Diet Quality Indexes and Health

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Many different indexes have been developed to describe diet quality. Some are based on the nutrient content of food and specific components that affect metabolic indicators of adverse outcomes. Some indexes identify foods that are characteristic of particular cuisines, whereas other indexes use a mix of foods and nutrients as their basis. The most recent index (NOVA) uses the presence of additives as a marker for classification. Some indexes are intended for health promotion purposes, whereas others are used in regulatory activities, such as front-of-pack labeling. This article examines the literature to determine what information is available on the ability of any index to predict important outcomes such as mortality. Articles were selected if they compared 2 or more indexes or if they described outcomes for any index related to the UK Office of Communication nutrient profiling algorithm or the recently developed NOVA index. Few comparative articles were found. All of the indexes predicted mortality, heart disease, or cancer to some extent. The associations were small and could be due to residual confounding or attenuation due to measurement error. Given the similarity in results across the indexes, other criteria would need to be used when deciding which index to select for any specific context. Nutr Today. 2020;55(2):62–74

In 1986, Kant[1] commented that people ate combinations of foods, not single foods, and so "conclusions about the effect of consumption level of a single nutrient, food, or dietary constituent on a specific health outcome may be misleading. For these reasons, it is useful to examine global indexes of food and nutrient intake that express several related aspects of diet concurrently." She then summarized and described the indexes available at the time. The validation of these indexes, at that point, used methods ranging from examination of their cross-sectional association with anthropometry and nutrient adequacy to assessment of their longitudinal associations with mortality and cancer incidence.[1]

Since then, many different indexes to summarize the quality of an individual's diet have been developed. These include 2010 and 2015 versions of the Healthy Eating Index (HEI) and their variations, which are designed to summarize the features of the US Dietary Guidelines. Some other indexes capture different facets of the so-called Mediterranean diet. The recommendations underlying a small number of indexes have been formally tested in randomized controlled trials, and these might be referred to as "diets" rather than indexes, for example, the AHA Step 1 diet and the Dietary Approaches to Stop Hypertension (DASH) diet; however, many indexes have not been subjected to this sort of validation.

During the last decade or so, there has been an increasing interest in certain countries in developing 1 or more systems for regulatory or quasi-regulatory purposes to support other activities to promote healthy eating. For example, in the United Kingdom, the Office of Communication (OfCom) uses a profiling system to determine which foods can and cannot be advertised during children's TV viewing time. It was developed by the Food Safety Authority in 2007, and technical guidance was subsequently transferred to the Department of Health.[2] The intention of the algorithm is to implement public health recommendations to reduce the intake of saturated fat, sugar, and sodium while ensuring that recommended foods in the food groups are not penalized even when they contain some of these components. It has been adapted by Food Standards Australia New Zealand for use as generic criteria to determine which foods can make health claims on their labels, providing all other requirements to make health claims are met.[3] The Irish have also adopted a variation of the OfCom model for regulating advertising to children. Other versions similar to the OfCom model are used in France to generate a 5-level front-of-pack system and in Australia and New Zealand to generate a 10-level system for front-of-pack labeling (Box 1: description of the OfCom algorithm and its derivatives).

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"Nutrient profiling is the science of classifying or ranking foods according to their nutritional composition for reasons related to preventing disease and promoting health" (https://www.who.int/nutrition/topics/profiling/en/).

Box 1: OfCom Family of Models

The algorithm in this model scores each food for increasing amounts of energy, saturated fat, total sugar, and sodium and then offsets the score by subtracting points for the protein and fiber content of food and its percentage of fruits, vegetables (including legumes), and nuts. Because fewer points are allocated for the 3 offset items, the final score is inverted such that lower scores are "better" than high scores. The function of the 3 offset items is to counteract the high amounts of the 4 components of concern, which are found in micronutrient-rich foods such as fruit, nuts, lean meats, and dairy products that are typically recommended in healthy eating guides. For example, the combination of total sugar and percentage fruit content means that the difference between total and added sugar in fruit and fruit products is recognized, although "added sugar" is not a specific scoring item in the algorithm. The final score is dichotomized.

The original model is used in the United Kingdom to determine which foods can be advertised in children's TV viewing time. Various derivatives of it, which allow better classification of unsaturated fats and spreads, and cheese, have been adopted in some other countries.

A different direction has been taken in Brazil where a system that classifies foods based on processing, not nutritional value, called NOVA has been developed. This uses the presence of additives in foods (with certain exceptions) as a marker for processing, not because additives are unsafe but because they are used to make food appealing.[4] The presence of additives also distinguishes foods according to who produced them so that commercially produced items such as pasta sauce, jams, and cakes are ultraprocessed (ULP), but their homemade counterparts are not, regardless of the amount of components of public health concern, such as sodium, that they contain. Consequently, the NOVA system has certain notable discrepancies relative to other food recommendations. For example, mass-produced bread, including wholemeal varieties; polyunsaturated margarines and spreads; and wholegrain breakfast cereals are classed as ULP and therefore to be avoided, whereas butter and alcoholic beverages such as beer and wine are not in the "avoid" category (Box 2: summary of NOVA).

Box 2: The 4 NOVA Food Classification Groups Summarized From Monteiro et al[4]

Unprocessed or minimally processed foods are natural foods that have had edible parts removed and may have been ground, filtered, boiled, pasteurized or frozen, or packaged or have undergone nonalcoholic fermentation. They also include mixtures of these foods and additives used to preserve the original properties of the food such as added antioxidants or stabilizers in ultrahigh-temperature treated milk.

Processed culinary ingredients are substances obtained from group 1 foods or nature by methods such as pressing, refining, grinding, milling, or spray drying. They are rarely eaten alone but used to prepare group 1 foods in the home or restaurant. Examples are salt from mines or seawater, sugar, honey, maple syrup, vegetables oils, butter, lard, and starch extracted from plants. Some might contain added vitamins and minerals or additives that preserve original properties.

