Development and Evaluation of the Healthy Eating Index-2005

Technical Report

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Preface

The first author of this technical report welcomes feedback on it. To that end, it is posted on the Center for Nutrition Policy and Promotion website not as a publication but as a preprint version of future publications. This report has been cleared for posting by the U.S. Department of Agriculture's Office of Communications but has not been formally peer reviewed. Please direct any suggestions to Patricia.Guenther@cnpp.usda.gov.

Introduction

The Dietary Guidelines for Americans are the basis of nutrition policy for the United States Government and the foundation of all Federal nutrition guidance (U.S. Department of Health and Human Services [HHS] & U.S. Department of Agriculture [USDA], 2005). The Dietary Guidelines are revised every 5 years by the U.S. Departments of Agriculture (USDA) and Health and Human Services (HHS), based on reports of expert advisory panels. Both USDA and HHS use the Dietary Guidelines as the foundation of their nutrition guidance and consumer communications. USDA's many food-assistance programs must comply with the Dietary Guidelines.

The USDA Center for Nutrition Policy and Promotion (CNPP) developed a Healthy Eating Index (HEI) to measure compliance with dietary guidance (Kennedy, Ohls, Carlson, & Fleming, 1995; USDA, Center for Nutrition Policy and Promotion [CNPP], 1995). The HEI is used by USDA to monitor change in the Nation's diet. Specifically, the USDA Strategic Plan for 2005-2010 includes a goal to "improve the nation's nutrition and health." One of the objectives under this goal is to "promote healthier eating habits and lifestyles," and a key outcome is "eating habits more consistent with *Dietary Guidelines for Americans*." Improvement in HEI scores for the general and low-income populations is one of the performance measures for this objective (USDA, 2006).

The original HEI, released in 1995, was comprised of 10 components (table 1). Five components assessed the nutrient adequacy of the diet by using the five major food groups of the original Food Guide Pyramid: fruit, vegetables, grains, milk, and meat (USDA, CNPP, 1992 [sl. rev. 1996]). Four components assessed aspects of the diet that should be limited or consumed in moderation: total fat, expressed as a percentage of total calories; saturated fat, expressed as a percentage of total calories; cholesterol; and sodium. The tenth component was a measure of variety in food choices regardless of food group.

Standards were set for scoring each of the components. Those related to food-group intake were based on recommended amounts found in the Food Guide Pyramid and average estimated energy requirements for each of 11 age-gender groups. Scores for each component ranged from 0 to 10; thus, the total maximum score was 100. By convention, a total score of more than 80 was considered "good," scores of 51-80 indicated "needs improvement," and scores of less than 51 were considered "poor" (USDA, CNPP, 1995). Since 1995, the HEI has been slightly modified to reflect changes in the Dietary Guidelines and as newer national survey data have been released (Basiotis, Carlson, Gerrior, Juan, & Lino, 2002; Bowman, Lino, Gerrior, & Basiotis, 1998).

The release of the 2005 Dietary Guidelines necessitated a revision of the HEI because of the increased emphasis on important aspects of diet quality, such as whole grains, various types of vegetables, specific types of fat, and the introduction of the new concept of "discretionary calories." Therefore, the goal set for this revision of the HEI was to develop a tool that measures compliance with the key diet-related recommendations of the 2005 Dietary Guidelines for Americans. The need for revision also provided the opportunity to evaluate the psychometric properties of the new index.

This report describes the process used to develop the revised HEI, which is called the HEI-2005, and the analyses conducted to evaluate its psychometric properties. It also discusses the major differences between the HEI-2005 and the original HEI and describes the strengths, limitations, and potential applications of the new index.

Development of the HEI-2005

Components

CNPP convened an interagency Working Group to begin the process of revising the HEI. The Working Group included members from CNPP, USDA's Food and Nutrition Service, and the HHS' National Cancer Institute (NCI), bringing expertise in nutrition, economics, and psychometrics. Both formally in a workshop setting and informally, the Working Group consulted with other experts who had expertise and experience in energy balance and measurement, econometrics, and the development of measures of diet quality.

The Working Group reviewed the original HEI and its uses and considered potential uses:

- Population monitoring
- Nutrition education
- Evaluation of nutrition interventions
- Epidemiologic research
- Economic research

The Working Group decided to base the revised index on the food patterns found in USDA's food guidance system, now called MyPyramid, which translates key recommendations in the 2005 Dietary Guidelines for Americans into specific, quantified dietary recommendations (Britten, Marcoe, Yamini, & Davis, 2006). Collectively, these documents specify amounts to consume from each of the major food groups and from oils and provide recommended limits for sodium, saturated fat, and discretionary calories. In addition, they advise that at least half of grain intake should be whole grain, recommend specific amounts of several vegetable subgroups, and suggest that less than half the fruit consumed should be juice. A subgroup of the HEI Working Group further developed the components of the index, constructed the scoring and weighting protocol, developed the evaluation plan, conducted the analyses, presented findings to the full Working Group, and held briefings for wider audiences.

As shown in table 1 and appendix 1, the components of the HEI-2005 represent all of the major food groups found in MyPyramid—Total Fruit; Total Vegetables; Total Grains; Milk, which includes soy beverages; and Meat and Beans, which includes meat, poultry, fish, eggs, soybean products other than beverages, nuts, seeds, and legumes. (See page 10 for an explanation of when legumes are counted in this food group.) Additional components represent Whole Fruit (i.e., forms other than juice); Dark Green and Orange Vegetables and Legumes; Whole Grains (which must include the entire grain kernel, bran, germ, and endosperm); Oils (non-hydrogenated vegetable oils and oils in fish, nuts, and seeds); Saturated Fat; Sodium; and Calories from Solid Fat, Alcohol, and Added Sugar (SoFAAS). Whole Fruit was added because the 2005 Dietary Guidelines suggest limiting juice to less than half of total fruit intake. A new component was added for Dark Green and Orange Vegetables and Legumes because those are the three subgroups of vegetables for which current intake is furthest from recommended levels. The Whole Grains component was added because the 2005 Dietary Guidelines specify that at least half of grain intake should be whole grain. New components were added for Oils to reflect the recommendations for oil found in MyPyramid and for Calories from SoFAAS, which serves as a proxy for discretionary calories and is described further below. Like the original, the HEI-2005 also includes components for Saturated Fat and Sodium.

The components do not necessarily directly represent foods as eaten. For example, all components include foods that are ingredients in mixed foods. Whole Grains include only the whole-grain portions of foods that contain both whole and refined grains. Only the lowest fat portions of milk and meat products are included in the Milk and Meat components, respectively. The fatty portions of milk and meat products count as Solid Fat; whereas, the fatty portions of fish, nuts, and seeds count as Oils as do nonhydrogenated vegetable oils. Alcohol includes beer, wine, and distilled spirits consumed as beverages, but not as ingredients in mixed dishes.

Table 1. Original Healthy Eating Index (HEI) and Healthy Eating Index-2005 (HEI-2005) components and standards for scoring

Component	Score				
	0	5	8	10	20
				points	
Original HEI					
Total Fruit	0			2-4 servings (approx. 1-2 cups[1])	
Total Vegetables	0			3-5 servings (approx. 1.5-2.5 cups[1])	
Total Grains	0			6-11 servings (approx. 6-11 oz eq[1])	
Milk	0			2-3 servings (2-3 cups[2])	
Meat (and beans)	0			2-3 servings (approx. 5.5-7.0 oz eq[1])	
Sodium	≥ 4.8			≤ 2.4 g	
Saturated Fat	≥ 15			≤ 10% energy	
Total Fat	≥ 45			≤ 30% energy	
Cholesterol	≥ 450			≤ 300 mg	
Variety	≤ 6			≥ 16 different foods in 3 days[3]	
HEI-2005[4]					
Total Fruit	0	≥ 0.8 cup eq/1000 kcal			
Whole Fruit	0	≥ 0.4 cup eq/1000 kcal			
Total Vegetables	0	≥ 1.1 cup eq/1000 kcal			
Dark Green and Orange Vegetables and Legumes	0	≥ 0.4 cup eq/1000 kcal			
Total Grains	0	≥ 3.0 oz eq/1000 kcal			
Whole Grains	0	≥ 1.5 oz eq/1000 kcal			
Milk	0			≥ 1.3 cup eq/1000 kcal	
Meat and Beans	0			≥ 2.5 oz eq/1000 kcal	
Oils	0			≥ 12 g/1000 kcal	
Saturated Fat	≥ 15		10	≤ 7% of energy	
Sodium	≥ 2.0		1.1	≤ 0.7 g/1000 kcal	
Calories from SoFAAS[5]	≥ 50				≤ 20% of energy

[1]According to gender and age.
[2]According to age.
[3]In 1994-96 and 1999-2000, 8 or more different foods in 1 day.
[4]See Appendix 1: Foods Included in Components of the Healthy Eating Index-2005.
[5]Solid Fat, Alcohol, and Added Sugar.

The components of the HEI-2005 are considered to be of two types. The food-group and Oils components are the "adequacy components" because the recommendations on which they are based were established to ensure adequacy of nutrient intake. The "moderation components" are Saturated Fat, Sodium, and Calories from SoFAAS.

Standards

Density Standards

For the HEI-2005, we have chosen to represent intakes of foods and nutrients on a density basis, that is, as amounts per 1,000 calories of intake. In MyPyramid, the recommendations for the amounts of food groups, oils, and discretionary calories are expressed in terms of absolute amounts that vary according to energy level (Britten et al., 2006). Thus, if an HEI standard were an absolute amount, that amount would also have to vary according to energy level. However, on a density basis, many of the recommendations are similar across energy levels (table 2). For saturated fat and sodium, a density standard was easy to derive. The saturated fat recommendation in the Dietary Guidelines is the same for all individuals and is given on a density basis—less than 10 percent of energy. The sodium recommendation in the Dietary Guidelines is derived from the *Dietary Reference Intakes* (DRI) (Institute of Medicine [IOM], Food and Nutrition Board, 2004) and, although the sodium DRIs are stated as absolute amounts that vary by age group, they were derived by using a density approach. That is, recommendations for younger and older persons were set at proportionately lower levels because their average energy intakes are lower. We were satisfied that each of these recommendations

is sufficiently similar across levels of energy intake, when expressed on a density basis, that a scoring system based on densities was the best approach.

