Indexes for Assessing Adherence to a Mediterranean Diet from Data Measured through Brief Questionnaires: Issues Raised from the Analysis of a Greek Population Study[1–3]

Christina Bamia,[4,5]* Georgia Martimianaki,[4] Maria Kritikou,[4] and Antonia Trichopoulou[4,5]

[4]Hellenic Health Foundation, Athens, Greece; and [5]WHO Collaborating Center for Nutrition and Health, Unit of Nutritional Epidemiology and Nutrition in Public Health, Department of Hygiene, Epidemiology, and Medical Statistics, National and Kapodistrian University of Athens Medical School, Athens, Greece

Abstract

Background: Adherence to a Mediterranean diet (MD) has been quantified through various indexes that rely on full-length questionnaires, but their application in data collected with brief questionnaires has not been systematically investigated.

Objective: We aimed to evaluate the ability of the commonly used MD score (MDS) to classify individuals according to their adherence to an MD when applied to data collected with brief questionnaires.

Methods: We assessed the diet of 200 participants from a Greek national health survey with the use of 2 instruments: *1*) a validated, detailed food-frequency questionnaire (FFQ) estimating grams per day of intake of individual foods and *2*) a selection of 19 questions from the Baseline Nutrition Credits4Health (BNC4H) electronic platform questionnaire that assessed servings with subjective serving sizes. We calculated the MDS_FFQ (referent) and MDS_BNC4H indexes from each questionnaire and estimated their correlation and the percentage of study participants who were ranked in an identical tertile in both indexes. We repeated the analyses for 2 additional indexes defined with criteria different from the MDS [Mediterranean Diet Index (MDI)_BNC4H and Mediterranean Diet Assessment Score (MEDAS)_ BNC4H].

Results: Spearman correlation coefficients for the MDS_FFQ were 0.31 with the MDS_BNC4H, 0.24 with the MDI_BNC4H, and 0.23 with the MEDAS_BNC4H. The proportion of participants ranked into the same adherence level as the referent MDS_FFQ was 50% for the MDS_BNC4H (weighted $\kappa = 0.27$) and lower for the other indexes. The use of medians as cutoffs (as in the MDS_FFQ) had low discriminative ability when applied to servings per day (MDS_BNC4H) in some MDS components, leading to comparability problems in the range of values between the 2 indexes.

Conclusions: Our findings highlight certain issues that need to be considered when applying pre-existing MD indexes in settings with different dietary assessments. Given the widespread use of electronic platforms for dietary assessment, our results may offer further insight into designing brief, simplified questionnaires that aim to estimate MD adherence with easily quantifiable scores. *Curr Dev Nutr* 2017;1:1–8.

Introduction

A Mediterranean diet (MD)[6] is traditionally consumed by populations in the Mediterranean basin. The salient components of an MD are the use of olive oil as the main type of added and cooking lipid; a high consumption of vegetables, legumes, fruit and nuts, cereals (mostly unrefined), and fish and shellfish; a low consumption of meat; and a moderate consumption of dairy products (mainly as cheese and yogurt) and alcohol (usually wine during meals) (1).

Keywords: dietary assessment, dietary patterns, Mediterranean diet, correlation, diet, food frequency

Manuscript received November 16, 2016. Initial review completed December 21, 2016. Revision accepted February 27, 2017. First published March 1, 2017; doi:10.3945/cdn.116.000075

[1] Supported by the Hellenic Health Foundation.

[2] Author disclosures: C Bamia, G Martimianaki, M Kritikou, and A Trichopoulou, no conflicts of interest.

[3] Supplemental Table 1 is available from the "Online Supporting Material" link in the online posting of the article and from the same link in the online table of contents at http://cdn.nutrition.org.

*To whom correspondence should be addressed. E-mail: cbamia@med.uoa.gr.

[6] Abbreviations used: BNC4H, Baseline Nutrition Credits4Health; C4H, Credits4Health; EPIC, European Prospective Investigation into Cancer and Nutrition; HYDRIA, Greek National Diet and Health Survey; MD, Mediterranean diet; MDI, Mediterranean Diet Index; MDS, Mediterranean Diet Score; MEDAS, Mediterranean Diet Assessment Score.

A protective association of an MD with various health outcomes has been shown over the past decades in epidemiologic studies conducted in Mediterranean, European, and US populations (2, 3). Quantification of adherence to an MD in these studies has been done through indexes and scores that *1*) use cutoffs for classifying subjects as high, moderate, or low adherers in each of the components of an MD; *2*) use scoring systems to credit or penalize people according to their level of adherence to each MD component; and *3*) apply calculating algorithms, mostly simple summations, on the adherence to each component to assess the total adherence to an MD (4). These indexes and scores may differ with respect to ≥1 of the aforementioned procedures. Nonetheless, the vast majority revealed favorable significant associations between adherence to an MD and various health outcomes (2, 5).

