Diet Quality Indices in the SUN Cohort: Observed Changes and Predictors of Changes in Scores Over a 10-Year Period

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ABSTRACT

Background Dietary quality indices (DQI) are widely used in nutritional epidemiology. However, how they might change over time in a Mediterranean population is not well understood.

Objective To evaluate within-participant longitudinal changes in scores for nine a priori–defined DQIs: Fat Quality Index (FQI), Carbohydrate Quality Index (CQI), Pro-vegetarian Dietary Pattern (PVG), Mediterranean Diet Adherence Screener (MEDAS), Mediterranean Diet Score (MDS), Dietary Approaches to Stop Hypertension (DASH), Mediterranean-DASH Intervention for Neurodegenerative Delay Diet (MIND), Prime Diet Quality Score (PDQS) and Alternate Healthy Eating Index (AHEI-2010) in the "Seguimiento Universidad de Navarra" (SUN) cohort, a well-known Mediterranean cohort of university graduates, and to identify baseline predictors of improvement in MEDAS and AHEI-2010 after 10 years of follow-up.

Design In this longitudinal cohort study, DQI scores were calculated based on responses from a validated semiquantitative food-frequency questionnaire (FFQ).

Participants/setting Spanish university graduates enrolled in the SUN cohort before March 2008, who completed the 10-year FFQ and reported total dietary intake at baseline and after 10 years of follow-up, included 2,244 men and 3,271 women, whose mean age at baseline was 36.3 years (standard deviation [SD], 10.7).

Main outcome measures Main outcome measures were within-participant longitudinal changes for FQI, CQI, PVG, MEDAS, MDS, DASH, MIND, PDQS, and AHEI-2010.

Statistical analyses performed Adjusted logistic regression models were used to evaluate within-participant longitudinal changes and to identify baseline predictors of improvements $\geq$10% in MEDAS and AHEI-2010 scores after 10 years of follow-up.

Results The comparison of the nine scores of DQI calculated at baseline and after 10 years of follow-up showed an improvement in all DQI scores except for PDQS. The greatest changes in DQIs were found for MEDAS (from 6.2 to 7.2, +22.9%) and MDS (from 4.3 to 4.4, +15.4%). The strongest predictors at baseline for $\geq$10% improvements in MEDAS or AHEI-2010 scores varied across indices. Being female, $\geq$35 years old, and more physically active at baseline were associated with improvement, whereas snacking between meals was associated with <10% improvements in both indices.

Conclusions In this cohort, the changes in nine a priori-defined DQI scores suggested modest improvements in diet quality, in which MEDAS and MDS scores showed the largest improvements. Additional longitudinal studies, especially intervention trials with long follow-up, are warranted to establish the most appropriate DQIs to assess long-term changes in diet quality in adult populations.
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DIETARY QUALITY INDICES (DQI) ARE WIDELY USED IN nutritional epidemiology to assess compliance with national nutrition guidelines and adherence to predefined high-quality or healthy dietary patterns, to monitor overall dietary changes, or to assess the risk of chronic diseases.[1] Most DQI were developed for adult populations based on specific traditional dietary patterns, such as the Mediterranean diet[2]; national dietary guidelines from high-income countries[3] such as American dietary guidelines,[4] or biological phenomena such as inflammation.[5] Most DQI are based on current evidence regarding the association between nutrition and major diet-related diseases or biological processes such as inflammation. DQI include items related to nutrients, foods or food groups or, most frequently, a combination of both. Although all employ an a priori approach, there are differences among the numerous DQI, not only in the number of nutrients and food items included, but also in the cutoff values, criteria for inclusion, and the scoring algorithms.[5-7]

A review published in 2018 analyzed, in great detail, the construction criteria of 57 DQI, showing that 21 of them were constructed to reflect dietary patterns in Mediterranean countries, and 36 were based on dietary guidelines or evidenced-based recommendations.[8]

Despite the extensive use of DQI, certain questions remain unresolved around the multidimensional concept of diet quality, as well as limitations in construction and application of predefined indices.[6,9,10] As a result, there is a lack of consensus regarding a common framework for developing a standard index, which depends on the specific purpose for which they are intended and involves many arbitrary choices related to the selection of specific items, assigning foods to food groups, adjustment (or not) for energy intake, and the choice of cutoff values for scoring.[6] With respect to the development of DQI sample heterogeneity, datasets, measurements, and composition of indices, it is difficult to find coherent recommendations across the multitude of existing indices.[8,9,11]

Reviews have previously studied the associations of major DQI such as Alternate Healthy Eating Index-2010 (AHEI-2010), Dietary Approaches to Stop Hypertension (DASH), or several Mediterranean Diet scores and multiple health outcomes and mortality in cohort studies.[12-15] In addition, some observational prospective studies have shown that improvements in diet quality as indicated by changes in DQI scores, may lead to better health outcomes.[16-20] However, evidence on changes in scores for a priori−defined DQI in large cohorts or on the predictors of dietary changes in community-dwelling adults is scarce.

Thus, the aims of this study were to evaluate within-participant longitudinal changes in scores for nine a priori−defined DQI in the Seguimiento Universidad de Navarra (SUN) cohort, a well-known Mediterranean cohort of university graduates, and to identify predictors at baseline associated with improvements in MEDAS and AHEI-2010 after 10 years of follow-up. The main hypothesis was that diet quality, as assessed by nine a priori−defined DQI, would improve after 10 years of follow-up among the participants in the SUN cohort.

MATERIALS AND METHODS

Study Design

The SUN project (http://medpreventiva.es/MvbqgK) is an ongoing cohort that started in 1999, and its recruitment is permanently open. All participants at the time of recruitment are aged 20 years and older and are graduates of the University of Navarra or from other Spanish universities. The design of the cohort ismodeled after two large cohort studies: the Nurses' Health Study[21] and the Health Professionals Follow-Up Study.[22]

At baseline, when participants agree to enter the study, they receive a baseline epidemiological assessment by postal mail or an e-mail with a personal code to answer the questionnaire via the study's website (this second alternative has been available since 2004).

Participants' information is collected biennially through mailed or electronically mailed questionnaires that gather information about lifestyle habits (eg, smoking habits, alcohol consumption, physical activity), diet, newly diagnosed illnesses, medical conditions, and several other sociodemographic factors.

> **RESEARCH SNAPSHOT**
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> **Research Question**: Did Diet Quality Indices (DQI) scores change after 10 years of follow-up in the "Seguimiento Universidad de Navarra" (SUN) cohort?
>
> **Key Findings:** In this Mediterranean cohort of university graduates, the evaluation of prospective changes in nine a priori defined DQI scores, suggests modest improvements in diet quality after 10 years of follow-up. Overall, Mediterranean Diet Adherence Screener (MEDAS) and Mediterranean Diet Score (MDS) showed better scores after 10 years of follow-up than at baseline.

Voluntary completion of the baseline epidemiological assessment implied informed consent, because participants received detailed information about the entire study at this stage. The details about the design and methods of this cohort have been previously published elsewhere.[23] The SUN Project was conducted according to the guidelines laid down in the Declaration of Helsinki; its protocol was approved by the Institutional Review Board of the University of Navarra, and this cohort is registered at clinicaltrials.gov as NCT02669602. Potential participants had the right to refuse to participate in the SUN study or to withdraw their consent to participate at any time without reprisal.

Participants

Diet was evaluated through a full-length validated semi-quantitative food frequency questionnaire (FFQ) administered at baseline and after 10 years of follow-up.[24-26] Only those participants who completed the general questionnaire after 10 years of follow-up (Q_10) online are invited to complete the FFQ after 10 years of follow-up. Thus, its completion is completely voluntary to ensure a high retention rate, and noncompletion does not compromise the rest of the information collected during follow-up. In this sample, approximately 62% of participants with a 10-year assessment decided to complete the FFQ after 10 years of follow-up. The rest of the participants (38%) completed the other sections of the Q_10, but not the entire FFQ, after 10 years.

