Preventive Medicine 118 (2019) 317–324

Contents lists available at ScienceDirect

Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

Adherence to the 2015 Dietary Guidelines for Americans and mortality risk in a Mediterranean cohort: The SUN project

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ARTICLE INFO

Keywords:
2015–2020 Dietary Guidelines for Americans
2015 Dietary Guideline for Americans Index
SUN project
Total mortality
Cardiovascular mortality
Cancer mortality

ABSTRACT

The 2015–2020 Dietary Guidelines for Americans (DGA) was issued in early 2016. It remains untested if adherence to these guidelines could reduce mortality risk. Using a modified version of the 2015 Dietary Guidelines for American Index (2015 DGAI), we investigated if adherence to the new DGA is associated with mortality in a Spanish (the Seguimiento Universidad de Navarra, SUN) cohort. We assessed the habitual diet of 16,866 participants of this cohort recruited between 1999 and 2014 and calculated their adherence scores to the new DGA using the modified 2015 DGAI (0–21points). Mortality data was determined from the yearly National Death Index reports. After adjusting for demographic and lifestyle confounders, high adherence scores (fourth quartile) were found to be associated with reduced all-cause, cardiovascular and cancer mortality risk, hazard ratios (HR) (95% confidence intervals [CI]) 0.42 (0.25–0.70), 0.30 (0.10–0.90) and 0.46 (0.22–0.96), respectively, compared to low adherence scores (first quartile). A 2-point increase in the 2015 DGAI score was linearly inversely associated with all-cause mortality (HR [95% CI] 0.78 [0.67–0.92]). Main sources of variability in the adherence scores were whole-fat dairy products, red/orange vegetables, fresh fruits, red meat, and dark green vegetables. In conclusion, higher adherence to 2015–2020 Dietary Guidelines for Americans was inversely associated with total, cardiovascular and cancer mortality risk in a Spanish cohort.

1. Introduction

Health status is determined, among other aspects, by dietary habits. Thus, promoting healthy diets is a useful tool for the management and prevention of diseases such as cardiovascular disease (CVD), a main cause of mortality (World Health Organization, 2003).

Several dietary guidelines have been issued in the past years (National Health and Medical Research Council, n.d.; Spanish Society of Community Nutrition (SENC), n.d.), and quite a lot of indices have been developed to evaluate the degree of adherence to them. These indices are reproducible tools. They have allowed the possibility of checking the relationship between dietary recommendations and different health outcomes, e.g., chronic diseases and all-cause mortality (Schwingshackl and Hoffmann, 2015).

In 1980, the USA issued dietary guidelines for the first time; since then, these guidelines, called the Dietary Guidelines for Americans (DGA), have undergone revisions approximately every five years (U.S. Department of Agriculture, n.d.). The latest version, the 2015 DGA, is based on the most up-to-date available information (U.S. Department of Health and Human Services and U.S. Department of Agriculture, n.d.). In an attempt to measure adherence to the DGA, the Healthy Eating Index was developed in 1995 (Kennedy et al., 1995). A more recent version of the index, the 2015 Dietary Guidelines for Americans Index (2015 DGAI), measures adherence to the latest DGA (Jessri et al., 2016). The 2015 DGAI evaluates the quality of the diet based on the recommended energy intake for each individual, an improvement

Abbreviations: 2015 DGAI, 2015 Dietary Guideline for Americans Index; BMI, body mass index; CVD, cardiovascular disease; DGA, Dietary Guidelines for Americans; FFQ, food frequency questionnaire; HR (95% CI), hazard ratios and their 95% confidence interval; MET, Metabolic Equivalent of Tasks; SUN project, *Seguimiento Universidad de Navarra*, University of Navarra follow-up; T2DM, type 2 diabetes; WHO, World Health Organization

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https://doi.org/10.1016/j.ypmed.2018.11.015
Received 17 April 2018; Received in revised form 1 November 2018; Accepted 19 November 2018
Available online 20 November 2018

compared to the typical "one-size-fits-all" approach. This index also penalizes overconsumption of energy-dense foods, which prevents inadvertent allotment of higher scores for excessive food intake.

To our knowledge, the 2015 DGAI had been evaluated in relation to obesity risk in a Canadian population (Jessri et al., 2016), but not for other health outcomes or populations. The 2015 DGA basically recommends a healthy diet that is similar in many ways to the Mediterranean dietary pattern, a diet that is mainly followed by our cohort. Therefore, we investigated if there is a relationship between adherence to the 2015 DGA as measured by the 2015 DGAI and all-cause and cause-specific mortality risk in a Spanish cohort. We also evaluated the influence of each component of the index to the total mortality, and the contribution of each group of food to the variability among participants in adherence to recommendations.

2. Subjects and methods

2.1. Study population

The SUN project (*Seguimiento Universidad de Navarra*, University of Navarra Follow-up) is an ongoing cohort composed of Spanish university graduates. Started in 1999, this study collects information from participants every two years via mailed or e-mailed questionnaires. In the study, voluntary completion of the baseline questionnaire implies informed consent, as participants receive detailed information about the whole study. The protocol was approved by the Research Ethics Committee of the University of Navarra.

Participants whose follow-up was at least 2 years were considered for this analysis (first baseline questionnaire answered in 2014 or earlier). Out of 22,320 participants (~10% of all the graduates invited for the study), 5454 were excluded: 2031 did not respond to follow-up questionnaires (retention in the cohort: 90.90%); 402 had improbable total energy intake (under 1st percentile or above 99th percentile); 197 women were pregnant at baseline; 1279 reported prevalent type 2 diabetes (T2DM), CVD or cancer at baseline; and, 1545 had 12 or more missing responses in the food frequency questionnaire (FFQ). This left a total of 16,866 participants for the analyses (Supplemental Fig. S1).