Processed foods are relatively simple products made by adding group 2 items to group 1 items such as fruit canned in syrup, sugared or salted nuts, cured meats, cheeses, freshly made unpackaged bread, beer, wine, and cider. They might also contain additives to preserve them.

Ultraprocessed foods are "industrial formulations typically with five or more ingredients and usually many ingredients." There are ingredients found only in ULP foods such as casein, lactose, whey, gluten, soy-protein isolate, and additives with technological purposes such as dyes and other colors, flavors, nonsugar sweeteners, bulking, defoaming, anticaking, emulsifiers, and so forth. "Group 1 foods are a small proportion of or are even absent from ultra-processed products." Common features of ULP foods are hyperpalatability, attractive packaging, extensive marketing, health claims, and ownership by multinationals. Examples in this category are mass-produced packaged bread and rolls, margarines, plant-based milk analogs, infant formula, baby food, artificially sweetened food, many ready-to-eat foods, confectionary, sodas, fortified wines and spirits, and so forth.

Studies of health outcomes typically collapse these into 2 groups: Ultraprocessed foods versus the other 3 groups combined.

Although the purpose of the OfCom-type algorithm and NOVA is to classify each food separately, researchers have developed methods to combine the scores of all foods eaten by study participants so that the participants can be ranked relative to each other.

The literature abounds with these and other diet quality indexes. From the foregoing, it will be clear that there is extensive similarity in the way all systems classify many foods but different systems place more or less emphasis on certain foods and so there are notable discrepancies. This article examines the literature to identify studies that directly compare the ability of diet quality indexes to predict mortality or other major outcomes as a validation mechanism.

Validity of Diet Quality Indexes

Concurrent Validity

For many years, the feasible way to investigate the validity of recommendations, and indexes based on them, was to examine concurrent validity, which measures how well a new test (or recommendation) compares with a well-established test (or recommendation). In 1 approach, indexes were (and are) compared to determine how they classified individual foods, or a composite score based on intake of individuals, against a stated view of "correct" classification. In another approach, food intakes measured in cross-sectional surveys, such as national nutrition surveys, can be converted into the indexes that are divided into levels, and the nutrient content of each index level is compared to assess whether micronutrient-rich foods were being separated from micronutrient-poor energy-dense foods. For example, the nutrient content of intakes with different degrees of adherence to a Mediterranean diet pattern could be examined. This is useful to determine whether an index picks up other recommendations in addition to the ones the index is based on and, therefore, whether it is coherent with other messages the public are being given (eg, do people who follow a paleo diet have intakes that conform to recommended fat ratios?).

Predictive Validity

A better method to test dietary recommendations is a trial to examine whether desirable changes in relevant biological parameters, such as blood pressure, cholesterol concentrations, weight, and so forth, are more likely to occur in those who are allocated to the recommended diet. A number of trials have used this approach for shorter periods such as weeks or months. The trial examining the DASH diet for blood pressure[5] is an obvious example as is a European trial examining which of several possible dietary recommendations leads to maintenance of weight loss for 6 months on an ad libitum intake.[6] Indexes might be based on these recommendations following this type of trial. Trials with longer duration testing outcomes such as disease incidence or mortality are more difficult to conduct, although a small number of trials testing common "healthy" dietary advice styles have been conducted for several years and have shown decreased incidence of diabetes in the United States[7] and Finland.[8]

There are several large cohort studies that collected dietary intake information at their commencement and now have many years of follow-up. Typically, the dietary information was collected by food frequency questionnaire. These data provide an alternative way of examining whether any of the diet quality indexes predict important health outcomes, although these analyses retain the usual caveats about drawing causal conclusions from observational data. There are numerous publications in the literature that summarize the dietary information using a single dietary quality index and then examine whether death or the incidence of various diseases differs according to the chosen index in the cohort. However, differences in the coverage of the food questionnaires and the methods used to control for confounding make it difficult to compare the performance of indexes between cohort studies. Even within a single cohort study, there are differences in subject restrictions, length of follow-up, and control for confounding between articles testing various diet quality indexes one at a time, which make comparisons difficult. Therefore, the most direct comparison of the predictive validity of different indexes would be found in an article in which the authors convert the dietary information into 2 or more diet quality indexes and calculate the relative risks for each index using consistent analytical methods. A more indirect comparison would compare indexes that have each been tested in different population groups, and this is less certain because it introduces additional possible confounding into the comparison.

Identification of Comparative Studies

For this article, PubMed was searched using the search term "diet quality index" in July 2019 to find cohort studies that described 2 or more diet quality indexes calculated in the same cohort study and reported in the same article and had mortality, incident cardiovascular disease, cancer, and the related conditions of obesity and metabolic syndrome in adults. Cross-sectional studies, including studies of concurrent validity, were excluded because they do not allow an assessment of the temporal association—that is, whether the outcome occurred before or after the measured diet—and ecological studies were excluded because it is not possible to attribute the effect at an individual level (generally referred to as *ecological fallacy*). Two research groups have examined data from several large cohort studies conducted in Europe and the United States to compare the ability of multiple diet quality indexes for a mortality end point using internally consistent methods.[9,10] Both articles included an index based on the 2010 US Dietary Guidelines. A subsequent article examining the index for the 2015 US Dietary Guidelines in one of the cohorts was included for noting. In addition, several other articles comparing only 2 indexes were also found. All of these are discussed hereinafter.

No article was found that compared any of the OfCom family or the NOVA index with other diet quality indexes. As these 2 indexes could be regarded as representing 2 extremes—namely, a nutrient profiling approach and a nonnutrition socially oriented approach—to index development and both are of current interest, additional articles that described the association of these indexes with mortality, cardiovascular disease, and some metabolic outcomes in cohort studies were ascertained from PubMed. With 1 exception, there was little overlap in the cohort studies used to investigate these 2 indexes, and so only indirect comparisons are possible.