Most of these indexes were originally perceived in the context of full-length FFQs with an exhaustive number of items, or other time-consuming methods (4). Brief tools that include only a small number of foods expressed in servings/d or servings/wk have also been proposed, and indexes for MD adherence also have been based on this type of data collection (4, 6, 7). To our knowledge, however, there has been no systematic investigation with respect to issues that may appear when indexes originally designed and successfully applied to data from detailed dietary assessments are "transferred" unaltered to data collected with quick and easy-to-use methods. This is particularly challenging because there is no "objective" method to measure MD adherence, nor are there commonly accepted criteria to evaluate each of these indexes.

We therefore sought to investigate whether indexes for MD adherence designed for data obtained from FFQs in the form of absolute intakes of individual MD components can be successfully applied for ranking purposes to data from brief questionnaires (e.g., servings) with no further quantification. We also assessed the performance of 2 additional indexes for data assessed with brief dietary questionnaires.

Methods

Participants

Participants were selected from the Greek National Diet and Health Survey (HYDRIA) (8), which was conducted between June 2013 to December 2014 according to the standards of the European Health Examination Survey. HYDRIA involves the collection of a large number of data on sociodemographic characteristics, medical history (including laboratory results), anthropometric measurements, as well as dietary and lifestyle habits including smoking, physical activity, etc. HYDRIA study participants were a representative sample of 1873 men and 2138 women selected from all regions of Greece, with 34% living in the area of Attiki (the Greek capital Athens, and the greater area around Athens), the most densely populated region of Greece. From Attiki residents, 396 were selected randomly (on the basis of HYDRIA distribution of age and sex) and were invited to participate in the study. Two hundred participants (79 men and 121 women), aged ≥18 y at recruitment, accepted the invitation and were included in the current study.

Dietary assessment

Participants were contacted through telephone interviews in April and during November–December 2015. For each participant, diet was assessed with the following 2 questionnaires: *1*) a validated, detailed semiquantitative FFQ (9, 10), which was previously used in the Greek segment of the European Prospective Investigation into Cancer and Nutrition (EPIC) (11), and *2*) a selection of questions referring to dietary habits that are included in the Baseline Nutrition Credits4Health (BNC4H) questionnaire, which was created by the partners of Credits4Health (C4H) study (12).

EPIC FFQ

Usual dietary intake during the year before enrollment was estimated from the FFQ, which included 150 foods and beverages commonly consumed in Greece, as well as questions on type of lipids used in cooking, etc. FFQs were mailed to the 200 participants, and subsequent telephone interviews were performed during which participants reported the frequency of consumption of each item according to prespecified portion sizes by referring to the respective photographs included in the FFQ. These data were subsequently used to estimate *1*) consumed quantities in grams or milliliters per day for foods and beverages, respectively, and *2*) nutrient intakes (grams per day) with the use of a food-composition database that had been modified to accommodate the particularities of the Greek diet (13).

BNC4H questionnaire

The C4H study (12) aims to develop a sustainable system for encouraging people living in Euro-Mediterranean countries to enhance their level of physical activity and to adopt healthy eating habits by means of a person-centric approach and a variety of incentives. From the original 37 questions of the BNC4H questionnaire, those specifying consumption of the following were used in this study: olive oil; fish and/or shellfish or seafood; fruit (including natural and dried fruit); nuts and seeds (salted or unsalted); olives (regular or low-salt); vegetables (raw or cooked, excluding potatoes); legumes; cereals (bread, pasta, rice, polenta, etc.); dairy (milk, yogurt, and cheese); red meat (beef, veal, pork, mutton, and goat meat), game, hamburger or meat products (ham, sausages, cured meat, etc.); white meat (chicken, rabbit, turkey, etc.); wine; beer; high alcohol–containing beverages (ouzo, whisky, cognac, etc.); seed oils, butter, margarine, and cream (including cooked meals, salads, and snacks); sweetened beverages; and commercial sweets or pastries (not homemade), such as cakes, cookies, biscuits, and *lathera*, a Greek homemade vegetable-based dish, or *sofrito*, a Spanish version of this dish (**Supplemental Table 1**). Each participant was asked to report the number of servings of each of these items that he or she consumed per week or day during a typical week over the past 3 mo, but with a subjective assessment of serving size. No further quantification was undertaken.

Indexes of adherence to an MD

By using data collected from the previously described questionnaires, 4 indexes indicating the degree of adherence to an MD were calculated. The components that are included in these

indexes are more or less detailed assessments of foods typical in an MD, specifically, vegetables, legumes, fruit and nuts, fish and seafood, cereals, meat and meat products, and dairy products. The main lipid used in an MD (i.e., olive oil) was assessed as such (BNC4H) or as the lipid ratio of monounsaturates to saturates (FFQ) (14), values of which indicate higher olive oil intake. Alcohol intake was assessed as the intake of specific alcoholic beverages (BNC4H) or as ethanol intake (FFQ).

