The Journal of Nutrition
Nutritional Epidemiology

The Development of the Mediterranean-Style Dietary Pattern Score and Its Application to the American Diet in the Framingham Offspring Cohort[1–3]

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Abstract

Previous Mediterranean diet scores were simple to apply but may not be appropriate for non-Mediterranean populations. We developed a Mediterranean-Style Dietary Pattern Score (MSDPS) to assess the conformity of an individual's diet to a traditional Mediterranean-style diet. The MSDPS is based on the recommended intakes of 13 food groups in the Mediterranean diet pyramid. Each food group is scored from 0 to 10 depending on the degree of correspondence with recommendations. Exceeding the recommendations results in a lower score proportional to the degree of overconsumption. The sum of the component scores is standardized to a 0–100 scale and weighted by the proportion of energy consumed from Mediterranean diet foods. We applied the MSDPS to dietary data collected at the 7th examination of the Framingham Offspring Cohort and tested the content validity of the score against selected nutrients known to be associated with the Mediterranean-style dietary pattern. The mean MSDPS was 24.8 (range, 3.1–60.7). Participants with a higher MSDPS were more likely to be women, older, multivitamin users, to have lower BMI and waist circumferences, and less likely to be current smokers. The MSDPS demonstrated content validity through expected positive associations with intakes of dietary fiber, (n-3) fatty acids, antioxidant vitamins, calcium, magnesium, and potassium, and inverse associations with those of added sugar, glycemic index, saturated fat, and trans-fat, and the (n-6):(n-3) fatty acid ratio. The MSDPS is a useful instrument to measure overall diet quality according to the principles of a Mediterranean-style dietary pattern. J. Nutr. 139: 1150–1156, 2009.

Introduction

Dietary recommendations promoting healthy dietary patterns that are rich in whole-grain foods, legumes, vegetables and fruits and limit intakes of full-fat dairy products, sweets, and red meat are an emerging approach for the prevention of type 2 diabetes mellitus and cardiovascular disease in the US (1,2). The Mediterranean-style diet embodies many of these recommendations as reflected by the Mediterranean diet pyramid, which was modeled after the typical dietary pattern from the Greek island of Crete in the 1950s (3,4). The potential health benefits of the Mediterranean diet were initially observed in the Seven Countries Study in the early 1950s (5,6). In this study of 16 different cohorts, the lowest coronary heart disease rate was reported in the cohort from Crete (5,7). The Mediterranean-style diet has been found to be an alternative heart-healthy dietary pattern for Americans (8).

Criterion-based diet scores can serve as useful tools to assess a population's adherence to a Mediterranean-style diet and to study the health benefits of this diet pattern (9). Only a few studies have used diet scores to assess adherence to, and examine the health benefits of, a Mediterranean-style diet (10–12). Some of these scores were constructed based on the actual intakes of the study population rather than applying the recommended intakes of a traditional Mediterranean diet as defined by the Mediterranean diet pyramid. Other studies developed scores based on the Mediterranean diet pyramid food groups but did

[1] Supported by the USDA (agreement 58-1950-7-707) and the Framingham Heart Study of the National Heart Lung and Blood Institute of the NIH (contract NO1-HC-25195). M. E. Rumawas was a recipient of the Helen Smith Brownstein Memorial Scholarship. N. M. McKeown was supported in part by the General Mills Bell Institute of Health. J. B. Meigs was supported by the American Diabetes Association's Career Development Award and by National Institute of Diabetes and Digestive and Kidney Diseases Grant K24 DK080140.
[2] Author disclosures: M. E. Rumawas, J. T. Dwyer, N. M. McKeown, J. B. Meigs, G. Rogers, and P. F. Jacques, no conflicts of interest.
[3] Supplemental Tables 1 and 2 and Supplemental Figure 1 are available with the online posting of this paper at jn.nutrition.org.
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Manuscript received January 14, 2009. Initial review completed February 3, 2009. Revision accepted March 9, 2009.
First published online April 8, 2009; doi:10.3945/jn.109.103424.

not consider the recommended intakes assigned to each food group (13,14). Although these earlier studies (10–14) contribute to the current scientific knowledge on the health benefits of the so called Mediterranean diet, their scores may merely reflect the dietary pattern of the study population rather than adherence to the traditional Mediterranean diet. Furthermore, these studies did not consider the negative implications of overconsumption of foods in the calculation of the Mediterranean diet score. Thus, one caveat of these studies using criterion-based scores is that better adherence to a Mediterranean diet may be achieved solely by consuming greater amounts of food (15). As a consequence of these aspects of earlier scores, results based on these scores, particularly when applied in a non-Mediterranean population, may not truly reflect adherence to a Mediterranean diet.