Although 19,563 participants had completed the baseline epidemiological assessment by March 2008, participants who died during the 10 years of follow-up (n = 260), those who did not complete the Q_10 online (n = 7,158), participants who did not complete the FFQ after 10 years of follow-up (n = 4,642) and, finally, participants with total energy intakes outside the predefined values at baseline or after 10 years of follow-up (n = 671 and n = 1,317, respectively) according to the sex-specific predefined limits of total energy intake proposed by Willett (<800 kcal/d or >4,000 kcal/d for men and <500 kcal/d or >3,500 kcal/d for women)[27] were excluded. Thus, the sample for this study included 5,515 participants.

Measurement Instruments

Dietary habits at baseline and after 10 years of follow-up were assessed with the semiquantitative 136-item FFQ.[24-26]

which assessed food habits in the previous year. This questionnaire had the following nine possible response categories: never/seldom, 1–3 servings/month, 1 serving/week, 2–4 servings/week, 5–6 servings/week, 1 serving/day, 2–3 servings/day, 4–6 servings/day, and >6 servings/day, with standard portion sizes specified. Nutrient intake was calculated by multiplying the frequency of consumption by the nutrient content of the specified portion, using data from the Spanish food composition tables.[28,29] The baseline epidemiological assessment also collected information on a wide array of characteristics, including health-related habits, clinical characteristics, and sociodemographic variables. For the current analysis, the following variables were used: age, sex, body mass index (BMI = weight [kg]/height [m]^2), leisure-time physical activity, time spent sitting, smoking status, years of university education, marital status, prevalent disease (hypertension, cancer, diabetes, dyslipidemia, or cardiovascular disease), weight gain over the previous 5 years, and information on whether individuals followed special diets, engaged in between-meal snacking, self-declared as a tense or relaxed person, and self-declared as either a dependent or an autonomous person.

Physical activity was assessed at baseline, using a questionnaire previously validated in Spain, which includes information on 17 leisure-time activities.[30] To obtain a value of overall weekly physical activity, the time spent in each activity was multiplied by its corresponding MET (Metabolic Equivalent Score) and then summed over all activities to derive METs-hours/week.

Diet Quality Indices

Diet quality was assessed using nine previously published DQI. These nine DQI were Carbohydrate Quality Index (CQI),[31,32] Fat Quality Index (FQI),[33] DASH index,[34] Provegetarian Dietary Pattern (PVG),[35] Mediterranean-DASH Intervention for Neurodegenerative Delay Diet (MIND),[36] Prime Diet Quality Score (PDQS),[37] Mediterranean Diet Adherence Screener (MEDAS),[38] AHEI-2010,[1] and Mediterranean Diet Score (MDS).[39] Figure 2 (available at www.jandonline.org) shows the criteria used to calculate each DQI.

The rationale for choosing these DQI was as follows. The CQI and the FQI have been recently used in the SUN cohort[31,33] and in the Prevención con Dieta Mediterránea (PREDIMED) study.[32] The DASH index pattern rewarded points for certain foods according to their quintile rankings.[34] One novel DQI is the MIND diet index. MIND is a combination of Mediterranean and DASH patterns, with modifications to include relevant foods and nutrients related to decreased risks of incident dementia and cognitive decline.[36] Another recently developed score is the PVG, which tries to capture a preference for foods of plant origin instead of animal sources.[35] The PDQS is a recent DQI based on a short diet assessment tool developed for clinical use to quickly assess diet quality, the Prime Screen questionnaire.[37] In relation to the Mediterranean dietary pattern, the 14-point MEDAS used in the PREDIMED study[38] and the MDS proposed by Trichopoulou et al[39] were used. Finally, the AHEI-2010 is a widely used, refined version of the AHEI created in 2002.[1] Incorporating current scientific evidence on diet and health, AHEI-2010 is based on food and nutrients predictive of chronic disease risk.[1]

The observed changes after 10 years for the scores in all nine DQI were assessed. However, given the observed pairwise correlations between the different DQI, because the MEDAS and the AHEI-2010 are the only indexes in which the participants' scores are not based on sample-specific rankings and for the sake of brevity, only the associations between potential baseline predictors and 10-year score changes for the MEDAS and the AHEI-2010 were assessed. A Mediterranean DQI that has been used in the PREDIMED randomized trial and the AHEI-2010 because of its wide use was chosen. Data were grouped into quintiles of adherence as best as possible to these DQI and then categorized into three categories (Q1: low, Q2–Q4: medium, and Q5: high).

Potential Predictors

The potential baseline predictors of changes in DQI from baseline to 10 years were based on clinical relevance and previously published findings. Self-reported information on all predictors was collected within the baseline epidemiological assessment. The potential predictors were sex, age, BMI (<18.5, 18.5–24.9, and >24.9), marital status (single, married, and others), smoking status (never smokers, former smokers, current smoking <15 cigarettes/d, and current smoking ≥15 cigarettes/d), leisure-time physical activity (METs-hours/week, in tertiles), time spent sitting (hours/week, in tertiles), between-meal snacking (yes/no), following special diets (yes/no), year of recruitment (<2002, ≥2002), weight gain over the previous 5 years (<3 kg, ≥3 kg), psychological strain (in tertiles), dependency (in tertiles), competitiveness (in tertiles), and medical diagnoses of prevalent cardiovascular disease, diabetes, cancer, and hypercholesterolemia (yes/no). The level of self-perceived psychological strain was evaluated through the following question: "Do you consider yourself a tense, aggressive, worrisome person or do you think of yourself as a relaxed and calm person?" The level of dependency was evaluated through the following question in the baseline questionnaire: "Do you think you have enough resources, preparation, and autonomy to solve any problems at work, or do you exclusively rely on others?" Finally, participants' self-described level of competitiveness was collected at baseline, using the question "Do you consider yourself a competitive, nonconformist, fighter, who demands everything of yourself at work and sometimes even more than what you can afford?"

Statistical Methods

Descriptive statistics were used to describe baseline characteristics and the differences observed between baseline and 10 years of follow-up in the nine DQI. Differences between baseline characteristics of participants according to completion of the FFQ_10 were evaluated using a two-sample test of differences in proportions.

Logistic regression models were run to assess the association between participants' baseline characteristics and the odds of making any improvement 10% or higher in AHEI-2010 or MEDAS after 10 years of follow-up. An odds ratio (OR) >1 indicates an improvement in the score. Two different models were calculated: a) a crude model and b) a multivariable model that adjusted for age, sex, smoking status (never

Table 1. Baseline characteristics of 5,515 participants of the SUN project [mean (standard deviations) or percentages] according to quintiles of baseline Mediterranean Diet Adherence Screener (MEDAS) and Alternate Healthy Eating Index-2010 (AHEI-2010) scores

	MEDAS			AHEI-2010		
	Q1	**Q2-Q4**	**Q5**	**Q1**	**Q2-Q4**	**Q5**
Scores	1-5	6-8	9-13	17-49	50-66	67-95
N	1,972	2,987	556	1,215	3,294	1,006
Variable						
Age (years)	33.9 (9.5)	37.1 (11.0)	40.5 (11.1)	33.4 (9.5)	36.0 (10.5)	40.5 (11.5)
Men (%)	47.2	37.9	32.9	41.2	40.8	37.8
BMI	23.4 (3.4)	23.4 (3.4)	23.2 (3.3)	23.4 (3.5)	23.4 (3.3)	23.5 (3.4)
Leisure-time physical activity (MET hours/week)	20.3 (18.5)	23.1 (20.7)	27.4 (25.8)	19.7 (18.3)	22.7 (20.8)	25.4 (22.5)
Sitting hours (hours/week)	5.7 (2.0)	5.7 (2.0)	5.2 (2.1)	5.8 (2.0)	5.5 (2.0)	5.3 (2.0)
Smoking status (%)						
Smokers	27.2	23	17.7	30.1	23.7	17.6
Former smokers	24.4	28.8	39.8	22.1	28.6	34.9
Never smokers	48.4	48.2	42.5	47.8	47.7	47.6
Years of university education	5.1 (1.5)	5.1 (1.5)	4.9 (1.4)	5 (1.5)	5.1 (1.5)	5.1 (1.6)
Marital status						
Married	44.3	52.8	54.9	43.8	50.7	54.9
Single	52.5	42.2	36.5	52.8	44.6	38.6
Others	3.3	5.1	8.6	3.5	4.7	6.5
Hypertension at baseline (%)	15.7	18.6	20.0	15.4	17.2	22.1
Cancer at baseline (%)	2.7	2.8	4	2.1	3.1	3.4
Diabetes at baseline (%)	0.6	1.7	1.6	0.8	1.1	2.6
Dyslipemia at baseline (%)	4.5	6.3	7.4	5.3	5.3	7.9
Cardiovascular disease at baseline (%)	0.9	1.3	0.9	0.9	0.9	1.9
Weight gain $\geq$ 3 kg in previous 5 years (%)	33.4	29.5	25.4	34.1	31.0	24.5
Following special diets (%)	4.5	8.9	12.8	3.9	7.1	14.3
Between-meals snacking (%)	35.6	30.4	24.6	37.8	31.1	26.1

