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

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

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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)).

The Mediterranean dietary pattern was the most overall sustainable option, closely followed by the Provegetarian pattern. The least overall sustainable pattern was the Western dietary pattern.

Conclusion: Following plant-based diets, like the Mediterranean or Provegetarian dietary patterns, could be a good option in order to achieve an overall sustainable diet.

Strengths and limitations of this study

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

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.

SUBJETS 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 about the whole study. The protocol was approved by the Research Ethics Committee of the University of Navarra.

Up to March 2014, 22320 participants were recruited (Supplemental Figure 1). Among them, we excluded 2031 who did not answer follow-up questionnaires (retention in the cohort: 90.90%), 404 with total energy intake beyond predefined limits (under percentile 1 or over percentile 99), 1286 with chronic disease as cardiovascular disease (CVD), cancer or type 2 diabetes (T2DM), and 170 who failed to answer 70 or more items of the food frequency questionnaire (FFQ), leaving a total of 18429 participants.

Dietary assessment

Usual diet was recorded using a validated semi-quantitative FFQ completed at baseline with 136 food items.[10-12] 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.[13, 14] Concisely, we adjusted for total energy intake 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). For that, we used the residual method, for men and women separately. 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). At last, we divided the adherence to this dietary pattern into quartiles (Q).

The index proposed by Trichopoulou and colleagues [15] 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 lipids to saturated ones 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 the median were assigned a value of 1. On the other way around, consumption below the median was assigned 1 point assessing a priori detrimental items (meat and meat products, and fatty dairy products) and the consumption at or above the median was valued as 0. Consumption of ethanol between 10 to 50 g/day or 5 to 25g/day, for men and women, respectively, were given one point. The total index score ranged from 0 to 9 points (minimal to maximal adherence to MeD). Finally, we divided the adherence to this diet into roughly quartiles.

We used Principal Component Analysis in order to establish a WDP in our cohort, because there is no specific a priori definition of the WDP. Food products were grouped into 30 categories, as described by Lopez et al (2009).[16] We excluded those food groups that their measure of sampling adequacy was lower than 0.65. Food groups that loaded >0.30 were considered to be making a contribution to the factor. The factor score for the diet was constructed by summing observed consumptions of the component food items weighted by their factor loadings. Thus, each individual received a factor score for each identified pattern.[17] The major dietary pattern factor identified was labelled as the WDP, which included fast food, fatty dairy products, red and processed meat, potatoes, industrial bakery, sauces, precooked foods and sugar-sweetened soft drinks (Supplemental Table 1). Participants were also categorized into quartiles according to their adherence to the WDP.

Assessment of Other Variables

The baseline questionnaire also included sociodemographic, lifestyle and medical history questions. Self-reported data, such as physical activity (total Metabolic Equivalent of Tasks (MET) per hour per week), body mass index (BMI) and hypertension, have been previously validated.[18-20]

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).[21, 22] 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. 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 spend in sedentary activities, prevalent hypertension, prevalent hypercholesterolemia and total energy intake were used to calculate point estimates of 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. 95% Confidence Interval (95%CI) for RAP were calculated by using variance and covariance estimates from regression coefficients.[21]

Environmental footprints

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

Price

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

Overall sustainable diet index

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

Statistical analyses

Linear Regression Models were used to assess the relationship between quartiles of adherence to each dietary pattern and overall sustainable diet index, and each of the three components separately (RAP, environmental footprints index and price). We estimated means and their 95%CI using analyses of covariance for each quartile, adjusting for age, sex and total energy intake. Moreover, we analyzed differences in mean values and their 95%CI of each dietary pattern quartile *versus* the lowest quartile, as the reference. Linear trends across different quartiles were conducted by assigning the medians to each quartile; this variable was treated as continuous.

We conducted sensitivity analyses refitting the models under different assumptions to assess the robustness of our results: excluding participants who had any of the outcomes gathered in the health composite end-point in the first 2 years of follow-up; including participants with prevalent CVD, cancer or T2DM at baseline (in this case, the model was additionally adjusted for prevalent CVD, cancer and T2DM at baseline); and excluding participants with total energy intake beyond predefined limits (<800 Kcal/day and <500 Kcal/day or >4000 Kcal/day and >3500 Kcal/day in men and women, respectively).

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

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).

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 and having less advance 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 less consumed for those who reported the highest pVD adherence. Fats, specially saturated fatty acids, were more popular for those in 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)[a]						
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)
Fast food[1]	0.1 (0.1)	0.3 (0.3)	0.3 (0.2)	0.1 (0.1)	0.3 (0.2)	0.1 (0.1)
Beverages	7.8 (3.3)	7.1 (3)	6.8 (3.2)	8.2 (3.4)	7.4 (3.4)	7.5 (3.2)
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)
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)
Other alcoholic 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)
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)
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)
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)
Nutrient intake (% total energy intake/day)						
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/day)[a]	37 (13)	23 (10)	21 (7)	40 (13)	23 (9)	37 (13)
Alcohol intake (g/day)[a]	6 (9)	7 (11)	5 (9)	10 (10)	7 (12)	6 (9)
Lifestyle data						
Physical activity (METs-h/week)	29 (25)	27 (25)	23 (21)	33 (28)	26 (23)	29 (26)
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)

[a]Adjusted for energy intake through the residual method.[1]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]

Comparing people in Q4 of these dietary patterns, the most overall sustainable pattern was the MeD, followed closely by the pVD. Taking into account health repercussion, after a median follow-up of 10.1 years, and 469 incident cases of the composite end-point, the healthiest dietary pattern was the MeD because the hazard of developing the end-point was postponed more than 3 years. Assessing the diet of subjects on the pVD and WDP, they had a retardation and advancement of the end-point respectively, although the lack of statistical significance. Regarding environmental footprints, the pVD seemed to be the eco-friendliest option, follow of those of the MeD. On average participants in Q4 of the MeD expended the highest amount of economic resources, while the food of participants in Q4 of the WDP was the most affordable.

Adjusted relative mean differences are shown in Figure 2, and specific values are presented in Supplemental table 3. In all the analyses, there was a statistical linear trend across quartiles ($p<0.001$).

[insert Figure 2]

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

DISCUSSION

The current study showed that the Mediterranean dietary pattern was the healthiest option, with relatively low environmental footprints. However, its price was the highest. The

Provegetarian dietary pattern was the eco-friendliest pattern, at the same time that relatively healthy and affordable. The Western dietary pattern was the less recommended pattern according to health and ecosystems consequences, but it was the most affordable food pattern. Taking into account health, environment and price as a whole, MeD and pVD would be sustainable dietary patterns. Adherence to a WDP seemed to have the opposite result.

Healthy diets have protective effects against diseases like cardiovascular, cancer, T2DM or even all-cause mortality.[25] We observed that the conformity to the MeD was the healthiest option, followed closely by the pVD. The high quality of the MeD and other pVD has been numerous times reported.[13, 26] Their benefits have been attributed to the high consumption of plant-origin foods and the low consumption of animal-based foods [25].In fact, the MeD could be considered as a special case of a pVD. MeD specifically suggests the consumption of nuts, olive oil or fish, which have reported health benefits.[1, 27] We have not assessed a "pure" Vegetarian/Vegan diet because the proportion of participants who followed these patterns was very low in our cohort. pVD is only a gentle and moderate approach. On the other hand, our results related to the WDP and its detrimental health repercussion are in agreement with previous publications.[28]

Previous research supports that a population shift to a more plant and less animal-rich diet, like the pVD or the MeD, may be positive for the environment.[7, 29-31] Conformity to the MeD, and especially to the pVD, implicated a reduction on environment footprints. The higher impact of the MeD than the pVD could be due to fish consumption, because of the great amount of energy used for fish production. It is necessary to reinforce fish consumption from sustainable sources, and in the case of wild caught fish to prevent overfishing.

It has been suggested a direct linear relationship between diet adequacy and cost of a dietary pattern.[32-34] A recent meta-analysis reported an average increment of 1.48$/day if a healthy diet is followed.[33] In our cohort, those with the highest *versus* the lowest adherence to the healthiest pattern, the MeD, spent a mean of 1.42€/day more in their daily diet. Again, fish consumption could be the main reason of the increasing price in parallel with the MeD adherence.[16, 34]

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

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

CONCLUSION

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

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Conflicts of Interest: The authors declare no conflicts of interest.

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Author Contributions: Conception and design: U.F., M.-A.M.-G. and M.B.-R. Acquisition, analysis and interpretation of data: U.F., M.-A.M.-G. and M.B.-R. Drafting of the manuscript: U.F. Critical revision of the manuscript for important intellectual content: J.S., M.-A.M.-G. and M.B.-R. Statistical analysis: U.F. Supervision: M.B.-R.

