



Original article

A food-based score and incidence of overweight/obesity: The Dietary Obesity-Prevention Score (DOS)



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SUMMARY

Background & aims: Given the enormous health, economic and societal consequences of the obesity pandemic, identifying effective primary prevention strategies represents a global priority. The aim of this study was to provide evidence on the association between adherence to a food-based score reflecting a set of targeted, well-informed, simple dietary recommendations and the incidence of overweight/obesity.

Methods: A total of 11,349 initially free of overweight/obesity young adults (mean [SD] age: 34.7 y [10.7]), were followed up biennially during a median of 9.3 years. The Dietary Obesity-Prevention Score (DOS) was created based on a priori evidence of foods associated with weight changes. The DOS positively weighted the consumption of vegetables, fruits, legumes, yogurt, nuts, fish, and a ratio of vegetable to animal protein; whereas the consumption of red meat, processed meat, saturated animal fat, refined grains, ultra-processed food, sugary beverages, beer and spirits were inversely weighted. Energy-adjusted tertiles of each item were used to build the DOS, ranging from 14 (lowest adherence) to 42 points (highest adherence). Adherence to the DOS was calculated at baseline and after 10 years of follow-up. We assessed both incident overweight/obesity (BMI ≥ 25 kg/m²) and average yearly weight changes in grams per year (g/y).

Results: During 104,887 person-years, 2153 incident cases of overweight/obesity were identified. A higher adherence to the DOS at baseline was significantly associated with lower risk of future development of overweight/obesity [multivariable-adjusted HR (95% CI) for the highest vs. lowest quintile = 0.63 (0.54–0.74)], with a significant linear dose–response relationship (p for trend < 0.001). When the analyses were updated with repeated measures, the results were similar and remained statistically significant. Consistently, increases in average yearly weight gain were significantly lower with better adherence to the DOS.

Conclusions: In this Mediterranean cohort of university graduates, a higher adherence to a food-based score was significantly associated with lower risk of overweight/obesity and lower average annual weight gain. These findings may help counsel patients regarding dietary risks and raise awareness of weight gain before the onset of overweight/obesity.

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Abbreviations: DOS, Dietary Obesity-Prevention Score; WHO, World Health Organization; BMI, body mass index; NCDs, non-communicable diseases; SUN, Seguimiento Universidad de Navarra/ Follow-up University of Navarra; FFQ, food frequency questionnaire; Q, quintiles; HR, hazard ratio; CI, confidence interval; SD, standard deviation; SES, socioeconomic status; MET, metabolic equivalent index.

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1. Introduction

The worldwide prevalence of obesity has tripled since 1975 [1]. According to WHO data, in 2016, more than 1.9 billion adults were overweight and over 650 million were obese [2]. If recent trends continue, by 2030, 3.3 billion adults (nearly 60% of the world's adult population) will suffer from obesity or overweight [3], which

means that, globally, excess body weight is not far from becoming the norm.

A high body mass index (BMI) is well known to be associated with increased risk of all cause mortality [4–6], and it is also a major risk factor for non-communicable diseases (NCDs) including type 2 diabetes, cardiovascular disease and certain types of cancer. The growing rates of overweight/obesity place an extensive burden on quality of life, morbidity, premature mortality and societal costs [7–13].

In fact, high BMI and dietary risks have been identified as the modifiable factors currently causing the greatest burden of disease [14,15]. In this context, it is a global priority to find effective weight gain prevention strategies through improvements in the diet quality. In particular, sound evidence illustrates the need to focus on the primary prevention of obesity and excessive weight gain during young adulthood [16], which provides a new target that could offer an effective transgenerational approach for obesity prevention [17].

Evidence shows that multiple factors acting at different scales may be contributing to obesity [18]. Among individual behaviors, dietary habits represent a recognized target for addressing and preventing obesity [19]. While individual macronutrients and calorie counting were a key focus for weight status in the 1980s, at present, growing evidence points to the importance of focusing on overall high-quality diet and food pattern analysis rather than looking at isolated foods or nutrients [20–24].