2.2. Dietary assessment

A validated semi-quantitative 136-item FFQ (dela Fuente-Arrillaga et al., 2010; Martin-Moreno et al., 1993; Fernandez-Ballart et al., 2010) was used to assess habitual diet at baseline. FFQ items include a typical portion size and 9 consumption frequency categories, from "never/almost never" to "more than 6 times/day". The SUN project FFQ's serving units were converted into the ones used in the original 2015 DGAI (i.e., 1 cup = 237 ml [US] = 0.946 cup in metric unit; 1 oz = 28.35 g; 1 drink = 118 ml wine, 355 ml beer, or 45 ml spirits) (Jessri et al., 2016). Daily intake of every food item was estimated by multiplying its standard portion size with the frequency of intake. Trained nutritionists calculated the nutrient and energy intake of the respondents using their daily intake of every food item and the corresponding nutrient composition of these foods based on several available Spanish Food Composition Databases (Mataix, 2003; Moreiras et al., 2005) and other sources. Missing values were regarded as no consumption.

2.3. 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 (Martinez-Gonzalez et al., 2005; Bes-Rastrollo et al., 2005; Alonso et al., 2005). We computed METs-h/day as validated data of METs-h/week divided by 7 (Martinez-Gonzalez et al., 2005) which we then used to categorize physical activity levels into sedentary (no physical activity reported during free time), low active (< 3 METs-h/day), moderately active (3-to- < 6 METs-h/day), and highly active (≥ 6 METs-h/day).

2.4. Mortality assessment

Participants who did not respond to any of the five follow-up mailings were contacted by telephone or email. The National Death Index was checked every year to identify deceased cohort members. Causes of death were established according to the International Classification of Diseases, 10th Revision (World Health Organization, n.d.), grouped as cardiovascular, cancer, or other causes. The last time when survival status and cause of death were verified was December 1, 2016.

2.5. 2015 Dietary Guideline for Americans Index (2015 DGAI)

In order to assess adherence to the new DGA (U.S. Department of Health and Human Services and U.S. Department of Agriculture, n.d.), we prepared a nutrient intake adequacy index by modifying certain criteria in the recently published 2015 DGAI (Jessri et al., 2016) (The rationale for modification of these criteria is included below).

The modified 2015 DGAI includes 21 components (Table 1). Each component is scored from 0 (lowest level of adherence) to 1 (highest level of adherence). Therefore, the highest possible score of the index is 21. The index has two sub-scores: (1) Food intake sub-score (food intake according to energy requirement), and (2) Healthy choice sub-score (healthy choice of foods that contribute to total energy intake). The first sub-score is energy dependent so we estimated the energy requirements of participants according to their height, weight, physical activity, age and sex, using the Institute of Medicine factorial equations (Trumbo et al., 2002).

The 2015 DGAI provides daily food intake recommendations for each component of the index for a person whose recommended energy intake is 2000 kcal. Daily food intake recommendations are assumed to be linearly proportional to theoretical energy intake recommendations. As shown in Table 1, the components of the first sub-score are: *vegetables* (5 subgroups: *dark green vegetables*, *red or orange vegetables*, *legumes*, *starchy vegetables*, and *other vegetables*), *fruits*, *variety of vegetables and fruits*, *cereals*, *meat and eggs*, *fish and seafood*, *dairy products*, and *added sugar*. The score for *variety of vegetables and fruits* is determined from the average score of the previous 6 components (5 *vegetables* subgroups and *fruits*). Overconsumption of energy-dense foods, such as *starchy vegetables*, *cereals*, *meat and eggs*, and *dairy products*, is penalized. We used the same approach presented in the 2015 DGAI: a proportional score reduction is applied when amount consumed exceeds the recommendation by < 25%, but the score is set at 0.5 point if amount consumed exceeds the recommendation by ≥ 25% (Jessri et al., 2016).

Three minor changes in the previously published 2015 DGAI were incorporated in the sub-scoring used for the current analysis: (1) legumes were only assessed as plant-derived foods, not as meat or egg substitutes, since the 2015 DGA count legumes as protein but not specifically as meat protein substitutes; (2) an item for fish and seafood consumption was included because 2015 DGA recommend fish consumption based on recognized health benefits (U.S. Department of Health and Human Services and U.S. Department of Agriculture, n.d.; Zhao et al., 2016); and, (3) the item for added sugar consumption used a different cut-off (< 10% of total energy intake), based on the 2015 DGA and the World Health Organization (WHO) recommendations (World Health Organization, 2015).

The second sub-score included components assessed in the validated 2015 DGAI—*percentage of whole grains*, *fiber intake*, *total fat*, *saturated fat*, *dietary cholesterol*, *low-fat products* (*dairy and meat*), *sodium intake*, and *alcohol consumption*—and *trans fat consumption*. Similar to the first sub-score, items were scored continuously from 0 to 1, but nutrients associated with adverse effects—*total*, *saturated* and *trans fats*, *dietary cholesterol*, *sodium*, and *alcohol*—were scored in the reverse (the higher

Table 1
Scoring criteria for 2015 Dietary Guidelines for Americans Index (2015 DGAI) based on food consumption recommendation for individuals with a theoretical energy requirement of 2000 kcal/day[a,b].