Density standards are appealing not only because they allow a common standard to be used, but also because they have the advantage of being independent of an individual's energy requirement, which is difficult to measure precisely. Consequently, this obviates the need to assign individuals to one of the 12 calorie levels found in MyPyramid (Britten et al., 2006). In effect, the density approach to setting standards allows the assessment of the quality of the mix of foods consumed, rather than the absolute amounts of foods consumed.

Table 2. Recommended amounts of food groups, expressed per 1,000 kcal, and discretionary calorie allowances, expressed as a percentage of total calories, found in MyPyramid

	Calorie level											
Food group	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200
Fruits (cup eq/1000 kcal)	1.0	0.8	1.1	0.9	0.8	1.0	0.9	0.8	0.8	0.9	0.8	0.8
Vegetables (cup eq/1000 kcal)	1.0	1.3	1.1	1.2	1.4	1.3	1.4	1.3	1.4	1.3	1.3	1.3
Dark green vegetables	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1
Orange vegetables	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Legumes	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Starchy vegetables	0.2	0.3	0.3	0.2	0.2	0.2	0.4	0.4	0.4	0.4	0.4	0.4
Other vegetables	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.5	0.4	0.5	0.5
Grains (oz eq/1000 kcal)	3.0	3.3	3.6	3.1	3.3	3.0	3.2	3.3	3.5	3.6	3.3	3.1
Whole grains	1.5	1.7	1.8	1.9	1.7	1.5	1.6	1.7	1.7	1.8	1.7	1.6
Other grains	1.5	1.7	1.8	1.3	1.7	1.5	1.6	1.7	1.7	1.8	1.7	1.6
Milk (cup eq/1000 kcal)	2.0	1.7	1.4	1.9	1.7	1.5	1.4	1.3	1.2	1.1	1.0	0.9
Meat and Beans (oz eq/1000 kcal)	2.0	2.5	2.9	3.1	2.8	2.8	2.7	2.7	2.5	2.5	2.3	2.2
Oils (g/1000 kcal)	15.0	14.0	12.0	14.0	13.0	14.0	13.0	13.0	13.0	13.0	15.0	16.0
Discretionary calories (%)	16.5	14.3	12.2	8.3	10.8	13.4	13.2	15.1	15.8	15.2	17.1	20.3

Food-group-based Components

Although appealing in concept, using a common standard and applying a density-based approach had its challenges. While the MyPyramid patterns are similar to each other on a density basis, they are not exactly the same (table 2). Therefore, we had to establish which of the MyPyramid patterns to use in determining the density standards for each of the food groups, oils, and discretionary calories. For the nutrient adequacy components (food groups and oils), we focused on the 1,200- to 2,400-calorie patterns because they were used to ensure nutrient adequacy when MyPyramid was constructed. Among these, the lowest amount per 1,000 calories (that is, the least restrictive or easiest to achieve) was selected as the standard for the maximum score for each of these components. For the discretionary calories component, which is described in detail on pages 5 and 32, we also selected the least restrictive amount across all the patterns; but in this case, that was the greatest amount on a per calorie basis.

For Fruits, Vegetables, Grains, Whole Grains, Milk, Meat and Beans, and Oils, the standards are the lowest amounts recommended in the patterns, expressed on a per 1,000 calorie basis (tables 1 and 2). For Whole Fruit, the standard is simply half the standard for Total Fruit because the 2005 Dietary Guidelines for Americans suggest that the majority of fruit intake should be whole fruit rather than fruit juice. For Dark Green Vegetables, Orange Vegetables, and Legumes, the recommendations found in MyPyramid are expressed on a weekly basis. To develop the standards, we converted them to a daily basis. The standard is the sum of the daily recommendations for those three subgroups of vegetables, expressed on a per 1,000 calorie basis. Any combination of them counts toward meeting the vegetable subgroup standard with one exception. As is the case in MyPyramid, legumes are counted as vegetables only after the Meat and Beans standard has been met (USDA, CNPP, 2005).

Saturated Fat and Sodium Components

In the Dietary Guidelines, the recommendation for saturated fat is not expressed as a single value, but rather as *less than* 10 percent of energy intake. This does not clearly indicate which, if any, value less than 10 percent might be the optimal level, so we looked to other guidance for where to set the standard. The *Dietary Guidelines for Americans* 2005 highlights two exemplary food guides as being consistent with its guidance, MyPyramid, developed by CNPP, and the Dietary Approaches to Stop Hypertension (DASH) Eating Plan, developed by the National Heart, Lung, and Blood Institute (NHLBI). The examples of these guides in this report have saturated fat levels of 7 to 8 percent of energy (HHS & USDA, 2005). Both the Dietary Guidelines Advisory Committee and the Food and Nutrition Board of the Institute of Medicine (IOM) have recommended that saturated fat consumption be as low as possible, suggesting that lower is better (Dietary Guidelines Advisory Committee, 2004) (IOM, Food and Nutrition Board, 2005). The DASH plan aims for 7 percent, and the 2006 American Heart Association (AHA) guidelines call for 7 percent or less (Lichtenstein et al., 2006). Based on these sources, 7 percent of calories was chosen as the standard for the maximum score of 10 for the Saturated Fat component. Rather than evenly prorating the score, we decided to recognize the Dietary Guideline by assigning a score of 8 to the level of 10 percent of calories.

The Dietary Guidelines recommendation for sodium for most individuals is "less than 2,300 mg/day," but for individuals with hypertension, blacks, and middle-aged and older adults, the recommendation is "no more than 1,500 mg/day." These values represent the Upper Limit (UL) and Adequate Intake (AI) levels, respectively, set by the Food and Nutrition Board (IOM, Food and Nutrition Board, 2004). In light of these recommendations, we chose 1,500 mg as the basis for the maximum score of 10 and 2,300 mg as the basis for the relatively good score of 8 for the Sodium component.

To express the sodium standard as a density, we used the same approach used to set the DRIs for older adults and children. The DRI panel divided the DRIs they had set for young and middle-aged adults by the estimated median energy intake for that age group (2,150 calories per day) and then used those same densities (mg of sodium per calorie) to set the DRIs for younger and older individuals. We calculated the density standards the same way. The highest possible score of 10 is assigned to diets that have less than 700 mg of sodium per 1,000 calories (1,500 mg sodium (AI)/2,150 calories), and a score of 8 is assigned to 1,100 mg of sodium per 1,000 calories (2,300 mg sodium (UL)/2,150 calories).

Discretionary Calories Component

The 2005 Dietary Guidelines Advisory Committee presented the concept of "discretionary calories," defined as the "difference between total energy requirements and the energy consumed to meet recommended nutrient intakes" (Dietary Guidelines Advisory Committee, 2004). The Dietary Guidelines further explain, "At each calorie level, individuals who eat nutrient-dense foods may be able to meet their recommended nutrient intake without consuming their full calorie allotment. The remaining calories—the discretionary calorie allowance—allow individuals flexibility to consume some foods and beverages that may contain added fats, added sugars, and alcohol" (HHS & USDA, 2005). Added fats or sugars *per se* are not directly limited. Rather, the allowance is a defined number of discretionary calories, and these calories may come from any mix of solid fat, added sugar, alcohol, or additional amounts of nutrient-rich foods beyond the recommended levels.

Nonetheless, the population generally consumes more calories from solid fat, added sugar, and/or alcohol than the allowance permits (Basiotis, Guenther, Lino, & Britten, 2006). In effect, these calories displace those needed to obtain the recommended amounts of the food groups and oils. Because of this imbalance, we decided to develop a component that captured specifically the Calories from Solid Fat, Alcohol, and Added Sugar (SoFAAS). This approach is consistent with our objective to capture the mix of foods eaten. Calories from SoFAAS is not intended to be a measure of solid fat, alcohol, and/or added sugar *per se*, but rather a measure of the calories in the diet that are obtained from dietary constituents other than nutrient-dense foods. The standard for the maximum score is the least restrictive, or easiest to achieve, of all the discretionary calorie allowances found in MyPyramid, 20 percent of calories (table 2).

Scoring

For all the components, intakes at the level of the standard or better are assigned the maximum number of total points allotted. Scoring the adequacy of food-group components is straightforward because there is a logical score of zero for no intake and the scores increase as intakes increase up to the standard. Scores for amounts between zero and the standard are prorated linearly; that is, the reported amount per 1,000 calories is divided by the standard and multiplied by the total possible number of points (5 or 10).

For the moderation components, it is less clear where to assign a zero score because increasing levels of intake get decreasing scores. This reverse scoring for the moderation components has no obvious mathematical equivalent to the zero for the adequacy components, and no scientific evidence clearly specifies how high an intake deserves a score of zero.

We wanted to ensure that a large proportion of the population did not get a score of zero because that would make it difficult to detect differences among individuals and groups and changes over time. In light of this objective, we looked at the distribution of 1-day intakes for the population in 2001-2002. We decided to choose a value at approximately the 85th percentile of the population distribution as described below.

Figure 1 shows the probability density of calories from saturated fat, expressed as a percentage of energy intake. The area under the curve is equal to 1 and represents the entire population. Forty-two percent of 1-day intakes met the Dietary Guideline of 10 percent of calories from saturated fat or lower, and 16 percent of intakes met the standard of 7 percent of calories or lower. At the other end of the distribution, 15 percent of the intakes were at 15 percent of calories from saturated fat or higher. We set the minimum score of zero at that level. In summary, the maximum score of 10 is assigned to intakes of 7 percent of energy or less; a score of 8 is assigned to 10 percent; and 0 is assigned to 15 percent or more. The amounts in between 7 and 10 percent and between 10 and 15 percent are prorated linearly.

