ref)	-0.05 (-0.12, 0.01)	0.03 (-0.04, 0.10)	0.11 (0.04, 0.18)

Adjusted for age, sex and total energy intake. <sup>a</sup>p for trend<0.001. Qn= nth quartile of diet adherence.

Supplemental Table 5. Sensitivity analyses. Adjusted mean values and 95% Confidence Intervals of first and fourth quartile of adherence to Western, Mediterranean and Provegetarian dietary patterns.

	Western dietary pattern		Mediterranean dietary pattern		Provegetarian dietary pattern	
	Q1	Q4	Q1	Q4	Q1	Q4
<b>Overall</b>						
N (frequency)	4608	4607	6802	4431	4672	4350
Cases/person-years	151/43804	97/49219	149/70310	121/42512	108/47626	140/42802
Overall sustainable diet index (0-9 points) <sup>a</sup>	6.39 (6.37, 6.41)	5.75 (5.72, 5.77)	5.67 (5.66, 5.69)	6.64 (6.62, 6.66)	5.65 (5.64, 5.67)	6.53 (6.52, 6.55)
Rate advancement period (years) <sup>a</sup>	-1.11 (-2.78, 0.59)	1.33 (-0.34, 3.00)	2.45 (1.21, 3.70)	-3.10 (-4.35, -1.85)	0.93 (-0.33, 2.19)	-1.02 (-2.27, 0.24)
Environmental footprints index (4-16 points) <sup>a</sup>	9.20 (9.13, 9.27)	10.80 (10.72, 10.87)	10.32 (10.26, 10.38)	9.48 (9.41, 9.55)	11.15 (11.09, 11.21)	8.82 (8.75, 8.88)
Monetary cost (€/day) <sup>a</sup>	7.55 (7.51, 7.60)	5.87 (5.82, 5.93)	6.10 (6.06, 6.14)	7.52 (7.47, 7.56)	6.70 (6.66, 6.75)	6.82 (6.77, 6.86)
<b>Excluding participants who had the health composite end-point<sup>1</sup> in the first 2 years</b>						
N (frequency)	4560	4568	6732	4396	4625	4310
Cases/person-years	130/43734	85/49157	126/70200	106/42458	96/47553	123/42743
Overall sustainable diet index (0-9 points) <sup>a</sup>	6.28 (6.26, 6.30)	5.65 (5.63, 5.67)	5.52 (5.51, 5.54)	6.59 (6.57, 6.61)	5.55 (5.53, 5.57)	6.43 (6.41, 6.45)
Rate advancement period (years) <sup>a</sup>	-0.94 (-2.76, 0.88)	1.12 (-0.70, 2.94)	2.42 (1.06, 3.78)	-3.06 (-4.42, -1.70)	0.83 (0.54, 2.20)	-0.91 (-2.28, 0.47)
Environmental footprints index (4-16 points) <sup>a</sup>	9.20 (9.13, 9.28)	10.80 (10.72, 10.88)	10.32 (10.26, 10.38)	9.48 (9.41, 9.55)	11.15 (11.09, 11.21)	8.82 (8.75, 8.89)
Monetary cost (€/day) <sup>a</sup>	7.56 (7.51, 7.61)	5.88 (5.82, 5.93)	6.10 (6.06, 6.14)	7.52 (7.47, 7.57)	6.71 (6.66, 6.76)	6.82 (6.77, 6.87)
<b>Including people with prevalent CVD, cancer and T2DM<sup>b</sup></b>						
N (frequency)	4920	4919	7140	4844	5276	3963
Cases/person-years	189/46513	121/52449	177/73585	173/46176	115/53972	132/38890

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Overall sustainable diet index (0-9 points) <sup>a</sup>	6.77 (6.75, 6.79)	6.06 (6.04, 6.08)	6.13 (6.12, 6.15)	6.83 (6.81, 6.85)	6.08 (6.06, 6.09)	6.84 (6.82, 6.86)
Rate advancement period (years) <sup>a</sup>	-1.42 (-2.87, 0.03)	1.69 (0.24, 3.14)	1.86 (0.73, 2.99)	-2.30 (-3.43, -1.17)	0.71 (-0.41, 1.84)	-0.84 (-1.96, 0.29)
Environmental footprints index (4-16 points) <sup>a</sup>	9.21 (9.14, 9.28)	10.80 (10.72, 10.87)	10.33 (10.28, 10.39)	9.47 (9.41, 9.54)	11.02 (10.97, 11.08)	8.81 (8.75, 8.88)
Monetary cost (€/day) <sup>a</sup>	7.57 (7.53, 7.62)	5.89 (5.84, 5.94)	6.11 (6.07, 6.14)	7.52 (7.47, 7.56)	6.69 (6.65, 6.73)	6.82 (6.77, 6.87)
<b>Excluding participants with total energy intake beyond predefined limits (&lt;800 Kcal/day and &lt;500 Kcal/day or &gt;4000 Kcal/day and &gt;3500 Kcal/day in men and women, respectively )</b>						
N (frequency)	4241	4241	6469	3938	6117	4703
Cases/person-years	135/40016	87/45713	147/66733	113/37707	153/62305	182/46046
Overall sustainable diet index (0-9 points) <sup>a</sup>	5.57 (5.55, 5.59)	4.98 (4.96, 5.00)	4.71 (4.70, 4.73)	6.13 (6.11, 6.15)	4.92 (4.90, 4.94)	5.77 (5.75, 5.79)
Rate advancement period (years) <sup>a</sup>	-1.23 (-2.72, 0.26)	1.33 (1.59, 2.83)	2.44 (1.15, 3.72)	-3.22 (-4.5, -1.94)	0.53 (-0.76, 1.81)	-0.62 (-1.91, 0.66)
Environmental footprints index (4-16 points) <sup>a</sup>	9.62 (9.54, 9.69)	10.54 (10.62)	10.42 (10.37, 10.48)	9.32 (9.24, 9.39)	11.11 (11.05, 11.16)	8.71 (8.64, 8.77)
Monetary cost (€/day) <sup>a</sup>	7.34 (7.29, 7.38)	5.51 (5.47, 5.56)	5.80 (5.76, 5.83)	7.17 (7.13, 7.22)	6.33 (6.29, 6.37)	6.47 (6.43, 6.52)

Adjusted for age, sex and total energy intake. <sup>a</sup>p for trend<0.001. <sup>1</sup>Composite end-point: all-cause mortality, non-fatal cardiovascular disease, non-fatal breast cancer or type 2 diabetes. <sup>b</sup>Additionally adjusted for prevalent CVD, cancer and T2DM. CVD: Cardiovascular Disease. Qn= nth quartile of diet adherence. T2DM: Type 2 Diabetes Mellitus.

Supplemental Table 6. Sensitivity analyses. Relative differences and 95% Confidence Intervals of the fourth compared to the first quartile of adherence to Western, Mediterranean and Provegetarian dietary patterns.

	Western dietary pattern		Mediterranean dietary pattern		Provegetarian dietary pattern	
	Q1	Q4	Q1	Q4	Q1	Q4
<b>Overall</b>						
N (frequency)	4608	4607	6802	4431	4672	4350
Cases/person-years	151/43804	97/49219	149/70310	121/42512	108/47626	140/42802
Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	-0.65 (-0.68, -0.62)	0 (Ref)	0.97 (0.94, 0.99)	0 (Ref)	0.88 (0.86, 0.91)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	2.44 (0.77, 4.11)	0 (Ref)	-5.55 (-6.80, -4.30)	0 (Ref)	-1.95 (-3.21, -0.69)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	1.60 (1.48, 1.71)	0 (Ref)	-0.84 (-0.93, -0.75)	0 (Ref)	-2.33 (-2.42, -2.24)
Monetary cost (€/day) <sup>a</sup>	0 (Ref)	-1.68 (-1.76, -1.60)	0 (Ref)	1.42 (1.36, 1.48)	0 (Ref)	0.11 (0.04, 0.18)
<b>Excluding participants who have the health composite end-point<sup>1</sup> in the first 2 years</b>						
N (frequency)	4560	4568	6732	4396	4625	4310
Cases/person-years	130/43734	85/49157	126/70200	106/42458	96/47553	123/42743
Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	-0.63 (-0.66, -0.60)	0 (Ref)	1.06 (1.04, 1.09)	0 (Ref)	0.88 (0.85, 0.90)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	2.06 (0.24, 3.88)	0 (Ref)	-5.48 (-6.84, -4.12)	0 (Ref)	-1.73 (-3.10, -0.36)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	1.60 (1.48, 1.71)	0 (Ref)	-0.84 (-0.93, -0.75)	0 (Ref)	-2.33 (-2.42, -2.24)
Monetary cost (€/day) <sup>a</sup>	0 (Ref)	-1.69 (-1.77, -1.61)	0 (Ref)	1.42 (1.36, 1.48)	0 (Ref)	0.11 (0.04, 0.18)
<b>Including people with prevalent CVD, cancer and T2DM<sup>b</sup></b>						
N (frequency)	4920	4919	7140	4844	5276	3963
Cases/person-years	189/46513	121/52449	177/73585	173/46176	115/53972	132/38890