smokers, former smokers, currently smoking <15 cigarettes/d, and currently smoking ≥15 cigarettes/d), physical activity (in tertiles), time spent sitting (in tertiles), total energy intake (continuous), following a special diet at baseline (yes/no), between-meal snacking (yes/no), educational level (years of university education, continuous), BMI (<18.5, 18.5–24.9, and >24.9) and the corresponding baseline score for each DQI.

For each participant and for each DQI, the percent change was calculated as follows: (Score after 10 years of follow-up − Baseline score) × 100/Baseline score. The mean of percent change after follow-up and the mean of this percent according to sex were also calculated. The results according to sex were represented as the mean and 95% confidence intervals (CI). Two-by-two Spearman's correlation coefficients between DQI at baseline and after 10 years of follow-up were displayed with a heat map, using a green–red scale.

Finally, sensitivity analyses—exclusion of participants who followed a special diet at baseline or who had at least one of cardiovascular disease, dyslipidemia, cancer, or diabetes—were conducted. Two alternative models were fit after selecting the alternative cutoff points of 5% improvement and a 20% improvement in the MEDAS and AHEI-2010 scores.

Analyses were performed using STATA.[40] All *P* values were two-tailed, and statistical significance was set at the conventional cutoff of $P < .05$.

RESULTS

Data from a total of 2,244 men and 3,271 women were included in this analysis. Mean age at baseline was 36.3 years (SD, 10.7). Baseline characteristics of study participants are presented according to quintiles of MEDAS and AHEI-2010 scores in Table 1. Women tended to exhibit healthier DQI scores than men. Participants in the fifth quintile of each dietary index, compared with those in the first quintile (poorest diet), were more likely to be older, more physically active, former smokers, more likely to report cancer, diabetes, or dyslipidemia at baseline, and more likely to follow special diets. Participants who showed worse quality diets, measured through MEDAS or AHEI-2010 scores, were more likely to be smokers, more prone to be sedentary, more likely to have gained ≥3 kg of weight over the past 5 years, and more likely to snack between meals.

There were only minor differences in baseline characteristics of participants at their 10-year follow-up who completed vs those who had not completed the FFQ_10 (Table 2, available at www.jandonline.org)

Baseline dietary information from the SUN Project participants according to baseline MEDAS and AHEI-2010 scores is summarized in Table 3. Overall, the results were

Table 3. Baseline food consumption, energy, and nutrient intakes of the participants of the SUN cohort (mean [SD]) according to the baseline quintiles of the Mediterranean Diet Adherence Screener (MEDAS) and Alternate Healthy Eating Index-2010 (AHEI-2010) scores[a]

	MEDAS			AHEI-2010		
	Q1	**Q2-Q4**	**Q5**	**Q1**	**Q2-Q4**	**Q5**
Scores	1—5	6—8	9—13	17—49	50—66	67—95
N	1,972	2,987	556	1,215	3,294	1,006
Food consumption						
Dairy products (g/d)	244 (213)	193 (188)	156 (179)	280 (243)	202 (185)	139 (153)
Vegetables (g/d)	325 (186)	562 (289)	792 (361)	357 (231)	500 (285)	675 (345)
Fruits (g/d)	213 (171)	352 (270)	572(381)	195 (178)	329 (256)	467(346)
Fish (g/d)	72 (43)	104 (60)	130 (65)	78 (50)	97 (58)	110 (63)
Meats (g/d)	182 (71)	169 (77)	139 (70)	194.7 (71)	174 (73)	130 (70)
Eggs (g/d)	25 (17)	24 (17)	21 (13)	25.7 (17)	24 (17)	21 (16)
Nuts (g/d)	4.2 (5.4)	7 (12)	16 (20)	3.7 (4.5)	6.0 (8.9)	13.7 (19)
Legumes (g/d)	19.5 (12)	23 (18)	27 (25)	17.7 (14)	23 (16)	26 (22)
Grains (g/d)	103 (75)	102 (71)	113 (71)	109 (84)	103 (71)	99 (62)
Olive oil (g/d)	13 (11)	20 (15)	27 (19)	16 (13.8)	18 (15)	21 (16)
Fast-food (g/d)	25.6 (23.8)	20 (18)	14 (14)	27 (23)	21 (19)	15 (16)
Energy and nutrient intakes						
Energy (kcal/d)	2,279 (601)	2,339 (594)	2,506 (594)	2,418 (611)	2,335 (589)	2,232 (606)
Carbohydrate (% E)	43 (6.9)	43 (7.1)	46 (7.8)	42 (7.4)	44 (7.0)	45 (7.0)
Protein (% E)	18 (3.3)	18 (3.1)	18 (3.2)	18 (3.3)	18 (3.2)	18 (3.3)
Total fat intake (% E)	38 (5.9)	36 (6.3)	34 (7.2)	38 (6.3)	36 (6.2)	35 (6.6)
PUFA[b] (% E)	5.4 (1.7)	5.1 (1.5)	5.0 (1.4)	5 (1.4)	5.2 (1.5)	5.5 (1.7)
MUFA[c] (% E)	16 (3.2)	16 (3.7)	16 (4.5)	16 (3.5)	16 (3.6)	16 (3.9)
SFA[d] (% E)	14 (3.0)	12 (2.9)	10 (2.8)	14 (3.3)	13 (2.8)	10.6 (2.6)
TFA[e] (% E)	0.4 (0.2)	0.4 (0.2)	0.3 (0.2)	0.5 (0.2)	0.4 (0.2)	0.3 (0.1)
n-3 fatty acids (g/d)	2.4 (1.3)	2.7 (1.2)	3.0 (1.2)	2.5 (1.3)	2.6 (1.2)	2.7 (1.2)
n-6 fatty acids (g/d)	20 (13.8)	17 (11)	16 (10.6)	20 (13)	18 (12)	17 (11)
Cholesterol (mg/d)	422 (138)	410 (149)	377 (130)	451 (142)	415 (141)	351 (134)
Fiber intake (g/d)	21 (7.7)	29 (9.7)	41 (14)	20 (7.9)	17 (10)	35 (14)
Alcohol intake (g/d)	1.8 (2.5)	2.1 (2.9)	2.3 (3.3)	2.4 (3.5)	2.0 (2.7)	1.7 (2.1)

[a]Values are expressed as mean (standard deviation).
[b]PUFA = polyunsaturated fatty acids.
[c]MUFA = monounsaturated fatty acids.
[d]SFA = saturated fatty acids.
[e]TFA = trans fatty acid.