We aimed to prospectively evaluate the association between adherence to a food-based Dietary Obesity-Prevention Score (DOS) and the incidence of overweight/obesity in the SUN (“Seguimiento Universidad de Navarra”) cohort.

2. Materials and methods

2.1. Study population

The SUN Project is a prospective, multipurpose, dynamic cohort of Spanish university graduates that started in 1999. Enrolment is permanently open and follow-up information is gathered by mailed questionnaires every two years. A more detailed description of the SUN methodology can be found elsewhere [25]. The study was conducted according to Declaration of Helsinki guidelines, and the protocol was approved by the Institutional Review Board of the University of Navarra. This study was registered at clinicaltrials.gov as NCT02669602.

We assessed 22,280 participants recruited before March 2014 to ensure they completed at least the two-year follow-up questionnaire. We excluded 6624 participants because they had prevalent overweight/obesity ($\text{BMI} \geq 25 \text{ kg/m}^2$) at baseline, 1615 participants with total energy intake out of pre-defined limits [26], 128 women who were pregnant at baseline, 779 participants who reported cardiovascular disease, diabetes, or cancer at baseline and 375 participants with $>10 \text{ kg}$ weight change over the past 5 years at baseline to reduce potential sources of confounding by other causes of weight changes. Among the remaining participants, 1162 were lost to follow-up (retention rate: 91%) and 248 participants had missing values in ≥ 1 variables of interest, leading to a final sample of 11,349 participants (Fig. 1).

2.2. The Dietary Obesity-Prevention Score (DOS)

Dietary intake at baseline and after 10 years of follow-up was assessed using a self-administered semiquantitative food frequency questionnaire (FFQ) previously validated in Spain [27,28] containing questions on the average consumption of 136 food items during the year preceding enrollment. A trained dietitian updated the

nutrient databank using the latest available information included in food composition tables for Spain [29].

Taking into account previous literature [19,30–39], we developed the Dietary Obesity-Prevention Score (DOS), a combined score based on foods previously reported to be associated with weight changes. The DOS positively weighted the consumption of vegetables, fruits, legumes, yogurt, nuts, fish, and vegetable-to-animal protein ratio; while the consumption of red meat, processed meat, saturated animal fat, refined grains, ultra-processed foods, sugary beverages, beer and spirits were inversely weighted (Supplemental Table 1).

To create the score, the consumption (g/d) of each of the 14 food groups was adjusted for total energy intake by using the residual method separately for men and women. The energy-adjusted estimates (residuals) were ranked according to their sex-specific tertiles. The tertile values for food groups associated with increased risks of weight gain or overweight/obesity in the literature were reversed (assigning a value of 3 for the first tertile and 1 to the third tertile).

To obtain the DOS, tertile values of positively weighted food groups and reverse tertile values of those negatively weighted were summed up. Thus, the final score could range from 14 (lowest adherence) to 42 (highest adherence). Adherence to the DOS was subsequently classified in quintiles (Q): Q1 (≤ 24), Q2 (25–27), Q3 (28–29), Q4 (30–32), and Q5 (≥ 33).

2.3. Outcome ascertainment

Weight was self-reported by participants at baseline and every 2 years of follow-up. BMI was calculated as weight in kilograms divided by the square of height in meters, which was ascertained at baseline. Self-reported weight and BMI have been previously validated in a subsample of this cohort finding good correlation results [40]. The outcomes were: 1) incidence of overweight/obesity ($\text{BMI} < 25 \text{ kg/m}^2$ at baseline and $\geq 25 \text{ kg/m}^2$ during follow-up); and 2) average yearly weight change (g/y).

2.4. Evaluation of covariates

In addition to anthropometric data, the baseline questionnaire (554 items) gathered abundant information on sociodemographic characteristics, medical history, lifestyle and health-related habits. It also included a 17-item physical activity questionnaire that has been validated in a subsample of the cohort [41]. Metabolic equivalents (METs) were estimated for each participant to yield METs-h/week scores.

2.5. Statistical analysis

Age- and sex-adjusted baseline characteristics of participants according to quintiles of adherence to the DOS were evaluated with ANCOVA.