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Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	-0.71 (-0.74, -0.68)	0 (Ref)	0.70 (0.68, 0.72)	0 (Ref)	0.76 (0.74, 0.79)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	3.11 (1.66, 4.56)	0 (Ref)	-4.17 (-5.30, -3.04)	0 (Ref)	-1.55 (-2.67, -0.43)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	1.59 (1.47, 1.70)	0 (Ref)	-0.86 (-0.95, -0.77)	0 (Ref)	-2.21 (-2.30, -2.13)
Monetary cost (€/day) <sup>a</sup>	0 (Ref)	-1.68 (-1.76, -1.61)	0 (Ref)	1.41 (1.35, 1.47)	0 (Ref)	0.13 (0.06, 0.19)
<b>Excluding participants with total energy intake beyond predefined limits (&lt;800 Kcal/day and &lt;500 Kcal/day or &gt;4000 Kcal/day and &gt;3500 Kcal/day in men and women, respectively )</b>						
N (frequency)	4241	4241	6469	3938	6117	4703
Cases/person-years	135/40016	87/45713	147/66733	113/37707	153/62305	182/46046
Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	-0.59 (-0.63, -0.56)	0 (Ref)	1.41 (1.39, 1.44)	0 (Ref)	0.85 (0.82, 0.88)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	2.57 (1.08, 4.06)	0 (Ref)	-5.65 (-6.93, -4.37)	0 (Ref)	-1.15 (-2.43, 0.13)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	0.92 (0.81, 1.03)	0 (Ref)	-1.11 (-1.20, -1.01)	0 (Ref)	-2.40 (-2.49, -2.31)
Monetary cost (€/day) <sup>a</sup>	0 (Ref)	-1.82 (-1.89, -1.76)	0 (Ref)	1.37 (1.31, 1.43)	0 (Ref)	0.14 (0.08, 0.21)

Adjusted for age, sex and total energy intake. <sup>a</sup>p for trend<0.001. <sup>1</sup>Composite end-point: all-cause mortality, non-fatal cardiovascular disease, non-fatal breast cancer or type 2 diabetes. <sup>b</sup>Additionally adjusted for prevalent CVD, cancer and T2DM. CVD: Cardiovascular Disease. Q<sub>n</sub>= nth quartile of diet adherence. T2DM: Type 2 Diabetes Mellitus.

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**STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology\***  
**Checklist for cohort, case-control, and cross-sectional studies (combined)**

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any pre-specified hypotheses	5
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	5
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-10
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-10
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-10
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	10
		(b) Describe any methods used to examine subgroups and interactions	10
		(c) Explain how missing data were addressed	6
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed	

		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	10
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	Online Supplemental material
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	13
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	13
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	13-14
		(b) Report category boundaries when continuous variables were categorized	11-14
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	14
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	14-15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16-17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	17
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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4 **Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE  
5 checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at  
6 <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).  
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# BMJ Open

## Global sustainability (health, environment, and monetary costs) of three dietary patterns: results from a Spanish cohort (the SUN project).

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<b>Primary Subject Heading</b>:	Epidemiology
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3 Title: Global sustainability (health, environment, and monetary costs) of three dietary  
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5 patterns: results from a Spanish cohort (the SUN project).  
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8 Author names: Ujué Fresán, Miguel A. Martínez-González, Joan Sabaté, and Maira Bes-  
9  
10 Rastrollo  
11  
12

13  
14 Author affiliations:  
15

16 Center for Nutrition, Healthy Lifestyles, and Disease Prevention, Loma Linda University,  
17  
18 Loma Linda, CA 92350, USA (U.F. and J.S.)  
19

20  
21 University of Navarra, Medical School, Department of Preventive Medicine and Public  
22  
23 Health, Irunlarrea 1, 31008 Pamplona, Spain (U.F., M.A.M-G and M.B-R)  
24

25  
26 Navarra Institute for Health Research (IdisNa), 31008 Pamplona, Spain (M.A.M-G and M.B-  
27  
28 R)  
29

30  
31 CIBER Physiopathology of Obesity and Nutrition (CIBERObn), Carlos III Institute of Health,  
32  
33 28029 Madrid, Spain (M.A.M-G and M.B-R)  
34

35  
36 Department of Nutrition, Harvard TH Chan School of Public Health, Boston, USA (M.A.M-  
37  
38 G)  
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42 Corresponding author:  
43

44  
45 Ujué Fresán; Loma Linda University, School of Public Health.  
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47  
48 24951 Circle Dr Nichol Hall 1304 Loma Linda, California 92350-1718 United States;  
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51 Tel. +1 909 558 1000 ext 15312; [ujuefresan@gmail.com](mailto:ujuefresan@gmail.com)  
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## Abstract

**Objective:** To evaluate the sustainability of the dietary patterns, according to their effects on health and environment, and their affordability.

**Design:** Prospective, ongoing cohort study of university graduates.

**Settings:** The Spanish SUN project (*Seguimiento Universidad de Navarra*, University of Navarra Follow-up), starting from 1999.

**Participants:** A total of 18429 participants.

**Methods:** Information from participants is collected every two years by validated questionnaires. We assessed three dietary patterns (the Mediterranean, the Western and the Provegetarian dietary patterns). The Rate Advancement Period (RAP) was used to assess the healthiness of each pattern (considering the composite end-point of all-cause mortality, cardiovascular disease, breast cancer or type 2 diabetes). We also assessed environmental footprints and monetary costs of each dietary pattern.

**Results:** After a median follow-up of 10.1 years, we identified 469 incident cases of the composite end-point. The Mediterranean dietary pattern exhibited the best RAP (3.10 years gained (95% confidence interval [CI] 4.35, 1.85) for the highest versus the lowest quartile), while the Western pattern was the unhealthiest pattern (1.33 years lost when comparing extreme quartiles). In a scale between 4 to 16 of harmful environmental effects (the lower, the more environmentally friendly) the Provegetarian pattern scored best (8.82 (95%CI 8.75, 8.88) when comparing extreme quartiles) whereas the Western pattern was the most detrimental pattern (10.80 (95%CI 10.72, 10.87)). Regarding monetary costs, the Western pattern was the most affordable pattern (5.87 €/day (95%CI 5.82, 5.93), for the upper quartile) while the Mediterranean pattern was the most expensive pattern (7.52 €/day (95%CI 7.47,



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3 7.56)). The Mediterranean dietary pattern was the most overall sustainable option, closely  
4 followed by the Provegetarian pattern. The least overall sustainable pattern was the Western  
5 dietary pattern.  
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10 **Conclusion:** Following plant-based diets, like the Mediterranean or Provegetarian dietary  
11 patterns, could be a good option in order to achieve an overall sustainable diet.  
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### 23 Strengths and limitations of this study

- 24 • The novelty of our study was in the assessment simultaneously of 3 dimensions of an  
25 overall sustainable diet (health, environment and monetary cost).  
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- 28 • We use a wide range score for food consumption of a large sample size, through a  
29 validated questionnaire.  
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- 32 • Information about food consumption is self-reported, therefore susceptible to  
33 information bias.  
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- 36 • The generalizability of our results could be challenged because the sample, all  
37 university graduates, is not representative of the general population.  
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## INTRODUCTION

Traditionally, nutritionists have been interested in the relationship between food and health outcomes. This association should be preferentially conducted according to complete dietary patterns, not solely by assessing specific food items or their nutrient compositions. [1] In general, plant-based diets such as the Mediterranean (MeD) or any other pattern which emphasizes the consumption of plant-origin food commodities against foods produced from animals, are reportedly healthy options. [2-4] On the other hand, nutrient-poor energy dense diets, such as the Western dietary pattern (WDP), rich in highly-processed and animal-based foods, have a detrimental health impact. [5]

In 2010, the Food and Agriculture Organization of the United Nations (FAO) indicated that other aspects of the diet should be taken into account, such as their environmental footprints and affordability, among others.[6] The association between dietary patterns and ecosystems was initially studied in the 80's.[7] Environmental footprints (the harmful effects of any activity on the ecosystems) are caused by the use of resources (such as land, water and energy) or environmental degradation (such as greenhouse gas (GHG) emissions, among others). The impact on the environment differs between food items, [8] with plant foods being the most eco-friendly and animal products the most adverse for the environment. [9-11] It seems plausible that those food patterns mainly based on plant-derived products are more environmentally friendly than others like the WDP, which includes larger amounts of animal commodities.[12-14]

Data on monetary costs of food products in relation to their consumption were assessed for the first time in the late 1990s.[15] Since then, several studies on economic aspects of the dietary patterns have been reported. Mainly, energy-dense elements provide calories at lower monetary costs than other foods like fish, vegetables and fruits - which are healthier. [16]

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3 Taste and retail prices are important factors for food choices. [16, 17] However, following a  
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5 cheaper diet could result in health problems for the consumer due to the decrease in  
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7 nutritional quality. This may finally lead to an increment in the global societal cost. [16, 18]  
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10 Previous investigations have assessed health, environment, and monetary cost, separately.  
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12 However, few studies have focused on these different dietary aspects at the same time. [19,  
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14 20] For this reason, we have assessed the association between the adherence to three different  
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16 dietary patterns (WDP, MeD and provegetarian dietary pattern –pVD-) and their  
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18 repercussions on the three aspects separately and all together.  
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## 23 **SUBJECTS AND METHODS**

### 24 **Study population**

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26 The SUN project (*Seguimiento Universidad de Navarra*, University of Navarra Follow-up) is  
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28 an ongoing cohort composed of Spanish university graduates.[21] Starting in 1999,  
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30 information from participants is collected every two years by questionnaires. Voluntary  
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32 completion of the baseline questionnaire implied informed consent, as participants received  
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34 detailed information about the whole study. The protocol was approved by the Research  
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36 Ethics Committee of the University of Navarra. The SUN cohort is registered at  
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38 clinicaltrials.gov as the number NCT02669602.  
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46 Up to March 2014, 22320 participants were recruited (Supplemental Figure 1). Among them,  
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48 we excluded 2031 who did not answer any follow-up questionnaires (retention in the cohort:  
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50 90.90%), 404 with total energy intake beyond predefined limits (under percentile 1 or over  
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52 percentile 99), 1286 with chronic disease as cardiovascular disease (CVD), cancer or type 2  
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54 diabetes (T2DM), and 170 who failed to answer 70 or more items of the food frequency  
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56 questionnaire (FFQ), leaving a total of 18429 participants.  
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## Dietary assessment

Usual diet was recorded using a validated semi-quantitative FFQ completed at baseline with 136 food items.[22-24] We recoded missing FFQ values as no consumption. Daily food intake was estimated by multiplying the frequency of consumption for each item and the typical portion size specified in the FFQ. We used consumption data to test the adherence of our population to 3 dietary patterns.