Table 4. Baseline and 10-year-follow up dietary scores of 5,515 participants of the SUN project (mean [standard deviations])

	Baseline dietary score	10-year follow-up dietary score
DASH[a]	24.1 (4.7)	24.3 (4.8)
MIND[b]	7.6 (1.5)	8.4 (1.4)
PDQS[c]	17.83 (3.8)	17.75 (3.8)
MEDAS[d]	6.2 (1.7)	7.2 (1.7)
AHEI-2010[e]	57.4 (10.2)	60.5 (10.8)
CQI[f]	11.2 (3.2)	11.5 (3.2)
FQI[g]	1.7 (0.5)	1.8 (0.5)
PVG[h]	36.6 (5.2)	37.6 (5.2)
MDS[i]	4.3 (1.8)	4.4 (1.7)

[a]Dietary Approaches to Stop Hypertension (DASH). The total score ranges from 0 (minimal adherence) to 40 (maximal adherence).
[b]Mediterranean-DASH Intervention for Neurodegenerative Delay Diet (MIND). The total score ranges from 0 (minimal adherence) to 15 (maximal adherence).
[c]Prime Diet Quality Score (PDQS). The total score ranges from 0 (minimal adherence) to 42 (maximal adherence).
[d]Mediterranean Diet Adherence Screener (MEDAS). Index ranges from 0 (no adherence at all) to 14 (perfect adherence).
[e]Alternate Healthy Eating Index (AHEI-2010). The total score ranges from 0 (minimal adherence) to 110 (maximal adherence).
[f]Carbohydrate Quality Index (CQI). Range from 4 (worst carbohydrate quality) to 20 (better quality)
[g]Fat Quality Index (FQI). Index ranges from 0.62 (worst fat quality) to 5.92 (better fat quality).
[h]Pro-vegetarian Dietary Pattern (PVG). The total score ranges from 12 (minimal adherence) to 60 (maximal adherence).
[i]Mediterranean Diet Score (MDS). The total score ranges from 0 (minimal adherence) to 9 (maximal adherence).

similar across the two assessed DQI. Participants with better scores in MEDAS and AHEI-2010 had a higher consumption of vegetables, fruits, fish, nuts, legumes, grains (except for the AHEI-2010), and olive oil; lower consumption of dairy products, meats, eggs, and fastfood. In addition, participants with better adherence to MEDAS and AHEI-2010 had higher intake of polyunsaturated fatty acids (except for the MEDAS), percentage of energy from carbohydrates, n-3 fatty acids, and fiber; by contrast, their intakes of total fat, saturated fatty acids, and cholesterol were lower.

As shown in Table 4, there were improvements observed for all DQIs calculated after 10 years of follow-up compared with baseline except for the PDQS. The largest improvements were shown in the scores of the MEDAS (from 6.2 to 7.2, +22.9%), MDS (from 4.3 to 4.4, +15.4%), MIND (from 7.6 to 8.4, +13.3%), FQI (from 1.7 to 1.8, +12.5%), and CQI (from 11.2 to 11.5, +8.6%) (data not shown). Smaller improvements were observed for DASH (from 24.1 to 24.3, +2.9%) score (data not shown).

Table 5 shows the results of the logistic regression analyses used to assess the association between baseline characteristics of participants and the likelihood of showing at least 10% improvements in MEDAS or AHEI-2010 after 10 years of follow-up with respect to their baseline scores. Positive changes toward better compliance with the MEDAS were more frequently observed among women (OR: 1.97 [95%CI: 1.69−2.30]), participants aged 35 to 50 years old (OR: 1.32 [95%CI: 1.14−1.54]) or ≥50 years old (OR: 1.77 (95%CI: 1.43−2.20]), who had gained ≥3 kg weight over the past 5 years (OR: 1.19 [95%CI: 1.03−1.37]), who were married (OR: 1.18 [95%CI: 1.02−1.38]) or who had a marital status other than married or single (OR: 1.42 [95%CI: 1.04−1.94]), or showed a high level of leisure-time physical activity (OR: 1.19 [95%CI: 1.02−1.39] and OR: 1.35 [95%CI: 1.16−1.58]) for the second and third tertile, respectively, and for former smokers (OR: 1.18 [95%CI: 1.02−1.38]). Conversely, having prevalent diabetes (OR: 0.59 [95%CI: 0.35−0.99]), spending a moderate time sitting (OR: 0.84 [95%CI: 0.72−0.98]) or snacking between meals (OR: 0.80 [95%CI: 0.69−0.91]) were the strongest baseline predictors of not improving at least 10% in adherence to MEDAS.

In relation to the AHEI-2010, the independent baseline predictors for obtaining a favorable score change of at least 10% included being women (OR: 1.18 [95%CI: 1.02−1.37]), being 35 to 50 years old (OR: 1.43 [95%CI: 1.24−1.66]) or ≥50 years old (OR: 1.56 [95%CI: 1.25−1.94]), having been recruited in 2002 or later (OR: 1.23 [95%CI: 1.08−1.39]), and being more physically active (OR: 1.37 [95%CI: 1.18−1.59] and OR: 1.36 [95%CI: 1.16−1.59] for the second and third tertiles, respectively). By contrast, snacking between meals (OR: 0.79 [95% CI: 0.69−0.91]), having a moderate level of psychological strain (OR: 0.82 [95%CI: 0.69−0.97]), or smoking ≥15 cigarettes/d (OR: 0.78 [95%CI: 0.63−0.98]) were significant baseline predictors of not improving at least 10% in the AHEI-2010 score.

Figure 1 represents the mean of percent change in each dietary score after 10 -years of follow-up, stratified by sex. Overall, greater changes in DQI were observed among women. The statistically significant major differences by sex, women vs men, were found for CQI (7.43 vs 10.33, $P = 0.006$), FQI (13.98 vs 10.38, $P < 0.001$), MIND (14.22 vs 11.98, $P < 0.001$), and PDQS (3.41 vs 0.56, $P < 0.0001$). On the contrary, the smallest differences not statistically significant, women vs men, were observed for MDS (15.6 vs 15.3), MEDAS (23.05 vs 22.77), and AHEI (7.53 vs 7.16).

Figure 3 (available at www.jandonline.org) represent two heat maps with the 2 × 2 Spearman's correlation coefficients (r) for the DQI at baseline (Figure 3A, available at www.jandonline.org) and after 10 years of follow-up (Figure 3B, available at www.jandonline.org). The AHEI-2010, MEDAS, PVG, DASH, MDS, and PDQS were correlated with a higher number of other DQI at baseline ($r > |0.50|$). Similarly, the AHEI-2010, MEDAS, and PDQS were strongly correlated with many of the other DQI after 10 years of follow-up ($r > |0.50|$). The highest correlation coefficients were observed between DASH and AHEI-2010, and between CQI and PDQS, both at baseline ($r = 0.70$) and between DASH and AHEI-2010 after 10 years of follow up ($r = 0.65$).

When participants who were following a special diet at baseline or who had prevalent cardiovascular disease, dyslipidemia, cancer, or diabetes (n = 1,368) were excluded, the results supported the robustness of the main findings. Moreover, the strongest baseline predictors of improving in at least 10% of adherence to MEDAS or AHEI-2010 did not substantially change (data not shown).

Table 5. Multivariable OR (95% confidence interval [CI]) for improvement of ≥10% in Mediterranean Diet Adherence Screener (MEDAS) or Alternate Healthy Eating Index (AHEI-2010) scores after 10 years of follow-up

Baseline predictors[a] of changes	Participants (%) with improvements of at least 10%	MEDAS		Participants (%) with improvements of at least 10%	AHEI-2010	
		Crude	Multivariate[b]		Crude	Multivariate[b]
Sex						
Men (n = 2,244)	58.7	1 (ref)	1 (ref)	40.3	1 (ref)	1 (ref)
Women (n = 3,271)	62.0	**1.15 (1.03—1.28)**	**1.97 (1.69—2.30)**	40.6	1.01 (0.91—1.13)	**1.18 (1.02—1.37)**
Age						
< 35 years (n = 2,724)	62.3	1 (ref)	1 (ref)	41.0	1 (ref)	1 (ref)
35—50 years (n = 2,075)	59.6	0.89 (0.79—1.00)	**1.32 (1.14—1.54)**	41.2	1.01 (0.90—1.13)	**1.43 (1.24—1.66)**
≥50 years (n = 716)	57.3	**0.81 (0.69—0.96)**	**1.77 (1.43—2.20)**	36.3	**0.81 (0.69—0.97)**	**1.56 (1.25—1.94)**
Prevalent diabetes						
No (n = 5,442)	60.8	1 (ref)	1 (ref)			
Yes (n = 73)	45.2	**0.53 (0.33—0.84)**	**0.59 (0.35—0.99)**			
Sitting (hours/week)						
Tertile 1 (n = 1,841)	61.2	1 (ref)	1 (ref)			
Tertile 2 (n = 1,850)	59.5	0.93 (0.82—1.06)	**0.84 (0.72—0.98)**			
Tertile 3 (n = 1,824)	61.3	1.01 (0.88—1.15)	0.87 (0.75—1.02)			
Weight gain in the past 5 years						
<3 kg (n = 3,833)	59.4	1 (ref)	1 (ref)	39.2	1 (ref)	1 (ref)
≥3 kg (n = 1,682)	63.6	**1.19 (1.06—1.34)**	**1.19 (1.03—1.37)**	43.5	**1.19 (1.06—1.34)**	1.11 (0.97—1.28)
Special diet at baseline						
No (n = 5,089)	61.2	1 (ref)	1 (ref)	40.9	1 (ref)	1 (ref)
Yes (n = 426)	54.2	**0.75 (0.62—0.92)**	1.07 (0.85—1.34)	35.0	**0.78 (0.63—0.95)**	1.17 (0.92—1.49)
Between-meals snacking						
No (n = 3,770)	60.7	1 (ref)	1 (ref)	50.0	1 (ref)	1 (ref)
Yes (n = 1,745)	60.4	0.99 (0.88—1.11)	**0.80 (0.69—0.91)**	39.4	0.94 (0.84—1.05)	**0.79 (0.69—0.91)**