Data sharing statement: No additional data are available.

Ethics approval: The protocol was approved by the Research Ethics Committee of the 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.

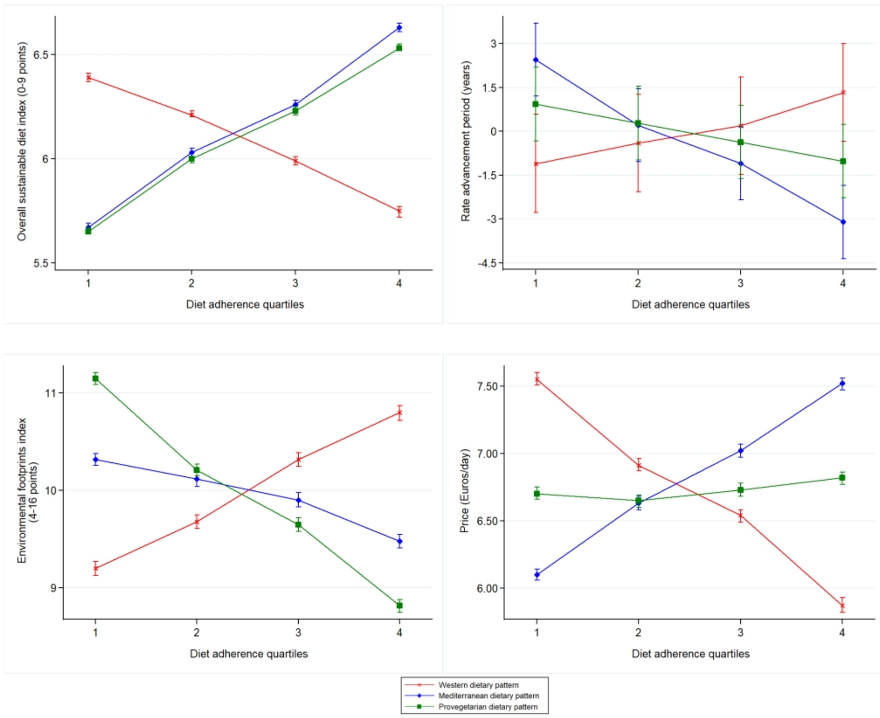

Figure 1. Adjusted means and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Price, according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence. Adjusted for age, sex and total energy intake. Red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

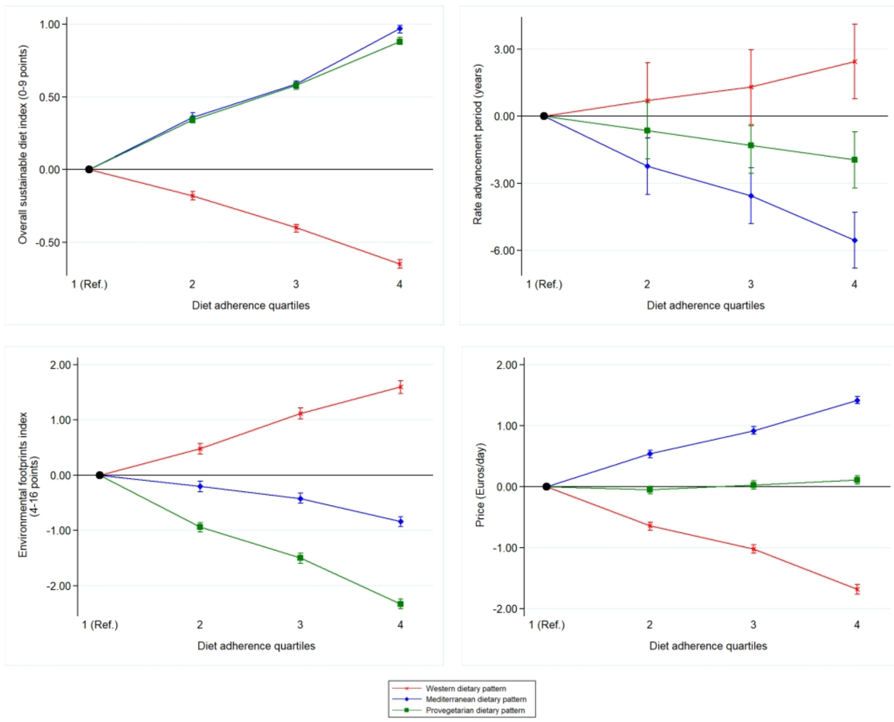

Figure 2. Adjusted relative means differences and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Price, according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence, taking as the reference category 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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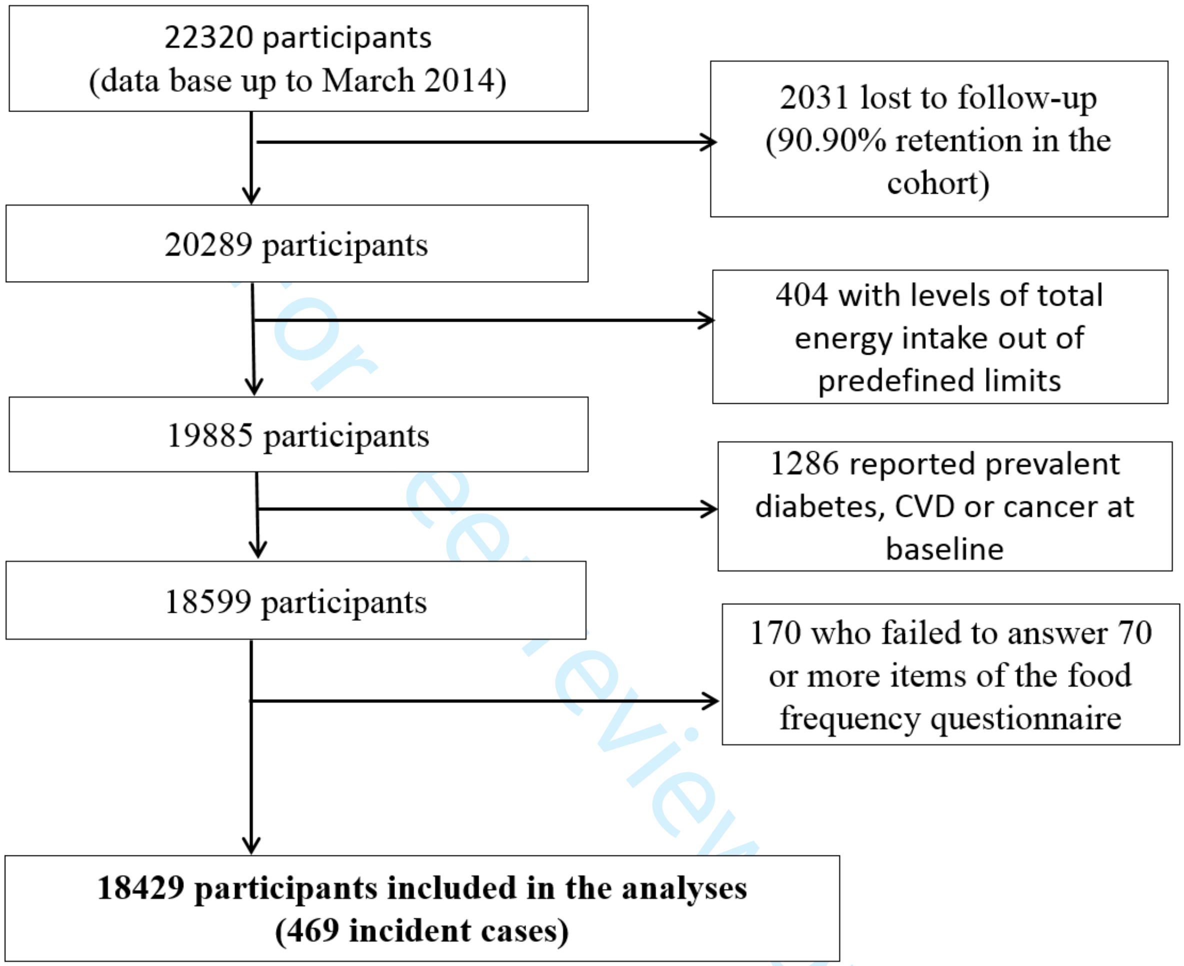
Supplemental Figure 1. Flow chart of the study participants in the Seguimiento Universidad de Navarra (SUN) Project 1999–2016.



