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Development and Validation of the Nutrient-Rich Foods Index: A Tool to Measure Nutritional Quality of Foods¹⁻³

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Abstract

Ranking and/or classifying foods based on their nutrient composition is known as nutrient profiling. Nutrition quality indices need to be tested and validated against quality of the total diet. A family of nutrient-rich foods (NRF) indices were validated against the Healthy Eating Index (HEI), an accepted measure of diet quality. All foods consumed by participants in NHANES 1999–2002 studies were scored using NRF_n.3 (where $n = 6-15$) indices based on unweighted sums, means, and ratios of percent daily values (DV) for nutrients to encourage (n) and for nutrients to limit (LIM) (3). Individual food scores were calculated based on 100 kcal (418 kJ) and FDA serving sizes [reference amounts customarily consumed (RACC)]. Energy-weighted food-based scores per person were then regressed against HEI, adjusting for gender, age, and ethnicity. The measure of index performance was the percentage of variation in HEI (R^2) explained by each NRF score. NRF indices based on both nutrients to encourage and LIM performed better than indices based on LIM only. Maximum variance in HEI was explained using 6 or 9 nutrients to encourage; index performance actually declined with the inclusion of additional vitamins and minerals. NRF indices based on 100 kcal (418 kJ) performed similarly to indices based on RACC. Algorithms based on sums or means of nutrient DV performed better than ratio-based scores. The NRF9.3 index, based on 9 nutrients to encourage and 3 LIM per RACC and per 100 kcal, explained the highest percentage of variation from HEI and could be readily expected to rank foods based on nutrient density. J. Nutr. 139: 1–6, 2009.

Introduction

Diet quality indices assess the overall nutritional quality of the total diet; in contrast, food nutritional quality indices are intended to measure nutrient quality of individual foods (1–6). The science of ranking and/or classifying foods based on their nutrient composition has become known as nutrient profiling (7,8). Much of the impetus for nutrient profiling has come from the European Union, where nutrition and health claims will be introduced in 2012 (9). Whereas foods with acceptable profiles will be allowed such claims, those with unacceptable profiles will be disqualified. Specific criteria to identify acceptable/unacceptable profiles are still being debated (10,11). In the US, nutrition and health claims have been permitted for some time (12). However, foods that exceed predefined levels of total fat, saturated fat, cholesterol, or sodium are disqualified from carrying a health claim (13,14). Additionally, to be considered “healthy” by the FDA, foods must not only meet the criteria

above but must also provide $\geq 10\%$ of the daily value (DV)⁷ of protein, fiber, vitamin A, vitamin C, calcium, or iron.

A number of existing nutrient profile models or nutrition quality indices have recently been developed by academic researchers, regulatory bodies, and the food industry (5,15–22). Some of those indices are based on only nutrients to encourage, others on only nutrients to limit (LIM), or on some combination of both. Rankings generated by existing models have been compared with each other and correlated with expert and/or consumer opinion (10,23–26). In rare cases, food rankings obtained from such models have been validated against independently obtained measures of a healthy diet (24).

If nutrient profiling is to remain a science, it needs to follow science-driven rules. First, indices of food nutritional quality need to be based on the prevailing scientific knowledge about diets and health. Such indices should take into account nutrients known to be beneficial to health as well as LIM based on scientific consensus or authoritative reports. Creating a composite nutritional quality index for individual foods raises a

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⁷ Abbreviations used: DV, daily value; HEI, Healthy Eating Index; LIM, nutrients to limit; NRF, nutrient-rich foods; NRF_n.3, nutrient-rich foods index, where n equals a range of nutrients to encourage and 3 equals the number of nutrients to limit; RACC, reference amount customarily consumed.

number of methodological issues (9), including the selection of index nutrients, the choice of reference DV, and the choice of reference amounts: 100 g, 100 kcal,⁸ or serving size (4). Most important, all indices need to be validated against an accepted independent measure of diet quality. The Healthy Eating Index (HEI), recently updated by the USDA (27), is a measure of diet quality based on compliance with the 2005 Dietary Guidelines for Americans and MyPyramid. HEI is based on a 100-point scale and awards points for adequate (or moderate) consumption of various food and nutrient components. The validity of HEI as a diet quality measure has been established following extensive analyses (28,29). The objective of this study was to develop food nutritional quality indices for individual foods, test their performance, and correlate food scores with independent measures of a healthy diet. Percent of variation in HEI explained (R^2) was the key criterion of index performance. The indices that best predicted variation in HEI were then further characterized by examining scores on a food group basis.

Methods

The algorithms evaluated. The nutrients in the algorithms evaluated were based on multiple criteria. The 2005 Dietary Guidelines for Americans have identified additional nutrients of concern that are underrepresented in the typical U.S. diet (30). In adults, these are fiber, vitamins A, C, and E, calcium, potassium, and magnesium. For children and adolescents, nutrients of concern are fiber, vitamin E, calcium, potassium, and magnesium. For specific population groups (30), they include vitamin B-12, iron, folic acid, and vitamin D. The FDA defines "healthy" foods as including 1 of 6 nutrients: protein, fiber, vitamins A and C, calcium, or iron.

Based on recent work (31,32), a number of nutrient-rich foods (NRF) indices were selected for testing and validation against HEI scores. The composite indices, described as NRF n .3, were based on n nutrients to encourage and on 3 LIM (Table 1). Whereas the number of nutrients to encourage was variable ($n = 6-15$), the 3 LIM were always the same: saturated fat, added sugar, and sodium. We also evaluated the impact of total sugars replacing added sugars.