Use of the EPIC FFQ

The first index that was applied to data collected through the EPIC FFQ was the Mediterranean Diet Score (MDS) index (MDS_FFQ), as proposed previously by Trichopoulou et al. (11). The MDS_FFQ was used in this study as a reference method for adherence to an MD because *1*) it was based on the most-detailed dietary assessment and *2*) it has been used widely in the literature and was consistently associated with various health outcomes (2). The construction of the MDS_FFQ was based on the sex-specific median consumption in each of the following food groups and nutrients as follows: values of 0/1 were assigned to participants whose consumption was below or at or was above the median intakes for vegetables, legumes, fruit and nuts, fish and shellfish, and cereals and the monounsaturated-to-saturated lipid ratio. The opposite rule was applied to meat and meat products and to dairy products. Ethanol intake was used as an indicator of alcohol consumption: a value of 1 was assigned to men and women with ethanol intakes from 10 and 5 g (1 and 0.5 units) to ≤50 and 25 g (6 and 3 units)/d, respectively, and a value of 0 otherwise. Thus, the MDS_FFQ takes values from 0 (minimal adherence to an MD) to 9 (maximal adherence to MD).

Use of the BNC4H questionnaire

The other indexes were based on data collected with the BNC4H questionnaire and are as follows:

1. The MDS_BNC4H was created by applying the MDS algorithm (i.e., by using sex-specific median number of servings as cutoffs for each MD component).
2. The Mediterranean Diet Index (MDI; MDI_BNC4H) was based on cutoffs developed by the C4H scientific consortium.
3. The Mediterranean Diet Assessment Score (MEDAS; MEDAS_BNC4H), as proposed by Martínez-González et al. (6), is based on a questionnaire similar to the BNC4H, which was originally developed for the Spanish population.

A list of the questions used, as well as the associated items evaluated by the FFQ, is shown in Supplemental Table 1.

As shown in Supplemental Table 1, the 3 indexes differ in the number of components and range of values used in their definition. The MDS_BNC4H and MDI_BNC4H use 9 and 11 components, respectively, which are very similar to those used in the MDS_FFQ. The MEDAS_BNC4H uses 14 components to capture subcategories of some of the original 9 MD components: for example, nuts are separated from fruit, and for each component the 0/1 assignment was based on different cutoffs, whereas total consumption of meat and products is considered as red meat and poultry, separately. To estimate the preference for poultry instead of red meat in the BNC4H data, the ratio of white to red meat was determined and values >1 were scored with 1 point [those with no consumption of red meat also were assigned a score of 1, although the corresponding ratio cannot be defined (due to zero intakes in the denominator)]. Additional items are also taken into account in the MEDAS_BNC4H, such as other types of oils and lipids used in cooking, consumption of sugar in drinks and sweets, as well as consumption of local foods that use olive oil, such as *sofrito* sauce (typical in Spain) or *lathera* (typical in Greece).

In all of the indexes, the range of values for each dietary component included in the respective definition was scored as 0 (minimal adherence to an MD component) or 1 (maximal adherence to a component of an index). Therefore, the ranges of values for each of the aforementioned indexes were as follows: MDS_BNC4H, 0–9; MDI_BNC4H, 0–11; and MEDAS_BNC4H, 0–14.

Statistical analysis

Participants' characteristics were analyzed by using cross-tabulations. Means, medians, ranges, and SDs were used to describe the distribution of the various MD indexes. For each index, tertiles were also computed.

Correlations between pairs of indexes were evaluated with Spearman rank correlation coefficients, overall as well as by sex, age group (≤30, 31–59, or ≥60 y), education (none, primary school, or gymnasium; high school or technical school; or university degree or higher), and occupational status (employed, unemployed, student, retired, or homemaker).

The concordance between each index based on the BNC4H questionnaire and the MDS_FFQ in ranking individuals in a similar manner with respect to their adherence to an MD was assessed by cross-classifying their respective tertiles. Cohen's κ (and weighted κ) statistic, which accounts for the possibility (and degree) of chance agreement, was calculated to statistically evaluate the coherence between the MDS_FFQ and each of the other indexes. All of the analyses were performed with the STATA statistical software (version 11.0 for Windows; StataCorp).

Results

Participants' baseline characteristics are presented in **Table 1**. There were more women (61%) than men. Most of the participants were aged between 31 and 59 y (47%) and were highly educated (~2 of 5 participants had completed university or higher level of education). Participants in this sample were mainly employed or had retired (67%), with only 12 participants (6%) being students.