The pVD captures a preference for plant origin foods instead of animal ones. To assess it, we followed a previously described method.[4, 25] Concisely, we adjusted for total energy intake, using the residual method separately for men and women. We also adjusted for the baseline consumption (g/day) of 12 food groups - 7 from plant origin (vegetables (including roasted potatoes and French fries); fruits (including fruit in syrup or juice, and dried fruits) and fruit juices; nuts; legumes; cereals (whole and refined); plant origin oils; and bakery products) and 5 from animals (dairy products; eggs; meat and meat products; fish and seafood; and animal fats). The residuals (energy-adjusted estimates) were ranked according to quintiles. Quintile values of plant foods and reverse quintile values for animal were summed up in order to evaluate the adherence. Final scores may range from 12 to 60 points (lowest and highest adherence, respectively). Lastly, we categorized the adherence to this dietary pattern into quartiles (Q).

The index proposed by Trichopoulou and colleagues [26] was used to measure the adherence to the MeD. A score of 0 or 1 was given to each of these nine components of this index (vegetables, legumes, fruits and nuts, cereals, fish, meat and meat products, fatty dairy products, alcohol and fat intake (as the ratio of monounsaturated lipid to saturated lipid intake)), using the sex-specific median as the cut-off value. Those who consumed below the median of presumed beneficial components (vegetables, legumes, fruits and nuts, cereals, fish and fat ratio) were assigned a value of 0, and participants whose consumption was at or above

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3 the median were assigned a value of 1. The other way around, consumption below the  
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5 median was assigned 1 point assessing a priori detrimental items (meat and meat products,  
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7 and fatty dairy products) and the consumption at or above the median was valued as 0.  
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9 Consumption of ethanol between 10 to 50 g/day or 5 to 25g/day, for men and women,  
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11 respectively, was given one point. The total index score ranged from 0 to 9 points (minimal to  
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13 maximal adherence to MeD). Finally, we roughly divided the adherence to this diet into  
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17 quartiles.

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19 We used Principal Component Analysis in order to establish a WDP in our cohort, because  
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21 there is no specific a priori definition of the WDP. Food products were grouped into 30  
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23 categories, as described by Lopez et al (2009).[27] We excluded those food groups whose  
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25 measure of sampling adequacy was lower than 0.65. Food groups that loaded  $>0.30$  were  
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27 considered to be making a contribution to the factor. The factor score for the diet was  
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29 constructed by summing observed consumptions of the component food items weighted by  
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31 their factor loadings. Thus, each individual received a factor score for each identified  
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33 pattern.[28] The major dietary pattern factor identified was labelled as the WDP, which  
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35 included fast food, fatty dairy products, red and processed meat, potatoes, industrial bakery,  
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37 sauces, precooked foods and sugar-sweetened soft drinks (Supplemental Table 1). Participants  
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39 were also categorized into quartiles according to their adherence to the WDP.  
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#### 45 **Assessment of Other Variables**

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48 The baseline questionnaire also included sociodemographic, lifestyle and medical history  
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50 questions. Self-reported data such as physical activity (total Metabolic Equivalent of Tasks  
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52 (MET) per hour per week), body mass index (BMI) and hypertension - had been previously  
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54 validated.[29-31]  
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#### 58 **Outcomes assessment**

## Health

We estimated the impact of each of the 3 dietary patterns on health using the metric of the Rate Advancement Period (RAP).[32, 33] The RAP is a method which measures the time by which a rate of a specific outcome is advanced (positive values for detrimental exposures) or it is postponed (negative values for protective exposures) among exposed subjects compared with unexposed individuals, conditional on being free of that outcome at the baseline age. It is useful to analyze outcomes which uniformly rise with age, as it happens with total mortality and with the incidence of most chronic diseases. In the current analysis, the end-point was a composite including death, non-fatal CVD (myocardial infarction or stroke), non-fatal breast cancer or T2DM, whichever occurred first (detailed data of the rates (cases/frequency; percentage) assessing specifically each individual health outcome that compose the overall health effect was reported in Supplemental Table 2). Time was measured in years from the entrance to the cohort. In order to minimize the bias produced by comparing dietary scores measured using different units, z scores were used. Each z score was calculated as the value of the diet minus the sample mean divided by its standard deviation. Cox regression models adjusted for sex, body mass index (BMI) (including a quadratic term for BMI), physical activity, smoking, time spent in sedentary activities, prevalent hypertension, prevalent hypercholesterolemia and total energy intake. These Cox models were used to estimate the RAP for each quartile of adherence to the three dietary patterns, by dividing the regression coefficient of the z score by the regression coefficient of age; the 95% confidence intervals (95%CI) for the RAP were calculated by using the variance and covariance estimates from the regression coefficients.[32]

## Environmental footprints

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3 Environmental footprints index was assessed as previously described by Fresan et al.[34] In  
4 brief, the impact of the production of 1kg of each food product reported in the FFQ on  
5 resource use (land, water and energy) and GHG emission was assessed using data previously  
6 reported by several institutions and/or research groups. The main data sources of each  
7 environmental domain were collected in Supplemental table 3. Those foods that are composed  
8 by more than one ingredient were broken down into their main ingredients. The  
9 environmental impact of these composed foods were assessed as the sum of the footprints of  
10 their individual ingredients, taking into account the proportion of each of them, and the food  
11 losses. For example, we took in consideration that 600 g of wheat flour, 180 g of butter, 180 g  
12 of sugar and 70 g of eggs were assumed to be necessary to produce 1 kg of cookies. Finally,  
13 the environmental impacts embodied in the processing of the ingredients into the final food  
14 product were added to the ingredients' production figures.

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31 The impact on the environment of each participant was estimated considering the amount of  
32 every item consumed per day, and the specific value of each of them. Total use of land, water  
33 and energy, and GHG emission were calculated as the sum of all items values, obtaining the  
34 impact on these 4 footprints according to the daily food consumption of each participant. We  
35 classified participants into quartiles of these total values, each of them ranking from 1 to 4  
36 (less to high resource consumption or GHG emission). A total environmental footprints index  
37 was created summing the quartile values of all the four footprints: land use, water use, energy  
38 use and GHG emission. Therefore, environmental footprints index ranked from 4 to 16 points  
39 (from low to high environmental repercussion).

### 50 51 52 53 Monetary cost

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56 Monetary cost of food was derived from the Ministry of Industry, Tourism and Commerce of  
57 Spain.[35] Annual cost of each item was calculated as the monthly reported national average  
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3 costs, and it was assessed according to the year in which that participant completed their  
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5 baseline questionnaires in order to control for differences between calendar years in retail  
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7 prices. Total daily monetary costs were calculated by multiplying the cost per kg (€/kg) of  
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9 each food item by the reported daily quantity consumed through the FFQ.  
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### 12 13 Overall sustainable diet index 14 15

16 We designed an index which gathered the impact of the daily diet on all the analyzed aspects:  
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18 health, environmental footprints and monetary costs. In order for all of these three aspects to  
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20 contribute equally for the overall index, a score from 0 to 3 points was given for each of them.  
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22 We estimated the RAP, the environmental footprints index and the daily monetary cost of the  
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24 diet of each participant. Of these values, the less suitable value for health (a specific hazard is  
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26 advanced more years), environment (more environmental footprints were produced) and  
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28 economy (the highest daily monetary cost) was given 0 points. On the other hand, we  
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30 assigned 3 points for the healthiest daily diet (a specific hazard is postponed more years), the  
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32 one that produced less environmental footprints, and the cheapest one. Proportional score was  
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34 given for the rest of values. Summing these three values, the overall sustainable diet index  
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36 ranked from 0 to 9 points, with 0 being the less suitable diet and 9 the most appropriate diet.  
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### 42 **Statistical analyses** 43 44

45 Linear Regression Models were used to assess the relationship between quartiles of adherence  
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47 to each dietary pattern and overall sustainable diet index, and each of the three components  
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49 separately (RAP, environmental footprints index and monetary costs). We estimated means  
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51 and their 95%CI using analyses of covariance for each quartile, adjusting for age, sex and  
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53 total energy intake. Moreover, we analyzed differences in mean values and their 95% CI for  
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55 each of the three upper quartiles of the respective dietary pattern using the lowest quartile as  
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3 the reference category. Linear trends across different quartiles were conducted by assigning  
4 the medians to each quartile; this variable was treated as continuous.  
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8 We conducted sensitivity analyses refitting the models under different assumptions to assess  
9 the robustness of our results: excluding participants who had any of the outcomes gathered in  
10 the health composite end-point in the first 2 years of follow-up; including participants with  
11 prevalent CVD, cancer or T2DM at baseline (in this case, the model was additionally  
12 adjusted for prevalent CVD, cancer and T2DM at baseline); and excluding participants with  
13 total energy intake beyond predefined limits (<800 Kcal/day and <500 Kcal/day or >4000  
14 Kcal/day and >3500 Kcal/day in men and women, respectively).  
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24 We assessed interactions, through a likelihood ratio test, between the respective dietary  
25 pattern and sex, BMI, age and physical activity (assessed as continuous variables).  
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29 All p-values presented are two-tailed;  $p < 0.05$  was considered statistically significant.