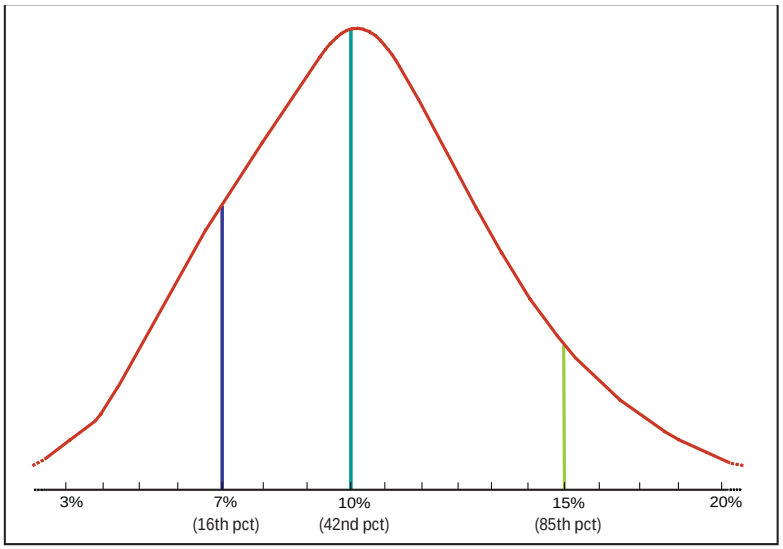

Figure 1. Distribution of 1-day saturated fat intake as a percentage of energy, United States, 2001-2002

Figure 2 shows the probability density of the population's 1-day intake of sodium per 1,000 calories. As described above, the AI is the basis for the standard of 700 mg/1,000 calories for the maximum score; 2.5 percent of intakes are at that level or lower. The Dietary Guideline limit is recognized by giving a score of 8 to 2,300 mg, converted to a density of 1,100 mg/1,000 calories; 18 percent of 1-day intakes are at that level or lower. The minimum score was set at 2,000 mg of sodium per 1,000 calories because about 15 percent (17 percent) of 1-day intakes are at that level or higher. In summary, 700 mg or less per 1,000 calories gets 10 points, 1,100 mg per 1,000 calories gets 8 points, 2,000 mg or more per 1,000 calories or more gets 0 points, and the amounts in between are prorated linearly.

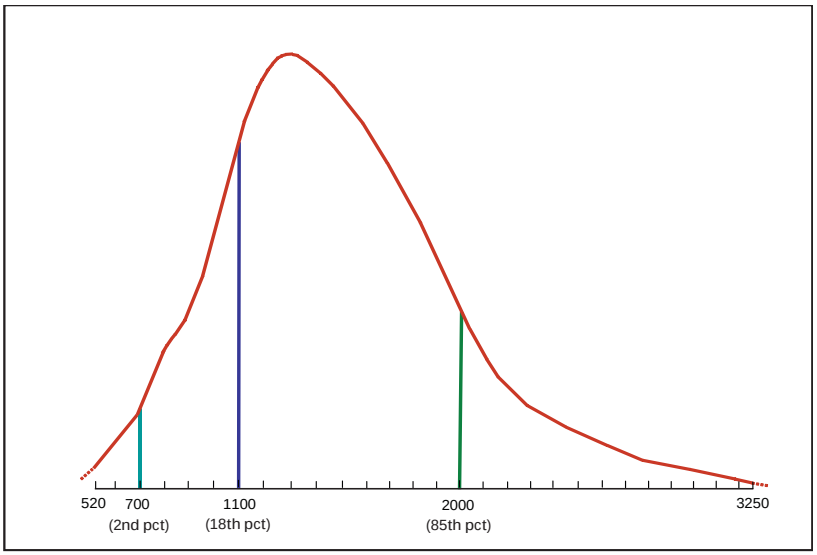

Figure 2. Distribution of 1-day sodium intake per 1,000 kcal of energy, United States, 2001-2002

Figure 3 shows the probability density of the population's 1-day intake of Calories from SoFAAS. About 10 percent of intakes were below the standard of 20 percent of calories, and 14 percent were at 50 percent of calories or more. The maximum and minimum scores were set at these levels, respectively, and the amounts in between are prorated linearly.

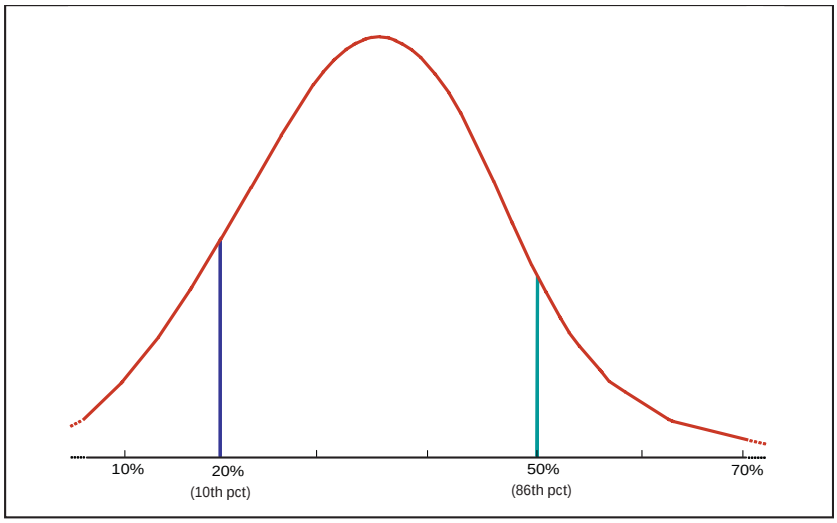

Figure 3. Distribution of 1-day energy intake from solid fat, alcohol, and added sugar as a percentage of total energy, United States, 2001-2002

Weighting for the HEI-2005 Total Score

For many purposes, the HEI-2005 components will be considered as a set of scores because they measure compliance with the many different aspects of the Dietary Guidelines. However, for population monitoring, it is useful to provide a single, summation score. For that purpose, the HEI-2005 components can be weighted to derive a total HEI-2005 score, which can vary between 0 and 100.

Weighting requires an assumption regarding the degree to which components are equal to each other in their contribution to diet quality or perhaps even to health. Equal weighting assumes that each component is equally important as all the others. Although equal weighting may seem arbitrary, it reflects the directive found in the *Dietary Guidelines for Americans* to take all the guidance as a whole. Scant evidence is available to suggest doing otherwise. Nonetheless, we decided to weight Calories from SoFAAS as if it were twice as important as any other for several reasons: (1) the 2005 Dietary Guidelines encourage the selection of "low-fat forms of foods in each food group and forms free of added sugar" (HHS & USDA, 2005); (2) solid fats, alcoholic beverages, and added sugars may displace nutrient-dense foods in the diet; (3) they may add energy without adding nutrients; and (4) they are currently consumed in amounts that far exceed the discretionary calorie allowances (Basiotis et al., 2006). Consequently, Calories from SoFAAS is weighted twice as heavily as any other component and has a maximum score of 20 points. The other components of the HEI-2005 are weighted equally—each receiving a maximum of 10 points—with a few exceptions. Fruit, vegetables, and grains each have two components (total and a subgroup) that get 5 points each, so these three food groups effectively are allotted 10 points each.

Evaluation of the HEI-2005

Methods

We evaluated the performance of the HEI-2005 by assessing its psychometric properties, including several types of validity and one type of reliability listed in table 3. To do this, we scored 1-day dietary intakes obtained from a national sample and several sets of exemplary menus. In some cases, we compared the results from the HEI-2005 with results from the original HEI, developed in 1995.

Data Sources and Calculated Variables

For most analyses, we used data from 8,650 respondents from the National Health and Nutrition Examination Survey 2001-2002 (NHANES 01-02). Children under the age of 2 years were excluded because the Dietary Guidelines and MyPyramid were not designed to meet their needs. Breast-fed children were excluded because dietary intake data are not available for them. Pregnant and lactating women were excluded in accordance with practices for calculating original HEI population scores (Basiotis et al., 2002; Bowman et al., 1998). Survey respondents provided one 24-hour recall of dietary intake, administered by an interviewer in a mobile examination center (National Center for Health Statistics, 2004). Only individuals who provided complete and reliable intake data, as judged by the interviewer and developers of the dataset, were included. Respondents who were fasting on the recalled day were assigned a score of zero for all HEI components. Sodium intake data in NHANES do not include salt added at the table.

All statistical analyses were conducted by using SAS, version 8.1 (1999-2000, Cary, NC), except when standards errors were estimated. In that case, SUDAAN, version 9.0 (2002, Cary, NC) was used. In all analyses, survey design and non-response were addressed through the use of the 2-year examination sampling weights. For analysis of the original HEI, we used the scores calculated previously by CNPP (USDA, CNPP, 2004). Sources of the data for the analyses of the menus are described on page 11.

Table 3. Psychometric properties of the Healthy Eating Index-2005 evaluated

Psychometric property	Evaluation question	Analysis strategy
Validity		
Content validity	Does the index capture the various key aspects of diet quality specified in *Dietary Guidelines for Americans 2005*?	Checked HEI components against the *Dietary Guidelines for Americans 2005* (table 4)
	Does the index measure what it is supposed to be measuring as judged by nutrition experts, i.e., does it have face validity?	Reviewed scores of selected NHANES 24-hour recall reports (appendix 2)
Construct validity	Does the index give maximum scores to menus developed by nutrition experts to illustrate high diet quality?	Computed scores for menus from USDA's MyPyramid, NHLBI's DASH Eating Plan, Harvard's Healthy Eating Pyramid, and American Heart Association's No-Fad Diet (table 5)
	Does the index distinguish between groups with known differences in diet quality, i.e., does it have concurrent criterion validity?	Compared scores of smokers and nonsmokers (table 6)
	Does the index measure diet quality independent of diet quantity?	Estimated Pearson correlations between component scores and energy intake (table 7A)
	What is the underlying structure of the index components, i.e., does it have more than one dimension?	Examined structure by using a principal components analysis (fig. 4)
	Are the total and component scores sufficiently sensitive to detect meaningful differences?	Examined population distributions of total component scores (table 8)
Reliability		
Internal consistency	How reliable is the total index score if diet quality is found to have one dimension?	Determined Cronbach's coefficient alpha
	What are the relationships among the index components?	Esimated Pearson correlations among component scores (table 7A)
	Which components have the most influence on the total score?	Estimated correlations between each component and sum of all others (table 7A)

To create the HEI-2005 scores, we needed to create a density value for the daily intake of each food group and nutrient of interest. To do so, we divided the reported amount of the food group or nutrient consumed by the reported total energy and multiplied by 1,000 ([total food-group or nutrient intake/total energy intake] * 1,000). We then compared that density value with the standard established for the respective component and determined the score as described above.