CVD: cardiovascular disease

Supplemental Table 1. Principal Component Analysis loadings >0.3 for Western dietary pattern.

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. 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.

	Western dietary pattern			
	Q1	**Q2**	**Q3**	**Q4**
N (frequency)	4608	4607	4607	4607
Cases/person-years	151/43804	117/45688	104/46749	97/49219
Overall sustainable diet index (0-9 points)[a]	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)[a]	-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)[a]	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)[a]	7.55 (7.51, 7.60)	6.91 (6.87, 6.96)	6.54 (6.49, 6.58)	5.87 (5.82, 5.93)
	Mediterranean dietary pattern			
	Q1	**Q2**	**Q3**	**Q4**
N (frequency)	6802	3796	3400	4431
Cases/person-years	149/70310	100/38942	99/33695	121/42512

Overall sustainable diet index (0-9 points)[a]	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)[a]	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)[a]	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)[a]	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)[a]	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)[a]	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)[a]	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)[a]	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. [a]p for trend<0.001. Qn= nth quartile of diet adherence.

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.

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

Overall sustainable diet index (0-9 points)[a]	0 (Ref)	0.36 (0.34, 0.39)	0.59 (0.56, 0.61)	0.97 (0.94, 0.99)
Rate advancement period (years)[a]	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)[a]	0 (Ref)	-0.20 (-0.30, -0.11)	-0.42 (-0.51, -0.32)	-0.84 (-0.93, -0.75)
Price (€/day)[a]	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)[a]	0 (Ref)	0.34 (0.32, 0.37)	0.58 (0.55, 0.60)	0.88 (0.86, 0.91)
Rate advancement period (years)[a]	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)[a]	0 (Ref)	-0.94 (-1.03, -0.86)	-1.50 (-1.60, -1.41)	-2.33 (-2.42, -2.24)
Price (€/day)[a]	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. [a]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**
Overall						
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)[a]	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)[a]	-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)[a]	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)[a]	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)
Excluding participants who had the health composite end-point[1] in the first 2 years						
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)[a]	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)[a]	-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)[a]	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)[a]	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)
Including people with prevalent CVD, cancer and T2DM[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)[a]	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)[a]	-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)[a]	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)[a]	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)
Excluding participants with total energy intake beyond predefined limits (<800 Kcal/day and <500 Kcal/day or >4000 Kcal/day and >3500 Kcal/day in men and women, respectively)						
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)[a]	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)[a]	-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)[a]	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)[a]	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. [a]p for trend<0.001.[1]Composite end-point: all-cause mortality, non-fatal cardiovascular disease, non-fatal breast cancer or type 2 diabetes. [b]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**
Overall						
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)[a]	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)[a]	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)[a]	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)[a]	0 (Ref)	-1.68 (-1.76, -1.60)	0 (Ref)	1.42 (1.36, 1.48)	0 (Ref)	0.11 (0.04, 0.18)
Excluding participants who have the health composite end-point[1] in the first 2 years						
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)[a]	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)[a]	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)[a]	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)[a]	0 (Ref)	-1.69 (-1.77, -1.61)	0 (Ref)	1.42 (1.36, 1.48)	0 (Ref)	0.11 (0.04, 0.18)
Including people with prevalent CVD, cancer and T2DM[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)[a]	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)[a]	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)[a]	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)[a]	0 (Ref)	-1.68 (-1.76, -1.61)	0 (Ref)	1.41 (1.35, 1.47)	0 (Ref)	0.13 (0.06, 0.19)
Excluding participants with total energy intake beyond predefined limits ((<800 Kcal/day and <500 Kcal/day or >4000 Kcal/day and >3500 Kcal/day in men and women, respectively)						
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)[a]	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)[a]	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)[a]	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)[a]	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. [a]p for trend<0.001. [1]Composite end-point: all-cause mortality, non-fatal cardiovascular disease, non-fatal breast cancer or type 2 diabetes. [b]Additionally adjusted for prevalent CVD, cancer and T2DM. CVD: Cardiovascular Disease. Qn= nth quartile of diet adherence. T2DM: Type 2 Diabetes Mellitus.

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
Introduction			
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
Methods			
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*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—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 *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	4-5
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—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*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	9-10
Results			
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) *Cohort study*—Summarise follow-up time (eg, average and total amount)	13
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	13
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—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
Discussion			
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
Other information			
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.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE 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 http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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

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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, 7.56)). The Mediterranean dietary pattern was the most overall sustainable option, closely followed by the Provegetarian pattern. The least overall sustainable pattern was the Western dietary pattern.

Conclusion: Following plant-based diets, like the Mediterranean or Provegetarian dietary patterns, could be a good option in order to achieve an overall sustainable diet.

Strengths and limitations of this study

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

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]

Taste and retail prices are important factors for food choices. [16, 17] However, following a cheaper diet could result in health problems for the consumer due to the decrease in nutritional quality. This may finally lead to an increment in the global societal cost. [16, 18]

Previous investigations have assessed health, environment, and monetary cost, separately. However, few studies have focused on these different dietary aspects at the same time. [19] For this reason, we have assessed the association between the adherence to three different dietary patterns (WDP, MeD and provegetarian dietary pattern –pVD-) and their repercussions on the three aspects separately and all together.

SUBJETS 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.[20] 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 about the whole study. The protocol was approved by the Research Ethics Committee of the University of Navarra. The SUN cohort is registered at clinicaltrials.gov as the number NCT02669602.

Up to March 2014, 22320 participants were recruited (Supplemental Figure 1). Among them, we excluded 2031 who did not answer any follow-up questionnaires (retention in the cohort: 90.90%), 404 with total energy intake beyond predefined limits (under percentile 1 or over percentile 99), 1286 with chronic disease as cardiovascular disease (CVD), cancer or type 2 diabetes (T2DM), and 170 who failed to answer 70 or more items of the food frequency questionnaire (FFQ), leaving a total of 18429 participants.

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

We used Principal Component Analysis in order to establish a WDP in our cohort, because there is no specific a priori definition of the WDP. Food products were grouped into 30 categories, as described by Lopez et al (2009).[26] We excluded those food groups whose measure of sampling adequacy was lower than 0.65. Food groups that loaded >0.30 were considered to be making a contribution to the factor. The factor score for the diet was constructed by summing observed consumptions of the component food items weighted by their factor loadings. Thus, each individual received a factor score for each identified pattern.[27] The major dietary pattern factor identified was labelled as the WDP, which included fast food, fatty dairy products, red and processed meat, potatoes, industrial bakery, sauces, precooked foods and sugar-sweetened soft drinks (Supplemental Table 1). Participants were also categorized into quartiles according to their adherence to the WDP.

Assessment of Other Variables

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

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

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

Monetary cost

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

Overall sustainable diet index

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

Statistical analyses

Linear Regression Models were used to assess the relationship between quartiles of adherence to each dietary pattern and overall sustainable diet index, and each of the three components separately (RAP, environmental footprints index and monetary costs). We estimated means and their 95%CI using analyses of covariance for each quartile, adjusting for age, sex and total energy intake. Moreover, we analyzed differences in mean values and their 95% CI for each of the three upper quartiles of the respective dietary pattern using the lowest quartile as the reference category. Linear trends across different quartiles were conducted by assigning the medians to each quartile; this variable was treated as continuous.

We conducted sensitivity analyses refitting the models under different assumptions to assess the robustness of our results: excluding participants who had any of the outcomes gathered in the health composite end-point in the first 2 years of follow-up; including participants with prevalent CVD, cancer or T2DM at baseline (in this case, the model was additionally adjusted for prevalent CVD, cancer and T2DM at baseline); and excluding participants with total energy intake beyond predefined limits (<800 Kcal/day and <500 Kcal/day or >4000 Kcal/day and >3500 Kcal/day in men and women, respectively).

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

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)[a]						
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)

Fast food[1]	0.1 (0.1)	0.3 (0.3)	0.3 (0.2)	0.1 (0.1)	0.3 (0.2)	0.1 (0.1)
Beverages	7.8 (3.3)	7.1 (3)	6.8 (3.2)	8.2 (3.4)	7.4 (3.4)	7.5 (3.2)
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)
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)
Other alcoholic 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)
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)
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)
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)
Nutrient intake (% total energy intake/day)						
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/day)[a]	37 (13)	23 (10)	21 (7)	40 (13)	23 (9)	37 (13)
Alcohol intake (g/day)[a]	6 (9)	7 (11)	5 (9)	10 (10)	7 (12)	6 (9)
Lifestyle data						
Physical activity (METs-h/week)	29 (25)	27 (25)	23 (21)	33 (28)	26 (23)	29 (26)
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)

[a]Adjusted for energy intake through the residual method.[1]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 the hazard of developing the end-point was postponed for more than 3 years when comparing the upper versus the lowest quartile. Assessing the diet of subjects on the pVD and WDP, we noticed a retardation and an advancement of the end-point, respectively, although both lacked statistical significance. Regarding environmental footprints, the pVD seemed to be the most eco-friendliest option, followed by the MeD. On average participants in the upper quartile of the MeD spent the highest amount of economic resources, while the upper quartile of the WDP included the most relatively affordable foods.