30 Analyses were performed using STATA/SE V.12.1 (StataCorp, College Station, Texas,  
31 USA).  
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### 37 **Patient and public involvement**

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40 Neither patients nor public were involved in the study.  
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## 43 **RESULTS**

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45 Our analysis included a total of 18429 participants (7042 men and 11387 women). The main  
46 baseline characteristics of participants according to adherence (extreme quartiles, Q1 and Q4)  
47 to each of the three dietary patterns are presented in table 1.  
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53 Participants with the highest adherence to the WDP (Q4) were more likely to be men,  
54 younger, single, current smokers with less advanced studies. They tended to intake more  
55 calories. On average, they consumed more animal products, bakery products, fast food and  
56 sugared sodas; but less fish, plant products and olive oil. The opposite results were obtained  
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3 for those participants in the Q4 of the MeD, whose consumption of fish and plant origin food  
4 was the highest. Dairy products, eggs and meat were consumed less frequently for those who  
5 reported the highest pVD adherence. Intake of fats, specifically saturated fatty acids, were  
6 higher in the Q4 of the WDP. Fiber was highly consumed by participants of the Q4 of the  
7 pVD and MeD, and the Q4 participants of the MeD also reported higher consumption of  
8 alcohol.  
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12 Figure 1 shows how the overall sustainable diet index, and the three elements that composed  
13 it (health as captured by the RAP, environmental footprints index and monetary costs)  
14 changed across successive quartiles of adherence to each of the three analyzed dietary patterns  
15 (specific values for means and confidence intervals are shown in Supplemental Table 4).  
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18 [insert Figure 1]  
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22 Comparing the dietary patterns of participants in the upper quartile of each dietary pattern, the  
23 most overall sustainable pattern was the MeD, followed closely by the pVD. Taking health  
24 repercussions into account, after a median follow-up of 10.1 years, and after observing 469  
25 incident cases of the composite end-point, the healthiest dietary pattern was the MeD because  
26 the hazard of developing the end-point was postponed for more than 3 years when comparing  
27 the upper versus the lowest quartile. Assessing the diet of subjects on the pVD and WDP, we  
28 noticed a retardation and an advancement of the end-point, respectively, although both lacked  
29 statistical significance. Regarding environmental footprints, the pVD seemed to be the most  
30 eco-friendliest option, followed by the MeD. On average participants in the upper quartile of  
31 the MeD spent the highest amount of economic resources, while the upper quartile of the  
32 WDP included the most relatively affordable foods.  
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Table 1. Distribution of baseline characteristics of participants according to quartiles of adherence to Western, Mediterranean and Provegetarian dietary patterns.

	Western dietary pattern		Mediterranean dietary pattern		Provegetarian dietary pattern	
	Q1	Q4	Q1	Q4	Q1	Q4
Frequency (n)	4608	4607	3487	1846	4672	4350
<b><i>Sociodemographic data</i></b>						
Sex (men %)	29	50	39	41	39	40
Age (years)	40 (12)	33 (10)	33 (10)	42 (13)	34 (11)	40 (12)
Civil status (%)						
Single	39	58	56	34	51	41
Married	54	39	41	60	44	54
Others	7	3	3	6	4	5
Smoking status (%)						
Current smoker	21	28	27	25	30	23
Former smoker	31	18	16	34	20	28
Studies (%)						
Technical/non graduated	4	9	9	4	7	5
Graduated	76	74	74	77	75	74
Master/doctoral	20	17	17	19	18	21
<b><i>Food and Nutrition</i></b>						
Total energy intake (Kcal/d)	2064 (639)	3184 (752)	2347 (719)	2724 (722)	2634 (786)	2539 (809)
Food items (g/d) <sup>a</sup>						
Dairy products	498 (281)	411 (273)	486 (255)	386 (259)	554 (296)	330 (206)
Non-fat/low-fat dairy products	359 (285)	117 (200)	188 (238)	282 (262)	257 (299)	191 (209)
Fatty dairy products	139 (109)	294 (269)	298 (215)	104 (139)	297 (251)	139 (140)
Eggs	19 (11)	28 (25)	26 (18)	22 (16)	30 (21)	18 (12)

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4	All types of meats	117 (51)	171 (82)	162 (65)	121 (62)	179 (75)	111 (52)
5	Red meat	29 (21)	53 (38)	49 (32)	32 (27)	53 (35)	31 (24)
6	White meat	46 (34)	49 (46)	49 (38)	46 (37)	56 (48)	39 (29)
7	Processed meat	42 (23)	69 (49)	64 (36)	43 (32)	70 (43)	41 (27)
8	Fish and seafood	117 (66)	86 (82)	78 (58)	128 (69)	111 (86)	92 (59)
9	Vegetables	789 (441)	486 (319)	474 (265)	832 (440)	501 (308)	782 (431)
10	Legumes	17 (11)	17 (15)	15 (11)	20 (14)	15 (11)	20 (14)
11	Fruits and nuts	630 (448)	256 (272)	299 (251)	597 (414)	289 (263)	578 (481)
12	Fresh fruit	594 (441)	238 (263)	278 (245)	562 (406)	273 (258)	540 (409)
13	Processed fruit	25 (51)	13 (34)	15 (27)	23 (51)	12 (26)	25 (53)
14	Nuts	11 (17)	5 (11)	6 (8)	12 (18)	4 (9)	13 (18)
15	Cereals	124 (68)	90 (77)	95 (61)	131 (76)	86 (65)	133 (72)
16	Oils and fats	24 (15)	17 (18)	17 (13)	25 (17)	17 (15)	23 (16)
17	Olive oil	20 (14)	11 (13)	12 (11)	21 (15)	12 (12)	20 (14)
18	Other oils	2 (5)	3 (8)	2 (6)	2 (7)	2 (6)	2 (7)
19	Margarine	1 (2)	1 (4)	1 (3)	1 (3)	1 (3)	1 (3)
20	Animal fats	1 (1)	2 (4)	2 (3)	1 (2)	2 (3)	0 (2)
21	Pastry products	47 (35)	54 (62)	58 (49)	41 (42)	48 (45)	58 (48)
22	Biscuits	19 (29)	11 (36)	19 (35)	13 (29)	13 (30)	19 (35)
23	Chocolate	11 (12)	13 (29)	15 (23)	9 (15)	10 (17)	13 (21)
24	Industrial bakery	7 (8)	21 (31)	16 (21)	8 (18)	13 (18)	12 (21)
25	Home-made bakery	4 (7)	5 (12)	5 (10)	4 (9)	4 (8)	5 (11)
26	Cakes	2 (2)	4 (5)	3 (4)	2 (4)	2 (4)	2 (4)
27	Fast food <sup>1</sup>	8 (7)	20 (18)	17 (14)	9 (11)	17 (15)	10 (10)
28	Beverages	1219 (577)	1114 (567)	1092 (552)	1248 (574)	1151 (587)	1177 (558)
29	Water	968 (538)	864 (513)	868 (508)	961 (530)	898 (535)	932 (518)
30	Red wine	27 (61)	23 (58)	18 (49)	37 (71)	24 (63)	27 (60)
31	Other alcoholic beverages	64 (104)	69 (137)	56 (120)	90 (127)	75 (149)	68 (116)
32	Sugared sodas	23 (34)	76 (146)	58 (104)	26 (61)	58 (112)	30 (60)
33	Regular coffee	16 (33)	9 (28)	11 (26)	15 (34)	12 (28)	14 (32)
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Bottled juice	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)
Nutrient intake (% total energy intake/d)						
Fat	33 (7)	39 (5)	40 (6)	33 (6)	39 (6)	34 (6)
Saturated fatty acids	10 (3)	14 (3)	15 (3)	10 (2)	15 (3)	11 (3)
Monounsaturated fatty acids	15 (4)	16 (3)	16 (3)	15 (4)	16 (3)	15 (4)
Polyunsaturated fatty acids	5 (1)	6 (2)	5 (2)	5 (2)	5 (2)	5 (2)
Carbohydrates	46 (8)	42 (6)	41 (7)	47 (7)	40 (7)	47 (7)
Protein	19 (4)	17 (3)	18 (3)	18 (3)	19 (3)	16 (3)
Dietary fibre intake (g/d) <sup>a</sup>	37 (13)	23 (10)	21 (7)	40 (13)	23 (9)	37 (13)
Alcohol intake (g/d) <sup>a</sup>	6 (9)	7 (11)	5 (9)	10 (10)	7 (12)	6 (9)
<b>Lifestyle data</b>						
Physical activity (METs-h/week)	29 (25)	27 (25)	23 (21)	33 (28)	26 (23)	29 (26)
Time watching TV (h/d)	1.5 (1.1)	1.6 (1.3)	1.6 (1.3)	1.6 (1.1)	1.7 (1.3)	1.5 (1.1)

<sup>a</sup>Adjusted for energy intake through the residual method.<sup>1</sup>Fast food includes hamburger, pizza and sausages. Q1=first quartile. Q4= fourth quartile.