Table 2 shows the cutoffs that were used to define adherence to each MD component, as well as the percentage of adherers based on the respective cutoffs for each of the MD indexes. It should be noted that values in Table 2 are shown for comparative purposes only and should not be used to draw conclusions for the intakes of the respective foods and nutrients in the study population. To facilitate direct comparisons across indexes, all cutoffs were transformed to daily intakes (in grams or servings). For the MDS_FFQ, adherers to each MD component represented ~50% of the sample, because the respective cutoffs denote median

TABLE 1 Characteristics of the study participants[1]

	Men	Women	Total
Age, y			
18–30	18 (22.8)	18 (14.9)	36 (18.0)
31–59	32 (40.5)	61 (50.4)	93 (46.5)
≥60	29 (36.7)	42 (34.7)	71 (35.5)
Education (highest level)			
None/primary school/gymnasium	14 (17.7)	21 (17.4)	35 (17.5)
High school/technical school	32 (40.5)	51 (42.2)	83 (41.5)
University or higher	33 (41.8)	49 (40.5)	82 (41.0)
Occupational status			
Employed	28 (35.4)	36 (29.8)	64 (32.0)
Unemployed	16 (20.3)	19 (15.7)	35 (17.5)
Student	6 (7.6)	6 (5.0)	12 (6.0)
Retired	29 (36.7)	41 (33.9)	70 (35.0)
Homemaker	0 (0.0)	19 (15.7)	19 (9.5)
Total	79 (100)	121 (100)	200 (100)

[1] Values are *n* (%) across categories of the indicated variables; *n* = 200. Participants were selected from the HYDRIA, which is a targeted action on the diet and health of the Greek population. Percentages do not always sum to 100% due to rounding. HYDRIA, Greek National Diet and Health Survey.

intakes, with the exception of ethanol intake. For the latter, only 17.5% adhered to the prespecified quantities, whereas the rest of the participants were apparently either low- or high-alcohol drinkers. Although median values represented the cutoffs used in most components of the MDS_BNC4H, participants were not equally divided (i.e., 50% adherers/50% nonadherers) in each of these components, because median servings per day was not a unique value but coincided with the actual intake for many participants. For fish consumption, for example, the most frequent answer was "1 serving per week" (0.14 servings/d), which was also the median intake, and thus 82% of participants were classified as adherers and met the "greater or equal to the median consumption" criterion. According to cutoffs proposed by the MDI_BNC4H, most participants were nonadherers for vegetable intake and adherers for meat intake, whereas less than one-quarter exceeded the minimum cutoffs for fruit, nuts and olives, cereals, and fish. According to cutoffs used in the MEDAS_BNC4H, most of the study participants did not adhere to legume, fish, or ethanol intake requirements; ~13% exceeded the cutoff for fruit and olive intake; and all met the red meat intake criterion. Moreover, participants responded favorably to all of the extra items that were included in this index (last 5 rows in Table 2). Almost all of the participants (95%) responded that they consume olive oil "always/mostly" and were thus classified as adherers to this MD component in all indexes based on the BNC4H questionnaire.

Table 3 shows participants' median and range of values for each MD index, overall as well as by tertile. Participants were not distributed equally across tertiles due to tied-score values in the upper limits of tertile ranges for all MD indexes and especially for the MDS_BNC4H and MEDAS_BNC4H. Overall median scores were 4 for the MDS_FFQ and MDI_BNC4H and 7 for the MDS_BNC4H and MEDAS_BNC4H. Participants classified in the second tertile of the MDS_BNC4H and MEDAS_BNC4H had similar scores (7 and 8, respectively), indicating a lack of greater discrimination when food assessment is conducted through brief, crude quantification of the respective quantities (i.e., servings per day or servings per week). Although actual median scores were not directly comparable across the estimated MD indexes due to the different questionnaires and algorithms used for their construction, only ~20% of participants were evaluated as high adherers in the MDS_FFQ and the MDS_BNC4H, whereas the rest of the participants were about evenly distributed between the low- and moderate-adherence categories in the MDS_FFQ. The MDS_BNC4H and MEDAS_BNC4H ranked approximately half of the participants as low adherers to an MD, whereas according to the MDI_BNC4H, 49% of participants adhered moderately to an MD.

Correlations between the MDS_FFQ and the rest of the MD indexes are depicted in **Table 4**. The Spearman correlation coefficients, overall, were positive (indicating an agreement in ranking order between the MDS_FFQ and the rest of the indexes), significant, and of low-to-moderate magnitude, ranging from 0.23 for the MEDAS_BNC4H to 0.31 for the MDS_BNC4H. Stronger correlations were evident for younger compared with older individuals and among students and employed persons than among those who were retired, unemployed, or occupied in housework only.

Table 5 shows the number and proportions of the study participants in each index based on the BNC4H questionnaire who were ranked identically to the MDS_FFQ tertile. Of the study sample, ~40% on the MDI_BNC4H and MEDAS_BNC4H and 50% on the MDS_BNC4H were ranked in the same tertile as on the MDS_FFQ. The weighted κ coefficient, however, indicated fair agreement between the MDS_FFQ and the MDS_BNC4H (0.27) and slight agreement for the MDI_BNC4H (0.14) and the MEDAS_BNC4H (0.14). With regard to the lowest tertile, 48% (MDI_BNC4H) to 65% (MDS_BNC4H) of those classified by the MDS_FFQ as low MD adherers were also classified as such in the BNC4H indexes. The corresponding values were lower when examining the higher tertile [high adherers; 21% (MDI_BNC4H) to 38% (MDS_BNC4H)], whereas the corresponding values between the MDS_FFQ and the MDS_BNC4H, MDI_BNC4H, and MEDAS_BNC4H in the second tertile were 44%, 49%, and 24% respectively.