To address these limitations, we developed the Mediterranean-Style Dietary Pattern Score (MSDPS)[9] based on the recommended intakes of foods in the traditional Mediterranean-style dietary pattern as defined by the Mediterranean diet pyramid. The purpose of the present paper is to describe the development of the MSDPS and to examine the content validity of this score.

Materials and Methods

MSDPS components and scoring. There are 4 unique features of our MSDPS relative to the other previously published scores of Mediterranean-style dietary pattern. The MSDPS: *1*) is based on adherence to recommended intake levels from the Mediterranean diet pyramid; *2*) is continuously scaled; *3*) accounts for overconsumption of foods; and *4*) considers not only consumption of foods included in the Mediterranean diet pyramid but also consumption of foods not identified as part of the Mediterranean diet.

The MSDPS was constructed on the basis of the Mediterranean diet pyramid (3). The score has 13 components (**Table 1**) that correspond to the 13 food groups of the Mediterranean diet pyramid, i.e. whole-grain cereals, fruits, vegetables, dairy, wine, fish, poultry, olives-legumes-nuts, potatoes, eggs, sweets, meats, and olive oil. For each food group, the food guide pyramid recommends the number of daily or weekly servings an individual should aim to consume. A food item is classified into 1 of these 13 food groups if the food or its characteristics approximated the traditional Mediterranean diet's principles as listed in several previous reports (3,16–21). For example, although soybeans were not part of a traditional Mediterranean diet, other legumes were a part of this diet pattern. Thus, we classified soybeans with other legumes. Classification of all foods is described in **Supplemental Table 1**.

With the exception of olive oil, each group is scored from 0 to 10 depending on the degree of correspondence with recommendation (e.g. consuming 60% of the recommended servings would result in a score of 6). We also took into account the negative implications of overconsumption, defined as exceeding the recommended intake of foods in the Mediterranean diet pyramid. Overconsumption incurs a penalty by subtracting a point proportionally to the number of servings consumed that exceeded the recommended intake for that group (e.g. exceeding the recommendation by 60% would result in a score of 4). Due to this "overconsumption penalty," the score of a food group can be negative (i. e. for exceeding the recommendation by >100%). In this case, the negative score is defaulted to zero. Olive oil's scoring is categorical in nature, based on the exclusive use of olive oil (score 10), the use of olive oil along with other vegetable oils (score 5), or no olive oil (score 0).

Next, the 13 component scores were summed and the total was standardized to a 0–100 scale by dividing the calculated sum by the theoretical maximum sum of 130 and multiplying by 100. Only foods that are part of the Mediterranean pyramid are included in the above scoring system. Given that this is a U.S. population, foods that are not part of the traditional Mediterranean diet are also consumed and therefore an individual's diet may include a mixture of Mediterranean and non-Mediterranean foods. To account for foods that are not on the Mediterranean pyramid (e.g. hot dogs, peanut butter, white rice, mayonnaise), the standardized sum of the 13 components is weighted by the proportion of energy intake derived from foods consumed as part of the Mediterranean diet pyramid. A weighting factor, which reflects a 0–100% energy intake attributed to the consumption of the foods that are part of the Mediterranean-style dietary pattern, is a continuous factor ranging from 0–1. For example, if a person consumes 35% of energy from foods not included on the Mediterranean diet pyramid, the calculated weighting factor is 0.65.

