RESEARCH
Original Research

The Grocery Purchase Quality Index-2016 Performs Similarly to the Healthy Eating Index-2015 in a National Survey of Household Food Purchases

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ABSTRACT

Background Household food purchases are potential indicators of the quality of the home food environment, and grocery purchase behavior is a main focus of US Department of Agriculture (USDA) nutrition education programs; therefore, objective measures of grocery purchases are needed.

Objective The objective of the study was to evaluate the Grocery Purchase Quality Index-2016 (GPQI-2016) as a tool for assessing grocery food purchase quality by using the Healthy Eating Index-2015 (HEI-2015) as the reference standard.

Design In 2012, the USDA Economic Research Service conducted the National Household Food Acquisition and Purchase Survey. Members of participating households recorded all foods acquired for a week. Foods purchased at stores were mapped to the 29 food categories used in USDA Food Plans, expenditure shares were estimated, and GPQI-2016 scores were calculated. USDA food codes, provided in the survey database, were used to calculate the HEI-2015.

Participants/setting All households in the 48 coterminous states were eligible for the survey. The analytic sample size was 4,276 households.

Main outcome measures GPQI-2016 and HEI-2015 scores were compared.

Statistical analyses performed Correlation of scores was assessed using Spearman's correlation coefficient. Linear regression models with fixed effects were used to determine differences among various subgroups of households.

Results The correlation coefficient for the total GPQI-2016 score and the total HEI-2015 score was 0.70. For the component scores, the strongest correlations were for Total and Whole Fruit (0.89 to 0.90); the weakest were for Dairy (0.67), Refined Grains (0.66), and Sweets and Sodas/Added Sugars (0.65) (all, $P<0.01$). Both the GPQI-2016 and HEI-2015 were significantly different among subgroups in expected directions.

Conclusions Overall, the GPQI-2016, estimated from a national survey of households, performed similarly to the HEI-2015. The tool has potential for evaluating nutrition education programs and retail-oriented interventions when the nutrient content and gram weights of foods purchased are not available.
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HOUSEHOLD RETAIL FOOD PURCHASES ARE potentially significant indicators of the quality of the home food environment and perhaps even of diet quality.[1] Furthermore, grocery purchase behavior is a main focus of nutrition education programs, such as the Supplemental Nutrition Assistance Program (SNAP) Education Program and the Expanded Food and Nutrition Education Program,[2,3] therefore, objective measures of grocery purchases are needed. In addition, SNAP benefits can generally be used at food stores only,[4] so assessing the quality of grocery purchases could be used to assess the impact of SNAP.

However, tools that have been evaluated for the purpose of assessing the overall quality of grocery purchases are lacking. Use of typical diet quality measures, such as the Healthy Eating Index (HEI), for this purpose would require matching of products to US Department of Agriculture (USDA) food codes and converting them to their as-consumed form. This constitutes a significant barrier for those working with grocery store–provided data or receipt data, which typically do not include gram weights and nutrient information. The Grocery Purchase Quality Index-2016 (GPQI-2016) overcomes these barriers by using expenditure shares in the as-purchased form and requires classifying products into broad food groups only, rather than matching to specific food codes.[5] The main objective of this study was to evaluate the GPQI-2016 as a tool for assessing the quality of household

grocery food purchases by comparing it to the most recent version of the HEI, the HEI-2015.[6] Data for this purpose are available from USDA's National Household Food Acquisition and Purchase Survey (FoodAPS), which was co-sponsored by the Economic Research Service (ERS) and the Food and Nutrition Service.[7]

RESEARCH SNAPSHOT

Research Question: How does the Grocery Purchase Quality Index-2016 (GPQI-2016) compare to the Healthy Eating Index-2015 (HEI-2015) as a tool for assessing grocery food purchase quality?

Key Findings: Using the HEI-2015 as the reference standard, the authors assessed 1 week of foods purchased at stores by 4,276 households from the US Department of Agriculture National Food Acquisition and Purchase Survey, 2012. The estimated Spearman's correlation coefficient for the total GPQI-2016 score and total HEI-2015 score was 0.70; correlations for 10 component scores ranged from 0.65 to 0.90 (all, $P<0.01$). Both the GPQI-2016 and the HEI-2015 were significantly different among subgroups of the population in expected directions ($P<0.05$).

METHODS

FoodAPS

FoodAPS data were collected from April 2012 to January 2013.[7] All households in the 48 conterminous states were eligible to be selected into the sample. FoodAPS participants recorded all foods that were purchased or otherwise acquired by household members for 1 week, including foods that were bought at retail grocery stores or other retail outlets, at restaurants and other eating places, and acquired at other locations, such as schools and other people's homes. Household members recorded all food acquisitions in booklets, scanned barcodes on foods, and saved their receipts. The details on food items reported by households included food descriptors, scanned product codes (ie, universal product codes [UPC] for packaged goods and product look-up codes [PLU] for foods that are not packaged), and the amount of money paid (expenditure). This information was used to calculate the GPQI-2016 scores. Additional information needed to calculate the HEI-2015 was also provided, including the package size and its equivalent weight in grams and the USDA food code found in the Food and Nutrient Database for Dietary Studies and the Food Pattern Equivalents Database or in the National Nutrient Database for Standard Reference. These linkages to food codes and gram weights were made by ERS and contractor staff.[8] The aim was to provide food composition data for foods in their as-purchased form; however, when such data were not available, codes for foods in their as-consumed form were used without consideration of fat and water losses or gains. Dietary supplements are not included in the HEI-2015 or the GPQI-2016 and are not considered in this study.