To assess the risk of overweight/obesity across quintiles of adherence to the DOS we used Cox proportional hazard models to calculate hazard ratios (HRs) and their 95% confidence intervals (CIs) considering the lowest quintile as the reference. Follow-up time was defined as the interval between the date of return of the baseline questionnaire to the date of a first report of a body weight corresponding to overweight/obesity, the date of death, or the date of the last questionnaire for non-cases. To minimize the potential effect of diet variation during follow-up, dietary data was updated after 10 years of follow-up and time-varying Cox proportional hazard models were fitted with repeated measures of the DOS.

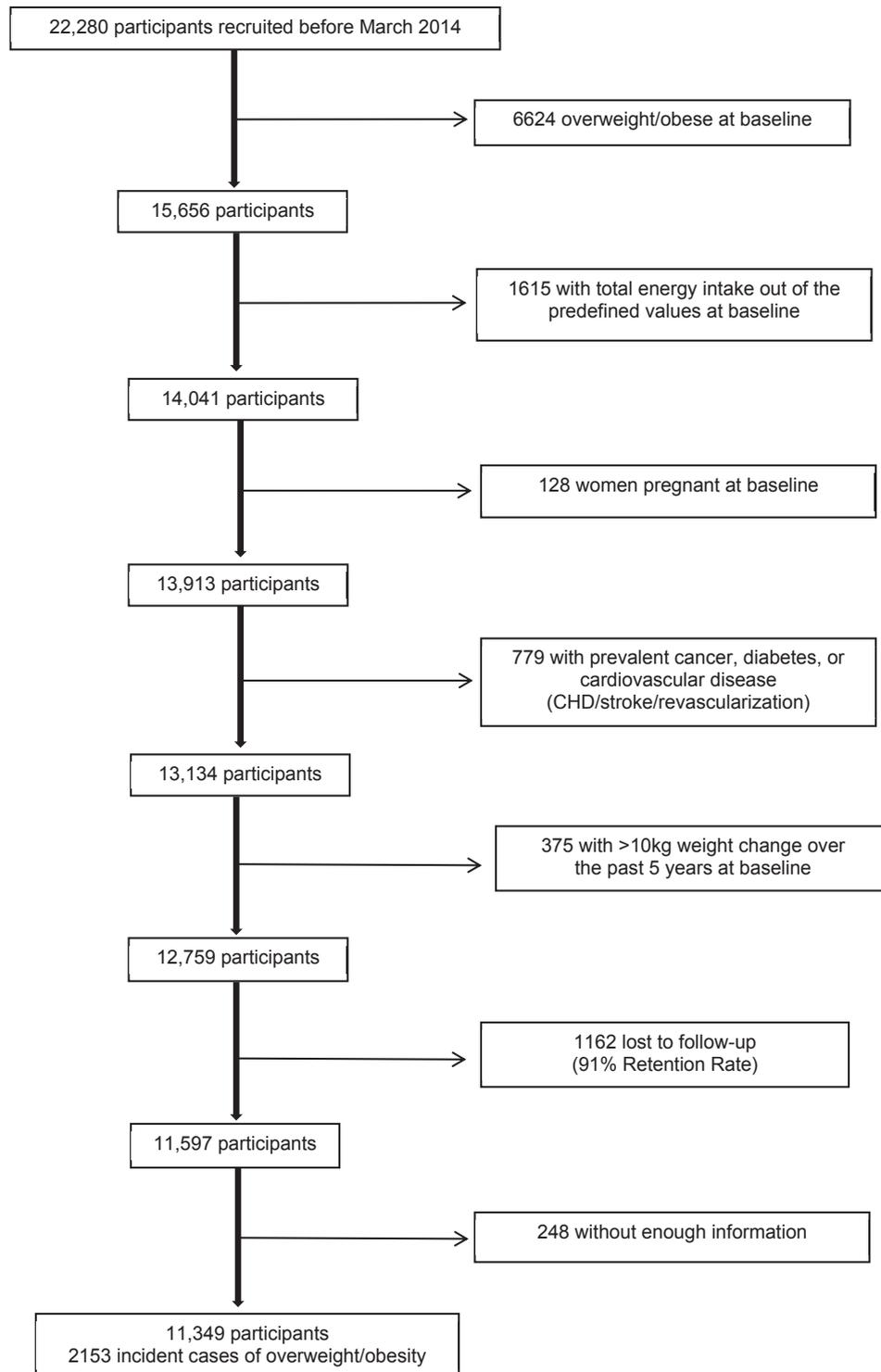


Fig. 1. Flow-chart of participants. The SUN Project, 1999–2014.