The most adjusted result from the data was extracted for each analysis. When results were reported in multiple ways, for example, the index was tested as both a

BOX 3 Summary of Diet Quality Indexes Referred to in Figures 1 and 2 (Summarized From Refs. 9, 10, and 20)

Abbreviation	Name	Basis of Scoring
MDS	Mediterranean Diet Scale	Food groups, fatty acid ratio
rMED	relative Mediterranean Diet Scale	Food groups as for MDS with different scoring, olive oil
MSDPS	Mediterranean Style Dietary Pattern Score	13 food types
DQI-I	Diet Quality Index-International	Food variety, several food types, 9 nutrients, macronutrient ratios
HNFI	Healthy Nordic Food Index	6 foods
HEI 2010	Healthy Eating Index 2010	Various food types, some nutrients (fatty acid balance, sodium, empty calories)
WHO HDI	World Health Organization Healthy Diet Index	6 nutrients, 1 food type
DASH	Dietary Approaches to Stop Hypertension	7 food types, sodium
HLI-diet	Healthy Lifestyle Index - diet components	3 foods, several nutrients, fatty acid ratio, glycemic load
HLI-total	Healthy Lifestyle Index - all components	As for HLI-diet plus smoking, activity, BMI, alcohol
WCRF	World Cancer Research Fund/ American Institute for Cancer Research	Selected foods, weight management, physical activity, breastfeeding (women only)
AHEI-2010	Alternative Healthy Eating Index 2010	10 components: various food types, some nutrients (various fatty acids, sodium)
aMED	Mediterranean Diet Index adapted for a US population	9 components
MEDI-LITE	Literature-based adherence score to the Mediterranean diet	9 components

(continues)

BOX 3 Summary of Diet Quality Indexes Referred to in Figures 1 and 2 (Summarized From Refs. 9, 10, and 20), Continued

Abbreviation	Name	Basis of Scoring
mPNNS-GS	Modified version of the Programme National Nutrition Sante guideline score	12 components: mostly food groups with added sugars, sodium, penalties for excess energy intake (modified by excluding physical activity)

categorical variable and a continuous variable, preference was given to categorical analysis and the relative risk for the highest versus lowest quantile was extracted. The focus was on mortality, incidence of cardiovascular disease and cancer, and, to a lesser extent, metabolic disease. In the interest of succinctness, studies of groups other than healthy adults and other types of outcomes have been excluded from this article.

Mortality in Relation to 10 Different Diet Quality Indexes in the European EPIC Study

The largest number of indexes that were compared directly came from the European Prospective Investigation into Cancer and Nutrition (EPIC), which followed 451 256 healthy adults. Dietary information collected using the specially developed EPIC meal-based food frequency questionnaire (in most countries, although multiple records were used in the United Kingdom) was classified using 10 different diet quality indexes, and the risks for 10-year all-cause, cardiovascular disease and cancer mortality were calculated for each index.[9] The indexes tested cover a range of types—based on dietary guidelines, summaries of the diet tested in a randomized controlled trial, or summaries of features of certain cultural foodways. Some use a mix of nutrients and foods to classify intake, whereas others include macronutrient ratios or other properties such as glycemic load, and yet others consider only food in the scoring. Two indexes include nondietary characteristics such as physical activity. The authors noted that their data did not capture sodium intake adequately, and so some of the indexes (HEI-2010, Diet Quality Index-International, and DASH) that use this were not calculated according to the original intent (Box 3: description of indexes referred to in Lassale et al[9] and Leise et al[10] figures).

For each index, the population was divided into 4 equal groups (quartiles) according to intake by the index,[9] and the hazard ratio (HR) was calculated to compare the highest scoring quartile (most desirable) to the lowest scoring quartile. (AHR is conceptually equivalent to a relative risk in that it is the ratio of the incidence in the 2 groups being compared; however, each incidence is calculated using the length of time that each subject was in the study, and this allows for dropouts, deaths due to other causes, and occurrence of the outcome at different times during a follow-up lasting years). Figure 1 shows that, regardless of which index is considered, people with the most desirable diet had approximately 22% to 25% lower death rates from all causes, cardiovascular disease, and cancer than those with the least desirable diet. All associations were statistically significant because their confidence intervals (CIs) did not include 1, which is the no-effect value for ratios. Not surprisingly, the index that included smoking as well as diet predicted risk better than the indexes involving only dietary factors (Figure 1).

The authors noted that all the dietary indexes had "poor predictive performance for 10-year mortality risk when used in isolation but display good predictive ability in combination with other non-invasive common risk factors." They also noted that the strength of association varied across the countries, that the Mediterranean Index had the strongest association in Spain, and that the Nordic Index had the strongest association in the Netherlands. The authors suggest that this reflects the different cuisines across the countries.

Mortality in Relation to 4 Indexes in the US Dietary Patterns Methods Project

In the other major analysis identified, Liese et al[10] summarized the results of the Dietary Patterns Methods Project,