For each individual, a MSDPS was calculated using the following equation:

$$MSDPS = \left[\left(\frac{\sum_{i=1}^{13} S\,i}{130}\right) x\,100\right] x\,P,$$

where S_i is the individual item score and P is the proportion of total energy intake from Mediterranean diet pyramid foods

Example of calculation. As an example for illustration, a person's score is calculated as follows: *1*) achieved 7 of the 13 recommended components (score 10 per component); *2*) exceeded one recommendation by 40% (score 6); *3*) exceeded one recommendation by 120% (score 0); *4*) consumed 50% of 2 recommendations (score 5); *5*) consumed 20% of one recommendation (score 2); *6*) reported the use of olive oil along with other vegetable oils (score 5); and *7*) foods not included on the Mediterranean diet pyramid contributed 35% of the total energy intake (weight = 0.65).

Thus, the standardized sum would be 71.5 {i.e. $\sum S_i/130 = [(7 \times 10) + (1 \times 6) + (1 \times 0) + (2 \times 5) + (1 \times 2) + 5]/130 = 93/130 = 71.5$} and the MSDPS would be 46.5 [i.e. 71.5×0.65].

Study participants. We applied the MSDPS to dietary data from the Framingham Heart Study (FHS) Offspring Cohort, a longitudinal community-based study of cardiovascular disease among the offspring of the participants of the FHS Original Cohort (22). In 1971, 5135 participants were enrolled in the study and examined every 3–4 y. During the 7th examination cycle (1998–2001), 3539 participants underwent a standardized medical history and physical examination. Of these participants, 3021 participants who had a valid FFQ data based on reported energy intakes of >2.51 MJ/d (600 kcal/d) for all or <16.74 MJ/d (4000 kcal/d) for women and <17.57 (4200 kcal/d) for men and <12 blank food items constituted the final sample. The Institutional Review Board for Human Research at Boston University and the Institutional Review Board at Tufts Medical Center approved the study protocols and procedures.

Dietary assessment. Dietary intake was assessed using the Harvard semiquantitative FFQ (23). The FFQ was mailed to the participants before the examination and they were asked to bring the completed questionnaire with them to their appointment. The FFQ consisted of 126 items, including a list of foods together with a standard serving size and a selection of 9 frequency categories ranging from never or <1 serving/mo to ≥6 servings/d. The questionnaires also included an area to write in foods usually consumed that were not listed on the FFQ as well as types of cold breakfast cereal and cooking oil usually used. Participants were asked to report their frequency of consumption of each food item during the past year. Nutrient intakes were calculated by multiplying the frequency of consumption of each unit of food from the FFQ by the nutrient content of the specified portion. The relative validity of the FFQ for both nutrients and foods was examined previously in several populations (23–25). In addition, the FFQ has been used successfully in the FHS Offspring Cohort, with several previous published papers observing expected relationships between nutritional exposures and metabolic risk factors for diabetes and cardiovascular disease (26,27).

[9] Abbreviations used: DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; FHS, Framingham Heart Study; LA, linoleic acid; LNA, linolenic acid; MSDPS, Mediterranean-Style Dietary Pattern Score; PAL, physical activity level.

TABLE 1 Components of the MSDPS

Food group components	Criteria for maximum score of 10[1]	Score[2]
	servings/d	*points/serving*
Whole grains	8	1.25
Fruits	3	3.33
Vegetables	6	1.67
Dairy	2	5.0
Wine		
Men	3	3.33
Women	1.5	6.67
	servings/wk	
Fish and other seafood	6	1.67
Poultry	4	2.5
Olives, legumes, and nuts	4	2.5
Potatoes and other starchy roots	3	3.33
Eggs	3	3.33
Sweets	3	3.33
Meat	1	10.0
Olive oil	Use only olive oil	0 (for no use of olive oil) 5 (for use of olive + other vegetable oils)

[1] Each component of the MSDPS was calculated based on the recommended intakes of food in the Mediterranean diet pyramid (3).
[2] Except olive oil, all other components of the MSDPS were continuous, ranging from 0 to 10 and computed proportionately. Within each component (except olive oil), if consumption exceeded the recommended intake, the score was deducted proportionally to the number of servings consumed that exceeded the recommended intake; the lowest possible score due to deduction was zero.

Because self-reported dietary intake tends to underestimate actual consumption (28), we used the Schofield equation to predict participants' resting metabolic rate (29) and identified under-reporters as those in whom the ratio of reported energy intake to predicted resting metabolic rate was less than the Goldberg cutoff for sedentary physical activity level (PAL) of 1.2 (30).