However, because ratios were involved, the specific operation depended on whether we were assigning values to 1-day intakes by individuals or to a set of menus designed to represent an individual's intake over several days. Using the Total Grains component as an example, we computed an individual's score based on a single day's intake as follows:

$$(TG/E*1{,}000)_{individual} \rightarrow \text{Assign Score}_{individual}$$

where TG = Total Grain Intake for the Day, and
E = Energy Intake for the Day

All of the component scores were then summed to get the individual's 1-day total HEI score.

In the case of the menus, for which the multiple days are meant to represent an individual's intake over several days, we calculated the scores by summing the appropriate dietary constituent over all the days, summing number of calories over all the days, dividing the total amount of the dietary constituent by the total number of calories, and comparing this ratio to the standard:

$$\frac{\Sigma\,(TG)_{day}}{\Sigma\,(E)_{day}} \rightarrow \text{Assign Score}_{\text{“individual”}}$$

The component scores were then summed to get the total HEI score.

The NHANES 01-02 data were merged with data from the MyPyramid Equivalents Database (MPED) (Friday & Bowman, 2006) to generate the number of pyramid equivalents (i.e., cup equivalents, ounce equivalents, grams, and teaspoon equivalents) for the following MPED food groups: total fruits; total vegetables; dark green vegetables; orange vegetables; legumes (cooked dry beans and peas); total grains; whole grains; total milk; meat, poultry, fish; eggs; soybean products; nuts and seeds; oils; solid fats; and added sugars. Foods included in these groups are listed in appendix 1. We used the NHANES 01-02 nutrient intake data file (drxtot_b) for sodium (mg), total saturated fatty acids (g), and energy (kcal). These data were sufficient to calculate the Total Fruit, Total Grains, Whole Grains, Oils, Saturated Fat, and Sodium component scores. Additional steps for other components are described below:

Whole Fruit. The MPED does not separate juices from whole forms of fruit. The procedures used to make this distinction and create the Whole Fruit component are described in appendix 1.

Legumes (Total Vegetables, Dark Green and Orange Vegetables and Legumes, and Meat and Beans). The MPED provides the option of classifying legumes as either part of the Meat and Beans group (lean meat ounce equivalents) or as part of the Vegetables group (cup equivalents). In MyPyramid and, thus, in the HEI, legumes are first counted toward meeting the recommendation for the Meat and Beans component (using lean meat ounce equivalents) (U.S. Department of Agriculture, Center for Nutrition Policy and Promotion, 2005). Once that recommendation is met, additional amounts of legumes are counted toward meeting the recommendations for both the Total Vegetables and the Dark Green and Orange Vegetables and Legumes components (using cup equivalents).

Milk. Consistent with new USDA regulations for school and the Women, Infants, and Children's programs, soy beverages are counted as part of the Milk component rather than in the Meat and Beans component.

Calories from Solid Fat, Alcohol, and Added Sugar (SoFAAS). We created a component for calories from solid fat, alcoholic beverages (beer, wine, and distilled spirits consumed separately or as an ingredient in a mixed drink), and added sugar. The procedure for calculating this component is described in appendix 1 (p. 32).

Analysis Plan

Content validity examines qualitatively the extent to which an index represents the variety of attributes that make up the intended domain—in this case, diet quality as specified by the 2005 *Dietary Guidelines for Americans*. We considered two questions in this regard. First, we asked whether the HEI-2005 captures the various key aspects of the Dietary Guidelines. To answer this question, we checked the set of components against the key recommendations of the *Dietary Guidelines for Americans* 2005. (These results are found in table 4, p. 13.)

Second, to determine face validity, a type of content validity, we used professional judgment to consider whether diets that receive high scores are qualitatively better than those that receive low scores. To do this, we sorted all the recalls from the NHANES 01-02 into 10 groups according to their total HEI scores (0-9.9, 10-19.9, etc.) and selected four diets from each group: the lowest calorie diet, the highest calorie diet, the diet that had the biggest difference between the HEI-2005 and the original HEI scores, and one diet selected at random. For each selected diet, the nutritionists on the team examined the descriptions and amounts (in grams) of foods reported, total calories, component and total HEI-2005 scores, and component and total original HEI scores (appendix 2).

Construct validity evaluates quantitatively how well an index measures what it is supposed to measure, in this case, diet quality. We assessed the construct validity of the HEI-2005 in five ways. First, we looked at four sets of menus developed by other nutrition experts to represent very high quality diets and scored them using the HEI-2005. (These results are found in table 5, p. 16.) These diets were the sample 7-day 2,000-calorie menu found on the MyPyramid website (USDA, CNPP, 2006b); the sample 7-day menu for the DASH Eating Plan, developed by NHLBI (National Heart Lung and Blood Institute, 2006); the two 1-week sample menus for Harvard Medical School's Healthy Eating Pyramid (Willett, 2005); and the two 1-day sample menus from the AHA's No-Fad Diet (American Heart Association, 2005a, 2005b). Each menu item was coded by an experienced registered dietitian using the Food Intake Analysis System, version 3.99 (1998, University of Texas-Houston School of Public Health), so that it could be linked to the MPED and the NHANES nutrient data files. The dietitian created recipes and modification codes as needed. The HEI-2005 component scores for each of the four sets of menus were calculated by using the ratio of means method described above.

Second, we examined concurrent-criterion validity, another type of construct validity that evaluates whether the index can distinguish between groups with known differences in the quality of their diets. Because previous studies have shown that smokers have poorer quality diets than do non-smokers (Larkin, Basiotis, Riddick, Sykes, & Pao, 1990; Subar, Harlan, & Mattson, 1990; Palaniappan, Jacobs, Starkey, O'Loughlin, & Gray-Donald, 2001; Dallongeville, Marecaux, Fruchart, & Amouyel, 1998), we assessed the ability of the HEI to distinguish differences in diet quality in terms of average 1-day diet scores between these two groups of adults age 20 years and older, using data from the NHANES 01-02. This analysis was conducted for both the HEI-2005 and the original HEI so that the relative ability of the two indexes to differentiate diet quality could be determined. (These results are found in table 6, p. 17.) Because of the large sample size, an alpha level of .01 was chosen to determine statistically significant differences.

Third, we determined whether the HEI-2005 could assess diet quality independent of diet quantity, as measured by the diet's energy value. Because nutrient intake is positively correlated with energy intake, a diet quality index could overrate high calorie diets, especially if nutrient adequacy is weighted more heavily than moderation and if intakes are measured in terms of absolute amounts

rather than as densities. To evaluate this independence, we examined the Pearson correlations of the HEI-2005 total and component scores with energy intake and compared the results with those of the original HEI. (These results are found in tables 7A and 7B, pp. 18 and 19.)

Fourth, the distributional properties of the HEI were also evaluated as an indicator of construct validity. As mentioned on page 6, a valid measure of diet quality should provide a range of scores among individuals that is consistent with the range of the values of diet quality in the population. To evaluate the range, we examined the deciles of the population 1-day distributions of the total and component scores and compared the distributions of the HEI-2005 scores with the distribution of the original scores. (These results are found in table 8, p. 20.)

Fifth, we examined the underlying structure of the index through principal components analysis (PCA). Based on the correlations among the 12 components, the PCA was used to determine the number of independent factors that comprise the HEI-2005. We were primarily interested in learning whether there was one or more than one factor that accounted for the systematic variation observed in the data.

Reliability. For both the original HEI and the HEI-2005, we assessed one form of reliability, internal consistency, the degree to which multiple components within an index measure the same underlying, unidimensional, latent construct, by using Cronbach's coefficient alpha. This statistic is mathematically equivalent to the average of the correlations among all possible split-half combinations of the 12 HEI-2005 components, and thus captures any systematic variation underlying the dietary components that are measured. To further understand the relationships among components, we examined the inter-component correlations. The coefficient alpha was expected to be low because diet quality is known to be a complex and multidimensional construct and because individuals do not consistently meet, or fail to meet, all the dietary standards used to assess diet quality. For example, a diet may meet the standard for Meat and Beans but fail to meet the standard for Whole Fruit. Thus, internal consistency is not a necessary characteristic of the HEI, but it does have implications for its interpretation in various research applications. To see which components have the most influence on the total score, we examined the correlations of each of the components with the total score minus that component for both the HEI-2005 and the original HEI.

Results

Content Validity

The key recommendations from the *Dietary Guidelines for Americans* 2005, linked to related components of the HEI-2005, are listed in table 4. All of the key recommendations that relate to diet quality vis-à-vis food choices are reflected in HEI-2005 components. By design, the index does not cover the key recommendations regarding body weight, physical activity, and food safety.

Three of the 10 diets reported in NHANES 01-02 that had the biggest differences between original HEI and HEI-2005 total scores are found in appendix 2 along with their respondent identification number (SEQN), HEI-2005 and original HEI total scores, and total calories. The 10 diets were chosen to appraise face validity and evaluate any improvements in the new scoring system by noting the differences between the way the original HEI and HEI-2005 score the same diets. This analysis revealed that the HEI-2005 was better at rewarding whole grains, key vegetable subgroups, and whole fruit and that the density approach worked well as a control for total calories. When HEI-2005 scores were very high, the original HEI scores were also high; however, the reverse was not necessarily true. For example, SEQN 19634 received 100 points with the original HEI, but only 47 points with the HEI-2005. Because the diet relied heavily on white bread for Grains, juice and fruit juice drink for Fruit, and French fries for Vegetables, it lost points with the HEI-2005 for the Whole Grains, Whole Fruit, and Dark Green and Orange Vegetables and Legumes.