2015 DGAI	Scoring criteria	
	0 point	1 point
Food intake sub-score[a]		
Vegetables (cups/week)		
Dark green vegetable	0	≥1.5
Red/orange vegetables	0	≥5.5
Legumes	0	≥1.5
Starchy vegetables[c]	0	5
Other vegetables	0	≥4
Fruits (cups/day)	0	≥2
Variety of vegetables and fruits[d]	0	1
Cereals (oz-equivalent/day)[c]	0	6
Meat and eggs (oz-equivalent/week)[c]	0	26
Fish and seafood (oz-equivalent/week)	0	≥8.5
Dairy products (cup/day)[c]	0	3
Added sugar (% energy)	≥10%	≤5%
Healthy choice sub-score		
Whole grain (% of cereals)	0	≥50%
Dietary fiber density (gram/1000 kcal)	0	≥14
Total fat (% energy)	≤10%, ≥45%	≥20%, ≤35%
Saturated fat (% energy)	≥15%	≤10%
Trans fat (% energy)	≥1.5%	≤1%
Cholesterol intake (mg/day)	≥450	≤300
Low-fat dairy, and lean meat products (%)[e]	0%	≥75%
Sodium (mg/day)	≥3450	≤2300
Alcohol (servings/day)[f]		
Men	≥2.5	≤2
Women	≥1.5	≤1

This table shows the score used in the current article, which has been based on the new 2015 DGAI (Jessri et al., 2016). American units are shown. One cup is 237 ml (US), 0.946 cup in metric unit; 1 oz = 28.35 g; one drink = 118 ml wine, 355 ml beer, 45 ml spirits.

[a] Theoretical energy requirement was calculated using the Institute of Medicine factorial equations (Trumbo et al., 2002).

[b] Intermediate intakes between criteria for 0 and 1.0 points were scored proportionally.

[c] Overconsumption had a penalty, reducing the score proportional to the amount exceeding the recommendation by < 25%. Consumption exceeding recommended amounts by 25% or more was given 0.5 point.

[d] Variety score was computed as the average of the five types of vegetables and fruits scores.

[e] Low-fat milk and lean meat products were scored separately from 0 to 0.5 points (for consuming ≥75% of low-fat options), and the proportional scores between them for intermediate percentages. The final scores of both were summed for a maximum of 1 point.

[f] Sex-specific cut-off was applied for alcohol consumption according to 2015 DGA (U.S. Department of Health and Human Services and U.S. Department of Agriculture, n.d.).

the intake, the lower the score). In this sub-score, we included an item to assess *trans* fats consumption, as the 2005DGAI did (Fogli-Cawley et al., 2006). Lack of *trans* fats intake data in the analyzed Canadian population precluded its inclusion in the 2015 DGAI (Jessri et al., 2016). *Alcohol consumption* was scored according to a sex-specific cut-off, since intake limit for men is twice that for women.

2.6. Statistical analysis

The relationships between quartiles of 2015 DGAI and all-cause, and cause-specific mortality risk (cardiovascular, cancer or other causes), were determined using Cox regression models. Hazard ratios (HR) and their 95% confidence interval (95% CI) were calculated using the lowest quartile as the reference category. Age was the underlying time variable used for building the risk sets. In addition, to obtain a better adjustment we also stratified the Cox models by deciles of age. Exit time was the date of death or when survivors completed the last follow-up questionnaire. When assessing specific causes of mortality, participants who died because of the analyzed cause were considered as cases while those who died of other causes were censored. We fitted a sex-adjusted model, stratified by age (deciles) and year of entrance to the cohort (1999–2001, 2002–2004, 2005–2007 and from 2008). Moreover, a multivariable model was additionally adjusted for the following potential confounders: BMI and its quadratic term, smoking status (never, former and current smoker), physical activity (continuous, METs-h/week), hours watching television (continuous, h/day), prevalent hypertension (dichotomous), prevalent hypercholesterolemia (dichotomous), marital status (single, married, others), and total energy intake (continuous, kcal/d). We assessed linear trends across increasing quartiles by assigning the medians to each category and this variable was treated as continuous. Proportionality over time was assessed through Schoenfeld's residual method.

All-cause death occurring over time was described through Nelson-Aalen cumulative hazard curves which were adjusted for potential confounders using inverse probability weighting. Predictor variables were age and its quadratic term, sex, BMI and its quadratic term, physical activity, smoking status, hours watching television, prevalent hypertension at baseline, prevalent hypercholesterolemia at baseline, marital status, year of entrance to the cohort and total energy intake. As an ancillary analysis, we fitted Cox models for competing risk analysis (command stcrreg in Stata).

Furthermore, we determined the association of two-point increment in the 2015 DGAI with all-cause mortality risk, using Cox regression in the multivariable model. We assessed the association between each component of the score and the mortality risk associated to two point increment in the 2015 DGAI, as previously described by Trichopoulou (Trichopoulou et al., 2009). At first, all components were included simultaneously in the Cox regression. To evaluate the influence of each component, components were removed one at a time from the original score, assessing the mortality risk. As the score was rescaled to 20 points, beta coefficients of the estimated mortality ratios were multiplied by 20/21 before exponentiating them.

In order to assess the between-person variability in the index, we classified FFQ items into 32 food groups (Supplemental Table S1). We performed nested regression analyses after a stepwise selection algorithm to estimate the contribution of each food group. Cumulative R^2 change showed the contribution of each group to the score variability.