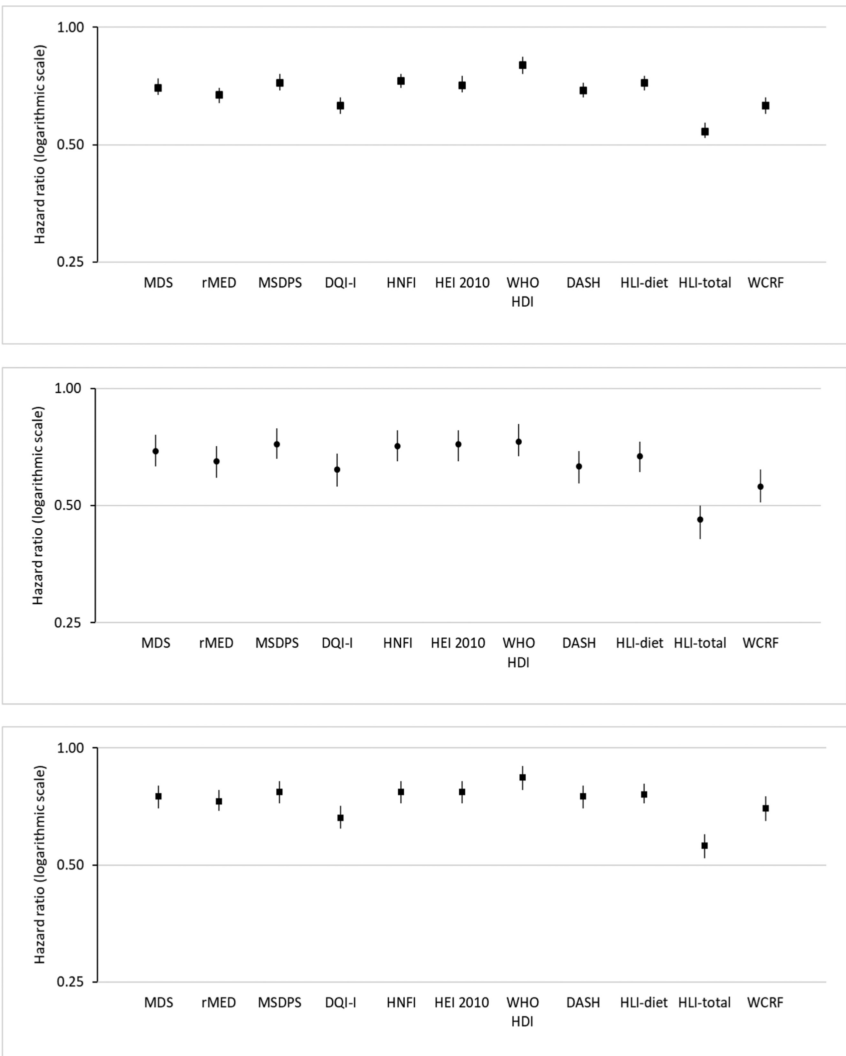

FIGURE 1. Hazard ratio for the highest (most desirable) quartile of intake versus the lowest quartile of intake for mortality (with 95% confidence interval) in the 10-year follow-up of the European EPIC study when baseline dietary intake is classified using 10 different diet quality indexes. Top, All-cause mortality. Middle, Cardiovascular mortality. Bottom, Cancer mortality (drawn from Lassale et al[9]; see Box 3 for a description of the indexes).

which had been "initiated in 2012 to strengthen research evidence on dietary indexes, dietary patterns, and health for upcoming revisions of the Dietary Guidelines for Americans, given that the lack of consistent methodology has impeded development of consistent and reliable conclusions."

They compared the association of 4 indexes (the HEI 2010, Alternative Healthy Eating Index [AHEI], Alt Med Diet, and DASH) with mortality in 3 different US cohort studies that had commenced in the 1990s. Two of these cohorts included men as well as women. Cohort size ranged from more than 63 000 participants to more than 420 000 participants. Diet was collected using food frequency questionnaires, and participants were divided into quintiles for each index. The authors note that each index was developed from a different set of guidelines but all focused on whole grains, vegetables, fruits, and plant-based protein. Some of them also considered polyunsaturated fat, monounsaturated fat, sodium, alcohol, low-fat dairy foods, refined grains, trans fats, or sugar-sweetened beverages.

With 1 exception (cancer mortality in one of the cohorts), all indexes were significantly associated with all-cause, cardiovascular, and cancer mortality in all cohorts over approximately 20 years of follow-up. In women, all-cause mortality, cardiovascular mortality, and cancer mortality were 11% to 28% lower in those in the highest ("most desirable") quintile compared with the lowest quintile of intake. Similar results were seen in men. Figure 2 shows the range of HRs found in the 5 groups from the 3 studies (Figure 2).

Given the correlation of 0.6 to 0.7 between the 4 indexes, the similarity in mortality results is not surprising. The strength of this project is the use of consistent analytical methods for multiple indexes across multiple cohort studies. Owing to the use of food frequency data, it is likely that some of the indexes were not calculated as originally intended owing to inadequate sodium intake assessment, as noted by Lasalle et al[9] in relation to the EPIC study mentioned previously.

Subsequently, the version of the HEI based on the 2015 US Dietary Guidelines [HEI-2015] was examined in the Multi-Ethnic Cohort, one of the cohorts included by Leise et al.[10] Like the AHEI-2010, a high (ie, "desirable") score for the HEI-2015 predicted lower mortality from all causes, cardiovascular disease, and cancer.[11]

Other Studies Comparing Indexes, and Mortality and Cancer

Several other articles that compared only 2 indexes were found.

Whalen et al[12] compared the association between a Mediterranean diet index and a Paleolithic diet index and all-cause mortality in 21 423 participants. A higher score indicated an intake more characteristic of the diet being described. The Paleolithic index base was based on 14 components; and the Mediterranean index, on 11 components. After adjustment, deaths were lower in the highest quintile versus the lowest quintile for the Mediterranean diet index (HR, 0.64) and also for the Paleolithic index (HR, 0.77). Results were similar for cancer and cardiovascular deaths, and all other deaths combined.

Shivappa et al[13] described a Dietary Inflammatory Index (DII) that combines a range of macronutrients and micronutrients with various nonnutrient naturally occurring chemicals (eg, caffeine, flavanols) and herbs and spices (such as onion, turmeric, saffron, thyme, rosemary, and green and black tea). The DII was compared with the AHEI-2010 in the UK Whitehall II study. Both were associated with all-cause mortality and risk of cardiovascular disease and cancer over 22 years of follow-up.[14] Over 19 years of follow-up in the Melbourne Collaborative Cohort study, "The hazard ratio for total mortality comparing the highest and lowest quintiles was 1.16 (95% CI, 1.08–1.24) for DII; and 0.86 (95% CI, 0.80–0.93) comparing the highest and lowest three categories of MDS [Mediterranean Diet Score]." The authors also concluded that there was no