Lifestyle variables. Height and weight were measured with the participant standing, with shoes off, wearing only a hospital gown. BMI was calculated as weight/height (kg/m^2). Waist circumference was measured at the level of the umbilicus while the participant was standing, with the tape measure parallel to the floor. Information on age, smoking during the past year, multivitamin use, and PAL, assessed as a weighted average of the proportion of a typical day spent sleeping and performing sedentary, slight, moderate, or heavy physical activities and expressed in metabolic equivalents, were also assessed at the same time (22,31).

Validity assessment. We tested the content validity of the MSDPS. An instrument is said to have content validity if it appears to measure what it is supposed to measure based on the established theories (32). Intake of certain nutrients (**Table 2**) have been previously documented to be different in the traditional Mediterranean diet than in a typical Western diet [such as β-carotene and (n-3) fatty acids] (7,33). Therefore, we hypothesized that the intake of those nutrients previously related to the Mediterranean diet will correlate accordingly with the MSDPS.

Statistical analysis. Statistical analyses were conducted using SAS statistical software (version 9; SAS Institute). The MSDPS was normally distributed. We used the MSDPS as a continuous measure and also divided this score into approximate quintile categories for analyses. SAS Base procedures, including PROC UNIVARIATES and PROC FREQ, were used to determine the intake distributions within each food group and component score. Spearman correlation coefficients were applied to examine the associations between the individual MSDPS component scores and the total score as well as among the individual component scores.

A natural logarithmic transformation was applied to normalize the positive-skewed distribution of the nutrient variables, BMI, waist circumference, and PAL. To express these variables on their original scale, geometric means were calculated by taking the exponent of the adjusted least-squares means. Age- and sex-adjusted participants' lifestyle characteristics were compared across quintile categories of MSDPS using the SAS procedures PROC GLM (for continuous characteristics) and PROC LOGISTIC (for dichotomous characteristics). Age- and sex-adjusted tests for trends across quintile categories of MSDPS were based on the linear or logistic regression model for continuous or dichotomous characteristics, respectively, by assigning the median MSDPS of each quintile category to each individual in that quintile category and treating it as a continuous variable. We performed similar analyses to examine the relationship between MSDPS and nutrient intakes with additional adjustment for total energy intake. Because self-reported dietary intake tends to underestimate actual consumption (28), and because the MSDPS was applied to dietary data that derived from a self-reported dietary assessment, i.e. FFQ, we tested the potential interaction of the accuracy of reporting energy intake on the associations between MSDPS and the nutrient intakes. To limit the potential for false positive interactions, we applied a Bonferroni correction, dividing our prespecified significance level (0.05) by the number of interactions considered (n = 24). Using this approach, an interaction with an observed P-value of <0.002 would be deemed significant. For all other analyses, significance was defined as $P < 0.05$.

Results

The mean MSDPS for the exam 7th of FHS Offspring Cohort was 24.8 (range 3.1–60.7) out of a maximum possible score of 100 (**Supplemental Fig. 1**). Among the 13 food groups of MSDPS, median component scores were highest for poultry and fruits and lowest for sweets and meat (**Table 3**). The proportion of the study population that attained the maximum score of 10 in a category, thus meeting the recommended intake of a food group, was highest for olive oil and eggs. Nearly all participants had an intake of whole grains below the recommendation. More than 90% of the sample intakes of sweets or meats exceeded the recommendation. Consumption of foods that are part of the Mediterranean-style dietary pattern on average contributed to ~73% of total energy intakes.

The correlation coefficients relating the total MSDPS and the individual component scores were all positive and significant and ranged from 0.11 for meat to 0.50 for vegetables (Table 3). Adjustment for age, sex, and energy intake did not change the correlations. The correlations between the MSDPS component scores were modest to negligible, ranging from 0.32 for vegetables with fish and other seafood to −0.18 for eggs with meat (**Supplemental Table 2**).