Household characteristics provided included income, SNAP participation, geographic region of residence, and nutrition-related behaviors. Individual characteristics included race/ethnicity and education level. When the sampling weights provided in the dataset are used, the results of analyses are estimates for households in the 48 conterminous states and may be considered to be nationally representative (excluding Alaska and Hawaii). The public use dataset analyzed for this study was pre-existing and de-identified; therefore, review by an institutional review board was not required.

Exclusion Criteria

Because the GPQI-2016 assesses foods purchased at stores, the analytic sample included only foods that were identified in the dataset as having been acquired at "food stores"; those acquired at "eating places," such as restaurants or fast-food places, or "other" places, such as school, work, or from a friend or family, were excluded. Food stores included, for example, supermarkets, super stores, convenience stores, gas stations, and dollar stores. Applying this criterion reduced the sample size from 4,826 to 4,407 (ie, 419 households reported no acquisitions from a food store).

The authors excluded food items from the dataset that did not have the information needed to calculate the GPQI-2016 or the HEI-2015. For the GPQI-2016, a valid expenditure value is needed; and for the HEI-2015, both a USDA food code and a gram weight for the food are needed. (Imputed expenditures and gram weights were considered acceptable.[9]) If after applying these exclusion criteria for foods a household had no eligible food items, the household was excluded from the sample. Applying these food-item selection criteria reduced the analytic sample size further from 4,407 to 4,276 (ie, 131 households were excluded because of missing food-item data). The final analytic sample size was 4,276 households, 89% of the original sample.

Justification for the Reference Standard

The authors chose the HEI-2015 to be the reference standard for this study for two reasons. The first was the very practical reason that the FoodAPS database[10] facilitated the calculation of both the GPQI-2016 and the HEI-2015 by providing information on food expenditures needed for the GPQI-2016 and converting the amounts of foods purchased to gram weights and linking the foods to the Food and Nutrient Database for Dietary Studies or National Nutrient Database for Standard Reference needed for the HEI-2015. The second reason was because several types of validity of the HEI-2015 for assessing diet quality have been established.[11,12]

Relationship of the GPQI-2016 to the USDA Food Plans, Dietary Guidelines for Americans, and HEI-2015

The GPQI-2016 is based on the USDA Food Plans, which list types and amounts of foods to purchase and prepare at home to provide diets that meet the 2005 Dietary Guidelines for Americans (DGA) at four cost levels.[13,14] The Food Plans are derived from the USDA Food Patterns, which list types and amounts of foods to consume to meet the DGA.[15-17] When the Food Plans are created, the amounts of foods in the Food Patterns are converted from their as-consumed forms to their as-purchased forms. For example, the water is removed from cooked rice and 100 g of cooked rice becomes 32 g of uncooked rice.[18] Subsequently, the amounts of food to purchase are expressed as expenditure shares (ie, as the percentage of total food expenditures to be spent on each of 29 food groups). Thus, the USDA Food Plans are also a means of

putting the DGA into practice. The HEI is a measure of how well any group of foods complies with the DGA as operationalized by the USDA Food Patterns. (Specifically, the HEI-2015 is based on the Healthy US-style Food Pattern.[19]) It follows then that the USDA Food Plans should meet HEI standards because both are based on USDA Food Patterns. The correspondence of the USDA Food Plans and the HEI-2015 scoring standards is presented in Table 1 and illustrates how the amounts of food in each of the four Food Plans meet or exceed the standards used for scoring the respective food-based components of the HEI-2015.

Created Variables

The authors categorized each food acquired at a food store into the appropriate USDA Food Plan category. This process was informed by the 82 food groups created by ERS staff and provided in the dataset and by a list of Food and Nutrient Database for Dietary Studies food codes assigned to Food Plan food categories obtained from the USDA Center for Nutrition Policy and Promotion. The Food Plans assume that most mixed dishes are prepared at home from ingredients; therefore, the authors developed two rules for categorizing mixed foods: (1) foods having one main ingredient and a sauce were included in the category of the main ingredient; and (2) foods having more than one main ingredient (ie, protein food; vegetable; and/or pasta, rice, or bread) were categorized as "frozen/refrigerated entrees."

The following Food Plan categories do not contribute to any component of the GPQI-2016 because they do not directly correspond to an HEI-2015 component: table fats, oils, salad dressings; gravies, sauces, condiments, spices; coffee, tea; soups, ready-to-serve/condensed; soups, dry; and frozen/refrigerated entrees. Plain bottled water is also not included in the Food Plans or as part of any component of the GPQI; however, expenditures for these items are included in total food expenditures. Alcoholic beverages are not part of the Food Plans and are not included in the GPQI-2016 at all.

The authors created a GPQI-2016 score and an HEI-2015 score for each household, using the expenditure share for each food category to calculate the GPQI-2016 and using the food composition data and the gram-weight equivalents for each food purchased to calculate the HEI-2015. The details for calculating the scores are described elsewhere[5,6]; and SAS code for each is publically available.[20,21] Briefly, for both indexes, higher amounts of foods that comprise the adequacy components get higher scores, whereas, for the moderation components, higher amounts get lower scores.