Examination of the correlations between the 3 indexes calculated from the same BNC4H questionnaire showed that these ranged from 0.13 (MDS_BNC4H with MEDAS_BNC4H score) to 0.40 (MDS_BNC4H with MDI_BNC4H score; data not shown), indicating better agreement between indexes that used similar components for their construction.

Discussion

We investigated whether indexes for measuring adherence to an MD that were extrapolated from FFQs by using estimated quantities of individual foods and nutrients can be extrapolated to abbreviated methods based on servings. With the use of the MDS (11) estimated for 200 Greek participants by both the detailed EPIC FFQ (9) and a collection of 19 questions on the BNC4H questionnaire (12), we found that the 2 indexes were moderately correlated and were in moderate agreement in classifying study participants as low, moderate, and high MD adherers. We also observed similar correlations and correspondence (although of lower magnitude) between the MDS_FFQ and 2 additional indexes applied to the short 19-item

TABLE 2 Cutoff values and numbers (percentages) of participants adhering (i.e., scored as "1") to each MD component by MD index[1]

	MDS_FFQ, g/d		MDS_BNC4H, servings/d		Men and women, servings/d	
MD components	**Men**	**Women**	**Men**	**Women**	**MDI_BNC4H**	**MEDAS_BNC4H**
Vegetables	≥548	≥482	≥1	≥1	≥4	≥2
n (%)	101 (50.5)		178 (89.0)		9 (4.5)	47 (23.5)
Fruits and nuts	≥278	≥264	≥1.57	≥1.57	—*	—*
n (%)	101 (50.5)		104 (52.0)		—*	—*
Fruits	—*		—*		≥3	—*
n (%)	—*		—*		25 (12.5)	—*
Fruits and olives	—*		—*		—*	≥3
n (%)	—*		—*		—*	27 (13.5)
Nuts	—*		—*		salted and/or unsalted: 0.57–1; salted only: 0.57–0.71	≥0.43
n (%)	—*		—*		35 (17.5)	51 (25.5)
Olives	—*		—*		regular only: 0.57–0.71; regular and/or low-salt: 0.57–1	—*
n (%)	—*		—*		23 (11.5)	—*
Legumes	≥14	≥12	≥0.29	≥0.14	≥0.29	≥0.43
n (%)	101 (50.5)		162 (81.0)		96 (48.0)	16 (8.0)
Cereals	≥138	≥125	≥2	≥1	≥3	—*
n (%)	101 (50.5)		155 (77.5)		39 (19.5)	—*
Fish	≥26	≥17	≥0.14	≥0.14	≥0.29	≥0.43
n (%)	102 (51.0)		163 (81.5)		48 (24.0)	5 (2.5)
Monounsaturated/saturated lipids	≥1.8	≥1.8	Always, mostly[2]	Always, mostly[2]	Always, mostly[2]	Always, mostly[2]
n (%)	101 (50.5)		189 (94.5)		189 (94.5)	189 (94.5)
Dairy	<206	<193	≤1	≤1	2	—*
n (%)	99 (49.5)		127 (63.5)		53 (26.5)	—*
Meat	<123	<95	≤0.43	≤0.43	0.14–0.71	Red meat only: <1
n (%)	99 (49.5)		118 (59.0)		180 (90.0)	200 (100.0)
Alcohol	10–50	5–25	0.14–2[3]	0.14–1[3]	Men (only wine and beer): (>0–2); women (only wine and beer) (>0–1)[3]	≥1[3] (only wine)
n (%)	35 (17.5)		107 (53.5)		108 (54.0)	17 (8.50)
Preference for chicken, turkey, or rabbit meat instead of veal, pork, hamburgers, or sausage	—*	—*	—*	—*	—*	>1[4]
n (%)	—*		—*		—*	56 (28.0)
Use of olive oil as the main cooking lipid	—*	—*	—*	—*	—*	Yes
n (%)	—*		—*		—*	194 (97.0)
Seed oils, butter, margarine, and cream	—*	—*	—*	—*	—*	<1
n (%)	—*		—*		—*	170 (85.0)
Sweetened beverages	—*	—*	—*	—*	—*	<1
n (%)	—*		—*		—*	194 (97.0)
Commercial sweets or pastries (frequency)	—*	—*	—*	—*	—*	<0.43
n (%)	—*		—*		—*	172 (86.0)
Sofrito or *lathera* (frequency)	—*	—*	—*	—*	—*	≥0.29
n (%)	—*		—*		—*	157 (78.5)

[1] *n* = 200. *These items were not part of the respective MD index. BNC4H, Baseline Nutrition Credits4Health; C4H, Credits4Health; MD, Mediterranean diet; MDI, Mediterranean Diet Index; MDS, Mediterranean Diet Score; MEDAS, Mediterranean Diet Assessment Score.
[2] Based on question about olive oil consumption. Servings per day were not available for this item. Only questions regarding frequency of consumption were administered.
[3] Based on glasses.
[4] Based on ratio of white to red meat.