In the FHS Offspring Cohort, the median MSDPS in the highest quintile category was approximately twice as much as

TABLE 2 Nutrients used in assessing content validity of the MSDPS

Energy intake	Folate	Alcohol	(n-6) Fatty acids
Dietary fiber	Vitamin C	Saturated fat	LA (18:2)
Added sugar	Vitamin E	Trans-fat	(n-3) Fatty acids
Glycemic index	Calcium	Monounsaturated fat	LNA (18:3)
β-Carotene	Magnesium	Oleic acid (18:1)	EPA (20:5) + DHA (22:6)
Lycopene	Potassium	Polyunsaturated fat	(n-6):(n-3) Fatty acid ratio

TABLE 3 Intake and score distributions and Spearman rank correlation of the MSDPS components in the Framingham Offspring Cohort

MSDPS components	Intake distribution[1]	Score distribution[1]	Met the recommended intakes	Below the recommended intake	Exceeded the recommended intake	Spearman rank correlation to total MSDPS[2]
Food groups	*Servings/d*		*%*	*%*	*%*	
Whole grains	0.93 (0.03, 3.53)	1.16 (0.04, 4.41)	0	99.9	0.1	0.40
Fruits	1.73 (0.24, 4.60)	5.18 (0.49, 9.47)	0.1	81.3	18.6	0.43
Vegetables	2.44 (0.76, 5.91)	4.04 (1.25, 8.73)	0	95.3	4.7	0.50
Dairy	1.23 (0.20, 3.93)	4.93 (0.07, 9.19)	0.2	73.4	26.4	0.30
Wine						
Men	0.05 (0, 1.60)	0.18 (0, 5.33)	0	99.6	0.4	0.32
Women	0.05 (0, 1.26)	0.36 (0, 5.90)	0	95.2	4.8	0.31
	servings/wk					
Fish and other seafood	2.24 (0.47, 6.90)	3.73 (0, 8.98)	0	92.0	8.0	0.42
Poultry	4.95 (0.78, 9.90)	5.69 (0, 8.25)	0	45.6	54.4	0.23
Olives, legumes, and nuts	1.47 (0, 6.06)	3.21 (0, 9.38)	1.6	86.0	12.4	0.36
Potatoes and other starchy roots	3.20 (0.47, 7.60)	4.90 (0, 9.33)	4.1	45.4	50.5	0.21
Eggs	1.00 (0, 5.0)	3.33 (0, 10.0)	30.2	64.6	5.2	0.30
Sweets	12.4 (1.88, 40.2)	0 (0, 7.60)	0.3	9.0	90.7	0.13
Meat	3.87 (0.54, 11.7)	0 (0, 7.55)	0.5	8.1	91.4	0.11
Olive oil			36.9	63.1[3]		0.45
Weighting factor						
Total energy intakes attributed to consumption of Mediterranean diet foods, *%*	73.1 (54.5–85.8)	0.73 (0.55–0.86)				

[1] Data are median (5th, 95th percentiles), $n = 3021$.
[2] Total MSDPS was the sum of 13 component scores, standardized to a 0–100 scale, and weighted by the proportion of energy consumed from Mediterranean diet foods.
[3] Sum of percent for use of olive oil and other vegetable oils (1.4%) and percent for no use of olive oil (61.7%).

that in the lowest quintile category (**Table 4**). Compared to participants in the lowest quintile category of MSDPS, those in the highest quintile category were older, had a lower BMI and waist circumference, were more likely to be women and multivitamin users, and were less likely to be current smokers. The MSDPS and PAL were not associated.

Content validity. **Table 5** shows the associations between MSDPS and selected nutrients previously shown to be related to the Mediterranean diet pattern. MSDPS was significantly and positively associated with dietary fiber, alcohol, and (n-3) fatty acids and its components such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), β-carotene, lycopene, folate, vitamins C and E, calcium, magnesium, and potassium. Conversely, participants with a higher MSDPS had significantly lower intakes of added sugar, saturated fat, trans-fat, (n-6) fatty acids, and linoleic acid (LA), a lower glycemic index, and a lower ratio of (n-6):(n-3) fatty acids. We also found a significant inverse association between the MSDPS and dietary polyunsaturated fat and a positive association with linolenic acid (LNA) intake. In contrast to these expected associations, we observed an unexpected positive association between the MSDPS and total energy intakes and an unexpected inverse association between the MSDPS and intakes of monounsaturated fat and oleic acid.