Table 4. Healthy Eating Index-2005 (HEI-2005) components mapped to Dietary Guidelines key recommendations

Dietary Guidelines key recommendation	HEI-2005 component	Comment
Adequate nutrients within calorie needs		
• Consume a variety of nutrient-dense foods and beverages within and among the basic food groups while choosing foods that limit the intake of saturated and *trans* fats, cholesterol, added sugars, salt, and alcohol.	Fruit Total Whole Vegetables Total Dark Green and Orange Vegetables and Legumes Grains Total Whole Milk Meat and Beans Oils Saturated Fat Sodium Calories from Solid Fat, Alcohol, and Added Sugars (SoFAAS)	The HEI-2005 assesses intake of Pyramid food groups and saturated fat directly. Solid fat, added sugars, and alcohol are represented in the Calories from Solid Fat, Alcohol, and Added Sugars (SoFAAS) component. *Trans* fats are reflected in solid fats; and, therefore, are also included in Calories from SoFAAS. Cholesterol is not included in the HEI-2005 *per se*. Salt is reflected in the Sodium component.
• Meet recommended intakes within energy needs by adopting a balanced eating pattern, such as the U.S. Department of Agriculture (USDA) Food Guide or the Dietary Approaches to Stop Hypertension (DASH) Eating Plan.	Fruit Vegetables Grains Milk Meat and Beans Oils Calories from SoFAAS	The HEI-2005 food group components and standards are based on the USDA Food Guide, now known as MyPyramid.
Weight management		
• To maintain body weight in a healthy range, balance calories from foods and beverages with calories expended. • To prevent gradual weight gain over time, make small decreases in food and beverage calories and increase physical activity.		The HEI-2005 does not measure energy intake because it assesses quality rather than quantity of the diet. Indicators of healthy body weight, such as body mass index and waist circumference, could be used in conjunction with the HEI-2005 and would provide a very good indicator of long-run energy balance.
Physical activity		
• Engage in regular physical activity and reduce sedentary activities to promote health, psychological well-being, and a healthy body weight. • Achieve physical fitness by including cardiovascular conditioning, stretching exercises for flexibility, and resistance exercises or calisthenics for muscle strength and endurance.		The HEI-2005 does not include physical activity. Measures of physical activity could be used in conjunction with the HEI-2005.
Food groups to encourage		
• Consume a sufficient amount of fruits and vegetables while staying within energy needs.	Total Fruit Total Vegetables	The HEI-2005 standards for fruits and vegetables are based on MyPyramid recommendations.
• Choose a variety of fruits and vegetables each day. In particular, select from all five vegetable subgroups (dark green, orange, legumes, starchy vegetables, and other vegetables) several times a week.	Fruit Total Whole Vegetables Total Dark Green, Orange, Legumes	Variety is specified. Whole fruit and particular subgroups of vegetables are emphasized because they tend to be lacking in diets.

Table 4. Healthy Eating Index-2005 (HEI-2005) components mapped to Dietary Guidelines key recommendations (cont.)

Dietary Guidelines key recommendation	HEI-2005 component	Comment
Food groups to encourage		
• Consume 3 or more ounce-equivalents of whole-grain products per day, with the remainder of the recommended grains coming from enriched or whole-grain products. In general, at least half of the grains should come from whole grains.	Grains Total Whole	The standard for Whole Grains is 1.5 ounce equivalents per 1000 calories, which is half the standard for Total Grains. The standard for Total Grains is 3 ounce equivalents per 1000 calories.
• Consume 3 cups per day of fat-free or low-fat milk or equivalent milk products.	Milk	The standard for Milk is 1.3 cup equivalents per 1000 calories. Higher fat Milk products result in lower scores for the Saturated Fat and Calories from SoFAAS components.
Fats		
• Consume less than 10 percent of calories from saturated fat, less than 300 mg/day of cholesterol, and keep *trans* fatty acid consumption as low as possible.	Saturated Fat Calories from SoFAAS	The standard for Saturated Fat is less than 10% of calories. *Trans* fatty acids are reflected in Solid Fats. Cholesterol is not included because limiting saturated fat is considered more important and because intakes of total fat and cholesterol are correlated with it.
• Keep total fat intake between 20 to 35 percent of calories with most fats coming from sources of poly- and mono-unsaturated fatty acids, such as fish, nuts, and vegetable oils.	Oils Saturated Fat Calories from SoFAAS	Total fat is not included because limiting saturated fat is considered more important and because intakes of total fat are correlated with it. Poly- and monounsaturated fat are reflected in the Oils component.
• When selecting and preparing meat, poultry, dry beans, milk or milk products, make choices that are lean, low-fat, or fat-free.	Saturated Fat Calories from SoFAAS	Excess fat from meat, poultry, and milk products is counted as Solid Fat and contributes to both the Saturated Fat and Calories from SoFAAS components.
• Limit intake of fats and oils high in saturated and/or *trans* fats and choose products low in such fats and oils.	Saturated Fat Calories from SoFAAS	Saturated Fat is a component. *Trans* fats are reflected in Solid Fats.
Salt, sodium, and potassium		
• Consume less than 2,300 mg (approximately 1 tsp of salt) of sodium per day.	Sodium	The standard for the relatively good score of 8 is 1100 mg per 1000 calories, which is approximately 2300 mg per 2150 calories, the basis of the UL set by the Food and Nutrition Board. The standard for the optimum score of 10 was based on the AI for sodium.
• Choose and prepare foods with little salt. At the same time, consume potassium-rich foods, such as fruits and vegetables.	Sodium Total Fruit Total Vegetables	MyPyramid recommendations for Fruit and Vegetables were set, in part, to meet the AIs for potassium.

Table 4. Healthy Eating Index-2005 (HEI-2005) components mapped to Dietary Guidelines key recommendations (cont.)

Dietary Guidelines key recommendation	HEI-2005 component	Comment
Alcoholic beverages		
• Those who choose to drink alcoholic beverages should do so sensibly and in moderation— defined as the consumption of up to one drink per day for women and up to two drinks per day for men.	Calories from SoFAAS	Alcohol is considered in the Calories from SoFAAS component; however, it is not limited to the amounts specified in the Dietary Guidelines.
• Alcoholic beverages should not be consumed by some individuals, including those who cannot restrict their alcohol intake, women of childbearing age who may become pregnant, pregnant and lactating women, children and adolescents, individuals taking medications that can interact with alcohol, and those with specific medical conditions.		Calories from alcohol are counted the same for everyone.
• Alcoholic beverages should be avoided by individuals engaging in activities that require attention, skill, or coordination, such as driving or operating machinery.		Activities at the time of alcohol consumption are not considered.
Food safety		
• To avoid microbial foodborne illness - Clean hands, contact surfaces, and fruits and vegetables. Meat and poultry should *not* be washed. - Separate raw, cooked and ready-to-eat foods while shopping, preparing, or storing foods. - Cook foods to a safe temperature to kill microorganisms. - Chill (refrigerate) perishable food promptly and defrost foods properly. - Avoid raw (unpasteurized) milk or any products made from unpasteurized milk, raw or partially cooked eggs or foods containing raw eggs, raw or undercooked meat and poultry, unpasteurized juices and raw sprouts.		The HEI-2005 does not address food safety.

Across all the NHANES diets that were selected for review, those with near-maximum HEI-2005 total and component scores were deemed to be consistent with the 2005 Dietary Guidelines; whereas, those with near-minimum scores were not. Mid-range scores reflected diets of varying quality; that is, they might have mid-range scores across all components or higher scores on some and lower on others with no discernible pattern of quality.

Construct Validity

The HEI-2005 scores for the four exemplary sets of menus—based on USDA's MyPyramid, NHLBI's DASH Eating Plan, Harvard's Healthy Eating Pyramid, and the AHA's No-Fad Diet—were very high, as shown in table 5. The scores for the menus based on MyPyramid and DASH were to be expected because the HEI scoring system is based on MyPyramid, and both of these systems are cited in the *Dietary Guidelines for Americans* 2005. The AHA menus scored similarly well. The Harvard menus scored full points for all the components except Milk; this too was expected because the Harvard food guide does not encourage the consumption of milk and milk products.

Table 5. Healthy Eating Index-2005 component and total scores for menus exemplifying USDA's MyPyramid, NHLBI's DASH Eating Plan, Harvard's Healthy Eating Pyramid, and American Heart Association's (AHA) No-Fad Diet

Component[1] (maximum score)	Food guide			
	MyPyramid[2]	DASH[2]	Harvard[3]	AHA[4]
Total Fruit (5)	5	5	5	5
Whole Fruit (5)	5	5	5	5
Total Vegetables (5)	5	5	5	5
Dark Green and Orange Vegetables and Legumes (5)	5	5	5	4.9
Total Grains (5)	5	4.8	5	5
Whole Grains[5] (5)	5	5	5	5
Milk (10)	10	10	0.9	8.7
Meat and Beans (10)	10	10	10	10
Oils (10)	10	10	10	10
Saturated Fat (10)	10	10	10	10
Sodium (10)	10	10	10	10
Calories from SoFAAS[6] (20)	20	20	20	20
Total HEI score (100)	100	99.8	90.9	98.6

[1]See Appendix 1: Foods Included in Components of the Healthy Eating Index-2005.
[2]Based on a 1-week sample menu.
[3]Based on two 1-week sample menus.
[4]Based on two 1-day sample menus.
[5]All grain products described as "whole" were assumed to be 100% whole grain.
[6]Solid Fat, Alcohol, and Added Sugar.

Differences in 1-day scores between smokers and non-smokers for both the HEI-2005 and the original HEI are shown in table 6. Nine of the 12 HEI-2005 component scores were significantly lower ($p<.01$) for the smokers, compared with the non-smokers; exceptions were Meat and Beans, Saturated Fat, and Sodium for which no differences were found. Smokers' mean total HEI-2005 score (44.7) was significantly lower than non-smokers' (53.3). With the original HEI, only 5 of the 10 individual component scores were significantly different. Smokers' mean total scores were also significantly lower than were non-smokers' but by a narrower range.