We also examined the relative influence of each of the food groups within the score by subtracting one group at a time from the original score (thus reducing the 42-point score to 39 points) and estimating the 14 HRs associated with quintiles of baseline adherence to the DOS (highest vs. lowest adherence) after alternate subtraction of each of its components. To ensure proper comparability, we multiplied the logarithm of the estimated HRs by 39/42 before exponentiating them.

Cox regression models included age as the underlying time variable. All multivariable models were adjusted for sex, baseline BMI (kg/m^2 , continuous), physical activity (METs-h/week, quartiles), hours of TV watching (quartiles), smoking status (never, current, or former), marital status (single, married, other), highest level of education achieved (graduate, postgraduate), total energy intake (kcal/day, continuous), snacking between meals (yes, no), following a special diet at baseline (yes, no), parental family history

of obesity (yes, no) and hours of siesta sleep (0, >0 – ≤0.5, >0.5). Analyses were stratified by age groups (10-y periods) and year of recruitment (4-y periods). Robust standard errors (SEs) were used.

For missing values of TV watching, data were imputed according to age, sex and BMI. Dummy variables were used to indicate missing data for marital status and smoking. The mean missing data rate for covariates was approximately 7%.

Nelson-Aalen survival curves were used to describe the incidence of overweight/obesity over time across quintiles of the DOS. Intermediate quintiles (Q2, Q3 and Q4) were merged to build the medium category for graphical purposes. We used inverse probability weighting to adjust the Nelson-Aalen curves for potential confounders (those mentioned above).

Multiple linear regression models were fitted to assess the relationship between quintiles of adherence to the DOS and average yearly weight change in grams during follow-up. In addition, to take into account repeated measures, generalized estimating equations with an unstructured correlation matrix were used to assess the relationship between updated DOS (after 10 y of follow-up) and yearly weight change. Analyses were adjusted for the same confounding factors as the main Cox regression analysis. Linear trend tests across increasing quintiles of adherence to DOS were conducted by assigning medians to each quintile and treating it as a continuous variable.

The potential non-linear association between the adherence to DOS and incident overweight/obesity was calculated with restricted cubic splines [42].

To determine the contribution of each food group to the between-person variance for DOS adherence, we constructed a series of nested least-squares linear regression models after stepwise-selection regression analyses. The additional contribution of a given food group was reflected in the increase in cumulative R^2 .

Potential effect modification by age, sex, baseline BMI or physical activity was evaluated by significance tests of the cross-product interaction terms using the Wald test.

Finally, to explore the robustness of the associations, we conducted several sensitivity analyses by repeating the multivariable-adjusted Cox regression model under different assumptions: 1) exclusion of participants with sex-specific total energy intake under the 5th percentile and over the 95th percentile, 2) exclusion of over-reporters according to Goldberg cut-offs [43], 3) exclusion of participants with no answer in >12 items of the FFQ, 4) inclusion of participants with baseline weight change >10 kg over the past 5 years before entering the cohort, 5) additional adjustment for weight gain ≥3 kg in the 5 y before to entering the cohort, 6) exclusion of participants who were early incident cases (those who became overweight/obese after 2 years of follow-up), 7) restricting analyses to 10 years of follow-up, and 8) restricting follow-up to young adulthood (excluding participants older than 41 years at end of follow-up).

All P values were 2-tailed, and $P < 0.05$ was considered significant. Statistical analyses were performed with the use of STATA version 14.0 software (StataCorp LP).

3. Results

A total of 3078 (27.1%) men and 8271 (72.9%) women were included in the study. The mean ± SD baseline age of the participants was 35 ± 11 y, the mean ± SD baseline BMI was 21.7 ± 1.9 kg/m², and the median baseline DOS score was 28 (observed range: 16 to 41).