(continued on next page)

Table 5. Multivariable OR (95% confidence interval [CI]) for improvement of ≥10% in Mediterranean Diet Adherence Screener (MEDAS) or Alternate Healthy Eating Index (AHEI-2010) scores after 10 years of follow-up *(continued)*

Baseline predictors[a] of changes	Participants (%) with improvements of at least 1 %	MEDAS Crude	MEDAS Multivariate[b]	Participants (%) with improvements of at least 10%	AHEI-2010 Crude	AHEI-2010 Multivariate[b]
Level of psychological strain						
Tertile 1 (n = 1,298)				42.5	1 (ref)	1 (ref)
Tertile 2 (n = 1,629)				38.8	**0.86 (0.74—0.99)**	**0.82 (0.69—0.97)**
Tertile 3 (n = 2,588)				40.5	0.92 (0.81—1.06)	0.89 (0.77—1.04)
Marital status						
Single (n = 2,498)	60.9	1 (ref)	1 (ref)			
Married (n = 2,754)	60.5	0.98 (0.88—1.10)	**1.18 (1.02—1.38)**			
Others (n = 263)	60.1	0.97 (0.75—1.25)	**1.42 (1.04—1.94)**			
Year of entry into the cohort						
<2002 (n = 2,194)				40.6	1 (ref)	1 (ref)
≥2002 (n = 3,321)				40.4	0.99 (0.89—1.11)	**1.23 (1.08—1.39)**
Smoking status						
Never smokers (n = 2,631)	60.4	1 (ref)	1 (ref)	40.7	1 (ref)	1 (ref)
Former smokers (n = 1,714)	59.7	0.97 (0.86—1.10)	**1.18 (1.02—1.38)**	39.2	0.94 (0.83—1.07)	0.99 (0.85—1.15)
<15 cig/d (n = 658)	62.3	1.09 (0.91—1.29)	1.01 (0.83—1.23)	40.6	0.99 (0.84—1.18)	0.86 (0.71—1.05)
≥15 cig/d (n = 512)	62.9	1.11 (0.92—1.35)	0.97 (0.78—1.22)	43.0	1.10 (0.91—1.33)	**0.78 (0.63—0.98)**
Physical activity during leisure time						
Tertile 1 (n = 1,298)	61.1	1 (ref)	1 (ref)	39.1	1 (ref)	1 (ref)
Tertile 2 (n = 1,629)	61.5	1.02 (0.89—1.16)	**1.19 (1.02—1.39)**	43.2	**1.18 (1.03—1.35)**	**1.37 (1.18—1.59)**
Tertile 3 (n = 2,588)	59.3	0.93 (0.81—1.06)	**1.35 (1.16—1.58)**	39.1	1.00 (0.88—1.14)	**1.36 (1.16—1.59)**

[a]Only the independent predictors for each dietary index are shown in this Table.

[b]Multivariate model adjusted for: age, sex, smoking status (never smokers, ex-smokers, <15 cig/d and ≥15 cig/d), physical activity (in tertiles), time spent sitting (in tertiles), total energy intake (continuous), use of special diet at baseline (yes/no), the habit of between-meal snacking (yes/no), educational level (years of university education, continuous), BMI (<18.5, 18.5—24.9, and >24.9).

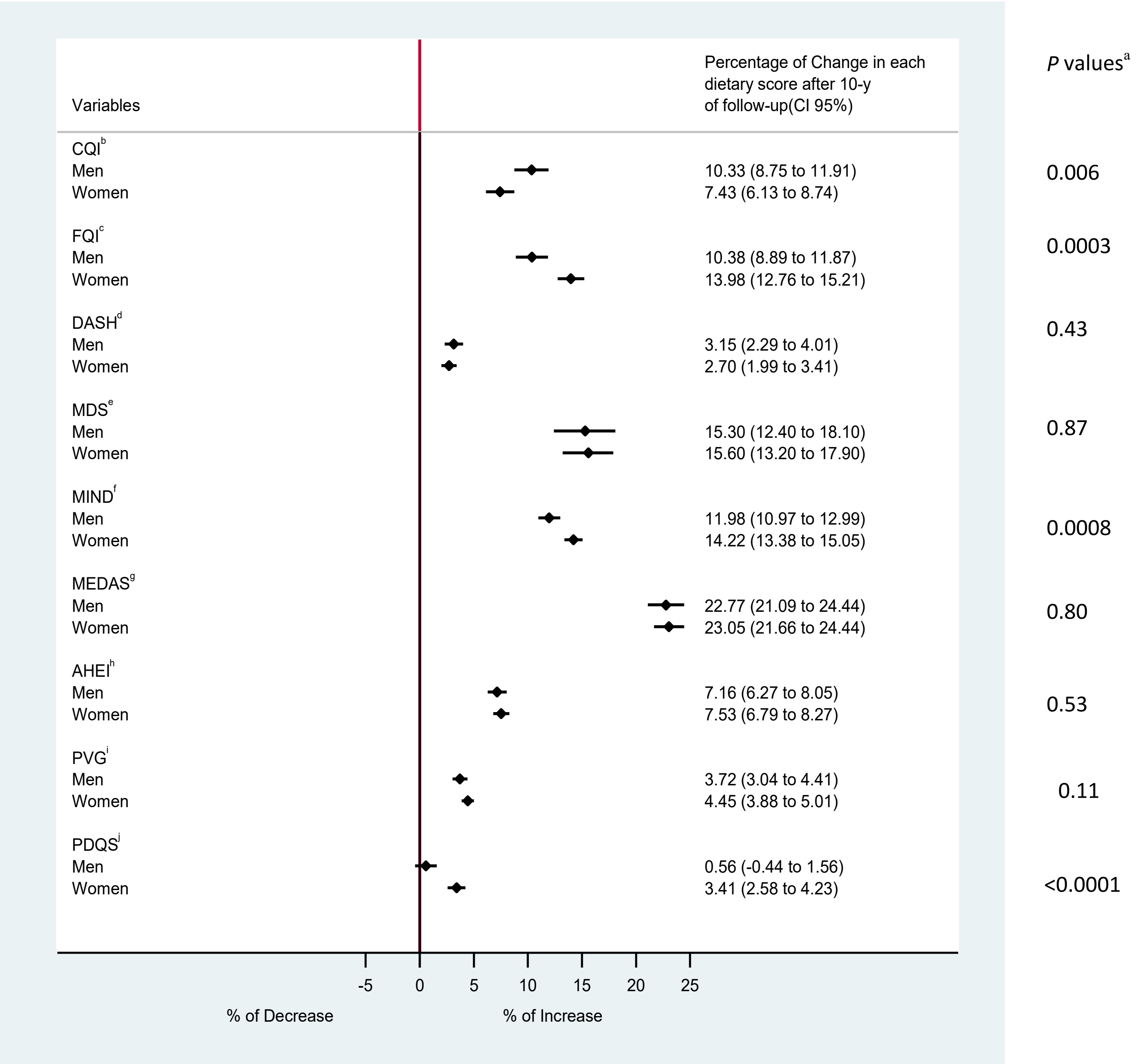

Figure 1. Percentage of change in each dietary score after 10 years of follow-up according to sex (mean and 95% confidence intervals). [a]The *P* values represent the statistical significance of the difference of change between women and men. [b]CQI = Carbohydrate Quality Index. [c]FQI = Fat Quality Index. [d]DASH = Dietary Approaches to Stop Hypertension. [e]MDS = Mediterranean Diet Score. [f]MIND = Mediterranean-DASH Intervention for Neurodegenerative Delay Diet. [g]MEDAS = Mediterranean Diet Adherence Screener. [h]AHEI = Alternate Healthy Eating Index. [i]PVG = Pro-vegetarian Dietary Pattern. [j]PDQS = Prime Diet Quality Score.