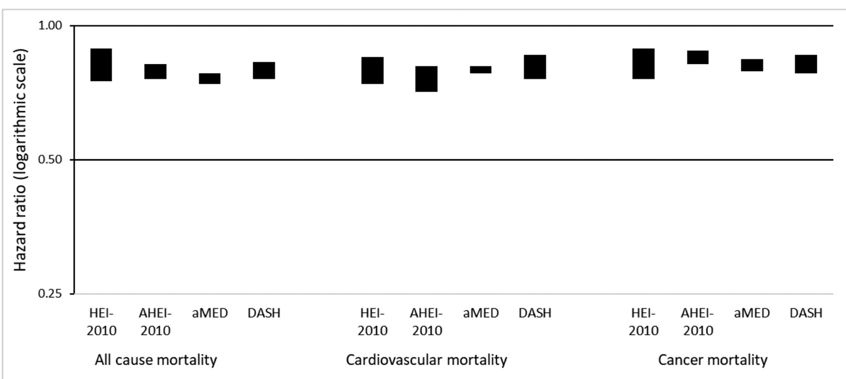

FIGURE 2. Range of hazard ratios for the highest (most desirable) quintile of intake versus the lowest quartile of intake for mortality in 5 different population groups from 3 cohort studies assessed in the Dietary Patterns Methods Project when baseline dietary intake is classified using 4 different diet quality indexes. Note that the 95% confidence intervals are not shown (drawn from Leise et al[10]; see Box 3 for a description of the indexes).

evidence that the DII was more strongly associated with mortality than the Mediterranean Diet Score.[15] It seems unlikely that the food frequency questionnaires used in these studies collected any information on the herbs and spices beyond tea, onion, and, possibly, garlic, and therefore it can be questioned whether the calculated DII was a good representation of the intended index or not.

> *"Not unexpectedly, the definition of diet quality depends on the attributes selected by the investigator."*[1]

Which Direction Does the Index Go in?

When reading the results of epidemiologic analyses, it is important to check which group is the referent and has a relative risk/hazard ratio of 1.0 by definition. It might not be immediately obvious that the results given by Hodge et al[15] previously compare an index in which the highest value would be regarded as undesirable (the DII) with an index in which the highest value would be regarded as desirable (Mediterranean diet) according to the philosophy of each index. Therefore, although the reported HRs of 1.16 and 0.86, respectively, are on opposite sides of 1 (the no-effect value), they both show that the most desirable intake, according to the philosophy of each index, is associated with lower mortality. This can make the literature confusing to read.

For exposures such as smoking, the unexposed are easy to identify—they are the nonsmokers—but this is not so clear-cut with dietary studies. When looking at individual foods, those who consume higher amounts are often compared with those who consume lower amounts. For example, in Table 1, greater consumption of coffee was associated with lower mortality such that 2 additional cups per day was associated with an HR of 0.78 or a 22% lower mortality, in this Spanish cohort study.[16] This poses a dilemma when analyzing the data: should those with the highest coffee consumption be classed as the "unexposed" because they have the lowest risk, or is it more intuitive to class the low consumers as the "unexposed"? In the nutritional epidemiology field, there is no consistency in expression, which does not make it easy for readers to compare articles (Table 1).

The concept of "exposed" versus "unexposed" becomes somewhat meaningless if increasing scores on an index sometimes indicate increasing adherence to recommendations and sometimes indicate decreasing adherence, and this creates a challenge for readers of the literature about dietary quality indexes. The OfCom family has an inverted scale, so that a low score indicates a more desirable profile and a high score indicates a less desirable profile. The articles about the NOVA index typically examine whether consumption of increasing amounts of ULP foods is associated with risk of adverse outcomes; that is, a high score indicates a less desirable diet, which is the opposite direction to the indexes found in Figures 1 and 2 in which a high score indicates a more desirable diet. Consequently, if a desirable diet according to either or both of the OfCom-type or NOVA indexes reduces risk, then the relative risk would be higher than 1.0 when the highest intake group is compared with the lowest intake group. In other words, the result would be inverted compared with the results shown in Figures 1 and 2, although the interpretation is the same—a more desirable diet (according to the philosophy of each index) is associated with a lower risk. However, it is possible to convert the reported values so that all results in a comparison go in the same direction.

Table 1 shows that, in the Spanish cohort study, an increment of 1 serving per day of ULP food was associated with a higher death rate of 18%.[17] This can be inverted to calculate the effect of consuming 1 less serving of ULP per day (1/1.18 = 0.85), and this makes the result easier to compare with other the results. In other words, consuming an additional 2 cups of coffee per day had a slightly

TABLE 1 Two Dietary Associations With All-Cause Mortality in the Seguimiento Universidad de Navarra Study, Illustrating the Inversion of the Hazard Ratio for Consumption of Ultraprocessed Food to Allow Easier Comparison With Another Risk Factor

Food/Diet Descriptor	Hazard Ratio	95% CI
Coffee, per 2 cups/d increment	0.78	0.66–0.93
Ultraprocessed[a] food, per 1-serving/d increment	1.18	1.05–1.33
Ultraprocessed food, as above, inverted to describe the effect of consuming 1 less serving per day	0.85	0.75–0.95

Abbreviation: CI, confidence interval.
Adapted from Navarro et al[16] and Rico-Campà et al.[17]
[a]As defined in the NOVA scheme.

greater effect on reducing all-cause mortality than did consuming 1 less serving of ULP food per day. In the case of Table 1, it is simple to do the conversion, but when reading the literature, the comparison might not always be so obvious or for the reader to know when it should be done.

Therefore, to aid the reader in the descriptions hereinafter, the results reported in the literature for the OfCom family models and NOVA have been inverted so that they show the effect of the greater intake of desirable food compared with less desirable food intake for each index. This direction was chosen because most of the results being discussed were done this way by the original authors of articles. This allows results for the OfCom family and NOVA indexes to be more easily compared with the results shown in Figures 1 and 2 for other indexes.

Cardiovascular Disease Incidence in the NutriNet-Santé Study

The NutriNet-Santé study is a cohort study of French adults recruited from 2009 onward via the web, and much of the information and follow-up, including the collection of 24-hour recall information about food and beverage intake, are done electronically. At least three 24-hour dietary recalls were completed during the first 2 years of follow-up by 96 716 participants. Depending on the goal of the analysis, different participants are excluded; for example, in a study of incident cardiovascular disease, those participants who already had cardiovascular disease at baseline must be excluded. In addition, the length of follow-up varies across the articles, which means that the results cannot be directly compared in a numerical sense.