Table 1 shows the age- and sex-adjusted main baseline characteristics of the study participants across quintiles of adherence to the DOS. On average, participants with higher values of DOS tended to be non-smokers, physically more active, watch less television,

avoid snacking between meals, consume less alcohol, consume more carbohydrates with lower glycemic index, consume less saturated fat, and have a higher intake of fiber and micronutrients.

3.1. Adherence to the DOS and risk of overweight/obesity

During a mean follow-up of 78,339 person-years among women and 26,548 person-years among men, there were 2153 incident cases of overweight/obesity (1047 in men and 1106 in women).

Participants with higher adherence to the DOS (>32 points; highest quintile) presented 37% lower risk of developing overweight/obesity than those in the lowest quintile. The adjusted HR was 0.63 (95% CI, 0.54–0.74) with a significant linear dose–response relationship (p for trend <0.001), as shown in Table 2. Updated DOS calculated with reported dietary data after 10 years of follow-up did not substantially change the reported association.

The Nelson-Aalen cumulative hazard function (Fig. 2) represents adjusted incidence of overweight/obesity across baseline quintiles of the DOS. Consistently, these curves exhibited a lower incidence of overweight/obesity across increasing baseline quintiles of the DOS.

The analysis using cubic splines of adherence to the DOS with new-onset overweight/obesity is shown in Fig. 3.

We also show the results of an alternative analysis that used specific round cut-offs instead of quintiles of the DOS: low (≤20), lower middle (21–27), upper middle (28–34) and high (≥35) adherence. The HRs of overweight/obesity decreased monotonically across successive categories of the DOS (Supplemental Figure 1).

Figure 4 shows how the HRs (highest vs. lowest quintile of adherence to the DOS) for developing overweight/obesity change with alternate exclusion of each of the 14 components of the score. We interpret these findings as suggesting that low intake of processed meats and sugary beverages were the main factors driving the association between a higher DOS and lower risk of overweight/obesity.

The contribution to variability of different food groups is shown in Supplemental Table 2. The main sources of variability were fruits and red meat.

In line with the already mentioned association, absolute average yearly weight changes (g/y) decreased across quintiles of DOS. Estimated annual weight change ranged from +480.7 g in the group with lowest adherence (Q1) to +250.2 g in the group with highest adherence (Q5), as shown in Table 3.

No significant interaction between sex, age, baseline BMI or physical activity and adherence to the DOS was observed.

Results in the sensitivity analyses described previously were not substantially changed in any of the scenarios. A stronger association was found when tighter energy limits were used (HR = 0.60; 95% CI: 0.51–0.70), while there was a slight attenuation of the protective effect when the follow-up period was restricted to 10 years (HR = 0.74; 95% CI: 0.62–0.88). However, independent of adjustments, the inverse association between adherence to the DOS and the incidence of overweight/obesity remained significant (Supplemental Figure 2).

4. Discussion

In this large prospective cohort we observed that a higher adherence to the DOS was inversely monotonically associated with average yearly weight gain and risk of developing overweight/obesity.

Using an a priori approach, we found a strong inverse association of an evidence-based dietary score and long-term weight gain.

Table 1

Age- and sex-adjusted baseline characteristics of participants (expressed as mean (SD), unless otherwise stated) according to quintiles of the Dietary Obesity-Prevention Score (DOS) in the SUN cohort, 1999–2014.