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3 Adjusted relative mean differences are shown in Figure 2, and specific values are presented in  
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5 Supplemental table 5. In all analyses, there was a statistical linear trend across quartiles  
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7 (p<0.001).  
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11 [insert Figure 2]  
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14 The main results were consistent in all our sensitivity analyses (Supplemental Table 6 and  
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16 Supplemental Table 7). Only including those participants who reported a prevalent chronic  
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18 disease, a higher adherence to the pVD presented a higher overall sustainable diet index than  
19  
20 higher adherence to the MeD. However, differences between these two dietary patterns were  
21  
22 not statistically significant. We did not observe any statistically significant interaction  
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24 between the dietary patterns and sex, BMI, age or physical activity (data not shown).  
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## 31 **DISCUSSION**

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34 The current study showed the Mediterranean dietary pattern as the healthiest option, with  
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36 relatively low environmental footprints. However, its monetary costs were the highest. The  
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38 Provegetarian dietary pattern was the most eco-friendliest pattern, relatively healthy and  
39  
40 affordable. The Western dietary pattern was the least recommended pattern according to  
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42 health criteria and ecosystems consequences, but it was the most affordable food pattern.  
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44 Considering in conjunction health, environment and monetary costs, the MeD and the pVD  
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46 would be sustainable dietary patterns, while the WDP would not be a sustainable dietary  
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48 pattern.  
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54 Healthy diets are inversely associated with the risk of diseases like CVD, cancer, T2DM and  
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56 also all-cause mortality.[36] We observed that better conformity to the MeD was the  
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58 healthiest option, followed closely by the pVD. The high quality of the MeD and other pVD  
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3 has been reported previously.[3, 4] Their benefits have been attributed to the high  
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5 consumption of plant-origin foods and the low consumption of animal-based foods. [36] In  
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7 fact, the MeD could be considered as a special case of a pVD. The similarity of these two  
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9 patterns can be appreciated in the recommendations of high intakes of fruit, vegetables, beans,  
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11 cereals, nuts, and seeds. Olive oil as the main source of fat, moderate to high consumption of  
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13 fish and other seafood, moderate amounts of red wine with meals as the main source of  
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15 alcohol, and a low intake of meat and dairy products is what specifically defines MeD  
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17 compared to a general pVD. Indeed, the specific suggestion in the MeD of the consumption  
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19 of olive oil or fish, could be one of the reasons why this diet achieved more health benefits.[2,  
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21 37] We have not assessed a “pure” Vegetarian/Vegan diet because the proportion of  
22  
23 participants who followed these patterns was very low in our cohort. pVD is only a gentle and  
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25 moderate approach. On the other hand, our results related to the WDP and its detrimental  
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27 health repercussion are in agreement with previous publications.[38]  
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34 Previous research supports that a population shift to a more plant and less animal-rich diet,  
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36 like the pVD or the MeD, may be positive for the environment.[8-10, 12-14, 39] Conformity  
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38 to the MeD, and especially to the pVD, implicated a reduction on environmental footprints.  
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40 The higher impact of the MeD than the pVD could be due to fish consumption, because of the  
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42 great amount of energy used for fish production than for fruits, vegetables and other plant-  
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44 derived foods. It is necessary to reinforce fish consumption from sustainable sources, and in  
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46 the case of wild caught fish to prevent overfishing.  
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51 A direct linear relationship between nutritional adequacy and the monetary costs of a  
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53 dietary pattern has been suggested.[40-42] A recent meta-analysis reported an average  
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55 increment of 1.48\$/day if a healthy diet is followed.[41] In our cohort, those participants with  
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57 the highest adherence to the healthiest pattern, the MeD, spent a mean of 1.42€/day more in  
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59 their daily diet than those with the poorest adherence to the MeD. Again, fish consumption  
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3 could be the main reason for the monotonically increasing monetary costs in parallel with  
4 better MeD adherence.[27, 42] However, it should be noticed that we only took into account  
5 the amount of money that people spent to buy their foods. The relevance of this item as part of  
6 an overall sustainability index could be discussed. It has been suggested that a full societal  
7 cost of diet (i.e. health care expenditures and loss of productivity) should be addressed when  
8 assessing sustainability evaluation. [43] Indeed, a recent publication concluded that moving  
9 towards plant-based dietary patterns, and specifically the MeD, could save huge amounts of  
10 money when the assessment is done from a full societal perspective taking into account all the  
11 costs. [44] We reran our analyses assessing the overall sustainability of the three dietary  
12 patterns without the cost item, and the main results supported the higher benefits associated  
13 with following plant-based diets, in particular the MeD (data non-shown).

14  
15 We observed only a modest magnitude for the differences between the extreme quartiles on  
16 the overall sustainable diet index (Supplemental table 2). This limitation could be due to the  
17 method used to construct the overall index according to quartiles of the three dimensions  
18 evaluated. This might explain why some of the differences according to dietary patterns were  
19 not well captured. In fact, although in the overall sustainability index, the health-related and  
20 environmental items seem to have been considered appropriately, their contribution is only  
21 qualitative, as their differences between the first and the fourth quartiles are small. This fact  
22 may limit the interpretability of the impacts reported here. There would potentially be much  
23 greater differences with the inclusion of the true global costs from a societal perspective of the  
24 food patterns. Some other limitations of our study include self-reported information, and the  
25 difficulties to generalize our results to other populations, given that the sample is not  
26 representative of the general Spanish population (cohort composed only by university  
27 graduates). However, the advantages of using a socially homogenous and well-educated  
28 cohort overcome this limitation because this approach removes part of the residual



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3 confounding and ensures a higher quality of the self-reported information. Another potential  
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5 limitation for the external validity of our results is the relatively young age of our cohort, that  
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7 we acknowledge. The interquartile range for age was 27 to 45. Only 1.53 percent of  
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9 participants in the cohort were older than 65 years at baseline. The percentage of women older  
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11 than 65 years at baseline was especially low (0.5 percent). These limitations highlight the  
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13 need for replication of our findings in other independent cohort with older age at baseline. We  
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15 assumed that foods were prepared and eaten at home, and this approximation may  
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17 underestimate the effect of the diet. The three dietary patterns were assessed by 3 different  
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19 methods. Assessing the adherence to the diets using different cut-offs could give different  
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21 results. The relevance of the RAP metric for health outcomes in a young people cohort could  
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23 be questioned. It would be interesting to assess in the future the impact on health using other  
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25 criteria; for instance, quality-adjusted life-years, which is another common measure used to  
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27 value health gains. The environmental footprints index does not contemplate other phases of  
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29 the food chain apart from production and processing. However, production is the most  
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31 contributive aspect by far.[45, 46]  
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38 Some of the strengths of the current study include the simultaneous assessment of the three  
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40 dimensions of an overall sustainable diet (health, environment and monetary costs). This  
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42 represents a novelty of our study. We used a wide range of scores for food consumption in a  
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44 large sample size through a validated questionnaire. We focused on GHG emission and  
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46 efficiency in using natural resources when assessing the environmental footprints, which is a  
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48 more holistic approach.  
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## 55 **CONCLUSION**

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57 Following plant-based diets, like the Mediterranean or another model of Provegetarian dietary  
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59 pattern, could be a good option to achieve an overall sustainable diet, according to a  
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3 concordant high score in three dimensions of an ideally healthy, environmental-friendly and  
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5 affordable diet. The Mediterranean dietary pattern was the healthiest pattern and relatively  
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7 environmentally sustainable. However, nowadays, it cannot be presented as an affordable  
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9 model. Some monetary policies, such as subsidizing healthy Mediterranean foods, may  
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11 contribute to increased adherence to a diet with recognized health benefit. This translates into  
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13 huge savings from a global societal perspective in terms of making healthier foods more  
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15 affordable for the general population.  
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6  
7

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27 U.F. Critical revision of the manuscript for important intellectual content: J.S., M.-A.M.-G.  
28 and M.B.-R. Statistical analysis: U.F. Supervision: M.B.-R.  
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35 **Data sharing statement:** No additional data are available.  
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38 **Ethics approval:** The protocol was approved by the Research Ethics Committee of the  
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## LEGENDS FOR FIGURES

Figure 1. Adjusted means and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Monetary cost, according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence. Adjusted for age, sex and total energy intake.

Red line, cross: adherence to the Western dietary pattern. Blue line, diamond: adherence to the Mediterranean dietary pattern. Green line, square: adherence to the Provegetarian dietary pattern.

Figure 2. Adjusted relative means differences and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Monetary cost, according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence, taking as the reference category the first quartile. Adjusted for age, sex and total energy intake.

Red line, cross: adherence to the Western dietary pattern. Blue line, diamond: adherence to the Mediterranean dietary pattern. Green line, square: adherence to the Provegetarian dietary pattern.