Adjusted relative mean differences are shown in Figure 2, and specific values are presented in Supplemental table 4. In all analyses, there was a statistical linear trend across quartiles ($p<0.001$).

[insert Figure 2]

The main results were consistent in all our sensitivity analyses (Supplemental Table 5 and Supplemental Table 6). Only including those participants who reported a prevalent chronic disease, a higher adherence to the pVD presented a higher overall sustainable diet index than higher adherence to the MeD. However, differences between these two dietary patterns were not statistically significant. We did not observe any statistically significant interaction between the dietary patterns and sex, BMI, age or physical activity (data not shown).

DISCUSSION

The current study showed the Mediterranean dietary pattern as the healthiest option, with relatively low environmental footprints. However, its monetary costs were the highest. The Provegetarian dietary pattern was the most eco-friendliest pattern, relatively healthy and affordable. The Western dietary pattern was the least recommended pattern according to health criteria and ecosystems consequences, but it was the most affordable food pattern. Considering in conjunction health, environment and monetary costs, the MeD and the pVD would be sustainable dietary patterns, while the WDP would not be a sustainable dietary pattern.

Healthy diets are inversely associated with the risk of diseases like CVD, cancer, T2DM and also all-cause mortality.[35] We observed that better conformity to the MeD was the healthiest option, followed closely by the pVD. The high quality of the MeD and other pVD has been reported previously.[3, 4] Their benefits have been attributed to the high consumption of plant-origin foods and the low consumption of animal-based foods. [35] In fact, the MeD could be considered as a special case of a pVD. The similarity of these two patterns can be appreciated in the recommendations of high intakes of fruit, vegetables, beans, cereals, nuts, and seeds. Olive oil as the main source of fat, moderate to high consumption of fish and other seafood, moderate amounts of red wine with meals as the main source of alcohol, and a low intake of meat and dairy products is what specifically defines MeD compared to a general pVD. Indeed, the specific suggestion in the MeD of the consumption of olive oil or fish, could be one of the reasons why this diet achieved more health benefits.[2, 36] We have not assessed a "pure" Vegetarian/Vegan diet because the proportion of participants who followed these patterns was very low in our cohort. pVD is only a gentle and moderate approach. On the other hand, our results related to the WDP and its detrimental health repercussion are in agreement with previous publications.[37]

Previous research supports that a population shift to a more plant and less animal-rich diet, like the pVD or the MeD, may be positive for the environment.[8-10, 12-14, 38] Conformity to the MeD, and especially to the pVD, implicated a reduction on environmental footprints. The higher impact of the MeD than the pVD could be due to fish consumption, because of the great amount of energy used for fish production that for fruits, vegetables and other plant-derived foods. It is necessary to reinforce fish consumption from sustainable sources, and in the case of wild caught fish to prevent overfishing.

A direct linear relationship between nutritional adequacy and the monetary costs of a dietary pattern has been suggested.[39-41] A recent meta-analysis reported an average increment of 1.48$/day if a healthy diet is followed.[40] In our cohort, those participants with the highest adherence to the healthiest pattern, the MeD, spent a mean of 1.42€/day more in their daily diet that those with the poorest adherence to the MeD. Again, fish consumption could be the main reason for the monotonically increasing monetary costs in parallel with better MeD adherence.[26, 41] However, it should be noticed that we only took into account the amount of money that people spent to buy their foods. The relevance of this item as part of an overall sustainability index could be discussed. It has been suggested that a full societal cost of diet (i.e. health care expenditures and loss of productivity) should be addressed when assessing sustainability evaluation. [42] Indeed, a recent publication concluded that moving towards plant-based dietary patterns, and specifically the MeD, could save huge amounts of money when the assessment is done from a full societal perspective taking into account all the costs. [43] We reran our analyses assessing the overall sustainability of the three dietary patterns without the cost item, and the main results supported the higher benefits associated with following plant-based diets, in particular the MeD (data non-shown).

We observed only a modest magnitude for the differences between the extreme quartiles on the overall sustainable diet index (Supplemental table 2). This limitation could be due to the method used to construct the overall index according to quartiles of the three dimensions evaluated. This might explain why some of the differences according to dietary patterns were not well captured. In fact, although in the overall sustainability index, the health-related and environmental items seem to have been considered appropriately, their contribution is only qualitative, as their differences between the first and the fourth quartiles are small. This fact may limit the interpretability of the impacts reported here. There would potentially be much greater differences with the inclusion of the true global costs from a societal perspective of the food patterns. Some other limitations of our study include self-reported information, and the difficulties to generalize our results to other populations, given that the sample is not representative of the general Spanish population (young cohort composed only by university graduates). However, the advantages of using a socially homogenous and well-educated cohort overcome this limitation because this approach removes part of the residual confounding and ensures a higher quality of the self-reported information. We assumed that foods were prepared and eaten at home, and this approximation may underestimate the effect of the diet. The three dietary patterns were assessed by 3 different methods. Assessing the adherence to the diets using different cut-offs could give different results. The relevance of the RAP metric for health outcomes in a young people cohort could be questioned. It would be interesting to assess in the future the impact on health using other criteria; for instance, quality-adjusted life-years, which is another common measure used to value health gains. The environmental footprints index does not contemplate other phases of the food chain apart from production and processing. However, production is the most contributive aspect by far.[44, 45]

Some of the strengths of the current study include the simultaneous assessment of the three dimensions of an overall sustainable diet (health, environment and monetary costs). This represents a novelty of our study. We used a wide range of scores for food consumption in a large sample size through a validated questionnaire. We focused on GHG emission and efficiency in using natural resources when assessing the environmental footprints, which is a more holistic approach.

CONCLUSION

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

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Data sharing statement: No additional data are available.

Ethics approval: The protocol was approved by the Research Ethics Committee of the 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 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.

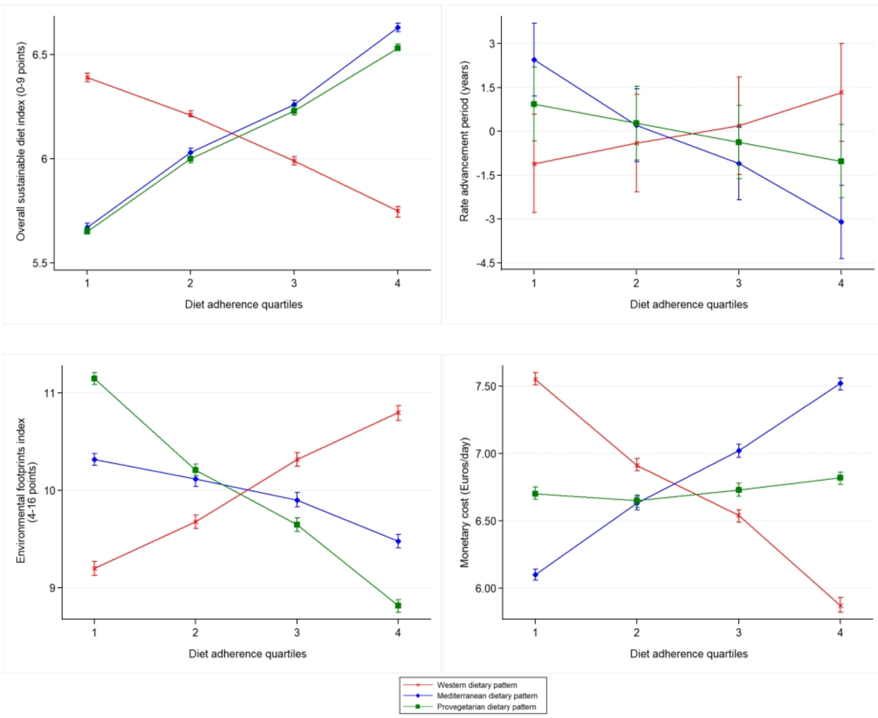
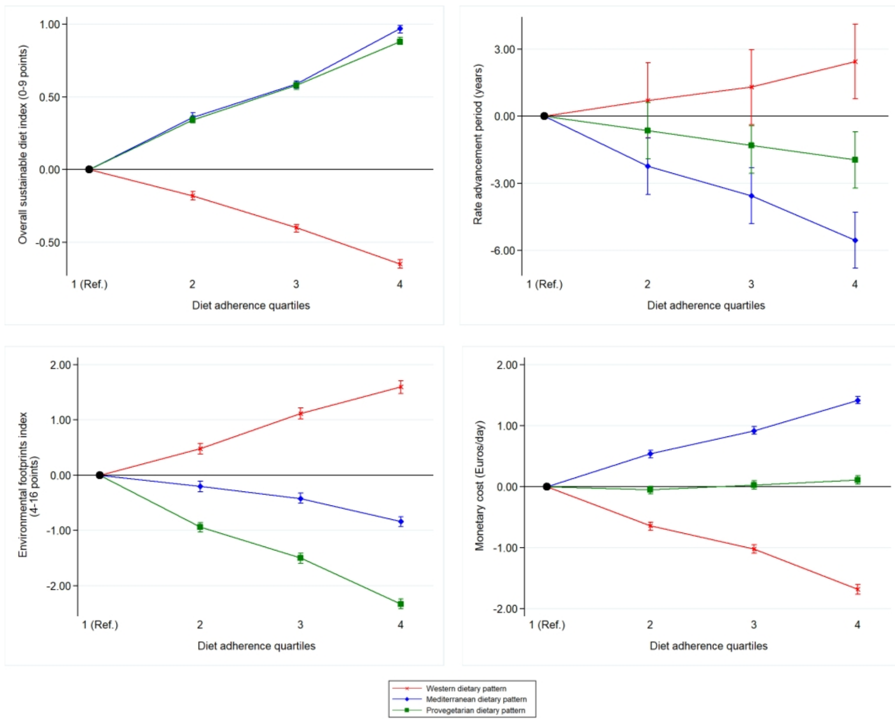