Previous efforts on nutrient profiling show that fats, sugars, and sodium are the commonly recommended LIM (4,17). Past systems were based on fat, saturated fat, cholesterol, and sodium (33); total and saturated fats, *trans* fats, sugars, and sodium (10,11); energy, saturated fat, total sugar, and sodium (7,20,34); or saturated fats, added sugars, and sodium (35). Our previous work using factor analysis indicated that energy, total fats, and saturated fats were highly correlated with each other, as were total and added sugars. Sugars were not linked to dietary energy and sodium was independent of sugars and energy/fat. Therefore, including both energy and fat content was superfluous, as was the inclusion of both total and saturated fat. In this study, we chose to define our LIM subscore as saturated fat, added sugar, and sodium (4,17,35). Including *trans* fat was not an option, because NHANES food and dietary data does not as yet contain *trans* fat values; given the limitations on *trans* fat data, we could not validate NRF algorithms with alternative HEI (36).

Indices were calculated as: 1) the sum of nutrients to encourage minus the sum of LIM; 2) the mean of nutrients to encourage minus the mean of LIM; and 3) the ratio of nutrients to encourage:LIM. In all indices, nutrient amounts were calculated as a percent of reference DV. Reference DV for a number of vitamins and minerals are summarized elsewhere (37). For LIM, reference values were 20 g of saturated fat, 50 g of added sugar (125 g for total sugars), and 2400 mg of sodium in a 2000-kcal/d diet, as based on a variety of authoritative sources (37-39).

Validation approach. Data from NHANES 1999-2002 were used as the principal data source for testing and validating the NRF algorithms.

NHANES, an ongoing data collection initiative conducted by the National Center for Health Statistics of the CDC, is designed to collect information about the health and diet of a cross-sectional, nationally representative sample of the noninstitutionalized civilian population in the US. Additional information pertaining to the NHANES 1999-2002 survey design, survey methodology, and public use of the data has been posted on the NHANES Web site (40).

The types and amounts of foods and beverages consumed during the previous 24-h period were collected in person using the multi-pass, 24-h dietary interview method. For the 1999-2000 NHANES, the USDA 1994-1998 Survey Nutrient Database was used to code and report intake of energy and nutrients. The USDA Food and Nutrient Database for Dietary Studies version 1.0 (41) was used for processing the dietary interview data for 2001-2002. We used the database released by the USDA to determine vitamin A in μ retinol activity equivalents and vitamin E in mg, alpha-tocopherol for NHANES 1999-2002 (42). Added sugars data were from the MyPyramid Equivalents Database (43).

We combined data from NHANES 1999-2000 and 2001-2002 and used data from participants ≥ 4 y with dietary interviews deemed "reliable and met minimum criteria" (total $n = 15,537$); pregnant and/or lactating women were excluded. First, we calculated HEI scores using programs recently released by the USDA (28). The revised HEI, a 12-component, 100-point score, is a composite measure of overall diet quality based on nutrients and food groups. The food components include total fruit, whole fruit, total vegetables, dark green and orange vegetables and legumes, total grains, whole grains, milk, meat and beans, and oils. The nutrient components include saturated fat, sodium, and energy from solid fat, alcohol, and added sugars. Second, we calculated a composite measure of food nutritional quality for each participant based on NRF indices. All foods consumed by each respondent were first scored using the NRF n .3 family of algorithms (Table 1), with percent reference DV capped at 100% DV to avoid overvaluing foods that provide very large amounts of a single nutrient. For each respondent, NRF scores were summed and then divided by the number of reference amounts customarily consumed (RACC) servings or 100-kcal units consumed, thus providing a "weighted average" daily food quality score. In this way, we obtained both daily HEI scores and daily NRF n .3 values for each respondent.

Statistical analysis. Regression analyses were conducted using HEI as the dependent variable and the weighted energy average food quality score provided by each NRF n .3 algorithm as the independent variable. All models were adjusted for gender, ethnicity, and age. All analyses were weighted using the NHANES examination 4-y sample weights and adjusted for the complex sample design of NHANES. Analyses were performed with the statistical packages SAS and SUDAAN version 9.0 (RTI). We used the percentage of the variation explained (R^2) and the P -value of models to assess validation of various algorithms. P -values < 0.001 were considered significant.

Past approaches used to validate various dietary assessment tools, typically FFQ, were based on simple correlations (44-46). Significant correlations of ≥ 0.5 , an R^2 of 0.25, were deemed indicative of a reasonable relationship between FFQ estimates of dietary intake and actual intake (44). The present goal was to evaluate the percent of variance in HEI accounted for to help select the optimal NRF algorithm(s).

Characteristics of NRF9.3 scores for foods. NRF algorithms with the best predictive relationship with HEI were then used to score all foods. We chose to use the algorithm using sums, because this is the simplest calculation and weights all nutrients equally (algorithm of means is actually a form of weighting). Foods consumed within NHANES 1999-2002 were scored via NRF9.3 per RACC ($n = 5096$) and per 100 kcal ($n = 5085$, because zero energy foods cannot be scored) and grouped into food groups primarily by the first digit of the USDA coding scheme. However, all mixtures or mixed dishes (e.g. soups, meat and vegetables, etc.) were put into a separate category. To avoid double-counting beans as both a vegetable and a protein source, beans were grouped with vegetables, as previously done by USDA in describing MyPyramid food patterns. Sweets, beverages, fats, and oils (foods