BNC4H questionnaire, which used different cutoffs and/or different foods in their definition.

The recommendation of an MD as a healthy eating pattern is based on evidence (2) accumulated since the first ecologic studies linked adherence to this diet with a lower prevalence of coronary artery disease (15). This consensus is currently reflected in dietary guidelines (16) that recommend an MD as a healthy diet. With regard to quantification of MD adherence, however, similar consensus is still lacking and several indexes and scores have appeared in the literature (17). Most of these indexes have been created by using data from detailed, time-consuming methods such as full-length FFQs or more than one 24-h recalls. This was a legitimate approach because most of the indexes aimed to estimate diet-disease associations, which meant that the respective

TABLE 3 MDS_FFQ, MDS_BNC4H, MDI_BNC4H, and MEDAS_BNC4H scores, by tertile of the respective index[1]

	Tertile			
	1: Low adherence to an MD	2: Moderate adherence to an MD	3: High adherence to an MD	Overall
MDS_FFQ	3 (0–3)	4 (4–5)	7 (6–9)	4 (0–9)
n (%)	75 (37.5)	78 (39.0)	47 (23.5)	200 (100.0)
MDS_BNC4H	6 (3–6)	7 (7)	8 (8–9)	7 (3–9)
n (%)	94 (47.0)	66 (33.0)	40 (20.0)	200 (100.0)
MDI_BNC4H	3 (1–3)	4 (4–5)	6 (6–10)	4 (1–10)
n (%)	79 (39.5)	98 (49.0)	23 (11.5)	200 (100.0)
MEDAS_BNC4H	7 (4–7)	8 (8)	9 (9–11)	7 (4–11)
n (%)	111 (55.5)	48 (24.0)	41 (20.5)	200 (100.0)

[1] Values are medians (ranges) unless otherwise indicated. BNC4H, Baseline Nutrition Credits4Health; C4H, Credits4Health; MD, Mediterranean diet; MDI, Mediterranean Diet Index; MDS, Mediterranean Diet Score; MEDAS, Mediterranean Diet Assessment Score.

quantification of diet should be as accurate as possible (18). There are situations, however, that call for the use of brief, easily administered questionnaires that assess only a small number of food items in easy-to-understand units such as servings per day or per week. Such situations include assessing adherence to an MD in clinical settings as part of patients' records, as well as in programs such as the C4H that aim to promote dietary changes and provide individualized advice and feedback on achievements of goals on a personal level (7). It is therefore important to know whether indexes that are based on a comprehensive dietary assessment can be "borrowed" by studies that use a brief assessment of diet.

The MDS (11), estimated by the Greek EPIC FFQ, was used in our study as the referent index. The MDS discriminates between adherers and nonadherers for each food or nutrient included in its definition by using sex-specific median intakes as cutoffs (except for alcohol intake), thus avoiding the arbitrary use of prespecified values. Notwithstanding criticism with regard to the generalizability of this "median approach" (19), the use of the median has the appealing simplicity of equally distributing adherers and nonadherers to each of the respective components. However, these desirable properties hold when median is a unique intake. Although this is true when grams per day or per week are used (as for the MDS_FFQ), it is no longer the case for less-comprehensive units of analysis such as servings per day, when medians may coincide with the most frequent intake. We observed this for components of the MDS_BNC4H, which explains, at least in part, the moderate degree of correlation between 2 indexes theoretically based on the "same" definition. A related reason that may also explain the lack of higher correlations between the 2 instruments was the reduced length of the BNC4H, which did not allow for detailed information on the amount, frequency of consumption, and portion sizes of items that contribute to an MD (compared with the EPIC FFQ).

When we cross-classified participants across categories of adherence on the MDS_FFQ and the MDS_BNC4H, 50% of the study sample was ranked in identical tertiles (adherence level). This finding, however, needs to be interpreted with caution. First, tertiles may not be comparable across indexes due to their different definitions and constructions. It might have been more informative to use a higher level of categorization (i.e., quintiles), but this was not possible given the limited ranges and apparent skewed distributions of the indexes. Second, the descriptive cross-classification can reflect, at least in part, chance. The weighted κ statistic indicated a modest level of agreement between the 2 indexes. Better correspondence was noted in those in the first tertile of the MDS_FFQ, indicating better agreement between the 2 indexes in classifying low adherers to an MD.