Variable	Quintiles of adherence to the DOS				
	Q1	Q2	Q3	Q4	Q5
Range of DOS	<24	25–27	28–29	30–32	>32
Mean DOS	22.6 (1.5)	26.0 (0.8)	28.5 (0.5)	30.9 (0.8)	34.7 (1.7)
N	2374	2992	2024	2279	1680
Sex (women), %	73.3	73.0	73.0	72.9	74.1
Age, years	34.8 (10.9)	34.6 (10.4)	34.7 (10.7)	34.7 (10.9)	34.5 (11.0)
Married, %	42.7	43.8	43.1	43.1	40.4
Years of university education	5.1 (1.5)	5.0 (1.5)	5.0 (1.5)	4.9 (1.4)	4.9 (1.5)
Baseline weight, kg	60.9 (9.1)	61.0 (9.2)	61.1 (9.1)	61.3 (8.9)	60.2 (8.8)
Baseline BMI, kg/m ²	21.6 (1.9)	21.7 (1.9)	21.7 (1.9)	21.8 (1.9)	21.5 (1.9)
Parental family history of obesity, %	17.5	19.8	19.9	22.4	22.0
Between-meal snacking, %	38.0	32.9	32.8	30.2	27.3
Special diet at baseline, %	3.2	5.4	5.8	6.8	10.1
Smoking status, %					
Never	45.0	48.7	52.5	54.9	60.8
Current	34.1	27.7	24.0	21.2	17.2
Former	18.8	20.5	20.8	21.4	19.9
Physical activity, METs-h/week	23.2 (21.1)	24.5 (20.3)	27.0 (22.7)	30.0 (25.1)	35.2 (31.3)
Television watching, h/d	1.7 (1.2)	1.6 (1.2)	1.5 (1.1)	1.6 (1.2)	1.4 (1.2)
Sleeping hours, h/d	7.4 (0.7)	7.4 (0.7)	7.4 (0.7)	7.4 (0.7)	7.3 (0.8)
Sleeping siesta, h/d	0.3 (0.6)	0.3 (0.6)	0.3 (0.6)	0.3 (0.6)	0.2 (0.5)
Total energy intake, kcal/d	2298 (641)	2286 (612)	2348 (595)	2410 (573)	2515 (543)
Food groups, g/d					
Fruits	181 (131)	257 (185)	346 (253)	441 (299)	598 (367)
Vegetables	299 (168)	383 (218)	459 (245)	531 (283)	681 (358)
Legumes	16.1 (11.2)	20.0 (15.0)	23.0 (15.7)	25.8 (18.9)	31.6 (25.5)
Nuts	3.7 (5.2)	4.9 (7.1)	6.3 (9.3)	8.8 (13.0)	15.4 (19.3)
Yogurt	48.7 (58.4)	70.2 (75.9)	86.5 (87.6)	99.3 (97.8)	137 (120)
Fish	69.4 (40.4)	83.7 (50.5)	94.7 (51.9)	109.6 (64.0)	128.7 (66.9)
Vegetable to animal protein ratio	0.4 (0.5)	0.4 (0.3)	0.5 (1.6)	0.6 (1.1)	0.7 (1.4)
Red meat	95.9 (45.6)	82.2 (46.8)	73.7 (43.0)	66.8 (42.0)	52.3 (37.8)
Processed meat	64.3 (34.1)	55.1 (32.3)	51.0 (33.0)	45.0 (29.3)	35.6 (26.5)
Animal fat	5.7 (7.5)	4.3 (6.9)	3.5 (6.8)	2.6 (5.6)	1.6 (4.6)
Refined grains	87.9 (63.2)	83.7 (67.5)	84.9 (71.9)	80.5 (65.2)	67.9 (59.2)
Sugary beverages	95.3 (119)	70.8 (108)	58.9 (92.7)	47.7 (86.8)	31.3 (74.0)
Ultra-processed food	202 (132)	177 (124)	167 (130)	159 (113)	129 (89.3)
Beer and spirits	68.0 (103)	59.1 (106)	52.3 (97.7)	46.0 (96.5)	32.9 (71.5)
Macronutrients, % energy					
Carbohydrate	40.5 (6.7)	42.3 (6.8)	43.9 (6.9)	45.5 (6.9)	47.6 (7.0)
Protein	17.8 (3.3)	18.0 (3.3)	18.0 (3.1)	18.1 (3.1)	18.3 (3.1)
Fat	39.6 (5.9)	38.0 (6.0)	36.4 (6.2)	35.0 (6.2)	33.0 (6.5)
SFAs	14.5 (3.0)	13.2 (2.7)	12.4 (2.8)	11.5 (2.8)	10.1 (2.8)
MUFAs	16.9 (3.5)	16.3 (3.6)	15.6 (3.7)	15.1 (3.6)	14.4 (3.7)
PUFAs	5.5 (1.6)	5.3 (1.7)	5.1 (1.5)	5.0 (1.6)	4.8 (1.5)
Glycemic index	53.4 (4.3)	52.5 (4.5)	52.0 (4.6)	51.8 (4.4)	51.0 (4.2)
Glycemic load	127 (47.5)	129 (48.6)	136 (48.8)	144 (41.1)	154 (46.7)
Total dietary fiber, g/d	19.1 (7.0)	23.4 (7.8)	27.8 (8.4)	32.8 (10.1)	42.7 (13.6)
Vitamin C, mg/d	182 (92.1)	234 (110)	286 (127)	336 (148)	440 (200)
Vitamin D, mg/d	2.8 (1.7)	3.3 (2.3)	3.6 (2.3)	4.1 (2.4)	4.9 (2.9)
Ca, mg/d	1074 (422)	1145 (426)	1236 (437)	1321 (470)	1495 (490)
Na, mg/d	4389 (2683)	3961 (2227)	3854 (2146)	3761 (1922)	3446 (1528)
K, mg/d	3819 (1134)	4270 (1197)	4753 (1278)	5306 (1448)	6409 (1704)
Mg, mg/d	341 (94.8)	375 (96.6)	412 (98.4)	456 (108)	540 (126)
Folate, µg/d	291 (106)	351 (119)	412 (133)	474 (158)	597 (200)