Statistical Analysis

Expenditure shares for the food groups that comprise the GPQI-2016 components were estimated using the population-ratio method because this method estimates the usual (ie, long-term average) population mean score when only one observation period is available, which is the case in FoodAPS.[22,23] Medians and interquartile ranges (25th and 75th percentiles) were estimated for the GPQI-2016 and HEI-2015 total and component scores.

Convergent validity is assessed by determining how well two measures of constructs that theoretically should be related actually correlate.[24] The distribution of the total scores for both the GPQI-2016 and the HEI-2015 were normal; however, distributions for the component scores were not (Kolmogorov-Smirnov D-statistic, $P<0.01$) because of the truncation at the minimum and maximum values. Therefore, convergent validity was assessed by estimating the nonparametric Spearman's rank correlation coefficient for the components found in both indexes.[25] (The score for the Sugars and Sweets component of the GPQI-2016 was correlated with the Added Sugars component of the HEI-2015.) Because total scores were normally distributed, both Pearson's and Spearman's correlations were calculated.

Table 1. Healthy Eating Index-2015 scoring standards for the food-based components and amounts[a] of food listed in the US Department of Agriculture Food Plans[13,14]

		Food Plans			
Component	**HEI-2015[b] scoring standard**	**Thrifty**	**Low cost**	**Moderate cost**	**Liberal**
Adequacy	← *amount per 1,000 kcal* →				
Total vegetables, cups	≥1.1	1.4	1.3	1.5	1.4
Greens and beans, cups	≥0.2	0.4	0.4	0.5	0.5
Total fruits, cups	≥0.8	0.9	1.0	0.9	1.0
Whole fruits, cups	≥0.4	0.8	0.8	0.7	0.8
Whole grains, oz	≥1.5	1.7.	1.7	1.9	1.8
Dairy, cups	≥1.3	1.3	1.3	1.3	1.2
Total protein foods, oz	≥2.5	2.6	2.7	2.7	2.6
Seafood and plant proteins, oz	≥0.8	1.2	NA[c]	NA	NA
Moderation					
Refined grains, oz	≤1.8	1.7	1.7	1.6	1.4

[a]Amounts include adjustments for waste factors and are expressed here as the population weighted average of 15 sex-age groups per 1,000 kcal.
[b]HEI-2015=Healthy Eating Index-2015.
[c]NA=not available.

Known-group validity, also known as concurrent criterion validity, is the ability to distinguish between groups with previously known differences.[26] The known-group validity of the GPQI-2016 was assessed by evaluating its ability to detect expected differences among groups of households having various demographic characteristics and nutrition-related attitudes and behaviors; that is, by asking whether the GPQI-2016 behaves in the way it would be expected to behave, based on prior knowledge of differences in dietary intakes of population subgroups. Linear regression models with fixed effects were used to determine the differences in total GPQI-2016 and HEI-2015 scores among the various subgroups of households. The *t*-statistic indicated the significance of each difference (least-squared means) compared to a reference group. Sampling weights were applied in all statistical analyses, an α level of <0.05 was used for all, and all were performed using SAS, version 9.4.[27]

A Bland-Altman plot was constructed to visualize the agreement of the two scores.[28] First, the normality of the distribution of the differences between the two scores was tested and confirmed by the Kolmogorov-Smirnov D statistic ($P>0.15$). Because the maximum total scores of the two indexes differ, the GPQI-2016 was normalized to 100. For each participating household, the total GPQI-2016 score was plotted against the difference between the total HEI-2015 and GPQI-2016 scores. The estimated (ie, weighted) mean difference in the scores for the population and its standard error were calculated; and the percentage of data points that were between ± 2 standard deviations of the mean difference, that is, the limits of agreement, was calculated along with 95% CIs for the limits of agreement.

RESULTS

Characteristics of the weighted, analytic sample are presented in Table 2. They may be considered to be representative of the households in the 48 conterminous states.

The estimated proportion of food expenditures spent on various food groups differed from the expenditure shares found in the USDA Food Plans (Table 3). The disproportionately high expenditures for refined grains (15.1% vs 5.4%), sweets and sodas (16.1% vs 2.2%), and for foods not included as components of the GPQI-2016 (17.8% vs 3.8%) contributed to disproportionally low expenditures for other more nutrient-dense foods, such as fruits, vegetables, and whole grains.

The estimated medians for the GPQI-2016 and HEI-2015 scores were generally quite low, indicating plenty of room for improvement (Table 4). The test of convergent validity, the Spearman's correlations, showed reasonable agreement between the GPQI-2016 and the HEI-2015 (Table 4). The strength of the correlations varied by component. Some adequacy components had associations as strong as 0.86 to 0.90 (Total Vegetables, Total Fruit, and Whole Fruit). The correlation for Dairy was the lowest among the adequacy components (0.67), while the rest fell in the range of 0.70 to 0.79. The two moderation components that could be compared had lower correlations than any of the adequacy components, and the lowest correlation of any was 0.65 for Sweets and Sodas in the GPQI-2016 with Added Sugars in the HEI-2015. The Spearman's correlation between the total GPQI-2016 score and the total HEI-2015 score was 0.70, and the Pearson's correlation was 0.71.