We also calculated 2 additional MD indexes by using different (from the MDS_BNC4H) components and scoring systems and examined their relation with the referent MDS_FFQ. We chose indexes with a range of values similar to those of the MDS_FFQ (and thus the MDS_BNC4H) to preserve comparability. We observed similar performance of these 2 indexes with respect to the MDS_FFQ, albeit the correlations were less strong than with the MDS_BNC4H, apparently due to the aforementioned differences from the referent index. Of note, correlations across the 3 indexes based on the 19-item BNC4H questionnaire were highest between the MDS and

TABLE 4 Spearman correlation coefficients between the MDS_FFQ and each of the 3 MD indexes estimated from the BNC4H questionnaire overall as well as by characteristics of the 200 study participants[1]

MDS_FFQ	MDS_BNC4H	MDI_BNC4H	MEDAS_BNC4H
Overall	0.31*	0.24*	0.23*
By sex			
Male	0.42*	0.19	0.29*
Female	0.25*	0.29*	0.21*
By age, y			
18–30	0.41*	0.54*	0.52*
31–59	0.44*	0.23*	0.13
≥60	0.04	0.08	0.21
By education			
None/primary school/gymnasium	0.18	0.36*	0.30
High school/ technical school	0.31*	0.30*	0.15
University degree or higher	0.37*	0.15	0.30*
By occupation			
Employed	0.50*	0.28*	0.22
Unemployed	0.20	0.34*	0.49*
Student	0.18	0.66*	0.26
Retired	0.14	0.00[2]	0.10
Homemaker	0.30	0.35	0.02

[1] *P value corresponding to the indicated Spearman rank correlation coefficient <0.05. BNC4H, Baseline Nutrition Credits4Health; C4H, Credits4Health; MD, Mediterranean diet; MDI, Mediterranean Diet Index; MDS, Mediterranean Diet Score; MEDAS, Mediterranean Diet Assessment Score.
[2] Actual value: −0.002.

TABLE 5 Concordance between the MDS_FFQ and each of the 3 MD indexes based on cross-classification of tertiles of MD indexes[1]

	MDS_FFQ tertile		
	1	2	3
Participants, *n*	75	78	47
MDS_BNC4H tertile[2]			
1	49 (65.3)	32 (41.0)	13 (27.7)
2	16 (21.3)	34 (43.6)	16 (34.0)
3	10 (13.3)	12 (15.4)	18 (38.3)
MDI_BNC4H tertile[3]			
1	36 (48.0)	30 (38.5)	13 (27.7)
2	36 (48.0)	38 (48.7)	24 (51.1)
3	3 (4.0)	10 (12.8)	10 (21.3)
MEDAS_BNC4H tertile[4]			
1	48 (64.0)	44 (56.4)	19 (40.4)
2	16 (21.3)	19 (24.4)	13 (27.7)
3	11 (14.7)	15 (19.2)	15 (31.9)

[1] Values are *n* (%) across the cross-classification of tertiles of MD indexes. Percentages do not always sum to 100% due to rounding. BNC4H, Baseline Nutrition Credits4Health; C4H, Credits4Health; MD, Mediterranean diet; MDI, Mediterranean Diet Index; MDS, Mediterranean Diet Score; MEDAS, Mediterranean Diet Assessment Score.
[2–4] Weighted κ for agreement with the MDS_FFQ: [2] 0.27, [3] 0.14, and [4] 0.14.

the MDI, moderate between the MDI and the MEDAS, and lowest between the MDS and the MEDAS, highlighting the importance of commonality of the components included (similar in the MDS and MDI but not in the MEDAS), as well as of the scoring systems used (prespecified cutoffs in the MDI and MEDAS and medians in the MDS).

The participants in this study had specific characteristics (e.g., highly educated). This selected sample could have resulted in higher correlations between the indexes, as compared with a more representative sample, but this was not supported by our data. It should also be noted that our study was not a validation of the BNC4H questionnaire but a practical exercise of applying indexes to different data collection settings. In this sense, the representativeness of the sample may be less important.

We were not able to examine the predictive ability of the different indexes to classify subjects according to MD adherence level by evaluating the degree to which their associations with health endpoints were in the expected direction or of the expected magnitude (20). If an index based on a brief FFQ showed at least similar (to the MDS_FFQ) predictability for the examined health outcomes, it would be considered a useful index for MD adherence, despite any low correlation or concordance with the referent index. It would be important for future studies on the same issues to follow this direction.

In conclusion, we observed a modest level of agreement between the MDS estimated by FFQ and by a short and flexible instrument and highlighted certain issues that need to be considered when applying pre-existing MD indexes in settings with different methods for data collection. Although we used specific MD indexes, these conclusions apply to other indexes as well. Given the widespread electronic platforms for dietary assessment, there is an urgent need to develop short, simplified questionnaires to estimate adherence to an MD with easily quantifiable scores. Our study findings may help in this direction by highlighting the potential limitations of applying pre-existing MD indexes, obtained from standard FFQs, when developing simplified questionnaires.

Acknowledgments

The authors' responsibilities were as follows—CB and AT: designed the study; MK: conducted the fieldwork; GM: analyzed the data; CB: wrote the manuscript; AT: had primary responsibility for final content; and all authors: read and approved the final manuscript.