Figure 1. Adjusted means and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Monetary cost, according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence. Adjusted for age, sex and total energy intake.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

199x150mm (300 x 300 DPI)



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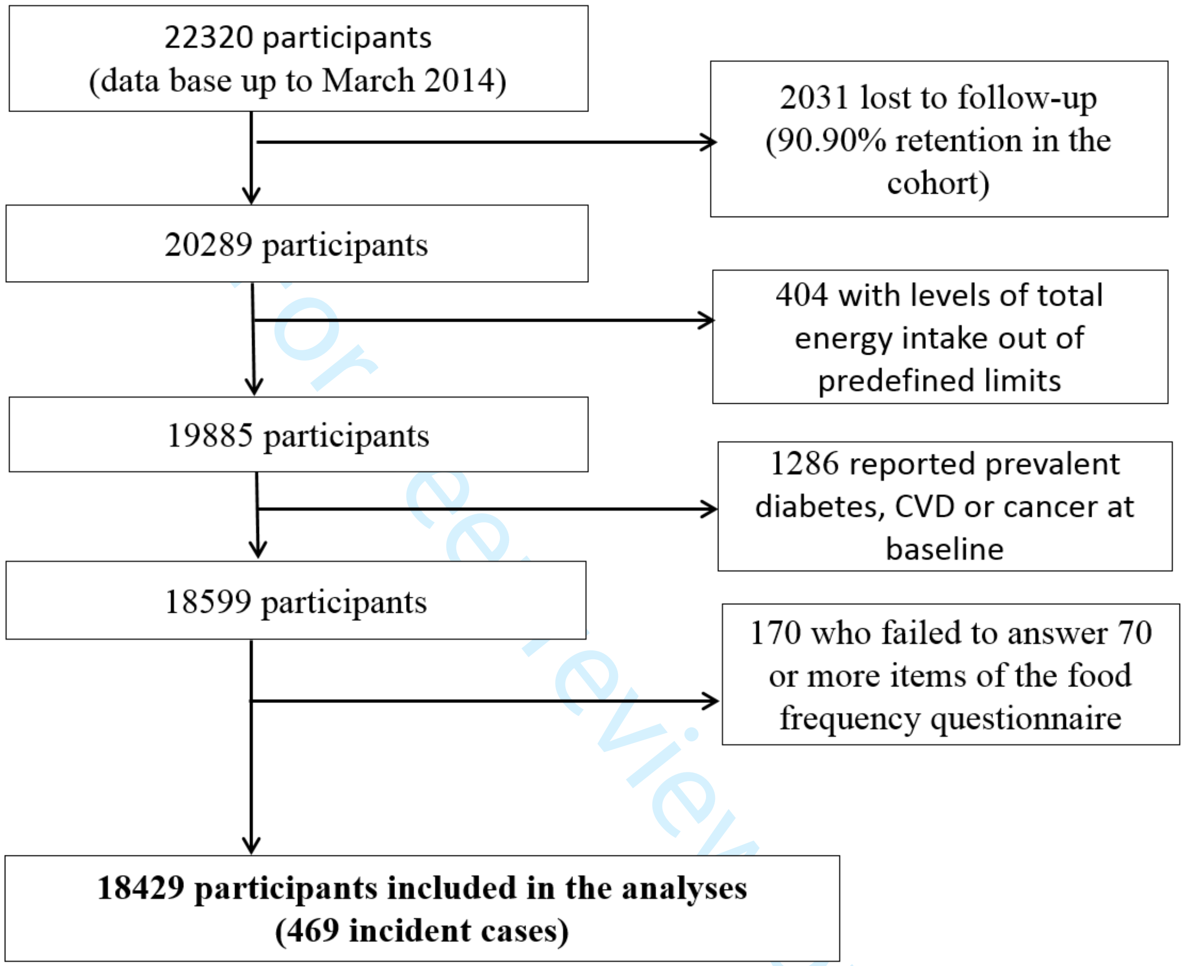
Supplemental Figure 1. Flow chart of the study participants in the Seguimiento Universidad de Navarra (SUN) Project 1999–2016.



CVD: cardiovascular disease

Supplemental Table 1. Principal Component Analysis loadings >0.3 for Western dietary pattern.

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.

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

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

[a]The endpoint is total mortality

[b]The endpoint is non-fatal cardiovascular disease

[c]The endpoint is non-fatal breast cancer

[a]The endpoint is type 2 diabetes

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.

	Western dietary pattern			
	Q1	Q2	Q3	Q4
N (frequency)	4608	4607	4607	4607
Cases/person-years	151/43804	117/45688	104/46749	97/49219
Overall sustainable diet index (0-9 points)[a]	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)[a]	-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)[a]	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)[a]	7.55 (7.51, 7.60)	6.91 (6.87, 6.96)	6.54 (6.49, 6.58)	5.87 (5.82, 5.93)
	Mediterranean dietary pattern			
	Q1	**Q2**	**Q3**	**Q4**
N (frequency)	6802	3796	3400	4431
Cases/person-years	149/70310	100/38942	99/33695	121/42512
Overall sustainable diet index (0-9 points)[a]	5.67 (5.66, 5.69)	6.03 (6.01, 6.05)	6.26 (6.24, 6.28)	6.64 (6.62, 6.66)

	Q1	Q2	Q3	Q4
Rate advancement period (years)[a]	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)[a]	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)[a]	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)[a]	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)[a]	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)[a]	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)[a]	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. [a]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.