The main novelties of our results are that we developed a system to integrate the combined effect of many foods and assess aggregate dietary effects, that a vegetable to animal protein ratio was included suggesting that dietary protein derived from plant sources is not only comparable to animal-based protein regarding weight maintenance but also more beneficial, that our cohort was young and free of obesity or overweight at baseline, and that the inverse association found between the DOS and long-term weight gain was linear and robust. These findings can help to raise public awareness of the fact that overweight and obesity are largely preventable through diet optimization. Prevention of obesity through anticipatory guidance is preferable as it is extremely difficult to reverse weight gain once it is established.

Small increments in weight, such as 0.5 kg per year, which, over a period of 20–30 years, will lead to major morbidity and mortality [44], are of particular concern to public health and obesity epidemiology. Generally, people gain small amounts of weight during their middle-age and nobody warns them until they are older and have already accumulated a considerable amount of weight gain, which has drastic impacts on their health. Effective non-surgical interventions for long-term weight loss are sparse, highlighting the importance of preventing the yearly cumulative small amounts of weight gain in the first place. As reported in Table 3, during a median follow-up of 9.3 years, participants who had a higher adherence to the DOS (>32) gained approximately 200 g less per year compared with participants who had lower adherence (<24).

Table 3

Multivariable-adjusted differences (95% confidence intervals) in average yearly weight change (g/y) according to quintiles of adherence to the Dietary Obesity-Prevention Score (DOS) in the SUN Project.

	Quintiles of adherence to the DOS					<i>p</i> trend
	Q1	Q2	Q3	Q4	Q5	
<i>N</i>	2374	2992	2024	2279	1680	
Absolute yearly weight change (g), adjusted mean ^a	480.7 (422.0, 539.3)	360.2 (309.0, 411.4)	399.2 (337.3, 461.0)	331.1 (272.3, 389.8)	250.2 (179.8, 320.5)	
Age- and sex-adjusted	0 (ref)	-139.1 (-216.2, -62.1)	-106.1 (-191.4, -20.8)	-184.9 (-268.1, -101.7)	-255.1 (-346.7, -163.5)	<0.001
Multivariable-adjusted ^b	0 (ref)	-120.5 (-197.5, -43.5)	-81.5 (-167.0, 4.0)	-149.6 (-233.8, -65.5)	-230.5 (-324.6, -136.4)	<0.001
	Updated quintiles of adherence to the DOS ^b					<i>p</i> trend
	Q1	Q2	Q3	Q4	Q5	
Absolute yearly weight change (g), adjusted mean ^a	375.7 (322.2, 429.1)	311.2 (265.5, 356.9)	313.2 (260.2, 366.2)	267.4 (213.1, 321.6)	181.2 (121.7, 241.9)	
Multivariable-adjusted GEE ^b	0 (ref)	-64.4(-133.9, 5.1)	-62.5(-138.4, 13.5)	-108.2(-184.9, -31.7)	-193.8(-276.7, -111.0)	<0.001

^a Adjusted for sex, age, baseline BMI, physical activity, hours of TV watching, smoking status, marital status, highest level of education achieved, total energy intake, snacking between meals, following a special diet at baseline, parental family history of obesity, hours of siesta sleep and year of recruitment.