Table 2. Characteristics of households in the 48 conterminous states, inferred from the National Household Food Acquisition and Purchase Survey, 2012 (n=4,276 households)

Characteristic	Sample size, n	% of population[a]
Census region		
West	954	17.8
Northeast	725	15.6
Midwest	1,044	31.3
South	1,553	35.3
Household income as percent of poverty		
<185%; SNAP[b] participants	1,164	10.7
<185%; SNAP nonparticipants	1,053	17.0
185% to 499%	1,594	48.1
≥500%	459	24.2
Race/ethnicity[c]		
White, non-Hispanic	2,581	70.5
Black, non-Hispanic	521	10.2
Asian, non-Hispanic	186	4.1
Other or multi-racial, non-Hispanic	133	2.5
Hispanic	840	12.6
Education level[c]		
Less than high school	724	9.2
High school graduate or GED[d]	1,206	24.3
Some college/associate's degree	1,395	33.2
College graduate or higher	936	33.2

[a]Weighted percentages.
[b]SNAP=Supplemental Nutrition Assistance Program.
[c]Characteristic of the household's main food shopper.
[d]GED=General Educational Development certification.

The test of concurrent criterion validity showed that in most cases both the GPQI-2016 and the HEI-2015 revealed differences in the expected direction among groups of households (Table 5). However, in one case, the self-assessment of the healthfulness of the family's diet, the GPQI-2016 detected a difference, while the HEI-2015 did not. Scores for both the GPQI-2016 and HEI-2015 were estimated to be 5% higher for those who had participated in "any events, lectures, or demonstrations about how to shop for or prepare nutritious food and meals" in the past 2 months, but the difference was statistically significant only for the HEI-2015.

The Bland-Altman plot of differences between the total GPQI-2016 and HEI-2015 scores is shown in the Figure. As expected, the GPQI-2016 scores were consistency lower than the HEI-2015 scores, with an estimated mean difference of 12.1 points (standard deviation=11.1). The limits of agreement were −10.1 (95% CI −10.7 to −9.5) and 34.3 (95% CI 33.7 to 34.9). Because these differences were normally distributed,

Table 3. Grocery Purchase Quality Index-2016 components and the US Department of Agriculture Food Plan food categories that comprise them; the standardized Food Plan expenditure share for each component and food category; and the mean population expenditure share for each component and food category, estimated from National Household Food Acquisition and Purchase Survey, 2012 (n=4,276 households)

GPQI-2016[a] component/ Food Plan category	Standardized Food Plan expenditure share (%)	Estimated population expenditure share (%)
Total vegetables	25.7[b]	11.6
All potato products	2.6	2.4
Orange vegetables	2.4	0.6
Other vegetables	8.9	6.8
Greens and beans	11.8[b]	1.9
Dark green vegetables	5.8	1.0
Canned/dry beans, lentils, peas	6.0	0.8
Total fruit	17.3[b]	9.7
Fruit juices	2.4	1.8
Whole fruit	14.9[b]	7.9
Whole fruits	14.9	7.9
Whole grains	11.0[b]	3.6
Whole-grain breads, rice, pasta, pastries	6.2	1.0
Whole-grain cereals	2.9	1.8
Popcorn, other whole-grain snacks	1.9	0.8
Dairy	13.7[b]	10.3
Whole milk, yogurt, cream	1.0[c]	3.1
All cheeses	0.8[c]	4.4
Lower-fat/skim milk, low-fat yogurt	11.9	2.8
Total protein foods	20.4[b]	11.6
Beef, pork, veal, lamb	5.9	2.7
Chicken, turkey	5.1	2.6
Eggs, egg mixtures	0.3	1.4
Seafood and nuts	9.1[b]	4.8
Fish, fish products	5.5	2.2
Nuts, nut butters, seeds	3.6	2.6
Processed meats	0.5[b]	4.3
Bacon, sausages, luncheon meats	0.5	4.3
Refined grains	5.4[b]	15.1
Non-whole-grain breads, cereals, rice, pasta, pies, pastries, snacks, flours	5.4	15.1
Sweets and sodas	2.2[b]	16.1
Milk drinks, milk desserts	0.5	4.0
Soft drinks, sodas, fruit drinks, fruit ades	1.3	7.5
Sugars, sweets, candies	0.4	4.6
Categories not used[d]	3.8	17.8
Table fats, oils, salad dressings	1.2	4.3
Gravies, sauces, condiments, spices	1.1	2.5
Coffee, tea	0.1	3.0
Soups, ready to serve/ condensed	1.1	1.4
Soups, dry	0.1	0.0
Frozen/refrigerated entrées	0.2	5.6[e]
Bottled water, plain	—	1.0
Total	100.0	100.0

[a]GPQI-2016=Grocery Purchase Quality Index-2016.
[b]Scoring standard for the GPQI-2016.
[c]Expenditure shares for full-fat products are capped at Food Plan levels when calculating dairy scores.
[d]Six of the 29 Food Plan categories, plus plain bottled water, are not accounted for in the GPQI-2016 because they do not readily align with any of the components of the Healthy Eating Index-2015.
[e]Includes foods having more than one main ingredient (ie, protein food; vegetable; and/or pasta, rice, or bread). Foods having one main ingredient and a sauce are included in the category of the main ingredient.

most of the individual differences were close to the 12.1 mean difference. For example, 63% of the differences were within ±5 points, and 93% were within ±10 points.