This seems to be the only study that has examined the NOVA index and any of the OfCom family of indexes: specifically the modified version of the Food Standards Agency Nutrient Profiling System (FSAm-NPS) used to calculate the French front-of-pack labeling NutriScore value. However, the results are reported in different articles that use slightly different methods.

Srour et al[18] examined the incidence of cardiovascular disease over 5.2 years of follow-up and found that it was lower in those with the lowest quartile (most desirable) of ULP food intake compared with those with the highest quartile (HR, 0.81; 95% CI, 0.69–0.96).[1] Over a shorter follow-up and in 76 647 participants who were free of cardiovascular and cancer disease at baseline, Adriouch et al[19] found a lower incidence of cardiovascular disease (HR, 0.71; 95% CI, 0.43–0.79)[2] and coronary heart disease in those in the lowest (most desirable) quartile of the FSAm-NPS index compared with those in the highest quartile. The incidence of stroke did not vary according to food intake. In late 2019, Trébuchet et al[20] described the relationship with cardiovascular disease when the same baseline intakes were classified using 3 other diet quality indexes, and again, the most desirable level of intake according to the philosophy of each index was associated with lower disease incidence for 2 of the 3 indexes. Figure 3 shows the results for the 5 different indexes[18–20] after inverting the NOVA and OfCom-style indexes. There are some important differences between these 3 sets of analyses, such as the extent of dietary information required at baseline, definition of the end point conditions, and the duration of follow-up, which introduces some noncomparability between the articles, but it would be difficult to conclude that one of the indexes is superior to the others from these analyses (Figure 3).

Other Studies of the OfCom Family and NOVA

Several articles examine only 1 of the 2 indexes. Schnabel et al[21] report the association with all-cause mortality for an increase in 10 percentage points of ULP food consumption in 44 551 participants older than 45 years in the NutriNet-Santé study. The mean (SD) intake of ULP food by gram weight in the population was 14.4% (7.6%). After inverting to allow comparison with other articles described in this review, the HR for mortality was 12% (HR, 0.88; 95% CI, 0.79–0.96[3]) lower per 10–percentage point decrease in ULP in the diet. The HR was not reported for quartiles or per serving like the other studies, but the analysis shows that a more desirable intake is associated with lower mortality. Over 5.4 years of follow-up in 22 821 participants, those in the highest quartile of intake of ULP had higher incidence of all cancers and colorectal cancers (HR, 0.81; 95% CI, 0.71–0.93 [for both][4]) but not breast cancer. However, when analyzed per 10–percentage point difference, the association was significant for breast cancer but not for colorectal cancer.[22] There does not seem to be a parallel article examining the OfCom model for mortality or cancer outcomes from this study.

The same research team examined one of the OfCom family (FSAm-NPS) and range of cancer- and metabolic disease–related outcomes using data from the Supplémentation en Vitamines et Minéraux Antioxydants (SU.VI.MAX), the follow-up of participants in a French randomized, double-blind, placebo-controlled trial with 12 741 participants. The trial tested the effect of a range of micronutrients delivered at nutritional doses on the prevention of cancer, ischemic heart disease, and mortality between 1994 and 2002. At the end of the trial period, participants could volunteer to be part of an ongoing observational cohort study, and

[1]Inverted from the reported result for the highest versus lowest quartile: HR, 1.23 (95% CI, 1.04–1.45).

[2]Inverted from the reported result for the highest versus lowest quartile: HR, 1.4 (95% CI, 1.12–2.32).

[3]Inverted from the reported result for a 10–percentage point increase: HR, 1.14 (95% CI, 1.04–1.27).

[4]Inverted from the reported result for the highest versus lowest quartile: HR, 1.23 (95% CI, 1.08–1.40).

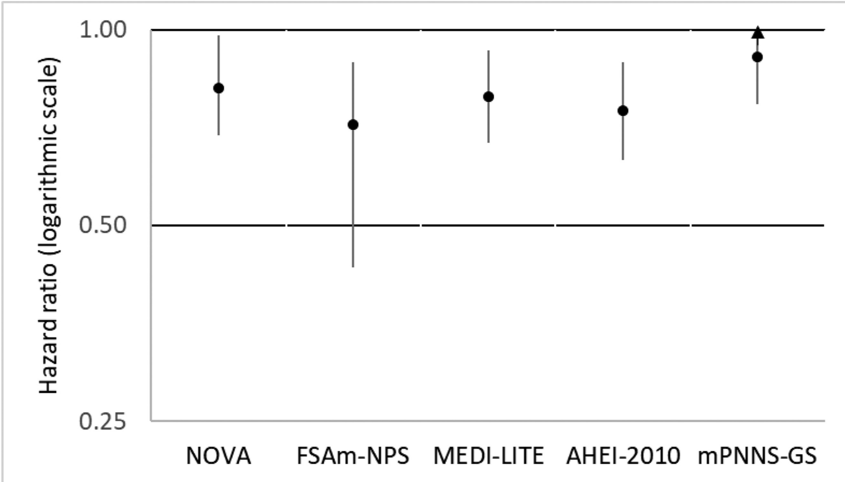

FIGURE 3. Hazard ratio (and 95% confidence interval) for the most desirable quartile of intake versus the least desirable quartile of intake for incident cardiovascular disease reported from the NutriNet-Santé study when baseline intake is classified using 5 different indexes. Note that results reported for the NOVA[18] and FSAm-NPS[19] indexes have been inverted to allow easy comparison with the remaining indexes[20] and with the other figures in this review (see Box 3 for a description of the indexes).