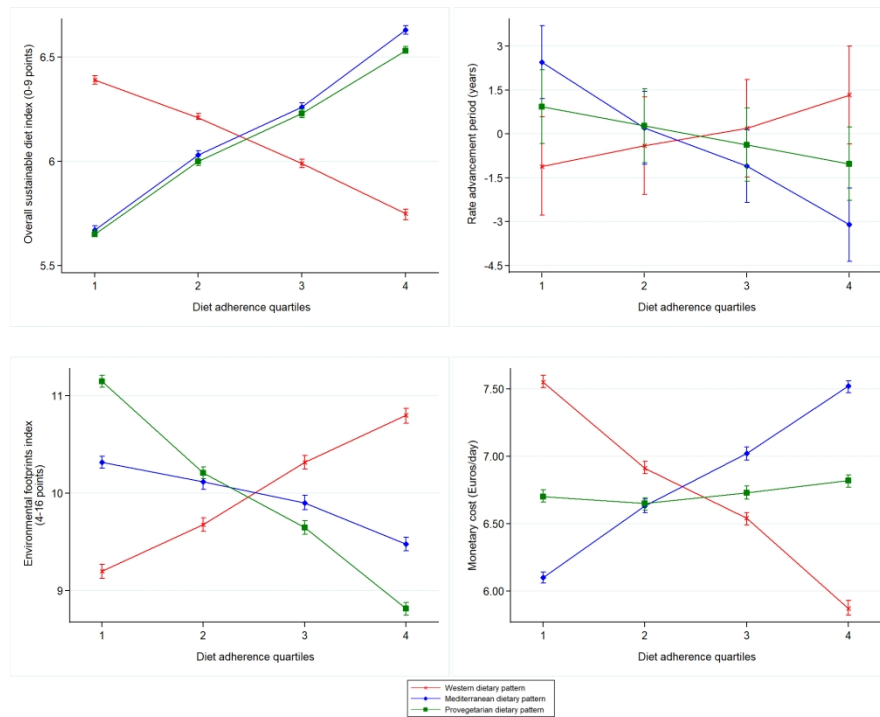


Figure 1. Adjusted means and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Monetary cost, according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence. Adjusted for age, sex and total energy intake. Red line, cross: adherence to the Western dietary pattern. Blue line, diamond: adherence to the Mediterranean dietary pattern. Green line, square: adherence to the Provegetarian dietary pattern.

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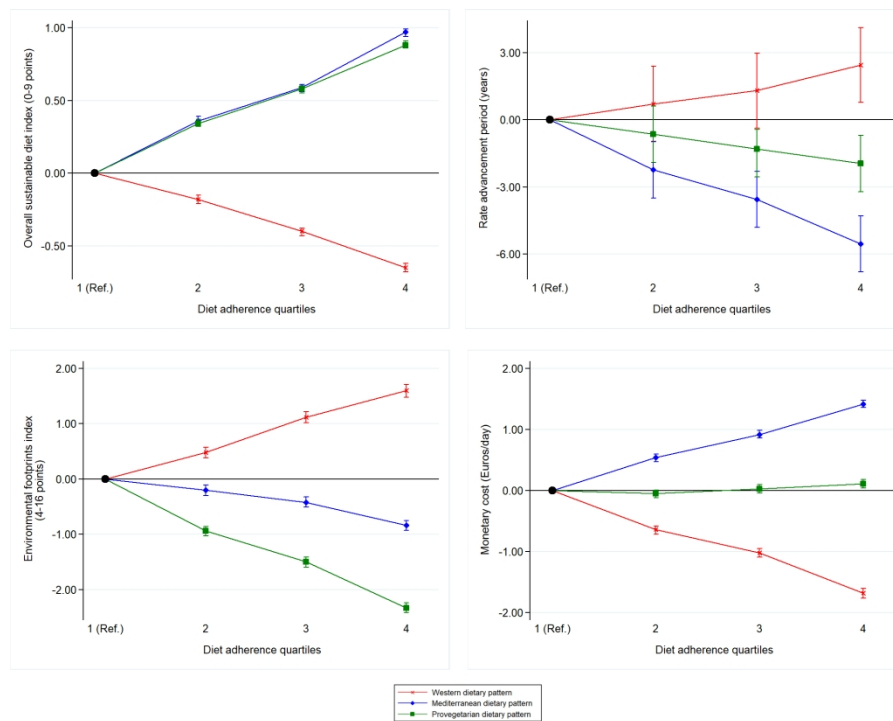
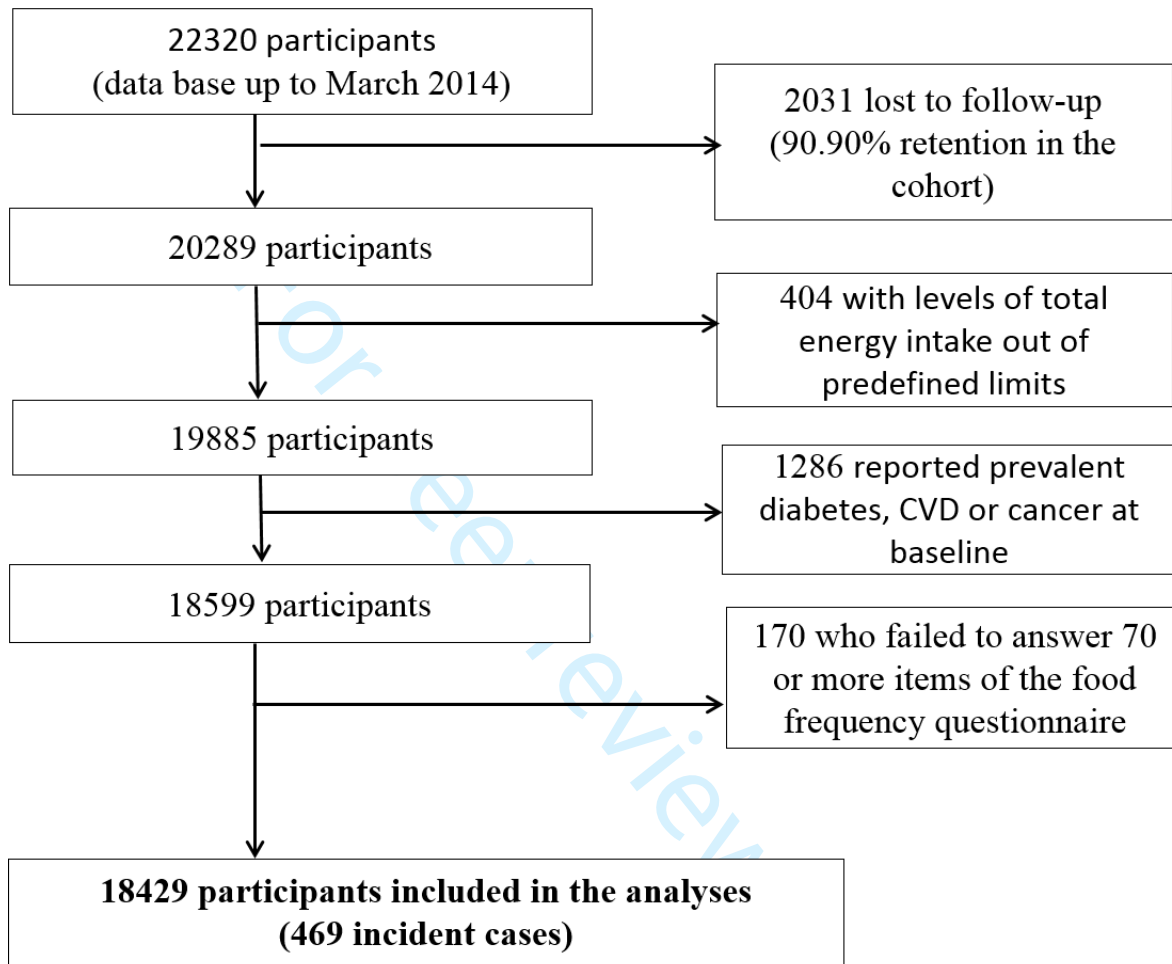


Figure 2. Adjusted relative means differences and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Monetary cost, according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence, taking as the reference category the first quartile. Adjusted for age, sex and total energy intake.

Red line, cross: adherence to the Western dietary pattern. Blue line, diamond: adherence to the Mediterranean dietary pattern. Green line, square: adherence to the Provegetarian dietary pattern.

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Supplemental Figure 1. Flow chart of the study participants in the Seguimiento Universidad de Navarra (SUN) Project 1999–2016.



CVD: cardiovascular disease

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3 Supplemental Table 1. Principal Component Analysis loadings >0.3 for Western dietary  
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Food products	Loading factors
Fast food	0.5172
Fatty dairy products	0.4871
Red meat	0.4841
Potatoes	0.4538
Industrial bakery	0.4535
Processed meat	0.4477
Sauces	0.4385
Precooked food	0.3954
Caloric soft drinks	0.3862

Supplemental Table 2. Rates (cases/frequency; percentage) assessing total mortality, non-fatal cardiovascular disease, non-fatal breast cancer and incidence of type 2 diabetes, according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence.