^b GEE, Generalized estimating equations for multivariable-adjusted differences (95% CIs) of yearly weight change (g/y) using repeated measures of dietary intake after 10 years of follow-up.

Unlike individual nutrients or food groups, overall dietary patterns better reflect the complexity of diets and enable appreciation of the combined effects of a variety of foods. Moreover, from a behavioral perspective, food-based dietary advice is simpler to implement and avoids confusion among consumers as it discriminates between quality choices and prevents food corporations from strategically exploiting the reductive focus on nutrients to market highly processed foods using nutrient content claims [24].

The optimal macronutrient composition of diet for weight management does not necessarily exist, as there are different approaches which seem to work [50]. However, dietary patterns provide a form of consistency that may be enough to maintain the equilibrium required for successful weight maintenance [51–53]. Other obesity risk scores have already been developed but most of them had some limitations such as the use of a cross-sectional design [54], relying on macronutrients rather than on food groups [55], or including restricted dietary factors [56].

Furthermore, there is a need for unbiased primary evidence, free from industry funding sources and consequent conflicts of interest, as this independence will ultimately contribute to developing reliable dietary guidelines [57].

In the absence of properly powered and conducted randomized clinical trials, non-industry-sponsored prospective cohort studies with repeated measurements and appropriate control for confounding provide the most adequate evidence to identify specific dietary targets for the prevention of obesity and excessive weight gain.

Nevertheless, our study has some potential limitations. Although we performed multivariable analyses adjusting for the main important known risk factors for weight gain, we cannot rule out the existence of unmeasured confounders that may have affected the estimated associations. Imprecise dietary measurements could have also influenced our observed associations and left room for residual confounding. Additionally, our cohort is restricted to Spanish university graduates, so we should be cautious about the generalizability of the results. However, this gives us confidence that, given the homogeneity of the cohort, socioeconomic status (SES) of participants was not a major confounder in our analyses as educational level can be considered a proxy of SES [58] (i.e. we used restriction to control for SES).

A potential inconvenience of this score is that quintiles used as cut-offs in the main analyses are dependent on the sample

characteristics and can compromise between-study comparisons or its generalizability. Nonetheless, using quantiles instead of a priori defined cut-off points is more consistent with the fact that dietary assessment has been done using food frequency questionnaire, which are tools better suited to rank individuals rather than to accurately measure absolute intakes. Moreover, the rationale for adjusting for total energy intake before ranking the elements in tertiles was our focus in the relative composition of the overall food pattern and the importance of quality over quantity regarding long-term weight gain prevention. In addition, adjustment for total energy intake usually leads to a reduction in the measurement error always present in self-reported dietary information.

The strengths of our study include its prospective design, high retention rate, the relatively large sample size, the sufficient number of overweight/obesity cases, the previous validation of the methods used for the measurement of the main variables and the detailed and repeated lifestyle information, which allows us to control for an important number of potential confounders.

In conclusion, a higher adherence to the DOS was significantly associated with a reduced risk of developing overweight/obesity in a Mediterranean cohort of initially normal-weight, middle-aged adults. This simple dietary score exclusively based on food groups may be applicable in clinical practice as a preventive and educational tool to help people improve their dietary habits and raise awareness of diet susceptibility to weight gain before the onset of overweight/obesity.

Statement of authorship

The authors' responsibilities were as follows: MBR obtained the funding, MBR and MAMG: designed the research; CGD and AG: analyzed and interpreted the data; CDG: wrote the original draft. All coauthors revised the manuscript critically for important intellectual content and approved the final version of the manuscript.

Conflicts of interest

None of the authors reported a conflict of interest related to the study.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.clnu.2018.11.003>.

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