Finally, two alternative models were fit as sensitivity analyses after selecting the following alternative cutoff points: a 5% improvement and a 20% improvement in MEDAS and AHEI-2010. Overall, the results further supported the robustness of the main findings (data not shown).

DISCUSSION

To the best of the authors' knowledge, this is the first investigation to specifically and prospectively assess changes in diet quality measured by nine a priori defined DQI during a 10-year follow-up in the same cohort. In this large Mediterranean cohort of university graduates, modest improvements in diet quality scores measured by nine a priori- defined DQI after 10 years of follow-up were found. Although no dietary intervention was conducted, the analysis provides evidence that diet quality improved slightly, possibly because of the completion of questionnaires related to diet and lifestyle every 2 years or selection factors related to voluntary participation in the cohort.[41] In fact, the shorter questionnaires that participants completed after the baseline assessment and before the 10-year follow-up assessment include a total of 33 questions on food intake summarizing all of the diet-related items.[23] Possibly these questions inquiring about dietary habits may have prompted some participants to improve their dietary habits. It is also possible that repeated questioning may have biased the answers toward healthier responses, which occurs in dietary assessments and tends to be more frequent in well-educated women.[42,43]

In general, DQI capture the essential components of a healthy diet that are commonly used to assess overall dietary habits.[11] Specific combinations of food groups largely depend on the research question and study design; nonetheless the use of a priori- defined indexes intends to capture specific dietary patterns, such as measuring adherence to dietary guidelines.[10] Clear differences exist between the nine a priori—defined DQI calculated in this research. For example, some of them are based on an absolute scoring system (MEDAS or AHEI-2010, for example), but other DQI award points based on ranking (MDS, CQI or FQI, among others). Moreover, there are differences in the dietary components (food, nutrients, or both) included in each DQI, as well as the criteria for optimal cutoff points. As a result, the use of DQIs also might be prone to some degree of misclassification.

Overall, modest improvements in diet quality measured by the DQI were observed in this study. These results are consistent with results of a subsample of the NEXT Generation Health Study in which three DQI were evaluated after 4 years of follow-up.[17] In addition, Fung et al[18] found similar improvement in three DQI in both Nurses' Health Study and Health Professionals Follow-Up Study cohorts, after 4 years of follow-up.[18] Previous studies have shown differences in dietary patterns according to sex, social class, and education level among other determinants of behavioral adherence.[44-48] However, only three constant baseline predictors of improvement in MEDAS and AHEI-2010; ie, being female, being $\geq$35 years of age, and being more physically active at baseline, in line with previously reported findings,[14,15,17-19] were found.

Overall, these results suggest that the improvement in DQI was higher among women than among men. One possible explanation may be that mothers and wives are more health conscious, more receptive to food and health information, and thus more prone to improve their dietary intake, as well as overestimate it.[49,50] In fact, the mother's role in particular has been suggested to serve as an opportunity to model healthy eating behavior and to set a positive example for other family members.[51]

According to the existing evidence, people's diets improve with age and in response to potential health events, such as a cancer diagnosis or other health diagnosis, that could lead to a "teachable moment" and increase motivation for dietary changes.[49] As a countervailing point, it also is known that diets tend to be relatively stable in adulthood.[52-55] Unhealthy dietary habits are known to increase the risk of chronic diseases such as cardiovascular disease or cancer.[56] When exclusion criteria were applied to participants with chronic conditions at baseline, the results barely changed. This finding suggests that these participants may have modified their diet before entering the cohort because of a previous medical diagnosis or diet-related disease.

As expected, higher physical activity was associated with a greater improvement in DQI. This result suggests that more active participants tended to have healthier lifestyles after 10 years of follow-up than those who were less active or sedentary at baseline. This same association had been also observed in previous research in the SUN Project[57] and in other epidemiological studies.[58,59]

An inverse association between snacking between meals and improvement in DQI was found, although some studies reported mixed results on associations between snacking and diet quality, depending on the snack composition and time of eating.[60-62]

Results in relation to other baseline predictors of improvement across MEDAS and AHEI-2010 scores in this sample of Spanish graduates were not consistent. However, previous research has concluded that sociodemographic variables, diet, physical activity, and sedentary behavior cluster together in complex ways that are not yet fully understood.[63]

Previous studies have shown that changes toward better compliance with the Mediterranean Diet were more frequent among individuals without diabetes.[49] In the current study, a similar association among participants without prevalent diabetes was observed.

Finally, in the current study conducted in the SUN cohort, AHEI-2010, MEDAS, and PDQS scores were correlated at baseline and after 10 years of follow-up as initially expected. The correlation between AHEI-2010 and DASH scores were highest. The Dietary Patterns Method Project evaluated four DQI in total (HEI-2010, AHEI-2010, aMED, and DASH scores); they also found moderate to strong correlations between pairs of them.[15]

Some strengths of this study are the use of nine previously published dietary indices, which are widely used and recognized; the high retention rate; and the use of an FFQ with a wide range of possible answers on frequency of food consumption. However, the current study has certain limitations. First, some DQIs scoring algorithms are based on population-based cutoffs. Thus, improvements of the DQI can occur only if the participants' diet improved beyond the overall improvement in the population. By contrast, if all participants improved their consumption of that food group by the same amount, then points for a given participant would not change as the sex-specific median of consumption increased. This may mask the ability of these DQI, which are based on relative scoring systems, to longitudinally detect diet changes. Second, the findings were based on a single FFQ administered at baseline and after 10 years of follow-up. This dietary assessment is not designed to obtain estimates of absolute intake, but rather derives estimates from a limited list of foods and beverages; however, it does provide a way to rank individuals.[64] Besides, the SUN cohort has a dynamic design and the recruitment is permanently open. For this reason, the follow-up for all participants is different, and in some cases the follow-up is lower than the 10 years required for this study. Thus, only 28% of the cohort was able to provide data for analyses. However, participants who completed the FFQ after 10 years of follow-up were slightly different from those who failed to complete it. However, these differences were of small absolute magnitude, generally lower than 5% (Table 2, available at www.jandonline.org). Third, data on food intake were self-reported, and for this reason, measurement error and misclassification cannot be ruled out. However, FFQs have been demonstrated to be a practical and feasible tool to evaluate diet in large epidemiological studies, despite their potential bias.[65] Fourth, there were differences in the way the baseline FFQ (paper) and the 10-year FFQ (electronically) were completed, which could introduce a systematic error into the results. However, they contained all the same items, portion sizes, and possible answers. Fifth, another limitation was the possible seasonal variation in the dietary patterns of the study participants. However, great variations in dietary patterns, as participants were asked to complete the FFQ including information on the entire previous year,[23] were not expected. Sixth, the study population consists of university graduates; thus it is not representative of the Spanish population. Therefore, translating results to the general population should be done cautiously. However, addressing a homogeneous cohort with the high educational level of the participants reduces the likelihood of misclassification bias, increases its internal validity, and reduces potential confounding, but also limits generalizability of findings.[66] Seventh, it should be noted that participants in the SUN Project are unpaid volunteers, university graduates, and mainly health professionals, who may be more aware of the importance of the accurate self-reporting. Possibly, participating in an observational study and responding to dietary questionnaires may improve their dietary pattern (Hawthorne effect) and could exacerbate biases.[67] Eighth, as in any observational study, residual confounding is a concern[68]; however, simultaneously controlling for lifestyle factors and medical conditions was possible. Ninth, the previously described Mediterranean and DASH diet scores from the FFQs was calculated, which may not fully capture the dietary patterns. In particular, the MDS has a small range (0−9 points), and more than half of this population scored 3, 4, or 5.[69] This finding suggests that this DQI may not be able to distinguish between individuals with different patterns of dietary intake. Tenth, some DQI are based on the population's relative intake, and thus participants with the same diet may obtain a different score depending on the sample distribution. Finally, only 5,515 (ie, 28%) of the original 19,563 cohort members provided data for the final analyses, thus raising the possibility of both selection and information bias.