To examine the impact of underreporting of energy intake on the validation of the MSDPS, we tested the potential interaction of the accuracy of reporting energy intake on the associations between MSDPS and nutrient intakes. After adjustment for multiple comparisons, the only significant interaction between the accuracy of reporting energy intake and the MSDPS was for total energy intakes (P for interaction < 0.001). No significant interactions were found for the other nutrient intakes.

We stratified total energy intakes by the accuracy of reporting energy intake (**Fig. 1**). The positive association between total energy intakes and MSDPS was attributed to the under-reporting participants. Among under-reporters, mean energy intakes from the lowest to the highest quintile categories of MSDPS were 5498, 5657, 5960, 6121, and 6291 kJ/d, respectively (P-trend < 0.001). Energy intakes and MSDPS were unrelated in participants who were considered to report energy intake accurately (9141, 9187, 9330, 9263, and 9217 kJ/d from the lowest to the highest quintile categories, respectively; P-trend = 0.63).

Discussion

We developed the MSDPS to assess the conformity of an individual's diet to a traditional Mediterranean-style dietary pattern. The Mediterranean diet pyramid was selected as the recommended dietary pattern on which to base the construction of the MSDPS in light of the following. First, the Mediterranean diet pyramid was formulated based on the typical diet of Crete in the early 1960s (3). Given the fact that there are several countries within the Mediterranean region, there are many Mediterranean diets. However, the dietary pattern of Crete prior to the 1960s has been well accepted as the generic model of a Mediterranean diet (5,7). Second, the construction of the Greek Mediterranean diet pyramid (3) was based on the Mediterranean diet pyramid that was developed by the Harvard School of Public Health (4). This latter pyramid was initially structured to

TABLE 4 Participant characteristics across quintile categories of the MSDPS in the Framingham Offspring Cohort [1]

	MSDPS quintile categories					
	Q1	Q2	Q3	Q4	Q5	*P*-trend
n	604	604	605	604	604	
MSDPS	14.7 (3.06–17.8)	20.3 (17.9–22.6)	24.8 (22.7–26.8)	29.0 (26.9–31.6)	35.6 (31.7–60.7)	
Age, *y*	60.2	60.5	61.5	62.1	61.5	<0.001
Women, *%*	45	55	51	56	65	<0.001
BMI, kg/m^2	27.9	27.6	28.2	27.4	27.3	0.02
Waist circumference, *cm*	100	99	100	98	97	<0.001
PAL,[2] *MET score/h*	1.5	1.6	1.6	1.6	1.6	0.31
Current smokers, *%*	18	17	10	11	7	<0.001
Current multivitamin users, *%*	46	51	49	54	64	<0.001

[1] Values are means, percent, or medians (range). Age is adjusted for sex only and sex, for age only. Other characteristics are adjusted for age and sex.
[2] MET, Metabolic equivalents.

reflect the traditional Mediterranean diet as one of the worldwide dietary traditions that is historically associated with good health, is palatable, and could be adopted by non-Mediterranean cultures throughout the world, including Americans (4). Third, the Mediterranean diet pyramid was compatible with the essential components needed for constructing a diet score, which is typically constructed on the basis of dietary recommendations.

A few earlier studies used scores based on the Mediterranean diet pyramid (13,14), but none incorporated the recommended intakes from the Mediterranean pyramid into a diet score. This is a unique feature of the MSDPS, which allows a quantitative assessment of the degree of adherence to the recommendations. A second unique feature of the MSDPS construction is the use of a continuous scale. This removed the necessity for assigning a

TABLE 5 Selected daily intakes of nutrients associated with the Mediterranean diet across quintile categories of the MSDPS in the Framingham Offspring Cohort[1]