Table 6. Mean component and total 1-day scores and energy intakes for current smokers and non-smokers, using the original Healthy Eating Index (HEI) and the Healthy Eating Index-2005 (HEI-2005), adults age 20 years and older, United States, 2001-2002

Component	Smokers (n = 1022) Mean (SE[1])	Non-smokers (n = 3386) Mean (SE)
Original HEI		
Total Fruit	2.5 (0.2)	4.3 (0.1)*
Total Vegetables	5.7 (0.1)	6.4 (0.1)*
Total Grains	6.0 (0.1)	6.7 (0.1)*
Milk	4.9 (0.2)	5.6 (0.1)*
Meat (and beans)	6.9 (0.1)	7.0 (0.1)
Sodium	6.2 (0.2)	6.1 (0.1)
Saturated Fat	6.8 (0.1)	6.9 (0.1)
Total Fat	6.5 (0.1)	6.5 (0.1)
Cholesterol	7.4 (0.1)	7.5 (0.1)
Variety	6.6 (0.1)	7.8 (0.1)*
Total score	59.3 (0.4)	64.8 (0.4)*
HEI-2005[2]		
Total Fruit	1.4 (0.1)	2.4 (0.1)*
Whole Fruit	1.1 (0.1)	2.2 (0.1)*
Total Vegetables	2.7 (0.1)	3.1 (0.0)*
Dark Green and Orange Vegetables and Legumes	0.9 (0.1)	1.3 (0.1)*
Total Grains	3.9 (0.1)	4.3 (0.0)*
Whole Grains	0.6 (0.0)	1.1 (0.0)*
Milk	4.1 (0.2)	4.9 (0.1)*
Meat and Beans	7.8 (0.1)	8.2 (0.1)
Oils	5.1 (0.1)	5.6 (0.1)*
Saturated Fat	6.1 (0.1)	6.1 (0.1)
Sodium	4.9 (0.1)	4.2 (0.1)
Calories from SoFAAS[3]	5.9 (0.4)	9.7 (0.2)*
Total score	44.7 (0.6)	53.3 (0.4)*
Energy (kcal)	2351(49)	2171(25)*

*p<.01.
[1]Standard error.
[2]See Appendix 1: Foods Included in Components of the Healthy Eating Index-2005.
[3]Solid Fat, Alcohol, and Added Sugar.
Note: Excludes pregnant and lactating women.
Source: National Health and Nutrition Examination Survey, 2001-2002.

The correlations between each of the HEI component scores and energy intake are found in tables 7A and 7B. As might be expected, among the HEI-2005 components, Calories from SoFAAS score has the highest correlation with energy, -.22. All other components had correlations with an absolute value of .11 or less. The component scores for the original HEI were more highly correlated with energy; the component scores with the highest negative correlations were the Sodium scores (-.69) and the Cholesterol scores (-.43). Those with the highest positive correlations were the Grains (.44), Meat (.41), and Variety (.39) scores.

The range of 1-day scores for the population in 2001-2002 for each component score and the total score for both the HEI-2005 and the original HEI are shown in table 8. The range of scores of the new food-group components, Whole Fruit, Dark Green and Orange Vegetables and Legumes, and Whole Grains, was limited by the fact that large proportions of the population had no intake of any of those foods on a given day. The distributions of the Saturated Fat and Sodium scores are wider in the HEI-2005 than in the original by design, while the distributions of the food-group scores are about the same.

Table 7A. Correlations of 1-day Healthy Eating Index-2005 (HEI-2005) component and total scores and energy intake, United States, 2001-2002

Component[1]	Total Fruit	Whole Fruit	Total Vegetables	Dark Green and Orange Vegetables and Legumes	Total Grains	Whole Grains	Milk	Meat and Beans	Oils	Saturated Fat	Sodium	Calories from SoFAAS[2]	Total score[3]	Energy
Total Fruit	1													
Whole Fruit	0.73	1												
Total Vegetables	0.06	0.09	1											
Dark Green and Orange Vegetables and Legumes	0.12	0.13	0.45	1										
Total Grains	0.04	0.06	-0.09	-0.05	1									
Whole Grains	0.15	0.18	0.00	0.07	0.24	1								
Milk	0.06	0.08	-0.10	-0.07	0.10	0.10	1							
Meat and Beans	-0.03	0.00	0.14	0.16	-0.11	-0.06	-0.24	1						
Oils	-0.04	0.00	0.14	0.05	0.03	0.05	-0.11	0.12	1					
Saturated Fat	0.19	0.14	0.06	0.10	0.08	0.11	-0.34	-0.04	-0.03	1				
Sodium	0.06	0.02	-0.27	-0.13	-0.23	-0.02	-0.04	-0.19	-0.08	0.11	1			
Calories from SoFAAS[2]	0.37	0.33	0.30	0.24	0.23	0.27	0.04	0.21	0.28	0.22	-0.28	1		
Total score[3]	0.43	0.45	0.18	0.26	0.07	0.26	-0.12	-0.01	0.10	0.14	-0.22	0.57	1	
Energy	-0.10	-0.09	-0.05	-0.05	-0.06	-0.10	0.00	0.08	0.06	-0.11	0.08	-0.22	-0.14	1

[1]See Appendix 1: Foods Included in Components of the Healthy Eating Index-2005.
[2]Solid Fat, Alcohol, and Added Sugar.
[3]Total HEI-2005 score minus specified component.
Note: Excludes children under age 2 years, breast-fed children, and pregnant and lactating women.
Source: National Health and Nutrition Examination Survey, 2001-2002.

Table 7B. Correlations of 1-day original Healthy Eating Index (HEI) component and total scores and energy intake, United States, 2001-2002

Component	Fruit	Vegetables	Grains	Milk	Meat (and beans)	Sodium	Saturated Fat	Total Fat	Cholesterol	Variety	Total score[1]	Energy
Fruit	1											
Vegetables	0.08	1										
Grains	0.11	0.09	1									
Milk	0.11	0.04	0.27	1								
Meat (and beans)	0.01	0.27	0.11	-0.02	1							
Sodium	0.02	-0.33	-0.45	-0.24	-0.43	1						
Saturated Fat	0.17	0.02	0.04	-0.32	-0.06	0.12	1					
Total Fat	0.19	-0.11	0.05	-0.04	-0.20	0.15	0.65	1				
Cholesterol	0.02	-0.15	-0.08	-0.09	-0.41	0.38	0.22	0.24	1			
Variety	0.38	0.47	0.36	0.35	0.38	-0.41	-0.02	-0.02	-0.22	1		
Total score[1]	0.34	0.11	0.15	0.02	-0.10	-0.31	0.24	0.28	-0.02	0.40	1	
Energy	0.05	0.29	0.44	0.30	0.41	-0.69	-0.09	-0.08	-0.43	0.39	0.09	1

[1]Total HEI score minus specified component.

Note: Excludes children under age 2 years, breast-fed children, and pregnant and lactating women.

Source: National Health and Nutrition Examination Survey, 2001-2002.

Table 8. Means and distributions of 1-day original Healthy Eating Index (HEI) and Healthy Eating Index-2005 (HEI-2005) component and total scores, United States, 2001-2002

Component[1]	Mean	Percentiles								
		10th	20th	30th	40th	50th	60th	70th	80th	90th
Fruit										
Original HEI	3.9	0.0	0.0	0.1	0.9	2.9	4.5	6.5	9.4	10.0
HEI-2005										
Total Fruit	2.2	0.0	0.0	0.1	0.6	1.7	2.9	4.3	5.0	5.0
Whole Fruit[2]	1.9	0.0	0.0	0.0	0.0	0.2	1.7	4.2	5.0	5.0
Vegetables										
Original HEI	5.9	0.6	2.1	3.4	4.7	6.1	7.8	9.7	10.0	10.0
HEI-2005										
Total Vegetables	2.8	0.4	1.1	1.6	2.2	2.7	3.4	4.2	5.0	5.0
Dark Green and Orange Vegetables and Legumes[2]	1.0	0.0	0.0	0.0	0.0	0.0	0.1	0.9	2.3	4.8
Grains										
Original HEI	6.7	2.8	4.1	5.1	6.0	6.8	7.9	9.0	10.0	10.0
HEI-2005										
Total Grains	4.3	2.6	3.5	4.1	4.7	5.0	5.0	5.0	5.0	5.0
Whole Grains[2]	1.0	0.0	0.0	0.0	0.0	0.1	0.6	1.2	1.9	3.2
Milk										
Original HEI	5.7	0.2	1.5	2.9	4.4	6.0	7.6	9.9	10.0	10.0
HEI-2005	5.3	0.2	1.4	2.6	3.9	5.1	6.4	8.1	10.0	10.0
Meat and Beans										
Original HEI	6.7	1.7	3.4	4.7	6.0	7.2	8.8	10.0	10.0	10.0
HEI-2005	7.7	2.7	4.9	6.6	8.0	9.6	10.0	10.0	10.0	10.0
Oils[2]										
HEI-2005	5.4	0.5	1.5	2.8	3.9	5.2	6.6	8.3	10.0	10.0
Saturated Fat										
Original HEI	6.7	0.0	2.3	4.8	6.8	8.6	10.0	10.0	10.0	10.0
HEI-2005	6.0	0.0	1.9	3.8	5.4	6.9	8.2	8.8	9.6	10.0
Sodium										
Original HEI	6.3	0.0	1.3	3.9	5.9	7.6	9.2	10.0	10.0	10.0
HEI-2005	4.5	0.0	0.8	2.3	3.5	4.6	5.6	6.6	7.7	8.7
Calories from SoFAAS[2,3]										
HEI-2005	8.5	0.0	0.8	3.5	5.8	8.1	10.0	12.4	15.2	19.1
Total Fat[4]										
Original HEI	6.7	0.2	3.0	4.9	6.5	7.9	9.4	10.0	10.0	10.0
Cholesterol[4]										
Original HEI	7.7	0.0	3.1	9.3	10.0	10.0	10.0	10.0	10.0	10.0
Variety[4]										
Original HEI	7.4	2.0	4.0	6.0	8.0	8.0	10.0	10.0	10.0	10.0
Total score										
Original HEI	63.8	46.7	52.3	56.6	60.5	64.1	67.7	71.5	75.5	80.6
HEI-2005	50.4	33.3	37.9	41.7	45.7	49.3	53.4	57.9	62.6	69.3

[1]See Appendix 1: Foods Included in Components of the Healthy Eating Index-2005.
[2]Does not appear in original HEI.
[3]Solid Fat, Alcohol, and Added Sugar.
[4]Does not appear in HEI-2005.
Note: Excludes children under age 2 years, breast-fed children, and pregnant and lactating women.
Source: National Health and Nutrition Examination Survey, 2001-2002.

The scree plot from the PCA revealed that multiple factors underlie the HEI-2005 (fig. 4). The plot shows the amount of variance contributed by each of the principal components or factors. The optimal number of factors is determined by looking for places where the curve formed by connecting the dots starts to form a flat, horizontal line. In figure 4, we observe that the line appears to plateau between five and eight factors. Additionally, other rules for determining the number of factors, such as eigenvalue greater than 1, indicate at least five factors exist. Either way, the PCA provides evidence that no one single linear combination of the components of the HEI-2005 accounts for a significant proportion of the covariation in dietary patterns observed in the NHANES 01-02 data. The weights on the first principal component have a structure similar to that of the correlations of the components with the total score, a common finding in PCA (data not shown).