CONCLUSIONS

In this Mediterranean adult cohort, the evaluation of dietary changes, based on prospectively collected data expressed in terms of nine a priori-defined DQI, suggests modest improvements in diet quality after 10 years of follow-up. Overall, AHEI-2010, MEDAS, and PDQS scores were correlated with a high number of DQI scores at baseline and after 10 years of follow-up. Despite their differences and limitations, DQI remain useful tools to assess diet quality. However, additional longitudinal studies, especially intervention trials with long follow-up, are warranted to establish the most appropriate DQI to assess the long-term changes in diet quality in adult populations. In designing future multi-behavioral programs, it will be important to identify and replicate predictors of long-term dietary changes and to evaluate how dietary patterns and determinants of adherence may vary across different populations in various social and geographical contexts.

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

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AUTHOR CONTRIBUTIONS

I. Zazpe and MA Martínez-González formulated the research questions and designed the study and were responsible for study oversight. I. Zazpe and MA Martínez-González performed the statistical analysis. I. Zazpe and S. Santiago drafted the manuscript and all authors contributed to its development. All authors read and approved the final manuscript.

Table 2. Supplementary online. Baseline characteristics of participants according to the completion of the 10-year FFQ (%)

	Participants with 10 years of follow-up but who did not complete the 10- year FFQ	Participants who completed the 10-ear FFQ	95% CI for the difference between both groups[a]
Characteristic (%)	11,800	7,503	
Male	37.7	40.5	0.014; 0.042
<35 years of age	48.9	51.7	0.505; 0.523
BMI ≤ 24.9	68.7	70.9	−0.035; −0.009
Leisure-time physical activity (MET hours/week) ≤ median	50.9	48.5	0.010;0.039
Alcohol intake ≤ median	50.4	48.8	0.001;0.03
Cancer at baseline	3.3	3.0	0.026;0.033
Diabetes at baseline	2.0	1.4	0.011;0.016
Depression at baseline	13.0	9.8	0.023;0.041
Dyslipidemia at baseline	7.0	6.0	0.033;0.174
Hypertension at baseline	20.4	18.3	0.010;0.192
Cardiovascular disease at baseline	1.5	1.2	0.009;0.014
Weight gain ≥ 3 kg in previous 5 years	31.4	30.6	−0.005; 0.029
Following special diets	8.0	7.7	0.071; 0.083
Between-meals snacking	35.1	33.4	0.002; 0.030

[a]Two-sample test proportions was used to calculated 95%CI for the difference in proportions.

Carbohydrate Quality Index (CQI)[31,32]			
Components	**Index range (points)[a]**	**Criteria for minimum index points**	**Criteria for maximum index points**
Dietary fiber intake (g/d)	1—5	Minimum dietary fiber intake (first quintile)	Maximum dietary fiber intake (fifth quintile)
Glycemic index	1—5	Maximum glycemic index (fifth quintile)	Minimum glycemic index (first quintile)
Ratio whole grains / (whole grains + refined grains or its products)	1—5	Minimum value of this ratio (first quintile)	Maximum value of this ratio (fifth quintile)
Ratio solid carbohydrates/ (solid carbohydrates + liquid carbohydrates)	1—5	Minimum value of this ratio (first quintile)	Maximum value of this ratio (fifth quintile)
Total index (range)	4—20		
[a] Proportional dietary scores were computed for intakes ranging between the maximum and minimum criteria.			
Fat quality index (FQI)[33]			
Components of dietary index	**Index range (points) [a]**	**Criteria for minimum index**	**Criteria for maximum index**
Ratio monounsaturated fatty acids + polyunsaturated fatty acids/(saturated fatty acids + trans fatty acids)	0.62—5.92	0.62	5.92
[a] Proportional dietary scores were computed for intakes ranging between the maximum and minimum criteria.			
DASH index[34]			
Components, by quintile	**1 Point scored for each component**		**Scoring criteria**
Fruits	All fruits and fruit juices		Q1 = 1 point Q2 = 2 points Q3 = 3 points Q4 = 4 points Q5 = 5 points
Vegetables	All vegetables except potatoes and legumes		
Nuts and legumes	Nuts and peanut butter, dried beans, peas, tofu		

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Figure 2. Supplemental online: Criteria used to calculate dietary indices.

Whole grains Low-fat dairy	Brown rice, dark breads, cooked cereal, whole grain cereal, other grains, popcorn, wheat germ, bran Skim milk, low-fat yogurt, low-fat cottage cheese	
Component, by reverse quintile		**Reverse scoring**
Sodium	Sum of sodium content of all foods in FFQ	Q1 = 5 points Q2 = 4 points Q3 = 3 points Q4 = 2 points Q5 = 1 points
Red and processed meats	Beef, pork, lamb, deli meats, organ meats, hot dogs, bacon	
Sweetened beverages	Carbonated and noncarbonated sweetened beverages	
Pro-Vegetarian Dietary Pattern (PVG)[35] [a]		
Vegetable food groups, by quintile[b]		
Vegetables	Carrot, Swiss chard, cauliflower, lettuce, tomatoes, green beans, eggplant, peppers, asparagus, spinach, other fresh vegetables	
Fruit	Citrus, banana, apple, pear, strawberry, peach, cherry, fig, melon, watermelon, grapes, kiwi, canned fruits	
Legumes	Lentils, chickpeas, beans, peas	
Potatoes	Potato chips, French fries, boiled potatoes	
Cereals	White bread, whole-grain bread, cold breakfast cereal, rice, pasta	
Nuts	Almonds, peanuts, hazelnuts, pistachios, pine nuts, walnuts	
Olive oil	Common (refined) olive oil, extra-virgin olive oil, pomace olive oil	
Animal food groups, by reverse quintile[c]		
Meats/meat products	Beef, pork, lamb, rabbit, liver, chicken, turkey, cooked ham, Parma ham, mortadella, salami, foie-gras, spicy pork sausage, bacon, cured meats, hamburger, hot-dog	
Animal fats for cooking or as a spread	Butter, lard	
Eggs	Eggs	
Fish and other seafood	White fish, dark-meat fish, salad or smoked fish, clams, mussels, shrimp, squid	

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Figure 2. *(continued)* Supplemental online: Criteria used to calculate dietary indices.

Dairy products	Whole milk, skim or low-fat milk, condensed milk, cream, milk shake, yogurt, custard, cheese, ice cream

[a]The overall PVG was built by summing both components with a potential range of 12—60.

[b]The consumption (g/d) of each food group was transformed into energy-adjusted quintiles by using the residuals method (1 = first quintile, 2 = second quintile, 3 = third quintile, 4 = fourth quintile, 5 = fifth quintile). The sum of quintile values across the 7 food groups gave a potential range of 7—35.

[c]Consumption (g/d) was transformed into energy-adjusted quintiles (residuals), and the quintile values were reversed (1 = fifth quintile, 2 = fourth quintile, 3 = third quintile, 4 = second quintile, 5 = first quintile). The sum of reverse quintile values across the 5 food groups had a potential range of 5—25.

Mediterranean-DASH Intervention for Neurodegenerative Delay Diet (MIND) index[36] [a]

Dietary component servings	Maximum score
Whole-grain foods ≥ 3/d	1 point
Green leafy vegetables ≥ 6/wk	1 point
Other vegetables ≥ 1/d	1 point
Berries ≥ 2/wk	1 point
Red meats and products < 4/wk	1 point
Fish ≥ 1/wk	1 point
Poultry ≥ 2/wk	1 point
Beans >3/wk	1 point
Nuts ≥5/wk	1 point
Fast/ fried foods < 1/wk	1 point
Olive Oil primary oil	1 point
Butter,margarine < 1/d	1 point
Cheese < 1/wk	1 point
Pastries or sweets < 5/wk	1 point
Alcohol/wine 1/d	1 point

[a](15 = perfect adherence to MIND DIET principles. 0 = no adherence at all.