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

Overall sustainable diet index (0-9 points)[a]	0 (Ref)	0.36 (0.34, 0.39)	0.59 (0.56, 0.61)	0.97 (0.94, 0.99)
Rate advancement period (years)[a]	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)[a]	0 (Ref)	-0.20 (-0.30, -0.11)	-0.42 (-0.51, -0.32)	-0.84 (-0.93, -0.75)
Monetary cost (€/day)[a]	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)[a]	0 (Ref)	0.34 (0.32, 0.37)	0.58 (0.55, 0.60)	0.88 (0.86, 0.91)
Rate advancement period (years)[a]	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)[a]	0 (Ref)	-0.94 (-1.03, -0.86)	-1.50 (-1.60, -1.41)	-2.33 (-2.42, -2.24)
Monetary cost (€/day)[a]	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. [a]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**
Overall						
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)[a]	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)[a]	-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)[a]	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)[a]	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)
Excluding participants who had the health composite end-point[1] in the first 2 years						
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)[a]	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)[a]	-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)[a]	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)[a]	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)
Including people with prevalent CVD, cancer and T2DM[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)[a]	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)[a]	-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)[a]	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)[a]	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)
Excluding participants with total energy intake beyond predefined limits (<800 Kcal/day and <500 Kcal/day or >4000 Kcal/day and >3500 Kcal/day in men and women, respectively)						
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)[a]	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)[a]	-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)[a]	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)[a]	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. [a]p for trend<0.001.[1]Composite end-point: all-cause mortality, non-fatal cardiovascular disease, non-fatal breast cancer or type 2 diabetes. [b]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**
Overall						
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)[a]	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)[a]	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)[a]	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)[a]	0 (Ref)	-1.68 (-1.76, -1.60)	0 (Ref)	1.42 (1.36, 1.48)	0 (Ref)	0.11 (0.04, 0.18)
Excluding participants who have the health composite end-point[1] in the first 2 years						
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)[a]	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)[a]	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)[a]	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)[a]	0 (Ref)	-1.69 (-1.77, -1.61)	0 (Ref)	1.42 (1.36, 1.48)	0 (Ref)	0.11 (0.04, 0.18)
Including people with prevalent CVD, cancer and T2DM[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)[a]	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)[a]	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)[a]	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)[a]	0 (Ref)	-1.68 (-1.76, -1.61)	0 (Ref)	1.41 (1.35, 1.47)	0 (Ref)	0.13 (0.06, 0.19)
Excluding participants with total energy intake beyond predefined limits ((<800 Kcal/day and <500 Kcal/day or >4000 Kcal/day and >3500 Kcal/day in men and women, respectively)						
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)[a]	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)[a]	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)[a]	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)[a]	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. [a]p for trend<0.001. [1]Composite end-point: all-cause mortality, non-fatal cardiovascular disease, non-fatal breast cancer or type 2 diabetes. [b]Additionally adjusted for prevalent CVD, cancer and T2DM. CVD: Cardiovascular Disease. Qn= nth quartile of diet adherence. T2DM: Type 2 Diabetes Mellitus.

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
Introduction			
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
Methods			
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*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—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 *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—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*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	10
Results			
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) *Cohort study*—Summarise follow-up time (eg, average and total amount)	13
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	13
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—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
Discussion			
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
Other information			
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.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE 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 http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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

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

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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, 7.56)). The Mediterranean dietary pattern was the most overall sustainable option, closely followed by the Provegetarian pattern. The least overall sustainable pattern was the Western dietary pattern.

Conclusion: Following plant-based diets, like the Mediterranean or Provegetarian dietary patterns, could be a good option in order to achieve an overall sustainable diet.

Strengths and limitations of this study

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

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]

Taste and retail prices are important factors for food choices. [16, 17] However, following a cheaper diet could result in health problems for the consumer due to the decrease in nutritional quality. This may finally lead to an increment in the global societal cost. [16, 18]

Previous investigations have assessed health, environment, and monetary cost, separately. However, few studies have focused on these different dietary aspects at the same time. [19, 20] For this reason, we have assessed the association between the adherence to three different dietary patterns (WDP, MeD and provegetarian dietary pattern –pVD-) and their repercussions on the three aspects separately and all together.

SUBJETS 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.[21] 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 about the whole study. The protocol was approved by the Research Ethics Committee of the University of Navarra. The SUN cohort is registered at clinicaltrials.gov as the number NCT02669602.

Up to March 2014, 22320 participants were recruited (Supplemental Figure 1). Among them, we excluded 2031 who did not answer any follow-up questionnaires (retention in the cohort: 90.90%), 404 with total energy intake beyond predefined limits (under percentile 1 or over percentile 99), 1286 with chronic disease as cardiovascular disease (CVD), cancer or type 2 diabetes (T2DM), and 170 who failed to answer 70 or more items of the food frequency questionnaire (FFQ), leaving a total of 18429 participants.

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

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

Assessment of Other Variables

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

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

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

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

Monetary cost

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

Overall sustainable diet index

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

Statistical analyses

Linear Regression Models were used to assess the relationship between quartiles of adherence to each dietary pattern and overall sustainable diet index, and each of the three components separately (RAP, environmental footprints index and monetary costs). We estimated means and their 95%CI using analyses of covariance for each quartile, adjusting for age, sex and total energy intake. Moreover, we analyzed differences in mean values and their 95% CI for each of the three upper quartiles of the respective dietary pattern using the lowest quartile as the reference category. Linear trends across different quartiles were conducted by assigning the medians to each quartile; this variable was treated as continuous.

We conducted sensitivity analyses refitting the models under different assumptions to assess the robustness of our results: excluding participants who had any of the outcomes gathered in the health composite end-point in the first 2 years of follow-up; including participants with prevalent CVD, cancer or T2DM at baseline (in this case, the model was additionally adjusted for prevalent CVD, cancer and T2DM at baseline); and excluding participants with total energy intake beyond predefined limits (<800 Kcal/day and <500 Kcal/day or >4000 Kcal/day and >3500 Kcal/day in men and women, respectively).

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

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.

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 4).

[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 the hazard of developing the end-point was postponed for more than 3 years when comparing the upper versus the lowest quartile. Assessing the diet of subjects on the pVD and WDP, we noticed a retardation and an advancement of the end-point, respectively, although both lacked statistical significance. Regarding environmental footprints, the pVD seemed to be the most eco-friendliest option, followed by the MeD. On average participants in the upper quartile of the MeD spent the highest amount of economic resources, while the upper quartile of the WDP included the most relatively affordable foods.

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 (g/d)[a]						
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)

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

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)[a]	37 (13)	23 (10)	21 (7)	40 (13)	23 (9)	37 (13)
Alcohol intake (g/d)[a]	6 (9)	7 (11)	5 (9)	10 (10)	7 (12)	6 (9)
Lifestyle data						
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)

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

Adjusted relative mean differences are shown in Figure 2, and specific values are presented in Supplemental table 5. In all analyses, there was a statistical linear trend across quartiles ($p<0.001$).

[insert Figure 2]

The main results were consistent in all our sensitivity analyses (Supplemental Table 6 and Supplemental Table 7). Only including those participants who reported a prevalent chronic disease, a higher adherence to the pVD presented a higher overall sustainable diet index than higher adherence to the MeD. However, differences between these two dietary patterns were not statistically significant. We did not observe any statistically significant interaction between the dietary patterns and sex, BMI, age or physical activity (data not shown).

DISCUSSION

The current study showed the Mediterranean dietary pattern as the healthiest option, with relatively low environmental footprints. However, its monetary costs were the highest. The Provegetarian dietary pattern was the most eco-friendliest pattern, relatively healthy and affordable. The Western dietary pattern was the least recommended pattern according to health criteria and ecosystems consequences, but it was the most affordable food pattern. Considering in conjunction health, environment and monetary costs, the MeD and the pVD would be sustainable dietary patterns, while the WDP would not be a sustainable dietary pattern.

Healthy diets are inversely associated with the risk of diseases like CVD, cancer, T2DM and also all-cause mortality.[36] We observed that better conformity to the MeD was the healthiest option, followed closely by the pVD. The high quality of the MeD and other pVD has been reported previously.[3, 4] Their benefits have been attributed to the high consumption of plant-origin foods and the low consumption of animal-based foods. [36] In fact, the MeD could be considered as a special case of a pVD. The similarity of these two patterns can be appreciated in the recommendations of high intakes of fruit, vegetables, beans, cereals, nuts, and seeds. Olive oil as the main source of fat, moderate to high consumption of fish and other seafood, moderate amounts of red wine with meals as the main source of alcohol, and a low intake of meat and dairy products is what specifically defines MeD compared to a general pVD. Indeed, the specific suggestion in the MeD of the consumption of olive oil or fish, could be one of the reasons why this diet achieved more health benefits.[2, 37] We have not assessed a "pure" Vegetarian/Vegan diet because the proportion of participants who followed these patterns was very low in our cohort. pVD is only a gentle and moderate approach. On the other hand, our results related to the WDP and its detrimental health repercussion are in agreement with previous publications.[38]

Previous research supports that a population shift to a more plant and less animal-rich diet, like the pVD or the MeD, may be positive for the environment.[8-10, 12-14, 39] Conformity to the MeD, and especially to the pVD, implicated a reduction on environmental footprints. The higher impact of the MeD than the pVD could be due to fish consumption, because of the great amount of energy used for fish production than for fruits, vegetables and other plant-derived foods. It is necessary to reinforce fish consumption from sustainable sources, and in the case of wild caught fish to prevent overfishing.