We conducted sensitivity analyses refitting the model under different assumptions to assess the robustness of our results: excluding participants with total energy intake beyond predefined limits (< 800 kcal/day or > 4000 kcal/day for men and < 500 kcal/day or > 3500 kcal/day in women (Willett, 2013)); including participants with prevalent T2DM, CVD or cancer at baseline (in this case, the model was additionally adjusted for prevalent T2DM, CVD and cancer at baseline); additionally adjusting for incident T2DM and CVD; additionally adjusting for following special diet; not adjusting for BMI and its quadratic term; not adjusting for BMI and its quadratic term, prevalent hypertension and prevalent hypercholesterolemia; and excluding participants who have died in the first 2 years of follow-up.

Additionally, we performed stratified analyses according to sex (women and men), baseline BMI (< 25 kg/m^2 or ≥25 kg/m^2), physical activity (below 20.67 METs-h/week versus ≥20.67 METs-h/week, where 20.67 METs-h/week is the median) and age (with median age at recruitment, 34 years, as cut-off point). Interactions were assessed through a likelihood ratio test. BMI, physical activity and age were assessed as continuous variables.

All *p*-values presented were two-tailed; $p < 0.05$ was considered statistically significant. Analyses were performed using STATA/SE V.12.1 (StataCorp, College Station, Texas, USA).

Table 2
Distribution of baseline characteristics of participants according to quartiles of 2015 Dietary Guidelines for Americans Index (2015 DGAI).

	2015 DGAI scores (0–21 points)			
	Q1	Q2	Q3	Q4
Frequency (*n*)	4217	4216	4217	4216
2015 DGAI (range)	4.5–11.3	11.4–12.7	12.8–14.2	14.3–19.4
2015 DGAI[a]	10.2	12.0	13.4	15.2
Food intake sub-score (0–12 points)[a]	6.3	7.5	8.1	8.8
Healthy choice sub-score (0–9 points)[a]	3.7	4.5	5.4	6.6
Sociodemographic data				
Sex (men %)	58	41	32	22
Age (years)	34 (10)	36 (11)	37 (11)	39 (12)
Civil status (%)				
Single	54	48	44	43
Married	42	48	51	51
Others	4	4	5	6
Smoking status (%)				
Current smoker	31	28	23	21
Former smoker	18	22	25	27
Studies (%)				
Technical	9	6	5	4
Graduated	73	75	76	77
Master/doctoral	18	19	19	19
Food and nutrition				
Total energy intake (kcal/d)	2652 (776)	2613 (768)	2522 (775)	2327 (695)
Food items (servings/day)				
Dairy products	3.3 (2.1)	3.2 (2.0)	3.2 (1.8)	3.0 (1.6)
Non-fat/low-fat dairy products	0.9 (1.3)	1.2 (1.5)	1.6 (1.5)	1.9 (1.4)
Whole-fat dairy products	2.4 (1.8)	2.0 (1.3)	1.6 (1.2)	1.1 (0.9)
Eggs	0.5 (0.4)	0.4 (0.3)	0.4 (0.3)	0.3 (0.2)
All types of meats	2.4 (1.1)	2.1 (1.0)	1.9 (0.9)	1.5 (0.8)
Processed meat	1.4 (0.9)	1.2 (0.8)	1.0 (0.7)	0.8 (0.6)
Red meat	0.7 (0.4)	0.6 (0.3)	0.5 (0.3)	0.4 (0.3)
White meat	0.3 (0.2)	0.3 (0.3)	0.3 (0.3)	0.3 (0.3)
Fish and seafood	0.6 (0.4)	0.7 (0.5)	0.8 (0.5)	0.8 (0.5)
Vegetables	1.8 (1.0)	2.6 (1.4)	3.1 (1.7)	3.7 (2.0)
Dark green	0.2 (0.2)	0.2 (0.2)	0.3 (0.3)	0.4 (0.3)
Red/orange	0.6 (0.5)	0.9 (0.7)	1.1 (0.9)	1.4 (1.0)
Starchy	0.2 (0.3)	0.3 (0.3)	0.3 (0.3)	0.4 (0.4)
Others	0.9 (0.6)	1.2 (0.8)	1.5 (0.9)	1.7 (1.0)
Legumes	0.3 (0.2)	0.3 (0.2)	0.3 (0.2)	0.3 (0.2)
Fruits and nuts	1.6 (1.3)	2.4 (1.8)	3.2 (2.5)	4.0 (2.8)
Fresh fruit	1.4 (1.2)	2.1 (1.7)	2.9 (2.4)	3.6 (2.6)
Nuts	0.1 (0.2)	0.2 (0.2)	0.2 (0.3)	0.2 (0.3)
Processed fruit	0.1 (0.2)	0.1 (0.2)	0.1 (0.3)	0.2 (0.3)
Cereals	1.7 (1.3)	2.0 (1.4)	2.1 (1.5)	2.2 (1.4)
Oils and fats	2.0 (1.7)	2.1 (1.7)	2.0 (1.6)	2.0 (1.5)
Olive oil	1.4 (1.4)	1.6 (1.5)	1.6 (1.4)	1.7 (1.3)
Other oils	0.3 (0.7)	0.2 (0.7)	0.2 (0.6)	0.2 (0.6)
Margarine	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)
Animal fats	0.2 (0.4)	0.1 (0.3)	0.1 (0.3)	0.1 (0.2)
Pastry products	1.5 (1.3)	1.3 (1.2)	1.1 (1.0)	0.8 (0.7)
Biscuits	0.4 (0.8)	0.4 (0.7)	0.4 (0.7)	0.2 (0.5)
Chocolate	0.4 (0.7)	0.4 (0.6)	0.3 (0.5)	0.2 (0.4)
Industrial bakery	0.4 (0.6)	0.3 (0.5)	0.2 (0.4)	0.1 (0.2)
Home-made bakery	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)	0.1 (0.1)
Cakes	0.06 (0.08)	0.05 (0.07)	0.04 (0.07)	0.03 (0.07)
Beverages	7.5 (3.3)	7.5 (3.2)	7.6 (3.3)	7.4 (3.3)
Water	4.4 (2.6)	4.5 (2.5)	4.7 (2.6)	4.8 (2.7)
Red wine	0.3 (0.7)	0.3 (0.6)	0.2 (0.6)	0.2 (0.4)
Other alcoholic beverages	0.4 (0.7)	0.4 (0.6)	0.3 (0.5)	0.2 (0.3)
Sugared sodas	0.4 (0.6)	0.3 (0.5)	0.2 (0.4)	0.1 (0.2)
Regular coffee	1.3 (1.3)	1.3 (1.3)	1.2 (1.3)	1.2 (1.2)
Juice	0.4 (0.5)	0.5 (0.6)	0.5 (0.8)	0.5 (0.7)
Fast food[b]	0.3 (0.2)	0.2 (0.2)	0.2 (0.2)	0.1 (0.1)
Nutrient intake (% total energy intake)				
Fat	41 (6)	38 (6)	36 (6)	32 (5)
Saturated fatty acids	15 (3)	13 (3)	12 (2)	10 (2)
Monounsaturated fatty acids	6 (2)	5 (2)	5 (1)	5 (1)
Polyunsaturated fatty acids	17 (3)	16 (3)	15 (3)	14 (3)
Carbohydrates	40 (7)	42 (6)	45 (7)	48 (6)
Protein	17 (3)	18 (3)	18 (3)	19 (3)
Animal source	14 (3)	14 (3)	13 (3)	13 (3)
Only animals	12 (3)	11 (3)	11 (3)	10 (3)
Only fish	2 (1)	2 (1)	2 (1)	3 (2)
Vegetable source	5 (1)	6 (1)	6 (1)	7 (1)