Prime Diet Quality Score (PDQS)[37]

(continued on next page)

Figure 2. *(continued)* Supplemental online: Criteria used to calculate dietary indices.

This DQI was based on a short diet assessment tool developed for clinical use to quickly assess diet quality, the Prime Screen questionnaire. Foods were classified as healthy and unhealthy. For the healthy food groups (dark leafy green vegetables, cruciferous vegetables, carrots, other vegetables, whole citrus fruits, other whole fruits, legumes, nuts, poultry, fish, eggs, whole grains, and liquid vegetable oils), points were assigned according to the following criteria: 0—1 serving/wk (0 point) compared with 2—3 servings/wk (1 point) compared with ≥4 servings/wk (2 points), while for the unhealthy food groups (red meat, potatoes, processed meat, whole milk dairy, refined grains, and baked goods, sugar-sweetened beverages, fried foods obtained away from home, and desserts and ice cream), scoring was reversed and points deducted. Points for each food group were then summed to give an overall score. The PDQS has 21 food groups and ranges from 0 to 42 total points.

14-point Mediterranean Diet Adherence Screener (MEDAS)[38]

Foods and frequency of consumption	Criteria for 1 point[a]
Do you use olive oil as the principal source of fat for cooking?	Yes
How much olive oil do you consume per day (including that used in frying, salads, meals eaten away from home, etc.)?	4 or more tablespoons
How many servings of vegetables do you consume per day? Count garnish and side servings as 1/2 point; a full serving is 200 g.	≥2
How many pieces of fruit (including fresh-squeezed juice) do you consume per day?	≥3
How many servings of red meat, hamburger, or sausages do you consume per day? A full serving is 100—150 g	< 1
How many servings (12 g) of butter, margarine, or cream do you consume per day?	< 1
How many carbonated and/or sugar-sweetened beverages do you consume per day?	< 1
Do you drink wine? How much do you consume per week?	≥7 glasses
How many servings (150 g) of pulses do you consume per week?	≥3
How many servings of fish/seafood do you consume per week? (100—150 g of fish, 4—5 pieces or 200 g of seafood)	≥3
How many times per week do you consume commercial sweets or pastries (not homemade), such as cakes, cookies, biscuits, or custard?	< 2
How many times do you consume nuts per week? (1 serving = 30 g)	≥3
Do you prefer to eat chicken, turkey, or rabbit instead of beef, pork, hamburgers, or sausages?	Yes
How many times per week do you consume boiled vegetables, pasta, rice, or other dishes with a sauce of tomato, garlic, onion, or leeks sautéed in olive oil?	≥2

[a] 0 points if these criteria are not met.

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Figure 2. *(continued)* Supplemental online: Criteria used to calculate dietary indices.

Alternate Healthy Eating Index-2010 (AHEI-2010)[1]

Components of dietary index	Criteria for minimum score (0)	Criteria for maximum score (10)
Vegetables, servings/d	0	≥5
Fruit, servings/d	0	≥4
Whole grains, g/d		
Women		75
Men		90
Sugar-sweetened beverages and fruit juice, servings/d	≥1	0
Nuts and legumes, servings/d	0	≥1
Red/processed meat, servings/d	≥1.5	0
Trans fat, % of energy	≥4	≤0.5
Long-chain (n-3) fats (EPA + DHA), mg/d	0	250
PUFA, % of energy	≤2	≥10
Sodium, mg/d	Highest decile	Lowest decile
Alcohol, drinks/d		
Women	≥2.5	0.5—1.5
Men	≥3.5	0.5—2.0
TOTAL	0	110

Mediterranean Diet Score (MDS)[39]

The MDS incorporate nine prominent components of the traditional Mediterranean diet. Sample sex-specific median cutoff points for eight items were used.

For beneficial components (vegetables, legumes, fruits and nuts, cereal, fish, and the ratio of monounsaturated lipids to saturated lipids), subjects whose consumption was below the median were assigned a value of 0 and subjects whose consumption was at or above the median were assigned a value of 1.

For components presumed to be detrimental (meat, poultry, and dairy products), subjects whose consumption was below the median were assigned a value of 1 and subjects whose consumption n was at or above the median were assigned a value of 0. For ethanol, a value of 1 was assigned to men who consumed between 10 and 50 g/d and to women who consumed between 5 and 25 g/d.

Thus, the total Mediterranean-diet score ranged from 0 (minimal adherence to the traditional Mediterranean diet) to 9 (maximal adherence).

Figure 2. *(continued)* Supplemental online: Criteria used to calculate dietary indices.

A

FFQ_0[a]	AHEI-2010[b]	CQI[c]	FQI[d]	MIND[e]	MEDAS[f]	PVG[g]	DASH[h]	PDQS[i]	MDS[j]
AHEI-2010	1.00								
CQI	0.58	1.00							
FQI	0.44	0.20	1.00						
MIND	0.53	0.42	0.31	1.00					
MEDAS	0.53	0.47	0.36	0.55	1.00				
PVG	0.53	0.40	0.51	0.44	0.50	1.00			
DASH	0.70	0.51	0.32	0.53	0.63	0.68	1.00		
PDQS	0.57	0.70	0.27	0.57	0.61	0.44	0.67	1.00	
MDS	0.52	0.43	0.46	0.47	0.59	0.65	0.66	0.59	1.00

B

FFQ_10[a]	AHEI-2010[b]	CQI[c]	FQI[d]	MIND[e]	MEDAS[f]	PVG[g]	DASH[h]	PDQS[i]	MDS[j]
AHEI-2010	1.00								
CQI	0.47	1.00							
FQI	0.50	0.20	1.00						
MIND	0.51	0.38	0.39	1.00					
MEDAS	0.50	0.43	0.42	0.51	1.00				
PVG	0.31	0.20	0.26	0.22	0.31	1.00			
DASH	0.65	0.39	0.37	0.49	0.62	0.37	1.00		
PDQS	0.53	0.56	0.36	0.58	0.64	0.28	0.64	1.00	
MDS	0.52	0.33	0.47	0.47	0.60	0.35	0.57	0.55	1.00

Figure 3. A, Supplementary online. Correlation matrix including the Spearman's correlation coefficients between the different dietary indices at baseline: the Seguimiento Universidad de Navarra (SUN) cohort.
Negative correlations are in red and positive correlations in green. [a]FFQ_0 = Food Frequency Questionnaire at baseline. [b]AHEI-2010 = Alternate Healthy Eating Index 2010. [c]CQI = Carbohydrate Quality Index. [d]FQI = Fat Quality Index. [e]MIND = Mediterranean-DASH Intervention for Neurodegenerative Delay Diet. [f]MEDAS = Mediterranean Diet Adherence Screener. [g]PVG = Pro-vegetarian Dietary Pattern. [h]DASH = Dietary Approaches to Stop Hypertension. [i]PDQS = Prime Diet Quality Score. [j]MDS = Mediterranean Diet Score. **B,** Supplementary online. Correlation matrix including the Spearman's *r* correlation coefficients between each dietary index after 10 years of follow-up: the Seguimiento Universidad de Navarra (SUN) cohort. Negative correlations are in red and positive correlations in green. [a]FFQ_10 = Food Frequency Questionnaire after 10 year of follow-up. [b]AHEI-2010 = Alternate Healthy Eating Index 2010. [c]CQI = Carbohydrate Quality Index. [d]FQI = Fat Quality Index. [e]MIND = Mediterranean-DASH Intervention for Neurodegenerative Delay Diet. [f]MEDAS = Mediterranean Diet Adherence Screener. [g]PVG = Pro-vegetarian Dietary Pattern. [h]DASH = Dietary Approaches to Stop Hypertension. [i]PDQS = Prime Diet Quality Score. [j]MDS = Mediterranean Diet Score.