A direct linear relationship between nutritional adequacy and the monetary costs of a dietary pattern has been suggested.[40-42] A recent meta-analysis reported an average increment of 1.48$/day if a healthy diet is followed.[41] In our cohort, those participants with the highest adherence to the healthiest pattern, the MeD, spent a mean of 1.42€/day more in their daily diet that those with the poorest adherence to the MeD. Again, fish consumption could be the main reason for the monotonically increasing monetary costs in parallel with better MeD adherence.[27, 42] However, it should be noticed that we only took into account the amount of money that people spent to buy their foods. The relevance of this item as part of an overall sustainability index could be discussed. It has been suggested that a full societal cost of diet (i.e. health care expenditures and loss of productivity) should be addressed when assessing sustainability evaluation. [43] Indeed, a recent publication concluded that moving towards plant-based dietary patterns, and specifically the MeD, could save huge amounts of money when the assessment is done from a full societal perspective taking into account all the costs. [44] We reran our analyses assessing the overall sustainability of the three dietary patterns without the cost item, and the main results supported the higher benefits associated with following plant-based diets, in particular the MeD (data non-shown).

We observed only a modest magnitude for the differences between the extreme quartiles on the overall sustainable diet index (Supplemental table 2). This limitation could be due to the method used to construct the overall index according to quartiles of the three dimensions evaluated. This might explain why some of the differences according to dietary patterns were not well captured. In fact, although in the overall sustainability index, the health-related and environmental items seem to have been considered appropriately, their contribution is only qualitative, as their differences between the first and the fourth quartiles are small. This fact may limit the interpretability of the impacts reported here. There would potentially be much greater differences with the inclusion of the true global costs from a societal perspective of the food patterns. Some other limitations of our study include self-reported information, and the difficulties to generalize our results to other populations, given that the sample is not representative of the general Spanish population (cohort composed only by university graduates). However, the advantages of using a socially homogenous and well-educated cohort overcome this limitation because this approach removes part of the residual confounding and ensures a higher quality of the self-reported information. Another potential limitation for the external validity of our results is the relatively young age of our cohort, that we acknowledge. The interquartile range for age was 27 to 45. Only 1.53 percent of participants in the cohort were older than 65 years at baseline. The percentage of women older than 65 years at baseline was especially low (0.5 percent). These limitations highlight the need for replication of our findings in other independent cohort with older age at baseline. We assumed that foods were prepared and eaten at home, and this approximation may underestimate the effect of the diet. The three dietary patterns were assessed by 3 different methods. Assessing the adherence to the diets using different cut-offs could give different results. The relevance of the RAP metric for health outcomes in a young people cohort could be questioned. It would be interesting to assess in the future the impact on health using other criteria; for instance, quality-adjusted life-years, which is another common measure used to value health gains. The environmental footprints index does not contemplate other phases of the food chain apart from production and processing. However, production is the most contributive aspect by far.[45, 46]

Some of the strengths of the current study include the simultaneous assessment of the three dimensions of an overall sustainable diet (health, environment and monetary costs). This represents a novelty of our study. We used a wide range of scores for food consumption in a large sample size through a validated questionnaire. We focused on GHG emission and efficiency in using natural resources when assessing the environmental footprints, which is a more holistic approach.

CONCLUSION

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

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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.

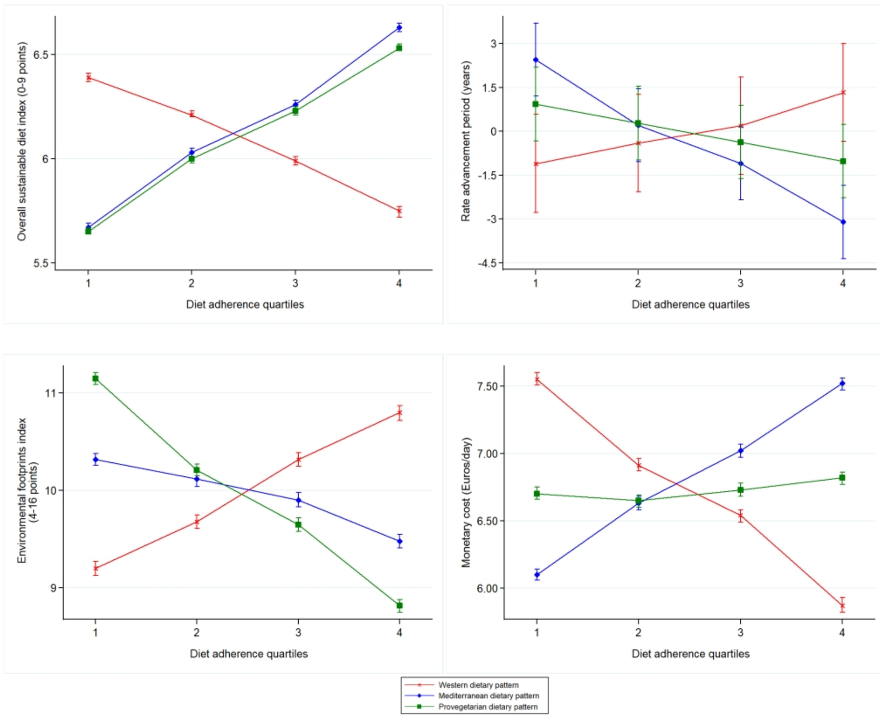

Figure 1. Adjusted means and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Monetary cost, according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence. Adjusted for age, sex and total energy intake.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

199x150mm (300 x 300 DPI)