	<b>Western diet</b>			
	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
Cases/N (frequency) <sup>a</sup>	72/4608	49/4607	52/4607	44/4607
% <sup>a</sup>	1.56	1.06	1.13	0.96
Cases/N (frequency) <sup>b</sup>	41/4608	31/4607	24/4607	19/4607
% <sup>b</sup>	0.89	0.67	0.52	0.41
Cases/N (frequency) <sup>c</sup>	16/4608	11/4607	17/4607	19/4607
% <sup>c</sup>	0.35	0.24	0.37	0.41
Cases/N (frequency) <sup>d</sup>	40/4608	38/4607	22/4607	24/4607
% <sup>d</sup>	0.87	0.82	0.48	0.52
	<b>Mediterranean diet</b>			
	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
Cases/N (frequency) <sup>a</sup>	62/6802	56/3796	44/3400	55/4431
% <sup>a</sup>	0.91	1.48	1.29	1.24
Cases/N (frequency) <sup>b</sup>	47/6802	20/3796	25/3400	23/4431
% <sup>b</sup>	0.69	0.53	0.74	0.52
Cases/N (frequency) <sup>c</sup>	27/6802	9/3796	16/3400	11/4431
% <sup>c</sup>	0.40	0.24	0.47	0.25
Cases/N (frequency) <sup>d</sup>	35/6802	23/3796	25/3400	41/4431
% <sup>d</sup>	0.51	0.61	0.74	0.93
	<b>Provegetarian diet</b>			
	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
Cases/N (frequency) <sup>a</sup>	43/4672	64/5450	44/3957	66/4350
% <sup>a</sup>	0.92	1.17	1.11	1.52
Cases/N (frequency) <sup>b</sup>	29/4672	35/5450	27/3957	24/4350
% <sup>b</sup>	0.62	0.64	0.68	0.55
Cases/N (frequency) <sup>c</sup>	21/4672	12/5450	11/3957	19/4350
% <sup>c</sup>	0.45	0.22	0.28	0.44
Cases/N (frequency) <sup>d</sup>	26/4672	35/5450	23/3957	40/4350
% <sup>d</sup>	0.56	0.64	0.58	0.92

Adjusted for age, sex and total energy intake. Qn= nth quartile of diet adherence

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3     <sup>a</sup>The endpoint is total mortality  
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5     <sup>b</sup>The endpoint is non-fatal cardiovascular disease  
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7     <sup>c</sup>The endpoint is non-fatal breast cancer  
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Supplemental table 3. Main environmental footprint information sources for items' production and processing phases

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13

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- 15  
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18 • Food Carbon emission calculator  
19 <http://www.foodemissions.com/foodemissions/Calculator.aspx>  
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Supplemental Table 4. Adjusted mean values and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Monetary cost according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence.

	<b>Western dietary pattern</b>			
	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
N (frequency)	4608	4607	4607	4607
Cases/person-years	151/43804	117/45688	104/46749	97/49219
Overall sustainable diet index (0-9 points) <sup>a</sup>	6.39 (6.37, 6.41)	6.21 (6.20, 6.23)	5.99 (5.97, 6.01)	5.75 (5.72, 5.77)
Rate advancement period (years) <sup>a</sup>	-1.11 (-2.78, 0.59)	-0.40 (-2.07, 1.27)	0.19 (-1.48, 1.86)	1.33 (-0.34, 3.00)
Environmental footprints index (4-16 points) <sup>a</sup>	9.20 (9.13, 9.27)	9.68 (9.61, 9.75)	10.32 (10.25, 10.39)	10.80 (10.72, 10.87)
Monetary cost (€/day) <sup>a</sup>	7.55 (7.51, 7.60)	6.91 (6.87, 6.96)	6.54 (6.49, 6.58)	5.87 (5.82, 5.93)
	<b>Mediterranean dietary pattern</b>			
	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
N (frequency)	6802	3796	3400	4431
Cases/person-years	149/70310	100/38942	99/33695	121/42512
Overall sustainable diet index (0-9 points) <sup>a</sup>	5.67 (5.66, 5.69)	6.03 (6.01, 6.05)	6.26 (6.24, 6.28)	6.64 (6.62, 6.66)

Rate advancement period (years) <sup>a</sup>	2.45 (1.21, 3.70)	0.21 (-1.04, 1.45)	-1.10 (-2.34, 0.15)	-3.10 (-4.35, -1.85)
Environmental footprints index (4-16 points) <sup>a</sup>	10.32 (10.26, 10.38)	10.12 (10.04, 10.19)	9.90 (9.83, 9.98)	9.48 (9.41, 9.55)
Monetary cost (€/day) <sup>a</sup>	6.10 (6.06, 6.14)	6.63 (6.58, 6.68)	7.02 (6.97, 7.07)	7.52 (7.47, 7.56)

### Provegetarian dietary pattern

	Q1	Q2	Q3	Q4
N (frequency)	4672	5450	3957	4350
Cases/person-years	108/47626	129/55222	92/39808	140/42802
Overall sustainable diet index (0-9 points) <sup>a</sup>	5.65 (5.64, 5.67)	6.00 (5.98, 6.01)	6.23 (6.21, 6.25)	6.53 (6.52, 6.55)
Rate advancement period (years) <sup>a</sup>	0.93 (-0.33, 2.19)	0.28 (-0.98, 1.54)	-0.37 (-1.62, 0.89)	-1.02 (-2.27, 0.24)
Environmental footprints index (4-16 points) <sup>a</sup>	11.15 (11.09, 11.21)	10.21 (10.15, 10.27)	9.65 (9.58, 9.72)	8.82 (8.75, 8.88)
Monetary cost (€/day) <sup>a</sup>	6.70 (6.66, 6.75)	6.65 (6.60, 6.69)	6.73 (6.68, 6.78)	6.82 (6.77, 6.86)

Adjusted for age, sex and total energy intake. <sup>a</sup>p for trend<0.001. Qn= nth quartile of diet adherence.

Supplemental Table 5. Adjusted relative differences of mean values and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Monetary cost according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence.

	<b>Western dietary pattern</b>			
	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
N (frequency)	4608	4607	4607	4607
Cases/person-years	151/43804	117/45688	104/46749	97/49219
Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	-0.18 (-0.21, -0.15)	-0.40 (-0.43, -0.38)	-0.65 (-0.68, -0.62)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	0.71 (-0.96, 2.38)	1.30 (-0.37, 2.97)	2.44 (0.77, 4.11)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	0.48 (0.38, 0.57)	1.12 (1.02, 1.22)	1.60 (1.48, 1.71)
Monetary cost (€/day) <sup>a</sup>	0 (Ref)	-0.64 (-0.71, -0.58)	-1.02 (-1.09, -0.95)	-1.68 (-1.76, -1.60)
	<b>Mediterranean dietary pattern</b>			
	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
N (frequency)	6802	3796	3400	4431
Cases/person-years	149/70310	100/38942	99/33695	121/42512

Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	0.36 (0.34, 0.39)	0.59 (0.56, 0.61)	0.97 (0.94, 0.99)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	-2.24 (-3.49, -0.99)	-3.55 (-4.80, -2.30)	-5.55 (-6.80, -4.30)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	-0.20 (-0.30, -0.11)	-0.42 (-0.51, -0.32)	-0.84 (-0.93, -0.75)
Monetary cost (€/day) <sup>a</sup>	0 (Ref)	0.54 (0.47, 0.60)	0.92 (0.86, 0.99)	1.42 (1.36, 1.48)
<b>Provegetarian dietary pattern</b>				
	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>
N (frequency)	4672	5450	3957	4350
Cases/person-years	108/47626	129/55222	92/39808	140/42802
Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	0.34 (0.32, 0.37)	0.58 (0.55, 0.60)	0.88 (0.86, 0.91)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	-0.65 (-1.91, 0.61)	-1.30 (-2.56, -0.44)	-1.95 (-3.21 -0.69)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	-0.94 (-1.03, -0.86)	-1.50 (-1.60, -1.41)	-2.33 (-2.42, -2.24)
Monetary cost (€/day) <sup>a</sup>	0 (Ref)	-0.05 (-0.12, 0.01)	0.03 (-0.04, 0.10)	0.11 (0.04, 0.18)

Adjusted for age, sex and total energy intake. <sup>a</sup>p for trend<0.001. Qn= nth quartile of diet adherence.

Supplemental Table 6. Sensitivity analyses. Adjusted mean values and 95% Confidence Intervals of first and fourth quartile of adherence to Western, Mediterranean and Provegetarian dietary patterns.

	Western dietary pattern		Mediterranean dietary pattern		Provegetarian dietary pattern	
	Q1	Q4	Q1	Q4	Q1	Q4
<b>Overall</b>						
N (frequency)	4608	4607	6802	4431	4672	4350
Cases/person-years	151/43804	97/49219	149/70310	121/42512	108/47626	140/42802
Overall sustainable diet index (0-9 points) <sup>a</sup>	6.39 (6.37, 6.41)	5.75 (5.72, 5.77)	5.67 (5.66, 5.69)	6.64 (6.62, 6.66)	5.65 (5.64, 5.67)	6.53 (6.52, 6.55)
Rate advancement period (years) <sup>a</sup>	-1.11 (-2.78, 0.59)	1.33 (-0.34, 3.00)	2.45 (1.21, 3.70)	-3.10 (-4.35, -1.85)	0.93 (-0.33, 2.19)	-1.02 (-2.27, 0.24)
Environmental footprints index (4-16 points) <sup>a</sup>	9.20 (9.13, 9.27)	10.80 (10.72, 10.87)	10.32 (10.26, 10.38)	9.48 (9.41, 9.55)	11.15 (11.09, 11.21)	8.82 (8.75, 8.88)
Monetary cost (€/day) <sup>a</sup>	7.55 (7.51, 7.60)	5.87 (5.82, 5.93)	6.10 (6.06, 6.14)	7.52 (7.47, 7.56)	6.70 (6.66, 6.75)	6.82 (6.77, 6.86)
<b>Excluding participants who had the health composite end-point<sup>1</sup> in the first 2 years</b>						
N (frequency)	4560	4568	6732	4396	4625	4310
Cases/person-years	130/43734	85/49157	126/70200	106/42458	96/47553	123/42743
Overall sustainable diet index (0-9 points) <sup>a</sup>	6.28 (6.26, 6.30)	5.65 (5.63, 5.67)	5.52 (5.51, 5.54)	6.59 (6.57, 6.61)	5.55 (5.53, 5.57)	6.43 (6.41, 6.45)
Rate advancement period (years) <sup>a</sup>	-0.94 (-2.76, 0.88)	1.12 (-0.70, 2.94)	2.42 (1.06, 3.78)	-3.06 (-4.42, -1.70)	0.83 (0.54, 2.20)	-0.91 (-2.28, 0.47)
Environmental footprints index (4-16 points) <sup>a</sup>	9.20 (9.13, 9.28)	10.80 (10.72, 10.88)	10.32 (10.26, 10.38)	9.48 (9.41, 9.55)	11.15 (11.09, 11.21)	8.82 (8.75, 8.89)
Monetary cost (€/day) <sup>a</sup>	7.56 (7.51, 7.61)	5.88 (5.82, 5.93)	6.10 (6.06, 6.14)	7.52 (7.47, 7.57)	6.71 (6.66, 6.76)	6.82 (6.77, 6.87)
<b>Including people with prevalent CVD, cancer and T2DM<sup>b</sup></b>						
N (frequency)	4920	4919	7140	4844	5276	3963
Cases/person-years	189/46513	121/52449	177/73585	173/46176	115/53972	132/38890