(*continued on next page*)

Table 2 (*continued*)

	2015 DGAI scores (0–21 points)			
	Q1	Q2	Q3	Q4
Dietary fiber intake (g/day)	21 (8)	27 (10)	32 (13)	38 (16)
Alcohol intake (g/day)	9 (13)	7 (11)	6 (9)	4 (6)
Medical and lifestyle data				
Body mass index (kg/m^2)	23.8 (3.6)	23.4 (3.6)	23.2 (3.5)	23.0 (3.3)
Hypertension (%)	5	6	6	7
Hypercholesterolemia (%)	12	16	16	19
Physical activity (METs-h/week)	27 (25)	26 (23)	27 (23)	28 (25)
Hours watching TV (h/day)	1.7 (1.2)	1.7 (1.2)	1.6 (1.1)	1.5 (1.2)

Mean and standard deviation (SD), or %. The SUN project (Spanish cohort) 1999–2016.
2015 DGAI: 2015 Dietary Guidelines for Americans Index. Q1–Q4: quartiles of 2015 DGAI. MET: Metabolic Equivalent of Tasks.
[a] Values are medians.
[b] Fast food includes hamburger, sausages and pizza.

3. Results

The study included 6431men and 10,435 women with a mean age of 36.2 years (range: 18–91) at baseline. We identified 177 deaths during the follow-up period (170,647 person-years), with 35, 81 and 61 deaths due to cardiovascular, cancer, and other causes, respectively. Median follow-up was 10.38 years. The median value of the 2015 DGAI for the entire sample was 12.7 (out of 21.0; range: 4.5–19.4). For the two subscores, the means were 7.7 (out of 12.0; range: 1.9–11.2) and 5.0 (out of 9.0; range: 0.6–9.0) for food intake and healthy choice, respectively. These values indicate that over half of the sample population followed > 50% of the DGA food recommendations.

The main baseline characteristics of participants across quartiles of 2015 DGAI are presented in Table 2. Among those who reported better adherence to the new DGA, there were more women, older participants, married subjects, former smokers and participants with a higher university educational level. They were more likely to have lower energy intake. On average, they consumed more non-fat/low-fat dairy products, fish and seafood, any type of vegetables, fresh fruits and cereals, olive oil and water. On the other hand, their consumption of whole-fat dairy products, alcoholic beverages, and sugared sodas was lower. In general, they consumed more fiber, carbohydrate and protein, but less saturated and polyunsaturated fatty acids. More people in this group have hypercholesterolemia, but lower BMI.

Moving from the lowest (reference) to the highest quartile of 2015 DGAI scores (from least to greatest adherence), the HR for all-cause mortality decreased with a significant linear trend (p for trend < 0.001) (Table 3). However, only the fourth quartile significantly differed from the first quartile (HR [95% CI] 0.38 [0.23–0.62]) in all-cause mortality but not the second and third quartiles. Further adjustment for other potential confounders attenuated the HR to 58% but this remained significant. Fig. 1 shows divergent incidence between the lowest (Q1) and highest (Q4) adherence to 2015 DGAI. Proportionality over time was checked (p = 0.57).