DISCUSSION

The comparison of the GPQI-2016 with the HEI-2015 in the present study demonstrated a reasonable degree of convergent validity. The Spearman's correlation of 0.70 and the

Table 4. Grocery Purchase Quality Index-2016 and Healthy Eating Index-2015 component and total scores and correlations between them, estimated from National Household Food Acquisition and Purchase Survey, 2012 (n=4,276 households)

GPQI-2016[a] component (maximum score)	GPQI-2016, median (IQR[b])	HEI-2015[c] component (maximum score)	HEI-2015, median (IQR)	Spearman's correlation coefficient ($P<0.01$)
Adequacy				
Total vegetables (5)	1.7 (0.2-3.4)	Total vegetables (5)	2.2 (0.6-4.6)	0.86
Greens and beans (5)	0.0 (0.0-0.6)	Greens and beans (5)	0.0 (0.0-3.0)	0.79
Total fruit (5)	1.7 (0.0-4.3)	Total fruits (5)	2.0 (0.2-4.8)	0.89
Whole fruit (5)	1.3 (0.0-4.0)	Whole fruits (5)	2.2 (0.0-5.0)	0.90
Whole grains (10)	0.0 (0.0-4.2)	Whole grains (10)	0.7 (0.0-4.7)	0.76
Dairy (10)	0.7 (0.0-2.8)	Dairy (10)	5.0 (1.4-9.8)	0.67
Total protein foods (5)	1.2 (0.0-3.8)	Total protein foods (5)	2.6 (0.7-5.0)	0.72
Seafood and nuts (5)	0.0 (0.0-2.4)	Seafood and plant proteins (5)	0.8 (0.0-5.0)	0.70
	—	Fatty acids (10)	4.8 (0.4-10.0)	—
Moderation				
Processed meats (5)	4.9 (2.2-5.0)	—	—	—
Refined grains (10)	6.7 (2.8-10.0)	Refined grains (10)	9.2 (4.1-10.0)	0.66
Sweets and sodas (10)	6.7 (3.0-10.0)	Added sugars (10)	6.6 (1.7-10.0)	0.65
	—	Sodium (10)	8.8 (4.0-10.0)	—
	—	Saturated fat (10)	7.1 (2.6-10.0)	—
Total score (75)	29.5 (21.4-37.1)	Total score (100)	51.2 (42.4-60.8)	0.70

[a]GPQI-2016=Grocery Purchase Quality Index-2016.
[b]IQR=interquartile range.
[c]HEI-2015=Healthy Eating Index-2015.

Pearson's correlation of 0.71 between the GPQI-2016 total score and the HEI-2015 total score indicated that these two indexes converged quite well.

The correlation between GPQI-2016 and HEI-2015 dairy component scores is lower than the correlations between the other adequacy components scores, in part, because the GPQI-2016 only counts nonfat and reduced fat dairy products, while the HEI-2015 counts all dairy products (the fat content is penalized in the saturated fat component and the fatty acids ratio component). The discrepancies for Total Protein Foods and Seafood and Plant Proteins can be explained in large part because in the HEI-2015, legumes are counted as plant proteins as well as vegetables, whereas in the GPQI-2016, they are counted as vegetables only, which reflects how they are counted in the USDA Food Plans. The correlation of Sweets and Sodas in the GPQI-2016 with Added Sugars in the HEI-2015 is among the lower correlations, in part because Sweets and Sodas include diet soda as well as sugar-sweetened beverages. Mixed dishes may explain much of the remaining variation in the correlations among the components of the two indexes. For the HEI, mixed foods are broken down into their ingredients; but for the GPQI-2016, they are not. For example, fruit is less likely to be purchased as part of a mixed dish; whereas refined grains and added sugars are more likely to be part of mixed dishes.

It is possible that correlated errors between the two indexes may have inflated the correlations of the component scores. For example, both indexes contain many scores of 0 for adequacy components. This is a potential source of measurement error attributable to the survey design because it is possible that although households did not purchase any foods that contribute to these components during the 1-week observation period, they may have purchased them at other times. Similarly, if a household's purchases were so high for foods that contribute to moderation components, such that a score of 0 was assigned, it is possible that during other periods of time, they purchased less of these items. The many scores of 0 would thereby inflate the component score correlations; however, fewer than 10 of the 4,276 households had a total score of 0 on either index (because they had purchased only water), so inflation of the correlation of the total scores would not be expected.

Future iterations of FoodAPS could ameliorate the problem of excess zeros by having shorter observation periods to reduce participant burden and a second observation period for at least a subsample of households.[29] This would allow researchers to adjust for the measurement error that is due to the fact that households do not acquire exactly the same foods every week and would facilitate the estimation of usual, longer-term food acquisitions and their distributions, as is commonly done with dietary survey data.[30]

Concurrent criterion validity for both the GPQI-2016 and the HEI-2015, as measures of quality of grocery purchases, was demonstrated by detecting significant differences among subpopulations that correspond with previous research on

Table 5. Mean Grocery Purchase Quality Index-2016 and Health Eating Index-2015 total scores by demographic and behavioral characteristics, estimated from National Household Food Acquisition and Purchase Survey, 2012 (n=4,276 households)