Overall sustainable diet index (0-9 points) <sup>a</sup>	6.77 (6.75, 6.79)	6.06 (6.04, 6.08)	6.13 (6.12, 6.15)	6.83 (6.81, 6.85)	6.08 (6.06, 6.09)	6.84 (6.82, 6.86)
Rate advancement period (years) <sup>a</sup>	-1.42 (-2.87, 0.03)	1.69 (0.24, 3.14)	1.86 (0.73, 2.99)	-2.30 (-3.43, -1.17)	0.71 (-0.41, 1.84)	-0.84 (-1.96, 0.29)
Environmental footprints index (4-16 points) <sup>a</sup>	9.21 (9.14, 9.28)	10.80 (10.72, 10.87)	10.33 (10.28, 10.39)	9.47 (9.41, 9.54)	11.02 (10.97, 11.08)	8.81 (8.75, 8.88)
Monetary cost (€/day) <sup>a</sup>	7.57 (7.53, 7.62)	5.89 (5.84, 5.94)	6.11 (6.07, 6.14)	7.52 (7.47, 7.56)	6.69 (6.65, 6.73)	6.82 (6.77, 6.87)
<b>Excluding participants with total energy intake beyond predefined limits (&lt;800 Kcal/day and &lt;500 Kcal/day or &gt;4000 Kcal/day and &gt;3500 Kcal/day in men and women, respectively )</b>						
N (frequency)	4241	4241	6469	3938	6117	4703
Cases/person-years	135/40016	87/45713	147/66733	113/37707	153/62305	182/46046
Overall sustainable diet index (0-9 points) <sup>a</sup>	5.57 (5.55, 5.59)	4.98 (4.96, 5.00)	4.71 (4.70, 4.73)	6.13 (6.11, 6.15)	4.92 (4.90, 4.94)	5.77 (5.75, 5.79)
Rate advancement period (years) <sup>a</sup>	-1.23 (-2.72, 0.26)	1.33 (1.59, 2.83)	2.44 (1.15, 3.72)	-3.22 (-4.5, -1.94)	0.53 (-0.76, 1.81)	-0.62 (-1.91, 0.66)
Environmental footprints index (4-16 points) <sup>a</sup>	9.62 (9.54, 9.69)	10.54 (10.62)	10.42 (10.37, 10.48)	9.32 (9.24, 9.39)	11.11 (11.05, 11.16)	8.71 (8.64, 8.77)
Monetary cost (€/day) <sup>a</sup>	7.34 (7.29, 7.38)	5.51 (5.47, 5.56)	5.80 (5.76, 5.83)	7.17 (7.13, 7.22)	6.33 (6.29, 6.37)	6.47 (6.43, 6.52)

Adjusted for age, sex and total energy intake. <sup>a</sup>p for trend<0.001. <sup>1</sup>Composite end-point: all-cause mortality, non-fatal cardiovascular disease, non-fatal breast cancer or type 2 diabetes. <sup>b</sup>Additionally adjusted for prevalent CVD, cancer and T2DM. CVD: Cardiovascular Disease. Qn= nth quartile of diet adherence. T2DM: Type 2 Diabetes Mellitus.



Supplemental Table 7. Sensitivity analyses. Relative differences and 95% Confidence Intervals of the fourth compared to the first quartile of adherence to Western, Mediterranean and Provegetarian dietary patterns.

	Western dietary pattern		Mediterranean dietary pattern		Provegetarian dietary pattern	
	Q1	Q4	Q1	Q4	Q1	Q4
<b>Overall</b>						
N (frequency)	4608	4607	6802	4431	4672	4350
Cases/person-years	151/43804	97/49219	149/70310	121/42512	108/47626	140/42802
Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	-0.65 (-0.68, -0.62)	0 (Ref)	0.97 (0.94, 0.99)	0 (Ref)	0.88 (0.86, 0.91)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	2.44 (0.77, 4.11)	0 (Ref)	-5.55 (-6.80, -4.30)	0 (Ref)	-1.95 (-3.21, -0.69)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	1.60 (1.48, 1.71)	0 (Ref)	-0.84 (-0.93, -0.75)	0 (Ref)	-2.33 (-2.42, -2.24)
Monetary cost (€/day) <sup>a</sup>	0 (Ref)	-1.68 (-1.76, -1.60)	0 (Ref)	1.42 (1.36, 1.48)	0 (Ref)	0.11 (0.04, 0.18)
<b>Excluding participants who have the health composite end-point<sup>1</sup> in the first 2 years</b>						
N (frequency)	4560	4568	6732	4396	4625	4310
Cases/person-years	130/43734	85/49157	126/70200	106/42458	96/47553	123/42743
Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	-0.63 (-0.66, -0.60)	0 (Ref)	1.06 (1.04, 1.09)	0 (Ref)	0.88 (0.85, 0.90)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	2.06 (0.24, 3.88)	0 (Ref)	-5.48 (-6.84, -4.12)	0 (Ref)	-1.73 (-3.10, -0.36)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	1.60 (1.48, 1.71)	0 (Ref)	-0.84 (-0.93, -0.75)	0 (Ref)	-2.33 (-2.42, -2.24)
Monetary cost (€/day) <sup>a</sup>	0 (Ref)	-1.69 (-1.77, -1.61)	0 (Ref)	1.42 (1.36, 1.48)	0 (Ref)	0.11 (0.04, 0.18)
<b>Including people with prevalent CVD, cancer and T2DM<sup>b</sup></b>						
N (frequency)	4920	4919	7140	4844	5276	3963
Cases/person-years	189/46513	121/52449	177/73585	173/46176	115/53972	132/38890

Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	-0.71 (-0.74, -0.68)	0 (Ref)	0.70 (0.68, 0.72)	0 (Ref)	0.76 (0.74, 0.79)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	3.11 (1.66, 4.56)	0 (Ref)	-4.17 (-5.30, -3.04)	0 (Ref)	-1.55 (-2.67, -0.43)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	1.59 (1.47, 1.70)	0 (Ref)	-0.86 (-0.95, -0.77)	0 (Ref)	-2.21 (-2.30, -2.13)
Monetary cost (€/day) <sup>a</sup>	0 (Ref)	-1.68 (-1.76, -1.61)	0 (Ref)	1.41 (1.35, 1.47)	0 (Ref)	0.13 (0.06, 0.19)
<b>Excluding participants with total energy intake beyond predefined limits ((&lt;800 Kcal/day and &lt;500 Kcal/day or &gt;4000 Kcal/day and &gt;3500 Kcal/day in men and women, respectively )</b>						
N (frequency)	4241	4241	6469	3938	6117	4703
Cases/person-years	135/40016	87/45713	147/66733	113/37707	153/62305	182/46046
Overall sustainable diet index (0-9 points) <sup>a</sup>	0 (Ref)	-0.59 (-0.63, -0.56)	0 (Ref)	1.41 (1.39, 1.44)	0 (Ref)	0.85 (0.82, 0.88)
Rate advancement period (years) <sup>a</sup>	0 (Ref)	2.57 (1.08, 4.06)	0 (Ref)	-5.65 (-6.93, -4.37)	0 (Ref)	-1.15 (-2.43, 0.13)
Environmental footprints index (4-16 points) <sup>a</sup>	0 (Ref)	0.92 (0.81, 1.03)	0 (Ref)	-1.11 (-1.20, -1.01)	0 (Ref)	-2.40 (-2.49, -2.31)
Monetary cost (€/day) <sup>a</sup>	0 (Ref)	-1.82 (-1.89, -1.76)	0 (Ref)	1.37 (1.31, 1.43)	0 (Ref)	0.14 (0.08, 0.21)

Adjusted for age, sex and total energy intake. <sup>a</sup>p for trend<0.001. <sup>1</sup>Composite end-point: all-cause mortality, non-fatal cardiovascular disease, non-fatal breast cancer or type 2 diabetes. <sup>b</sup>Additionally adjusted for prevalent CVD, cancer and T2DM. CVD: Cardiovascular Disease. Q<sub>n</sub>= nth quartile of diet adherence. T2DM: Type 2 Diabetes Mellitus.

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**STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology\***  
**Checklist for cohort, case-control, and cross-sectional studies (combined)**

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any pre-specified hypotheses	5
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	5
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-10
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-10
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-10
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	10-11
		(b) Describe any methods used to examine subgroups and interactions	11
		(c) Explain how missing data were addressed	6
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed	

		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	10
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	Online Supplemental material
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	12
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	12
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12
		(b) Report category boundaries when continuous variables were categorized	11-16
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	16
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	18-19
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16-20
Generalisability	21	Discuss the generalisability (external validity) of the study results	18-19
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	21

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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2 **Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE  
3 checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at  
4 <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).  
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