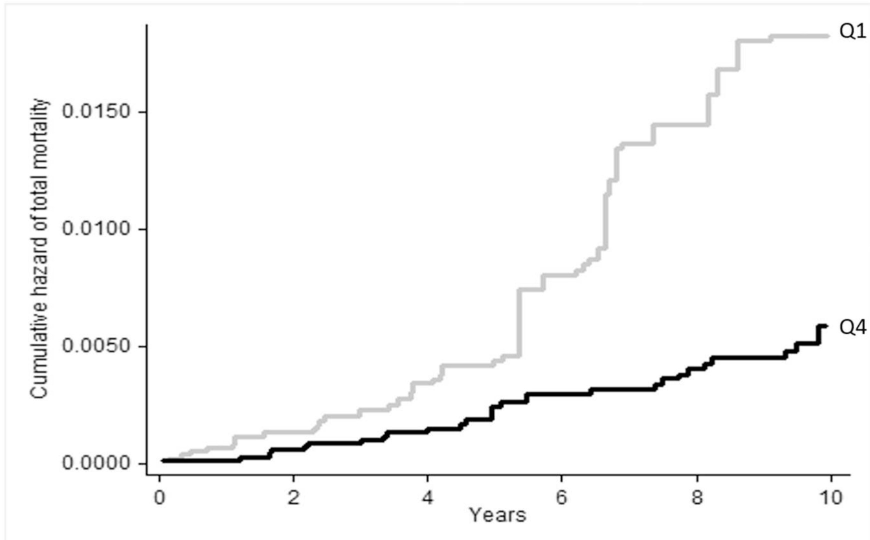
Q1, Q4: first and fourth quartiles of 2015 Dietary Guidelines for Americans Index scores. Adjusted for age, adding a quadratic age term, sex, body mass index, adding a quadratic BMI term, smoking status, physical activity, hours watching television, prevalent hypertension at baseline, prevalent hypercholesterolemia at baseline, marital status, year of entrance to the cohort, and total energy intake, using Inverse Probability Weight method (Xie and Liu, 2005).

The relationship between quartiles of 2015 DGAI scores and risk of mortality were also assessed for the three causes of death. In the age- and sex-adjusted model, an inverse association was found with a significant linear trend across quartiles. Significant reductions in risk were found when comparing the fourth and the first quartiles, with HR (95% CI) 0.26 (0.09, 0.72), 0.46 (0.23, 0.93) and 0.36 (0.14, 0.91) for cardiovascular, cancer, and other-cause mortality, respectively (Table 3). The inverse linear trends remained significant after further adjustment for confounders for cardiovascular mortality (p for trend = 0.033), but not for cancer or other-cause mortality. For cardiovascular and cancer mortality, but not for other-cause mortality,

Table 3
Risk (hazard ratio and 95% confidence intervals) for all-cause, cardiovascular, cancer and other-cause mortality according to quartiles of 2015 Dietary Guidelines for Americans Index (2015 DGAI) scores.

	Q1	Q2	Q3	Q4
2015 DGAI				
N (frequency)	4217	4216	4217	4216
Person-years	44,653	43,932	41,530	40,532
All-cause mortality				
Cases	51	49	47	30
Age, sex adjusted model[a]	1 (Ref.)	0.92 (0.61, 1.37)	0.87 (0.57, 1.32)	0.38 (0.23, 0.62)
Multiple adjusted model[b]	1 (Ref)	0.92 (0.61, 1.39)	0.89 (0.58, 1.38)	0.42 (0.25, 0.70)
Cardiovascular mortality				
Cases	13	8	7	7
Age, sex adjusted model[a]	1 (Ref.)	0.56 (0.22, 1.41)	0.48 (0.19, 1.26)	0.26 (0.09, 0.72)
Multiple adjusted model[b]	1 (Ref)	0.62 (0.24, 1.62)	0.55 (0.20, 1.53)	0.30 (0.10, 0.90)
Cancer mortality				
Cases	21	22	23	15
Age, sex adjusted model[a]	1 (Ref.)	0.93 (0.50, 1.71)	0.92 (0.49, 1.70)	0.46 (0.23, 0.93)
Multiple adjusted model[b]	1 (Ref.)	0.92 (0.49, 1.71)	0.96 (0.51, 1.80)	0.46 (0.22, 0.96)
Other-cause mortality[c]				
Cases	17	19	17	8
Age, sex adjusted model[a]	1 (Ref.)	1.22 (0.61, 2.41)	1.15 (0.56, 2.36)	0.36 (0.14, 0.91)
Multiple adjusted model[b]	1 (Ref.)	1.22 (0.61, 2.44)	1.09 (0.51, 2.31)	0.42 (0.16, 1.08)

The SUN project (Spanish cohort) 1999–2016.
2015 DGAI: 2015 Dietary Guidelines for Americans Index. Q1–Q4: quartiles of 2015 DGAI.
[a] Age was the underlying time variable. Adjusted for sex, and stratified by age and year of entrance to the cohort.
[b] Additionally adjusted for body mass index, adding a quadratic BMI term, total energy intake, physical activity during free time, hours watching television, smoking status, marital status and prevalent hypertension and hypercholesterolemia.
[c] Other-cause mortality included any cause of mortality different for cardiovascular and cancer.



Number at risk

Q1	4217	4184	3906	3526	3104	2692
Q4	4216	4191	3823	3433	2877	2212

Fig. 1. Nelson-Aalen estimation of cumulative hazard of total mortality comparing first and fourth quartiles of 2015 Dietary Guidelines for Americans Index Scores. The SUN project (Spanish cohort) 1999–2016.

statistically significant reduced HRs were found for Q4 compared to the reference, Q1.

Table 4 shows that for all-cause mortality, each additional two-point increment in 2015 DGAI exhibited a reduction in the HR of 22% (HR [95% CI] 0.78 [0.67, 0.92]). This relationship lost statistical significance when *variability of vegetables and fruits*, *dietary fiber density*, *red/orange vegetables*, and *fruits* component was alternately removed from the index one at a time.