8111 ongoing participants completed at least three 24-hour records during the first 2 years of follow-up. Analyses of the relationship between the French adaptation of the OfCom model and outcomes in the SU.VI.MAX cohort were conducted as part of the validation work when developing their front-of-pack labeling system. Over 12 years of follow-up, those in the most desirable quintile of intake by the FSAm-NPS model had a 25% lower (HR, 0.75; 95% CI, 0.55–1.0)[5] overall cancer incidence.[23] In addition, the odds of developing metabolic syndrome and elevated blood pressure was lower with a more desirable diet according to the index, but there was no association with waist circumference, fasting glucose concentration, or blood lipids.[24,25] The odds of gaining weight were less in men with the more desirable diet but not in women.

The dietary data from the EPIC study used by Lassale et al[9] (see Figure 1) have also been classified using the FSAm-NPS index and linked with cancer outcomes. Those in the most desirable quintile of intake had a 7% lower incidence compared with those in the least desirable quintile (HR, 0.93; 95% CI, 0.91–0.97[6]), and there were specific associations for cancers of the colon-rectum, upper aerodigestive tract and stomach, lung for men, and liver and postmenopausal breast for women.[26] EPIC-Norfolk is the British subcomponent of the EPIC study. Food intakes from the 7-day diary completed by this group were classified using an index derived from the original OfCom algorithm. After 16.5 years of follow-up, those in the most desirable quintile of intake had a 10% lower all-cause mortality rate (HR, 0.9; 95% CI, 0.83–1.0)[7] than those in the least desirable quintile of intake, although there was no association with cardiovascular incidence or mortality.[27] The NOVA index does not seem to have been examined with the SU.VI.MAX or EPIC data sets to date.

The Seguimiento Universidad de Navarra study started recruitment of Spanish university graduates in 1999. Participants are contacted every 2 years to complete questionnaires. A 136-item semiquantitative food frequency questionnaire based on the Willett questionnaire was administered. There were 34 items on the list that were classified as ULP using the NOVA definition. The frequency of consumption of these 34 foods was summed, and participants were divided into quartiles. Among 19 899 participants with at least 2 years of follow-up, there was an inverse association with all-cause mortality, as shown in Table 1. Lower consumption of ULP foods was also related to lower incidence of hypertension and overweight in this cohort.[28,29]

The NOVA classification was also associated with mortality but not cardiovascular disease in the National Health and Nutrition Examination Survey follow-up study.[30] Two other studies have found that changes in anthropometry of incidence of obesity were associated with higher intake of ULP foods in adults.[31,32]

Not All Items in a Group Have the Same Association

The relative risk found for a composite group does not necessarily apply to all items in the group. Groupings that are too large are likely to include extraneous items. This is 1 form of measurement bias, and it reduces the relative risk

[5] Inverted from the reported result for the highest versus lowest quintile: HR, 1.34; 95% CI, 1–1.81.

[6] Inverted from the reported result for the highest versus lowest quintile: HR, 1.07; 95% CI, 1.03–1.1.

[7] Inverted from the reported result for the highest versus lowest quintile: HR, 1.11; 95% CI, 1–1.2.

toward 1 if it occurs equally in all participants. In fact, examining the components in a composite group separately is a common way of trying to identify the active items. Items that are truly associated will have a higher relative risk than the group average, whereas no association is observed for extraneous items. Without knowing what the relevant factor is, it is difficult generalize the results beyond the specific trial. For example, if 1 species of nut has a metabolic effect, then this cannot be generalized to other nut species or other foods with certainty unless the active component is known and used as the criterion for generalization.

For example, Fiolet et al[22] found that a higher intake of ULP foods according to the NOVA index was associated with higher cancer incidence in the NutriNet-Santé study. Chazelas et al subsequently examined three types of beverages consumed in this cohort for their association with incident cancer.[33] Table 2 shows how these 3 beverages are classified by NOVA and the OfCom type of model and that the association for each separate beverage does not follow either classification scheme. If this is confirmed by other studies, then it suggests that both indexes should be refined with respect to these foods (Table 2).

Some foods in a group might be infrequently eaten, and so their risk cannot be properly assessed, and they are often considered to be part of a larger group of more frequently eaten similar types. For example, if a questionnaire might ask about consumption of cheeses, then any relative risk with an outcome will be driven by the consumption of the items in the group eaten most frequently or in the largest amounts. Whether infrequently consumed gourmet cheeses really have the same association as the most consumed cheese, which drives the association at the group level, cannot be determined from a group-level question. Data collection and analysis need greater granularity to examine the association for individual foods, as illustrated in Table 2. There are 2 reasons why this is difficult for infrequently eaten foods. First, there are many more foods that can be eaten than are listed separately on food frequency questionnaires, and second, the number of participants needed to assess the risk properly for infrequently eaten items would make a study expensive and complex to conduct.

CONCLUSION

This review compared the predictive validity of dietary quality indexes for selected outcomes and focused on 2 types of index with divergent origins, which are currently topical. This led to the exclusion of many articles that examined only 1 index or different outcomes and all concurrent validity and other cross-sectional analyses. It has highlighted the difficulty in trying to compare the performance of different possible dietary quality indexes directly using the predictive validity of important health outcomes. Suitable data sets are clearly available, as evidenced by the studies found in the literature review; however, researchers typically examine 1 question per article and use different methods between articles describing analyses from the same study, and this reduces the comparability of the results across articles. Trending interests over time are evident, and researchers write articles about the latest index without necessarily going back and reexamining previous models and indexes with their updated data or longer follow-ups. Consequently, a sudden flurry of articles using a new index may reflect new opportunities to analyze available data in an academic's "publish or perish" life rather than a real shift in scientific opinion. It is worth remembering that authors can only analyze the data that have been collected and absence of results relating to outcomes such as mental health from longer running studies reflects the interests of the era in which the study commenced.

All dietary quality indexes are reductionist, irrespective of whether they are based on cuisine styles, nutrients, foods, or the presence of additives.