Characteristic	Percent of population	Total GPQI-2016[a] (mean±SE[b])	Between group *t*-statistic *P* value	Total HEI-2015[c] (mean±SE)	Between-group *t*-statistic *P* value	*P*<0.05
Census region						
West	17.8	32.4±0.7	—[d]	54.4±0.7	—	—
Northeast	15.6	31.2±0.7	0.21	52.6±1.0	0.14	N[e]
Midwest	31.3	29.8±0.7	0.01	51.6±0.9	0.02	B[f]
South	35.3	28.1±0.5	<0.0001	50.8±0.7	<0.001	B
Household income as percent of poverty						
<185%; SNAP[g] participant	10.7	25.4±0.4	—	46.4±0.5	—	—
<185%; SNAP non-participant	17.0	28.2±0.6	<0.001	49.8±0.6	<0.001	B
185% to 499%	48.1	30.0±0.6	<0.0001	52.5±0.6	<0.0001	B
≥500%	24.2	32.8±0.6	<0.0001	54.8±0.9	<0.0001	B
Race/ethnicity						
White, non-Hispanic	70.5	30.1±0.4	—	52.2±0.5	—	—
Black, non-Hispanic	10.2	26.4±0.7	<0.0001	48.1±1.0	<0.001	B
Asian, non-Hispanic	4.1	36.3±1.2	<0.0001	56.9±1.4	<0.01	B
Other or multiracial, non-Hispanic	2.5	29.6±1.8	0.81	50.2±1.9	0.35	N
Hispanic	12.6	29.2±0.6	0.22	52.6±0.6	0.62	N
Education level						
Less than high school	9.2	26.9±0.6	—	49.6±0.7	—	—
High school graduate or GED[h]	24.3	27.4±0.6	0.50	48.4±0.7	0.21	N
Some college/associate's degree	33.2	29.0±0.5	0.02	51.3±0.6	0.05	B
College graduate or higher	33.2	33.4±0.5	<0.0001	56.0±0.6	<0.0001	B
Uses Nutrition Facts label						
Always	17.2	34.0±0.7	<0.0001	56.6±0.7	<0.0001	B
Most of the time	25.5	31.7±0.7	<0.0001	53.6±0.8	<0.0001	B
Sometimes	29.3	29.8±0.4	<0.0001	51.8±0.5	<0.001	B
Rarely	10.9	26.4±0.8	0.22	48.9±0.9	0.11	N
Never	16.4	25.3±0.6	—	47.2±0.8	—	—
Never seen	0.6	25.5±2.4	0.93	43.7±3.3	0.38	N
Shops with grocery list						
Almost always	33.4	31.1±0.5	<0.0001	53.4±0.6	<0.0001	B
Most of the time	20.1	30.5±0.7	<0.0001	52.3±0.7	0.01	B
Sometimes	19.6	29.7±0.7	0.01	51.9±0.8	0.02	B
Seldom	10.2	29.3±0.8	0.03	51.4±1.4	0.12	G[i]
Never	16.6	27.1±0.5	—	49.1±0.7	—	—
Self-assessment of family's diet quality						
Excellent	4.7	33.7±1.2	0.0001	56.8±1.4	0.12	G
Very good	19.6	33.3±0.9	0.0001	54.5±0.6	0.32	G
Good	30.3	29.0±0.4	0.07	51.4±0.6	0.84	N

(*continued on next page*)

Table 5. Mean Grocery Purchase Quality Index-2016 and Health Eating Index-2015 total scores by demographic and behavioral characteristics, estimated from National Household Food Acquisition and Purchase Survey, 2012 (n=4,276 households) (*continued*)

Characteristic	Percent of population	Total GPQI-2016[a] (mean±SE[b])	Between group *t*-statistic *P* value	Total HEI-2015[c] (mean±SE)	Between-group *t*-statistic *P* value	*P*<0.05
Fair	11.8	25.8±0.5	0.62	48.1±0.8	0.46	N
Poor	2.0	26.5±1.3	—	50.6±3.8	—	—
Any tobacco user(s)?						
Yes	30.2	25.8±0.5	<0.0001	47.8±0.7	<0.0001	B
No	69.7	31.6±0.3	—	53.7±0.4	—	—
Any nutrition education in past 2 mo?						
Yes	6.1	31.3±1.2	0.23	55.2±1.2	0.015	H[j]
No	93.9	29.8±0.4	—	51.8±0.4	—	—

[a]GPQI-2106=Grocery Purchase Quality Index-2016.
[b]SE=standard error.
[c]HEI-2015=Healthy Eating Index-2015.
[d]Dash=reference group.
[e]N=Neither GPQI-2016 nor HEI-2015 detect difference.
[f]B=Both GPQI-2016 and HEI-2015 detect a significant between-group difference relative to the reference group.
[g]SNAP=Supplemental Nutrition Assistance Program.
[h]GED=General Education Development certification.
[i]G=GPQI-2016 detects a significant difference but HEI-2015 does not.
[j]H=HEI-2015 detects a significant difference but GPQI-2016 does not.