References

1. Willett WC, Sacks F, Trichopoulou A, Drescher G, Ferro-Luzzi A, Helsing E, Trichopoulos D. Mediterranean diet pyramid: a cultural model for healthy eating. Am J Clin Nutr 1995;61(6 Suppl): 1402S–6S.
2. Schwingshackl L, Hoffmann G. Adherence to Mediterranean diet and risk of cancer: a systematic review and meta-analysis of observational studies. Int J Cancer 2014;135:1884–97.
3. Sofi F, Macchi C, Abbate R, Gensini GF, Casini A. Mediterranean diet and health status: an updated meta-analysis and a proposal for a literature-based adherence score. Public Health Nutr 2014;17: 2769–82.
4. Hernández-Ruiz A, García-Villanova B, Guerra Hernández EJ, Amiano P, Azpiri M, Molina-Montes E. Description of indexes based on the adherence to the Mediterranean dietary pattern: a review. Nutr Hosp 2015;32:1872–84.
5. Reedy J, Krebs-Smith SM, Miller PE, Liese AD, Kahle LL, Park Y, Subar AF. Higher diet quality is associated with decreased risk of all-cause, cardiovascular disease, and cancer mortality among older adults. J Nutr 2014;144:881–9.
6. Martínez-González MA, García-Arellano A, Toledo E, Salas-Salvadó J, Buil-Cosiales P, Corella D, Covas MI, Schröder H, Arós F, Gómez-Gracia E, et al. A 14-item Mediterranean diet assessment tool and obesity indexes among high-risk subjects: the PREDIMED trial. PLoS One 2012;7:e43134.
7. Zazpe I, Sanchez-Tainta A, Estruch R, Lamuela-Raventos RM, Schröder H, Salas-Salvado J, Corella D, Fiol M, Gomez-Gracia E, Aros F, et al. A large randomized individual and group intervention conducted by registered dietitians increased adherence to Mediterranean-type diets: the PREDIMED study. J Am Diet Assoc 2008;108:1134–44; discussion: 1145.
8. Hellenic Health Foundation. HYDRIA: program and targeted action on the diet and health of the Greek population: development and implementation of methodology and documentation [Internet]. [cited 2017 Mar 13]. Available from: http://www.hydria-nhns.gr/index_eng.html.
9. Gnardellis C, Trichopoulou A, Katsouyanni K, Polychronopoulos E, Rimm EB, Trichopoulos D. Reproducibility and validity of an extensive semiquantitative food frequency questionnaire among Greek school teachers. Epidemiology 1995;6:74–7.
10. Katsouyanni K, Rimm EB, Gnardellis C, Trichopoulos D, Polychronopoulos E, Trichopoulou A. Reproducibility and relative validity of an extensive semi-quantitative food frequency questionnaire using dietary records and chemical markers among Greek school teachers. Int J Epidemiol 1997;26(Suppl 1):S118–27.
11. Trichopoulou A, Costacou T, Bamia C, Trichopoulos D. Adherence to a Mediterranean diet and survival in a Greek population. N Engl J Med 2003;348:2599–608.
12. Credits4Health. Credits-based, people-centric approach for the adoption of healthy life-styles and balanced Mediterranean diet in the frame of social participation and innovation for health promotion. [cited 2017 Mar 13]. Available from: http://www.credits4health.eu/.
13. Trichopoulou A, Georga K. Composition tables of simple and composite foods. Athens (Greece): Parisianos; 2002.
14. Trichopoulou A, Kouris-Blazos A, Wahlqvist ML, Gnardellis C, Lagiou P, Polychronopoulos E, Vassilakou T, Lipworth L, Trichopoulos D. Diet and overall survival in elderly people. BMJ 1995;311:1457–60.

15. Keys A. Seven countries: a multivariate analysis of death and coronary heart disease. Cambridge (MA): Harvard University Press; 1980.
16. US Department of Health and Human Services; USDA. 2015–2020 Dietary guidelines for Americans. 8th ed. 2015 [Internet]. [cited 2017 Mar 13]. Available from: http://health.gov/dietaryguidelines/2015/guidelines/.
17. Milà-Villarroel R, Bach-Faig A, Puig J, Puchal A, Farran A, Serra-Majem L, Carrasco JL. Comparison and evaluation of the reliability of indexes of adherence to the Mediterranean diet. Public Health Nutr 2011;14(12A):2338–45.
18. Plummer M, Clayton D. Measurement error in dietary assessment: an investigation using covariance structure models. Stat Med 1993;12:925–35.
19. Möller E, Galeone C, Andersson TM, Bellocco R, Adami HO, Andrén O, Grönberg H, La Vecchia C, Mucci LA, Bälter K. Mediterranean diet score and prostate cancer risk in a Swedish population-based case-control study. J Nutr Sci 2013;2:e15.
20. Liese AD, Krebs-Smith SM, Subar AF, George SM, Harmon BE, Neuhouser ML, Boushey CJ, Schap TE, Reedy J. The Dietary Patterns Methods Project: synthesis of findings across cohorts and relevance to dietary guidance. J Nutr 2015;145:393–402.