	MSDPS quintile categories					
	Q1 (3.06–17.8)	Q2 (17.9–22.6)	Q3 (22.7–26.8)	Q4 (26.9–31.6)	Q5 (31.7–60.7)	*P*-trend
n	604	604	605	604	604	
Energy intake, *kJ*	6437	6995	7246	7596	7749	<0.001
Dietary fiber, *g*	13.4	15.7	17.1	18.0	20.4	<0.001
Alcohol, *g*	3.82	2.95	3.53	4.22	5.19	<0.001
Added sugar,[2] *g*	39.1	41.9	39.3	37.6	35.3	0.001
Glycemic index[3]	54.3	54.2	54.0	53.6	52.7	<0.001
Saturated fat, *g*	20.8	20.7	19.8	19.8	18.6	<0.001
Trans fat,[4] *g*	2.65	2.47	2.30	2.22	1.97	<0.001
Monounsaturated fat, *g*	22.0	21.6	21.0	20.7	20.0	<0.001
Oleic acid (18:1), *g*	20.1	19.6	18.9	18.5	17.8	<0.001
Polyunsaturated fat, *g*	10.9	10.8	10.8	10.7	10.6	0.04
(n-6) Fatty acids,[5] *g*	9.40	9.20	9.10	9.00	8.80	<0.001
LA (18:2), *g*	9.28	9.10	8.95	8.83	8.71	<0.001
(n-3) fatty acids,[6] *g*	1.19	1.28	1.33	1.37	1.43	<0.001
LNA (18:3), *g*	1.01	1.06	1.05	1.07	1.05	0.02
EPA (20:5) + DHA (22:6), *g*	0.19	0.23	0.28	0.33	0.37	<0.001
Ratio (n-6):(n-3) fatty acids	7.86	7.18	6.83	6.52	6.20	<0.001
β-Carotene, μg	2235	3172	3685	4217	5161	<0.001
Lycopene, μg	5107	5924	6512	6949	7214	<0.001
Folate, μg	232	268	301	317	345	<0.001
Vitamin C, *mg*	94	116	139	149	158	<0.001
Vitamin E, *mg*	5.04	5.29	5.81	6.10	6.53	<0.001
Calcium, *mg*	584	657	689	717	757	<0.001
Magnesium, *mg*	242	264	282	294	324	<0.001
Potassium, *mg*	2428	2734	2937	3058	3314	<0.001

[1] Data are means. Energy intake was adjusted for age and sex; all other nutrients were adjusted for age, sex, and energy intake.
[2] Added sugar included sugars added to foods or beverages by individuals or by processing.
[3] Glycemic index was based on a 50-g glucose standard.
[4] Trans-fat included *trans* 16:1, *trans* 18:1, *trans-trans* 18:2, and *cis-trans* 18:2.
[5] (n-6) Fatty acids included 18:2(n-6) (LA) and 20:4(n-6).
[6] (n-3) Fatty acids included 18:3(n-3) (LNA), 20:5(n-3) (EPA), 22:5(n-3), and 22:6(n-3) (DHA).

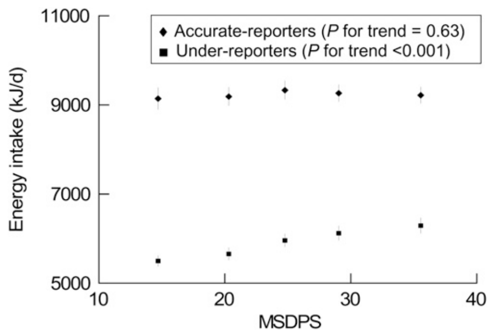

FIGURE 1 Association between the MSDPS and total energy intakes by the accuracy of reporting dietary intake in the Framingham Offspring Cohort. Values are age- and sex-adjusted means (95% CI), n = 1660 (under-reporters) and 1361 (accurate reporters). $P < 0.001$ for the interaction between MSDPS and the accuracy of reporting energy intake.

cut-off point to each component score, which may limit the previous scores due to the subjectivity in selecting the cut-off points. Moreover, a continuous score can minimize bias due to misclassification of diet exposure. The consideration of the impact of overconsumption is another unique feature of the MSDPS. Failure to account for overconsumption may result in confounding by energy intake, because it may be easier to achieve recommended intakes by consuming more foods and, consequently, more energy. In the US, increases in the amount of foods consumed, especially foods that contribute to a higher amount of energy intake per a given weight of food (i.e. high energy-dense foods), is associated with increased obesity prevalence (34,35). The Mediterranean diet pyramid does not incorporate the principle of energy dense foods into their recommendations, so we applied the overconsumption penalties to the food components of the Mediterranean-style dietary pattern independent of the energy density of the foods, except for olive oil, for which there was no quantitative recommendation. The last unique feature of the MSDPS was the consideration of the consumption of non-Mediterranean foods. The significance of this feature to the overall MSDPS is that the consumption of foods not included in the Mediterranean-style dietary pattern will affect the adherence to the overall diet pattern proportionally based on the amount of non-Mediterranean diet foods consumed.