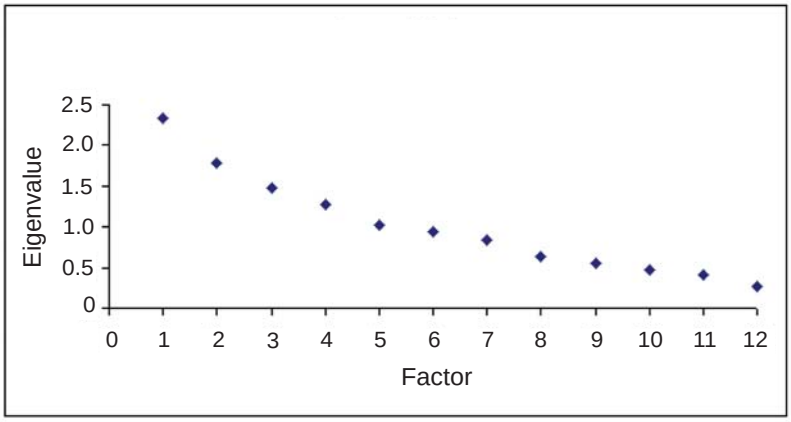

Figure 4. Scree plot from principal component analysis of the Healthy Eating Index-2005 showing the amount of variance accounted for by each successively extracted factor

Reliability

Table 7A shows the relationships among the HEI-2005 components. For the most part, the correlations are quite low. The subgroups of grains, vegetables, and fruit varied in the degree with which they correlated with their respective total group, ranging from .24 for Whole Grains with Total Grains to .73 for Whole Fruit with Total Fruit. Calories from SoFAAS is moderately correlated with all of the adequacy components (.21 to .37), except for the lower correlation with Milk (.03).

The correlations among the original HEI components are shown in Table 7B. The highest correlation among the components is .65 for Saturated Fat with Total Fat, followed by -.43 and -.41 for Meat with Sodium and Cholesterol, respectively. Variety is moderately correlated with all the adequacy components (.35 to .47).

For the HEI-2005, the Cronbach's coefficient alpha is .43. The component scores most highly correlated with the total score are Calories from SoFAAS (.57) and the fruit components (.43 and .45) (table 7A). Three of the component scores have low negative correlations with the total score, Sodium (-.22), Milk (-.12), and Meat and Beans (-0.01). The correlations for the other components range from .07 to .26.

For the original HEI, coefficient alpha is .28. The component scores with the highest positive correlation with the total score are Variety (.40) and Fruit (.34). Three component scores are negatively correlated with the total score, Sodium (-.31), Meat (-.10), and Cholesterol (-.02) (table 7B). The correlations for the other components range from .02 to .28.

Discussion of Psychometric Properties

The psychometric analyses of the HEI-2005 demonstrated that it has content and construct validity. The PCA and reliability analysis confirmed the multidimensional nature of diet quality.

Content Validity

Content validity was supported through a careful review that ensured that the components of the HEI-2005 reflect the key recommendations found in the *Dietary Guidelines for Americans 2005* (table 4). The review of the original HEI scores and the HEI-2005 scores for sample 1-day diets from NHANES 01-02 (appendix 2) for face validity yielded two major conclusions: (1) the HEI-2005 reflects diet quality as defined in the 2005 Dietary Guidelines and (2) any total score other than the very highest and the very lowest can indicate a great number of dietary patterns, that is, diets that are better or worse in terms of the various key components of diet quality measured. A few of the selected 1-day diets from NHANES 01-02 are found in appendix 2.

Construct Validity

The analyses of exemplary menus demonstrate that the HEI-2005 captures the theoretical construct of a high-quality diet (table 5). As expected, the MyPyramid and DASH menus received perfect or near perfect scores.

The Harvard menu intentionally is very low in milk products; the guide recommends the use of calcium supplements instead (Willett, 2005). The menu achieves perfect scores for all other components because so many other aspects of the Harvard guide are consistent with the Dietary Guidelines. The Milk component score captured the one major difference.

The exemplary menus were not scored according to the original HEI. However, the expectation is that they would have also scored very high because all the menus were moderate in calories, nutritionally adequate, low in saturated fat and sodium, and comprised of a variety of foods. The nature of the differences between the original HEI and the HEI-2005 can be appreciated by considering how the same menus would have scored if the calories had been doubled for each. If the doubling in energy would occur by doubling the amounts of all foods, the HEI-2005 would score exactly the same on all menus because the densities would be the same; whereas, the original scores would have increased (but only slightly because they would already have been very high) for the DASH, Harvard, and AHA menus. If the doubling in energy would occur by the addition of only calories from SoFAAS—making them more similar to typical American diets—then the HEI-2005 scores would drop precipitously while the original scores would remain unchanged.

The HEI-2005 was able to detect significant differences in the quality of 1-day diets of smokers and non-smokers, demonstrating concurrent criterion-related validity (table 6). Compared with the original HEI, the HEI-2005 had greater differences in scores.

The HEI-2005 has succeeded in uncoupling diet quality and diet quantity. The total and component scores have low correlations with energy intake (table 7A). For the original HEI, the component correlations were higher (table 7B). The original total HEI score had a low correlation with energy because the adequacy components were positively correlated with energy and the moderation components were negatively correlated with it.

The ability to detect meaningful changes over time or differences among groups at one point in time in the score is especially important when scores are truncated as they are in the HEI. Truncated scores may result in undesirable floor and ceiling effects. Floor effects can occur when scores bunch at the low (0) end of the scale, and ceiling effects can occur when they bunch at the high end (5, 10, or 20, depending on the component). We addressed this point in two ways. First, we set the minimum score of

zero for Saturated Fat, Sodium and Calories from SoFAAS—several components for which intakes tend to be at odds with recommendations—at about the 85th percentile of the intake distribution. We designed the scores so that a large proportion of the population would not get a zero because we want the low end of the scoring range to be able to detect change. Second, because the range of scores applied to each component is relatively large, each 1-point change or difference is indicative of a small change in intake. In a 2,000-calorie diet, for example, a 1-point change in a component score would reflect approximately 0.3 cup equivalents of Total Fruit, 0.2 cups of Whole Fruit, 0.4 cup equivalents of Total Vegetables, 0.2 cup equivalents of Dark Green and Orange Vegetables and Legumes, 1.2 ounce equivalents of Total Grains, 0.6 ounce equivalents of Whole Grains, 0.5 lean ounce equivalents of Meat and Beans, 2 g of Oil, 0.3 cup equivalents of Milk, 225 mg of Sodium, 1.4 g of Saturated Fat, or 30 Calories from Solid Fat, Alcohol, and Added Sugar if the scores were independent of each other. The ability of the HEI to detect changes and differences is determined not only by the scoring system, but also by the study sample size, the precision of the dietary assessment instrument, and the ability of the coding system to capture the dietary components of interest.

The choice of the least restrictive of the various MyPyramid food intake recommendations as the basis for the density standards led to the scores being more specific in identifying intakes that do not meet recommendations. The trade-off is that the scores are slightly less sensitive in this regard; in other words, scores are higher than they might be otherwise. Nonetheless, except for Total Grains and Meat and Beans (table 8), very high component and total scores are quite rare. This suggests that, as a practical matter, choosing the least restrictive standard did not limit the range of scores appreciably.

The distribution of the HEI-2005 total scores was in fact slightly wider than that of the original HEI (table 8). For Saturated Fat and Sodium, the ceiling effects caused by many maximum-value scores with the original HEI were mitigated by making the standards more stringent. On the other hand, the ceiling effects were increased for Total Grains and Meat and Beans because fewer diets get more points when higher amounts of these food groups are eaten when scored using the HEI-2005 than when using the original HEI. The new components for Whole Fruit, Dark Green and Orange Vegetables and Legumes, and Whole Grains introduced floor effects caused by many scores of zero. While this limited the distributions of scores, it affords a good opportunity to detect improvement should it occur.

If the HEI were to be used with dietary data that represent observation periods longer than 1-day, such as might be collected with multi-day food records or a food frequency questionnaire, the floor and ceiling effects would be mitigated. More days of intake data or estimates of usual intake would reduce within-person variance and result in fewer component scores at the minimum and maximum levels. However, the greater accuracy and precision of 24-hour recall data compared to, for example, what can be expected from a food frequency questionnaire, may well be of greater value than any concomitant loss of precision that may be attributable to a floor or ceiling effect in the distribution of the scores.

Reliability

Test-retest and inter-rater reliability. The most widely recognized form of reliability is test-retest reliability, which determines whether an index can be expected to yield the same score, time after time, in identical situations. We did not evaluate this type of reliability because the HEI, by definition, will be identical for identical diets that are recalled, recorded, and coded the same way. That is, all sources of test-retest measurement error can be attributed to respondent recall or data collection and processing. Inter-rater reliability is not an issue with the HEI because no judgment is required for scoring. We therefore expect these two types of reliability to be perfect.

Internal consistency, the third type of reliability, addresses the question of whether the HEI-2005 component scores all measure the same underlying, unidimensional, latent construct. Given that we know that diet quality, as specified in the Dietary Guidelines, is multidimensional, as demonstrated by the principal components analysis and the correlation matrix (table 7A), we neither expected nor desired internal consistency. The coefficient alpha, a statistic that measures internal consistency, was moderate (.43) as expected because the components measure different, independent aspects of diet. This result suggests that the index does not measure a strong, systematic underlying relationship among all the components. A commonly accepted criterion for the use of an index for group comparisons is a reliability of .70 or higher (Scientific Advisory Committee of the Medical Outcomes Trust, 2002); therefore, especially when the HEI scores of groups are compared, more information and insight regarding differences in diet quality can be gained by examining the component scores in addition to the total scores. In keeping with its mandate, CNPP monitors the U.S. diet with a total HEI score; CNPP also monitors the individual component scores (Basiotis et al., 2002).