Main sources of variability in the 2015 DGAI of our population were whole-fat dairy products ($R^2 = 0.14$), red/orange vegetables ($R^2 = 0.13$), fresh fruit ($R^2 = 0.09$), red meat ($R^2 = 0.06$), dark green vegetables ($R^2 = 0.04$), fast food ($R^2 = 0.03$) and processed meat ($R^2 = 0.02$). Altogether, these explained > 50% of the variability in the 2015 DGAI among our participants.

Sensitivity analyses did not substantially change the main findings (Supplemental Table S2), confirming its robustness. Main results in subgroup analyses concurred with the overall results (Supplemental Fig. S2) although in women (cases/person-years: 54/104243), inverse associations lost their significance in participants with BMI ≥ 25 kg/m^2 (cases/person-years: 85/47263) and in participants < 34 years (cases/person-years: 26/81468). There were no significant interaction effects between 2015 DGAI and sex, BMI or age.

4. Discussion

Our results showed that higher adherence to the 2015–2020 Dietary Guidelines for Americans is inversely associated with the risk of premature all-cause, cardiovascular, and cancer mortality in a Mediterranean population. To the best of our knowledge, this is the first investigation of how adherence to the new DGA is related to mortality risk, specifically in a non-US population.

The Mediterranean diet is considered as a healthy eating pattern in the 2015–2020 DGA (U.S. Department of Health and Human Services and U.S. Department of Agriculture, n.d.). The food recommendation for those who follow this dietary pattern is basically the same as the

Table 4
Risk (hazard ratio and 95% confidence intervals (HR (95% CIs))) for all-cause mortality according to two-point increment in the 2015 Dietary Guidelines for Americans Index (2015 DGAI) (in bold) and after removing alternately each of its dietary components[a].

Dietary variable	HR (95% CIs)
2015 DGAI minus variety of vegetables and fruits	0.90 (0.72, 1.11)
2015 DGAI minus dietary fiber density	0.86 (0.68, 1.08)
2015 DGAI minus red/orange vegetables	0.85 (0.71, 1.01)
2015 DGAI minus fruits	0.85 (0.71, 1.01)
2015 DGAI minus cereals	0.82 (0.70, 0.96)
2015 DGAI minus legumes	0.80 (0.69, 0.94)
2015 DGAI minus meat and eggs	0.80 (0.69, 0.94)
2015 DGAI minus dark green vegetables	0.80 (0.68, 0.95)
2015 DGAI minus starchy vegetables	0.80 (0.68, 0.93)
2015 DGAI minus alcohol	0.80 (0.68, 0.93)
2015 DGAI minus dairy products	0.79 (0.68, 0.92)
2015 DGAI minus added sugar	0.79 (0.68, 0.92)
2015 DGAI minus trans fatty acids	0.79 (0.68, 0.92)
2015 DGAI minus total fat	0.79 (0.67, 0.94)
2015 DGAI minus cholesterol intake	0.79 (0.66, 0.93)
2015 DGAI overall	**0.78 (0.67, 0.92)**
2015 DGAI minus fish and seafood	0.78 (0.67, 0.91)
2015 DGAI minus low-fat dairy, and lean meat products	0.78 (0.66, 0.92)
2015 DGAI minus sodium	0.77 (0.66, 0.90)
2015 DGAI minus whole grain	0.77 (0.65, 0.90)
2015 DGAI minus other vegetables	0.76 (0.65, 0.90)
2015 DGAI minus saturated fatty acids	0.76 (0.63, 0.92)

The SUN project (Spanish cohort) 1999–2016.
HR (95% CIs): hazard ratio and 95% confidence intervals. 2015 DGAI: 2015 Dietary Guidelines for Americans Index.
Age was the underlying time variable. Adjusted for sex, body mass index, adding a quadratic BMI term, total energy intake, physical activity during free time, hours watching television, smoking status, marital status and prevalent hypertension, hypercholesterolemia and corresponding subtracted components, and stratified by age and year of entrance to the cohort.
[a] Originally estimated logarithms of HRs were multiplied by 20/21 and then exponentiated to correct for 20-point scale.

2015 DGA, but contains more fruits and seafood and less dairy than does the Healthy U.S. Style Eating Pattern. Therefore, it is reasonable to test the association between 2015 DGA and mortality in a Mediterranean cohort. In the current study, participants in the healthiest quartile of the 2015 DGAI could still improve their adherence to the recommendations, because their median score was only 15.2, out of 21. Nevertheless, despite the lack of complete adherence, those with highest adherence still experienced relevant HR reductions from all-cause, cardiovascular, and cancer deaths—0.42, 0.30 and 46, respectively—compared to the lowest adherence group. Further investigation would determine if better adherence to the DGA recommendations would yield higher reduction in mortality risk. An increase in two points in the 2015 DGAI seems a reasonable goal since we found such an increase to be associated with a 22% all-cause premature mortality HR reduction.

Our results confirm previous findings on the inverse associations between adherence to dietary guidelines and total, cardiovascular, and cancer mortality risks (Harmon et al., 2015; Schwingshackl and Hoffmann, 2015; Onvani et al., 2017; Liese et al., 2015). However, while other findings showed risk reduction of ~20% for these mortality causes, we obtained a HR reduction of 54% for cancer mortality and even higher (70%) for cardiovascular mortality. It is possible that this new index could assess adherence more accurately since it differentiates between quantity and quality of food consumption, preventing higher scores due to greater food intake. Nevertheless, we cannot discount the possibility that our findings were different due to the fact that our cohort is relatively homogeneous and young.