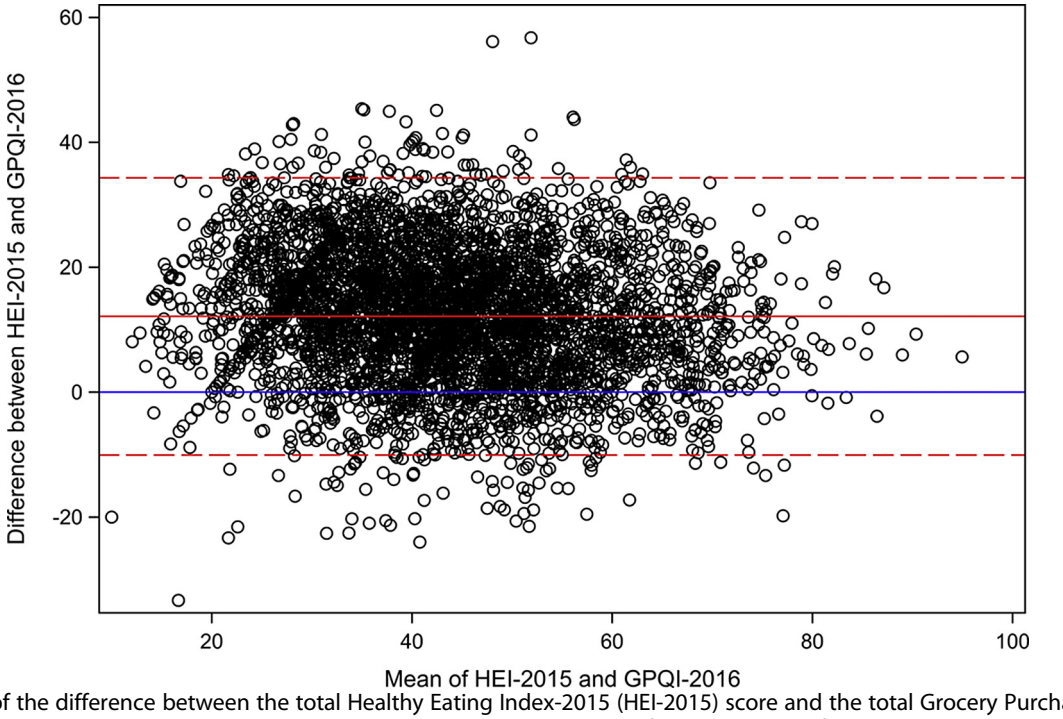

Figure. Plot of the difference between the total Healthy Eating Index-2015 (HEI-2015) score and the total Grocery Purchase Quality Index-2016 (GPQI-2016) score (ie, HEI-2015 minus GPQI-2016) by the mean of the two scores for each household (n=4,276). The blue line indicates a mean difference of 0; the solid red line indicates the observed, estimated mean difference of 12.1 points; and the dotted red line indicates the limits of agreement, 34.3 and −10.1.

diet quality in these groups. For example, those who use the Nutrition Facts label,[31,32] shop with a grocery list,[33,34] are not SNAP recipients,[35,36] have higher perceived diet quality,[37] and do not use tobacco[11,38] have better diet quality than their counterparts; and they have higher total GPQI-2016 scores in the present study. Demographic characteristics, such as income, education, region of residence, and race/ethnicity, have been associated with differences in diet quality,[39-42] and similar differences were found in the present study for both the GPQI-2016 and the HEI-2015.

The Bland-Altman analysis can be used to determine whether the two scoring schemes can be used interchangeably, although such a property is not necessary because either scheme can be used without the other. If, for some reason, one wished to estimate an HEI-2015 score for food purchases from a household's GPQI-2016 score, one could use the formula, HEI-2015=(GPQI-2016/75)×100+12.1. Sixty-three percent of the time this estimate would be accurate to ±5 points, and 93% of the time it would be accurate to ±10 points.

Previous studies have evaluated grocery purchase quality in a number of ways. For example, Franckle and colleagues[43] manually categorized food items into food groups and subgroups and evaluated expenditures for each of the categories. They did not include an overall quality indicator. In contrast, Jahns and colleagues[44] used the HEI-2010 as an overall quality indicator. However, they made no attempt to convert as-purchased forms of food to as-consumed forms. Rather, they used the nutrient content of the as-consumed form without considering yield (L. Jahns, personal communication, January 2018).

The GPQI-2016 builds on work by Stewart and Blisard[45] and Volpe and Okrent,[46] who also used food-group expenditure shares to assess compliance with the DGA. Volpe and colleagues[47] described five scoring metrics. The two that have been used most frequently in the literature are Healthshare[48-50] and USDAScore1.[48-51] The Healthshare score is the proportion of expenditures on "healthy foods." The definition of healthy foods is based on the 52 food groups found in the ERS Quarterly Food at Home Price Database,[52] categorized based on whether the DGA recommends increased (healthy) or decreased (unhealthy) consumption of each food group. USDAScore1 is based on the same categorization, but it also takes into account household size and composition and how well household expenditure shares correspond to the USDA Food Plans. An important difference between the USDAScore1 and the GPQI-2016 is that the GPQI-2016 only penalizes expenditures that are lower than the standards for adequacy components or higher than the standards for moderation components. In contrast, any deviation, whether higher or lower, from the standard results in a lower USDAScore1.[47] Volpe and colleagues also created a score called USDAScore3, which is closer to the GPQI-2016 in this regard.[47]

To the authors' knowledge, only one other study has compared a food purchase quality metric to the HEI.[47] That study compared the Healthshare and the USDAScores, described here, with the total HEI-2005 score. Their database did not contain nutrient composition of the food items, so the authors used the nutrient content of foods from the National Health and Nutrition Examination Survey 2003-2004 database, which closely matched the food groups. The authors suggested that this use of out-of-sample data may help to explain why the highest correlation (USDAScore1 with the HEI-2005) was only 0.36. In contrast, the FoodAPS database contained the nutrient information for each food item required to calculate the HEI-2015. That, plus the fact that the GPQI scoring system is much more like the HEI scoring system than are the scores used by Volpe and colleagues,[47] contribute to the much stronger correlation between the GPQI-2016 and the HEI-2015 total scores in the present study.