A new instrument, such as the MSDPS, ideally should be calibrated against a gold standard. However, there are no direct methods against which the MSDPS can be validated. Thus, we applied a test of content validity in which the MSDPS was compared against certain nutrients that were previously reported to be associated with the Mediterranean-style dietary pattern. All the selected nutrients had the expected associations with the MSDPS, except for total energy intake and monounsaturated fats. The inability of the semiquantitative FFQ used in the present analysis to quantify energy intake accurately could have affected the observed score-nutrient associations. Using a surrogate method to detect inaccuracy of reporting energy intake, we found that the positive association between the MSDPS and total energy intake remained significant only among those who we classified as under-reporter participants, but not among those classified as accurate reporters. Thus, the MSDPS did not seem to associate with energy intake per se, but rather under-reporters were more likely to score higher if they reported more energy intake.

The inverse association with monounsaturated fats may be a consequence of the qualitative nature of the Mediterranean diet pyramid's recommendation for olive oil. The Mediterranean diet pyramid recommends the use of only olive oil but provides no quantitative intake recommendations for intake levels, which led us to design the corresponding score in a categorical scale. However, given the relatively low consumption of olive oil in the US, much of the monounsaturated fat comes from beef (36). We found that consumption of meat (including poultry) was by far the largest contributor of oleic acid intake in our study population.

The MSDPS needs to be interpreted according to the overall nature of the dietary pattern. The MSDPS reflects the complexity of the entire Mediterranean-style diet. No single component drove the score; the correlation coefficients between individual component scores and total MSDPS as well as those among the component scores were modest to negligible. Thus, the degree of conformity to the Mediterranean-style dietary pattern is the result of the joint impact of all component scores and is not influenced by any individual component.

Unless an individual achieves the maximum score of 100, the person's diet does not conform completely to the Mediterranean-style dietary pattern. Although a higher value of the MSDPS reflects a greater conformity to a Mediterranean-style dietary pattern, a higher observed score can be achieved in several different ways using various combinations of food groups that comprised the Mediterranean-style dietary pattern. Given the large numbers of patterns that may produce moderate to higher scores, interpretation of the finding with respect to health outcomes may be difficult if specific subpatterns are more strongly associated with the different outcomes.

Although the Mediterranean diet pyramid has a component of physical activity, the MSDPS was constructed to focus only on the dietary components. Given that physical activity may be a potential confounder, we recommend that physical activity be adjusted for in any analyses relating the MSDPS and health outcomes.

Potential limitations in the application of the MSDPS include possible concerns arising from the use of dietary data derived from an FFQ. However, earlier validation studies of the Harvard FFQ showed that many of the foods included in the MSDPS were validly captured on the FFQ based on correlations with diet records (37). Furthermore, FFQ is an advantageous method to characterize individuals' usual intake over a long period of time and to rank individuals according to their usual intake with respect to associations with health outcomes (38). Another limitation of our analysis is the difficulty in estimating reporting accuracy of energy intake. In spite of this, we observed a differential association between energy intake and the MSDPS based on estimated intake accuracy. Lastly, the Mediterranean diet pyramid does not distinguish recommendations based on age, sex (except for wine recommendation), and energy expenditure, which may in part contribute to residual confounding for the associations between the MSDPS and participant characteristics. However, this is a limitation of the Mediterranean diet pyramid per se and not the MSDPS.

In conclusion, the MSDPS is an instrument for characterizing dietary patterns of a population according to the dietary principles of a healthy Mediterranean-style diet so that dietary patterns can be monitored over time. It also permits examination of how the dietary patterns affect health outcomes. Dietary studies using the MSDPS are expected to enhance our understanding of the Mediterranean-style dietary pattern as one strategy for preventing type 2 diabetes mellitus, cardiovascular disease, and other age-related conditions.

Acknowledgments

We thank Dr. Robert Houser, Dr. Walter Willet, Dr. John Anderson, and Dr. Flaminio Fidanza for their review and suggestions regarding the creation of the MSDPS.

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