Inverse association between 2015 DGAI and mortality occurrence did not remain significant when we removed alternately from the score the components *variety of vegetables/fruits*, *dietary fiber density*, *red/orange vegetables* or *fruits*. This indicates that these items were the most influential in the score. The current DGA recommends a diet rich in plant-based foods (the more varied, the better) and low in animal products, although small amounts of low-fat products are allowed. Red/orange and dark green vegetables, fresh fruits, whole-fat dairy products and red meat were the food groups that showed higher variability in 2015 DGAI in our cohort. These food groups are either recommended to be eaten in greater amounts or limited in the diet according to the current guidelines. Therefore, it could be expected that removing these specific items from the overall score will nullify the association.

Findings on relationship between diet and cancer mortality are inconsistent. Previous validated indices on adherence to the DGA have shown an inverse association with cancer mortality (Schwingshackl and Hoffmann, 2015; Onvani et al., 2017) but high adherence to the Mediterranean diet, cited as a healthy eating pattern in the 2015 DGA, could not demonstrate this association (Buckland et al., 2011; Martinez-Gonzalez et al., 2012). Since cancer-diet relationship seems to depend on the type of cancer (Buckland et al., 2011; Verberne et al., 2010), further analyses according to cancer specific locations would provide better answers.

We chose to use a cause-specific hazard model over a subdistribution hazard model because the former is the standard approach used in the majority of studies of etiological research. However, as an ancillary analysis, we also run the competing risk model proposed by Fine and Gray (1999) and the point estimates did not change substantially.

The current analysis has some limitations. Food consumption was self-reported through a FFQ, thus, susceptible to reporting errors. However, this technique is considered the most appropriate approach to assess habitual food consumption in large cohorts (Willett, 2013). We removed from the analysis those participants with > 12 missing values in the FFQ. Non-response to 11 or less items in the FFQ (≤8%) was treated as non-consumption, assuming that participants who answered 125 out of 136 FFQ items most likely considered not answering items for foods they did not consume. In addition, we excluded from the analyses those with improbable total energy intake. Dietary assessment was performed only at baseline. Changes in diet over time are possible. Repeated measurements better captures the exposure (Fine and Gray, 1999), and diet could have improved among participants with subclinical disease because of the health status. Thus, our results may have underestimated the reported HR estimates. Our cohort only includes university graduates, so it is not representative of the Spanish population. However, the homogeneity among participants reduces the likelihood of misclassification bias, increasing internal validity and reducing potential confounding. Absolute mortality risk in our cohort was very low, maybe because we assessed a young, slim and well-educated cohort. Thus, risk reduction may not result in large differences in absolute numbers. The whole-fat dairy product group includes a diverse range of dairy foods with different nutritional profiles including whole-fat milk, whole-fat yogurt, condensed milk, cream, milkshake, Petit Suisse cheese, curd, cream and wedge cheese, old cheese (hard and semi hard cheese, Swiss/Emmental cheese, Manchego cheese…), custard and ice-cream. They are likely to exert different effects on health (Thorning et al., 2017). We acknowledge that there is a significant heterogeneity in the nutritional profiles and food matrices of the foods included within this grouping and that there are alternative approaches for their grouping. The approach used for grouping these products may affect a major source of variability in subtypes of dairy product intake in our cohort. Additionally, the generalizability of this finding is uncertain as many countries would consider some of these products (e.g., condensed milk, ice cream or cream) as 'fatty/sugary foods' instead as 'dairy products'.

Some strengths of our study include the relatively large sample size and high retention rate. The FFQ was previously validated, and allows assessing food consumption in a wide range score. Additionally, we were able to control for several confounding variables and performed sensitivity analyses. The young average age of our cohort and their initial healthy characteristics can contribute to allay any reverse causality bias associated with older age and prevalent chronic conditions leading to changes in dietary habits.

5. Conclusion

The current study provides evidence that higher adherence to the 2015 DGA is associated with lower risk of all-cause mortality, and mortality risk specific to cardiovascular disease and cancer, in a Mediterranean population. Our findings suggest that a small increase in adherence to the 2015 DGA recommendations may have non-trivial benefits for maintaining good health, and thus, have important public health implications. Results of this study lend validity to the recently developed guidelines even in a population for which they were not originally designed. Further investigations should be carried out to confirm this relationship in other populations, particularly in North America (the population for whom the 2015 DGA has been developed for), and in relation to other health outcomes beyond mortality.

Acknowledgments

We would like to thank the participants of the SUN cohort for their continuous involvement in the project and all members of the SUN study for their support and collaboration.

Funding sources

The Seguimiento Universidad de Navarra (SUN) Project has received funding from the Spanish Government-Instituto de Salud Carlos III, and the European Regional Development Fund (FEDER) (CIBER-OBN, Grants PI10/02658, PI10/02293, PI13/00615, PI14/01668, PI14/01798, PI14/01764, PI17/01795 and G03/140), the Navarra Regional Government (45/2011, 122/2014), and the University of Navarra. There were no sources of funding that could have influenced the outcome of this work.

Conflicts of interest

The authors declare no conflicts of interest.

Author contributions

U.F. and J.S. designed research; C.F.-A. collected mortality data. U.F. analyzed data; U.F. and M.B.-R. interpreted data; U.F. wrote the manuscript; M.-A.M.-G., J.S., G.S.-S. and M.B.-R. had primary responsibility for final content. All authors read and approved the final manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2018.11.015.

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