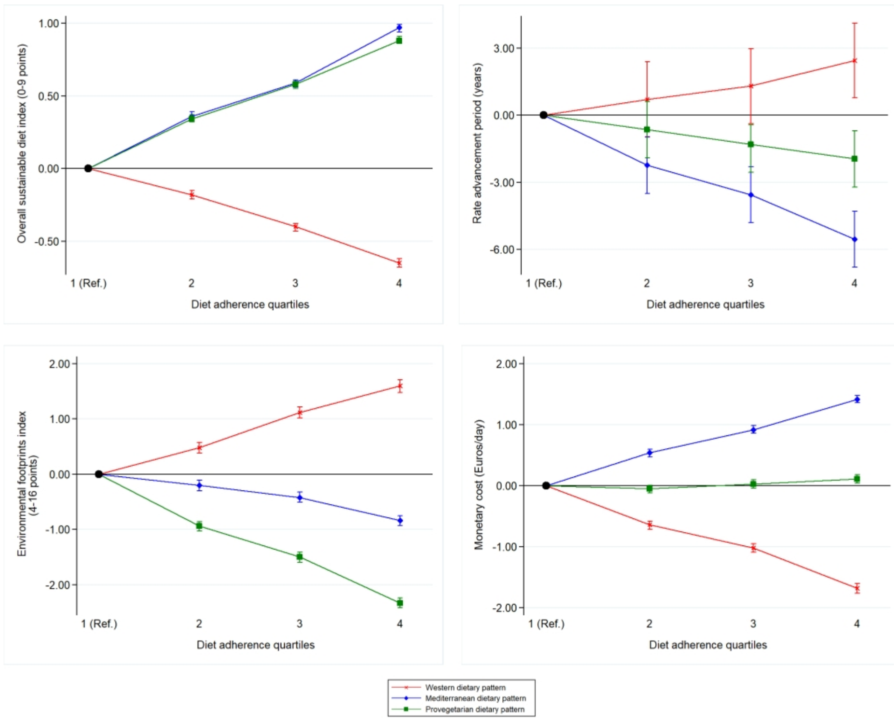

Figure 2. Adjusted relative means differences and 95% Confidence Intervals of Overall sustainable diet index, Rate advancement period, Environmental footprints index and Monetary cost, according to quartiles of Western, Mediterranean and Provegetarian dietary patterns adherence, taking as the reference 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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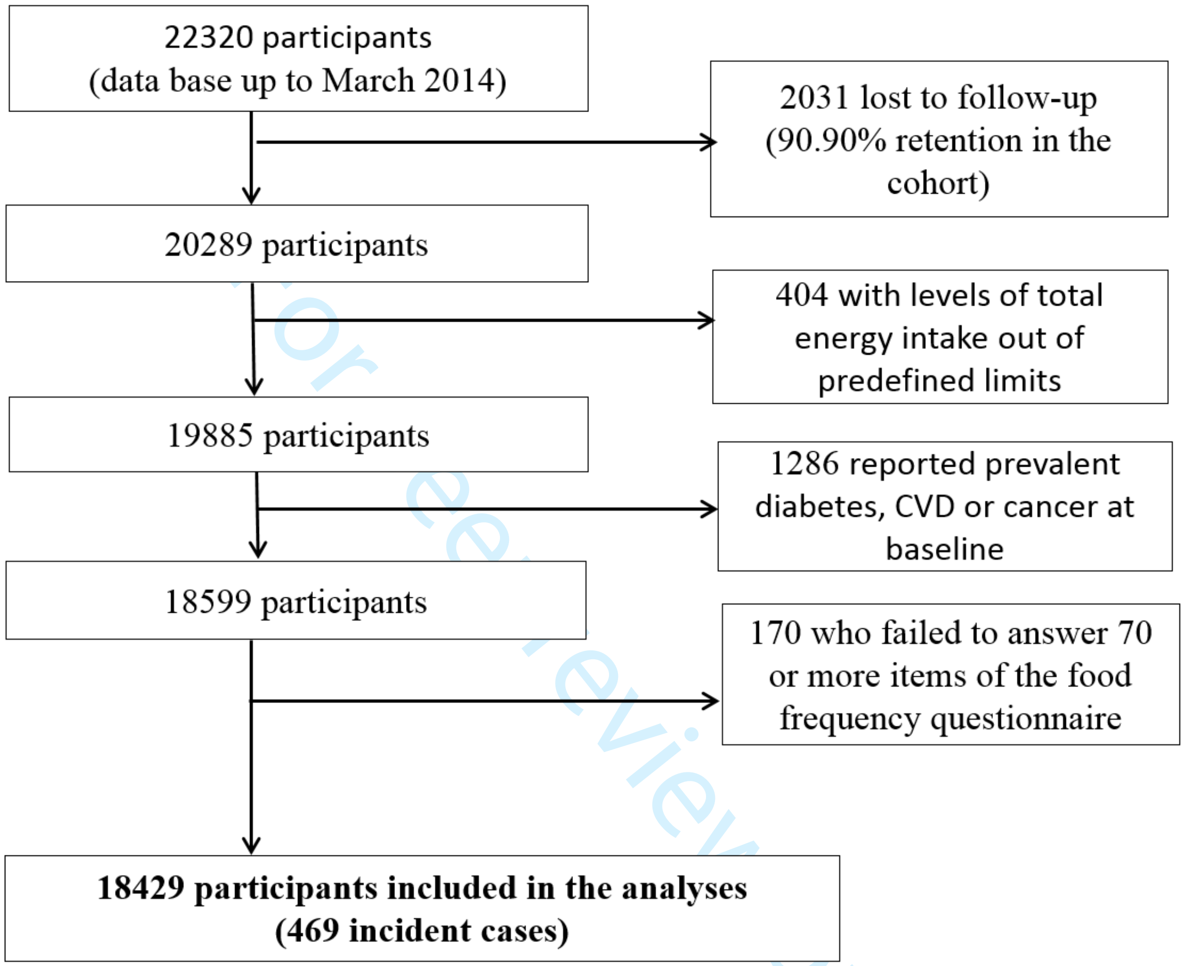
Supplemental Figure 1. Flow chart of the study participants in the Seguimiento Universidad de Navarra (SUN) Project 1999–2016.



CVD: cardiovascular disease

Supplemental Table 1. Principal Component Analysis loadings >0.3 for Western dietary pattern.

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.

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

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

[a]The endpoint is total mortality

[b]The endpoint is non-fatal cardiovascular disease

[c]The endpoint is non-fatal breast cancer

[a]The endpoint is type 2 diabetes

Supplemental table 3. Main environmental footprint information sources for items´ production and processing phases

LAND USE:

- Food and Agriculture Organization of the United Nations: data base 2009 FAOSTAT [http://faostat.fao.org/]
- Cederberg C, Mattsson B: Lifecycle assessment of milk production – a comparison of conventional and organic farming. *Journal of Cleaner Production* 2000, 8:49-60.
- LCA food data base [www.lcafood.dk]

WATER CONSUMPTION:

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- Ministerio de Medio Ambiente y Medio Rural y Marino: (Ministry of environment, rural and marine, Spain). Guía de Mejores Técnicas Disponibles en España del sector de Productos del mar (Best Available Techniques Guide of Sea products sector in Spain). Spain; 2006.
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ENERGY CONSUMPTION:

- International Dairy Federation. “Environmental/Ecological Impact of the dairy sector: Literature review on dairy products for an inventory of key issues. List of environmental initiatives and influences on the dairy sector”. Bulletin of the IDF 2009; Nº 436.
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GHG EMISSION:

- LCA food data base [www.lcafood.dk].
- Food Carbon emission calculator http://www.foodemissions.com/foodemissions/Calculator.aspx

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.

	Western dietary pattern			
	Q1	**Q2**	**Q3**	**Q4**
N (frequency)	4608	4607	4607	4607
Cases/person-years	151/43804	117/45688	104/46749	97/49219
Overall sustainable diet index (0-9 points)[a]	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)[a]	-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)[a]	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)[a]	7.55 (7.51, 7.60)	6.91 (6.87, 6.96)	6.54 (6.49, 6.58)	5.87 (5.82, 5.93)
	Mediterranean dietary pattern			
	Q1	**Q2**	**Q3**	**Q4**
N (frequency)	6802	3796	3400	4431
Cases/person-years	149/70310	100/38942	99/33695	121/42512
Overall sustainable diet index (0-9 points)[a]	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)[a]	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)[a]	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)[a]	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)[a]	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)[a]	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)[a]	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)[a]	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. [a]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.

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

Overall sustainable diet index (0-9 points)[a]	0 (Ref)	0.36 (0.34, 0.39)	0.59 (0.56, 0.61)	0.97 (0.94, 0.99)
Rate advancement period (years)[a]	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)[a]	0 (Ref)	-0.20 (-0.30, -0.11)	-0.42 (-0.51, -0.32)	-0.84 (-0.93, -0.75)
Monetary cost (€/day)[a]	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)[a]	0 (Ref)	0.34 (0.32, 0.37)	0.58 (0.55, 0.60)	0.88 (0.86, 0.91)
Rate advancement period (years)[a]	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)[a]	0 (Ref)	-0.94 (-1.03, -0.86)	-1.50 (-1.60, -1.41)	-2.33 (-2.42, -2.24)
Monetary cost (€/day)[a]	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. [a]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**
Overall						
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)[a]	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)[a]	-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)[a]	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)[a]	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)
Excluding participants who had the health composite end-point[1] in the first 2 years						
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)[a]	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)[a]	-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)[a]	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)[a]	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)
Including people with prevalent CVD, cancer and T2DM[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)[a]	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)[a]	-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)[a]	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)[a]	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)
Excluding participants with total energy intake beyond predefined limits (<800 Kcal/day and <500 Kcal/day or >4000 Kcal/day and >3500 Kcal/day in men and women, respectively)						
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)[a]	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)[a]	-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)[a]	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)[a]	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. [a]p for trend<0.001.[1]Composite end-point: all-cause mortality, non-fatal cardiovascular disease, non-fatal breast cancer or type 2 diabetes. [b]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**
Overall						
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)[a]	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)[a]	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)[a]	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)[a]	0 (Ref)	-1.68 (-1.76, -1.60)	0 (Ref)	1.42 (1.36, 1.48)	0 (Ref)	0.11 (0.04, 0.18)
Excluding participants who have the health composite end-point[1] in the first 2 years						
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)[a]	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)[a]	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)[a]	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)[a]	0 (Ref)	-1.69 (-1.77, -1.61)	0 (Ref)	1.42 (1.36, 1.48)	0 (Ref)	0.11 (0.04, 0.18)
Including people with prevalent CVD, cancer and T2DM[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)[a]	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)[a]	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)[a]	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)[a]	0 (Ref)	-1.68 (-1.76, -1.61)	0 (Ref)	1.41 (1.35, 1.47)	0 (Ref)	0.13 (0.06, 0.19)
Excluding participants with total energy intake beyond predefined limits ((<800 Kcal/day and <500 Kcal/day or >4000 Kcal/day and >3500 Kcal/day in men and women, respectively)						
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)[a]	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)[a]	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)[a]	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)[a]	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. [a]p for trend<0.001. [1]Composite end-point: all-cause mortality, non-fatal cardiovascular disease, non-fatal breast cancer or type 2 diabetes. [b]Additionally adjusted for prevalent CVD, cancer and T2DM. CVD: Cardiovascular Disease. Qn= nth quartile of diet adherence. T2DM: Type 2 Diabetes Mellitus.

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
Introduction			
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
Methods			
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*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—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 *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—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*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	10
Results			
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) *Cohort study*—Summarise follow-up time (eg, average and total amount)	12
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	12
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—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
Discussion			
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
Other information			
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.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE 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 http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.