The GPQI-2016 has several potential uses. For example, in studies that compare food purchases paid for using SNAP benefits with purchases that do not, such as those by Franckle and colleagues[43] and by Garasky and colleagues,[53] the GPQI-2016 could provide a meaningful summary of the detailed differences found. The GPQI-2016 has the potential to be a useful outcome measure for interventions aiming to change grocery purchase behavior, such as point-of-purchase interventions, Expanded Food and Nutrition Education Program and SNAP Education Program, or other SNAP-related interventions. The GPQI-2016 allows investigators to examine the impact of the intervention on the entire market basket, rather than just on the intervention's focus, which might be on only one or two food groups, for example, fruits and vegetables.

Researchers at the National Cancer Institute have described how the HEI can theoretically be used at any level of the food stream from farm to fork, including the national food supply, the community food environment, and food intake by individuals.[21] The community food environment consists of foods that are available for people to acquire and includes both foods that are ready to eat, such as at restaurants, and those that are not, such as most foods sold in stores. The use of the HEI has been limited at this level because of the lack of food composition databases for foods in their as-purchased, unprepared form.[21] The GPQI overcomes this problem by providing a quality measure of food purchased at stores that does not require the calculation of nutrient composition, thereby eliminating the need for sophisticated databases that are unavailable. The GPQI and HEI could potentially be used together to evaluate the effect of policies or interventions on the whole food stream from farm to fork.

One limitation of the GPQI-2016 methodology is the fact that it is very time-consuming to match UPC/PLU to food categories. However, the process is somewhat easier for the GPQI-2016 than for other grocery assessment methods that have been reported because the UPC/PLU have to be matched to only 1 of 12 categories, significantly fewer than, for example, the 34 categories used by Franckle and colleagues,[43] the 52 categories required for the Volpe methods,[47] or the thousands of USDA food codes required for the HEI. A second limitation is the fact that the current Food Plans are based on the 2005 DGA. However, the GPQI-2016 can be easily updated whenever the Food Plans are revised. A third limitation is that the prices used to create the Food Plans are national averages, so a dollar's worth of any given food could equate to different amounts of food, depending on factors such as whether the item was a national brand or generic store brand, organic or not, sold by individual serving or in bulk, and in a small or large package. A fourth limitation is that the GPQI-2016 does not directly assess the quality of all foods purchased at stores because not all Food Plan categories align with HEI-2015 components. Consequently, foods accounting for an estimated 18% of household expenditures at food

stores were not assigned to a GPQI-2016 component; however, these expenditures are part of the score because they are part of the denominator (total food expenditures). These foods include mixed foods (5.6% of expenditures) because the Food Plans assume that nearly all foods are prepared in the home from ingredients, fats and oils (4.3%) because they are in the same Food Plan category so expenditure shares for them cannot be determined separately, and coffee and tea (3.0%) because they are not included in the HEI.

A final limitation of this study is that the FoodAPS had a low overall response rate of 41.5%.[29,54] Sampling weights for the FoodAPS are intended to make the results representative of the US population; however, they cannot be expected to correct fully for bias introduced when respondents differ from nonrespondents. This is not a threat to internal validity, which is of paramount importance in this study comparing two indexes. It is a threat to the external validity of the population estimates presented. Even with statistical weights applied, these estimates are subject to potential nonresponse bias.[29]

A strength of the GPQI-2016 is the fact that it assesses the large majority of grocery purchases rather than only a few food groups.[55-57] Further, the GPQI-2016 is better suited than the HEI for assessment of food purchases because it considers foods in their as-purchased form. Conversion of amounts of foods purchased to grams and imputation of missing amounts are not required, and estimation of the nutrient content of foods in their as-purchased form is not required. Another strength of this expenditure-based approach compared to an approach that requires determining the gram weights and nutrient values of foods is that it takes advantage of the strengths of expenditure data, namely, that prices paid are "clean," that is, free of error, and well characterized in grocery purchase datasets that are available directly from stores; that is, the dollar amounts paid for food items are easy for researchers to identify and understand, unlike the often-cryptic food descriptions and difficult-to-decipher weight or volume measures found in UPC descriptors.

CONCLUSIONS

In summary, GPQI-2016 scores correlate well with HEI-2015 scores, indicating reasonable convergent validity. Significant differences in expected directions in GPQI-2016 scores by demographic characteristics and shopping behaviors demonstrate known-group validity. The GPQI-2016 performed similarly to the HEI-2015 in these comparisons. The tool has potential as a means of evaluating large nutrition education programs, especially the SNAP Education Program, because SNAP benefits are used in grocery stores, and retail-oriented interventions when the nutrient content and gram weights of foods purchased are not available.

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

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AUTHOR CONTRIBUTIONS

P. J. Brewster designed the research and analyzed the data. G. J. Stoddard directed and interpreted parts of the analysis. P. M. Guenther, C. M. Durward, P. J. Brewster, and G. J. Stoddard wrote the paper. P. M. Guenther and J. F. Hurdle provided project oversight. P. J. Brewster had primary responsibility for the final content. All authors read, commented on, and approved the final manuscript.