TABLE 2 Association Between Individual Foods and Cancer in the NutriNet-Santé Study (Chazelas et al[33]) and Their Classification by 2 Indexes

Beverage	FSAm-NPS Classification	NOVA Classification	All Cancer Incidence, HR (95% CI)
Sugar-sweetened beverages[a]	Many/most not eligible	Ultraprocessed	1.19 (1.08–1.32)
Artificially sweetened beverages	Eligible	Ultraprocessed	1.02 (0.94–1.10)
100% fruit juice	Eligible	Not ultraprocessed	1.12 (1.03–1.23)

Abbreviations: CI, confidence interval; FSAm-NPS, modified version of the Food Standards Agency Nutrient Profiling System; HR, hazard ratio.
[a]Beverages with more than 5% simple carbohydrate including soft drink, fruit drinks, sweetened milk drinks, and sports drinks.

All indexes are reductionist in that they try to summarize a mass of advice or analysis into a few factors to classify dietary intake, irrespective of whether the factors are intake of marker of cuisine styles, nutrients, or the presence of additives in food. A wide range of indexes have been developed that summarize dietary intakes into groups that reflect degree of adherence to different types of dietary advice. Some of these are based on dietary guidelines, others are based on specific dietary components that have been linked to disease (notably the DASH diet for hypertension), and some are based on scores using specific components or preparation methods. It should also be noted that not all indexes have a single definition. For example, Noah and Truswell[34] found that the Mediterranean diet varied by country and period in history and stated that researchers should describe it more fully.

Across several cohort studies conducted in the United States and Europe, all the indexes included in this review predicted an increased rate of death and/or incidence of key diseases in those with the "least desirable" diet compared with those with the "most desirable" diet according to the philosophy of each index. The lower risk associated with a desirable diet would generally be described as small.[35] This is not to suggest that a 20% reduction in disease would not be worthwhile, but it relates to the limitations in drawing causal conclusions from observational studies alone. A small association can be due to residual confounding that is still present in the analysis. Alternatively, it might reflect a much larger effect of diet that has been hidden by measurement error relating to varying degrees of difficulty in describing the intake of some foods compared with others. Another type of measurement error occurs when items that confer risk are combined with items that have no risk. Consequently, a risk observed for a grouping should not be assumed to apply to all components of the grouping.

This review did not seek to replicate the work of others by doing a full systematic review of the association between any particular index and outcomes. Rather, the focus was on examining the comparability of diet quality indexes by restricting the inclusion criteria to articles that had analyzed more than 1 index. The range of outcomes was also restricted. This allows results for different indexes to be compared directly. In recognition of current interest, the association between the OfCom-type and NOVA indexes and the same outcomes were also included regardless of whether they were compared with other indexes within the same article. Only indirect comparisons were possible for these 2 indexes.

The approach taken led to the exclusion of many articles that examined only 1 index. For example, intakes from the SU.VI.MAX study have been classified using a Mediterranean diet index or the DII[36,37] and examined in relation to the incidence of metabolic syndrome. Mortality in the Seguimiento Universidad de Navarra study (see Table 1) is also associated with the DII.[38] Furthermore, the search in PubMed was limited by using the term *diet quality index*. The term *dietary patterns* could have been added to the search because work in that area often includes examining the associations with specific indexes as well as nutrients and other food components.[39] Adding the term *dietary pattern* would have retrieved an additional set of studies, which would have increased the length of this review. Hence, data from each cohort study referred to previously support the predictive power of a number of indexes in addition to those specifically described in this article.

There is a substantial agreement among classification systems about foods to encourage in the population's diet and foods to discourage. Therefore, it is not surprising whether these systems yield similar relative risks when they are used to examine the data from a particular cohort study. Given the varying difficulty in describing the frequency and/or amount of foods that are consumed, all classification indexes would be affected by measurement errors, and this will make it more difficult to detect an effect. However, it is difficult to determine the extent to which each classification is affected by these errors, and so it would not be possible to draw strong conclusions about which classification is "best" based on the magnitude of the relative risk, especially when the possibility of residual confounding from other factors such as smoking or physical activity, due to their imperfect measurement, is taken into account.

Leise et al's[10] summary of their own study is also a good summary of the wider situation:

> This project also provides a partial answer to the question as to whether there is one overarching approach to healthful eating associated with reduced mortality of whether there are multiple ways that a healthy, high-quality diet can be achieved. Our findings suggest that all 4 indexes are capturing the essential and common components (ie, foods and nutrients) of a healthy diet, although there are likely multiple ways to prepare and consume foods that would include the aforementioned common and essential components. However, the nature of FFQ data and the aggregation of items into food groups do not allow us to reach conclusions that would distinguish between food and meal preparation methods.

As there are multiple ways of describing a good dietary intake, it becomes important to take other factors into account when deciding which to promote. Firstly, broad-brush large food groupings capture a range of foods, and it is important to avoid restrictive recommendations that would adversely impact on less well-off sectors of society and thus increase inequalities in society, especially when there are studies with contradictory results about certain widely eaten foods. Second, recommendations that are widely divergent from previous dietary advice need to be scrutinized carefully, and thought should be given to whether unnecessary confusion or loss of trust in public advice might result or whether, in fact, there is good scientific reason to modify preceding advice. Similarly, classification schemes that undermine current public programs would also need scrutiny before being adopted.

Although it may be possible to say that a healthy diet decreases mortality, and various measures of diet quality show similar associations with mortality and related end points, it is not possible to determine which index is "best." Therefore, the choice of index will depend on other contextual factors, and these factors could vary among government departments owing to the different purposes for which an index is used or the constraints within which the department or agency works. Description of dietary intake for public education differs from description of individual qualities of food in legislation. It is possible that these 2 purposes might sometimes have conflicting requirements, which would lead to the use of different indexes by different government agencies.

All the diet quality indexes reviewed were associated with 1 or more important health outcomes.

At this point, it is not possible to say which of the diet quality indexes is better, as all the indexes examined previously capture some common elements while also having unique features. The choice of index will depend on other contextual factors and will vary because of the different purposes for which an index is used or the constraints within which it operates. Consequently, pragmatic reasons such as ease of implementation, clarity of definitions, equity, and other factors become important when choosing an index for a specific context.

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