Correlations between components and the total score indicate how much variance each component contributes to the total score. Thus, variation in the total score is more reflective of the variation observed in those components that have higher correlations with the total score. For example, if the Total Fruit score had been highly correlated with the total HEI-2005 score, then one could have been comfortable in saying that people with high total HEI-2005 scores are likely to be meeting the standard for fruit consumption. On the other hand, a component with zero correlation with the total score indicates independence, that is, whether a group's total score is high or low is unrelated to its score on the component. For example, because the Total Grain component score has a very low correlation (.07) with the total HEI-2005 score, one group of people could be high on the total score and another group could be low on the total score, but the total score conveys no information regarding whether the groups met the standard for total grain consumption since there is no association between the Total Grain score and the total HEI-2005 score. Thus, the component score provides information about a person's diet regarding grains independent of what the total score is telling us.

The correlations of the component scores with the total score were generally quite low for both the original HEI and the HEI-2005. They indicated that the Calories from SoFAAS and the two Fruit components are the ones that have the most influence on the total HEI-2005 score; that is, more than any other component, they determine whether a total HEI score is high or low. For the original HEI, the scores were driven by Variety, Fruit, and Sodium. For both versions, Fruit was most highly correlated with the total score. The components having correlations with the total score that are less than .4 may not be adding much information to the total score, but rather provide important, independent information.

As expected, most component scores had a positive correlation with the total HEI-2005 score. Sodium and Milk scores, however, had low, negative correlations with the total score (-.23 and -.13, respectively). For Sodium, this reflects the fact that sodium is widely distributed in foods, both naturally occurring and added in processing and preparation of many foods. The higher the Grains and Vegetable component scores are, and to a less degree, the higher the Milk and Meat and Beans scores are, the higher sodium intake is and, therefore, the lower the Sodium component score is. The negative correlation of the Milk and Saturated Fat component scores (-.34) appears to be the main reason why the Milk component is negatively correlated with total HEI score. The low, negative correlation between Milk and the total score (-.13) reflects the fact that most milk products currently consumed have saturated fat (e.g., whole milk and ice cream) and/or are high in sodium (e.g., cheese) (Britten, Marcoe, Juan, Guenther, & Carlson, 2007).

Using a Set of Component Scores Versus a Total Score

By definition, an index is a single number derived from a series of observations and used as an indicator or measure. For example, the SAT score is a number used to predict academic success. It has three components: verbal, mathematical, and writing. Both the total score and the component scores are considered by college admissions officers. The Consumer Price Index (CPI) is a measure of a weighted average of prices of a specified set of goods and services purchased by consumers. As economists monitor the CPI, they

also monitor the various market sectors. The CPI could appear to have a flat overall index trend, but that could be hiding the fact, for example, that energy costs had gone down a few percentage points and other costs, such as housing and medical care, had gone up a few points.

Just as the SAT reflects several aspects of academic achievement and the CPI reflects a market basket of prices, the HEI-2005 was designed to reflect multiple aspects of diet quality. As with the other indexes, a lack of difference in the total HEI score over time, among groups or among individuals, can mask important differences among the components. Therefore, the rating (such as good, fair, or poor) or grading (such as A, B, C, or D) of diet quality based solely on the total HEI-2005 score is not recommended. Nonetheless, there are situations where the total score can be instructive. It provides a summary assessment across the components and can be used, in much the same way as the other indexes have been. Specifically, the total score is useful in distinguishing very high scoring diets from very low scoring diets, as in epidemiological dietary pattern analyses that model disease risk among those in the highest quintile compared to those in the lowest quintile of diet quality.

Using Labels to Describe Diets With Varying Scores

The fact that mid-range total scores can indicate a range of diet quality across the various components suggests that ratings (such as good, fair, or poor) or grades (such as A, B, C, or D) to describe the mid-ranges would be equally difficult to interpret. A “fair” overall assessment could mean “fair” on all components or “outstanding” on some and “poor” on others. Therefore, the rating or grading of diets according to total HEI score is not recommended.

Ratings or grades applied to individual components may be less troublesome because they would each correspond to a single scale for the respective component. Nonetheless, such attempts to simplify scores generally would result in a loss of information. The scores as numbers supply the most information when used as is and are considered to be relative indicators of diet quality.

Future Research

Possibilities for further research include additional validity testing and adaptations of the index for specific subpopulations. Further validation of the HEI-2005 is planned. To compare the ability of the original HEI and the HEI-2005 to detect changes over time, an aspect of construct validity, we will examine the changes in the population mean values of the total HEI-2005 score and the 12 component scores between 1994-96 and 2003-2004, when the necessary data become available.

Another type of validity that has not been assessed is predictive criterion validity, the ability to distinguish between groups at a future point in time. This could be tested by using the HEI-2005 with one of the NHANES datasets that has some health outcome or mortality information in a follow-up survey or with other longitudinal studies. We encourage others to further validate the HEI-2005 and to compare its efficacy to other indexes of diet quality that have been developed. This type of research could add to the evidence base for future Dietary Guidelines for Americans.

A more evidence-based weighting scheme could be developed through analyses that use HEI-2005 components as predictors of disease outcomes, such as cancer, osteoporosis, or age-related macular degeneration. The weighting scheme could also be varied according to the desired use or target population.

Discussion of the HEI-2005

Strengths of the HEI-2005

The four major strengths of the HEI-2005 are (1) it captures the key recommendations regarding diet quality found in the 2005 Dietary Guidelines for Americans, (2) it assesses diets on a per 1,000 calorie basis in order to characterize diet quality while controlling for diet quantity, (3) it addresses the consumption of energy-dense, nutrient-poor foods and ingredients, and (4) it emphasizes those aspects of the American diet that are furthest from current recommendations: whole fruit, dark green vegetables, orange vegetables, legumes, whole grains, sodium, and discretionary calories (HHS & USDA, 2005).

The reliance on food-group rather than nutrient standards reflects a basic premise of the *Dietary Guidelines* which is that nutrient needs should be met primarily through consuming foods because foods provide an array of nutrients as well as phytochemicals, antioxidants, and other compounds that may have beneficial health effects (HHS & USDA, 2005). The HEI-2005 also is consistent with the assertion that the Dietary Guidelines are inter-related and mutually dependent and should be used together.

The density standards uncouple diet quality from diet quantity. The HEI-2005, accordingly, assesses the mix of foods eaten, and the effects of day-to-day variability in amounts of food eaten are mitigated to some degree. Furthermore, if one assumes that all food groups are equally underreported, then the effects of underreporting are also mitigated; however, the extent to which this is true is unknown.

Another advantage of the density standards is that they eliminate the need to determine an individual's appropriate energy intake level. Determining these levels requires estimating individual physical activity levels (IOM, Food and Nutrition Board, 2005); however, it is not yet possible to estimate energy expenditure with accuracy in large-scale surveys. Even with objective data from accelerometers, there is no easy algorithm for calculating energy expenditure.

The new Calories from SoFAAS component reflects an important element of diet quality that was missing from the original HEI. It captures the consumption of energy-dense, nutrient-poor foods and ingredients that create dietary imbalance. Not only are these solid fats, alcoholic beverages, and added sugars displacing more nutritious foods, they may be contributing to excess energy intake as well. Our findings suggest that energy intake is positively related to the intake of SoFAAS. Although the HEI-2005 was designed to assess what is eaten versus how much is eaten, that is, quality versus quantity, it also captures this important aspect of over-consumption. The HEI-2005 can be used together with body mass index (BMI) or waist circumference, measures of long-term energy balance, to study the effects of diet quality and quantity together.

Limitations of the HEI-2005

One limitation of the HEI-2005 stems from a limitation of MyPyramid, which is that it does not apply to children under 2 years of age. The validity of the HEI-2005 for ethnic and cultural groups whose dietary patterns are markedly different from the American norm, for example Alaska Natives, remains to be determined (Bersamin, Luick, Ruppert, Stern, & Zidenberg-Cherr, 2006). Because the food patterns in MyPyramid did not meet Recommended Dietary Allowances (RDAs) for vitamin E or AIs for potassium, a perfect score on the HEI may not ensure adequate intake of these nutrients to the same degree it does other nutrients. When the HEI is used in education, good sources of these nutrients could be emphasized as they were in the 2005 *Dietary Guidelines for Americans* report. Furthermore, the HEI-2005 does not measure compliance with MyPyramid precisely.

The recommendations in MyPyramid were set to meet the RDAs and AIs established by the Food and Nutrition Board of the IOM. The RDAs are appropriate standards for MyPyramid because the patterns provide plans for individuals to follow to ensure nutrient adequacy (IOM, Food and Nutrition Board, 2000). However, the RDAs are too high for assessment purposes, and standards analogous to the Estimated Average Requirements (EARs) would be more appropriate for use in the HEI. We cannot, however, set food-group-based standards that would provide average nutrient requirements until EARs are available for all nutrients of interest. Lacking EAR-based standards, we set the standards at the lowest level among the MyPyramid recommendations for sedentary individuals.

The density standards used in the HEI-2005 have limitations. The Meat and Beans and the Milk recommendations in MyPyramid, when expressed per 1,000 calories, vary more than the other food groups. Iron and calcium requirements are much higher for some age-gender groups who have relatively low energy requirements; therefore, iron and calcium requirements are generally inversely correlated with energy requirements. The discretionary calorie allowances also vary more than the food-group recommendations because energy and nutrient requirements are not well correlated. For example, the lowest discretionary calorie allowance is found in the 1,600-calorie MyPyramid pattern and reflects the low energy but high nutrient needs of women. In contrast, the highest allowance, found at 3,200 calories, reflects the high energy needs and in comparison to their energy needs, the relatively lower nutrient requirements of active teenage boys. In short, the density standards do not capture the variability among age-gender groups in iron and calcium requirements (as reflected in the Meat and Beans and Milk recommendations, respectively) nor in the discretionary calorie allowances as well as they capture the variability of the other food-group recommendations.

The HEI-2005 is limited because it does not directly capture excess intake of the major food groups or oils. For example, since the mean intakes of refined grains and meat are above recommended levels for at least some age-gender groups (HHS & USDA, 2005), it can be concluded that they are contributing discretionary calories to some people’s diets.

The HEI-2005 does not address total fat, *trans* fats, or cholesterol directly, although they are mentioned in the 2005 Dietary Guidelines (table 4). To reflect the 2005 Dietary Guidelines, the HEI-2005 has one component for Saturated Fat and one for Oils from fish, nuts, and vegetable oils. The fat-related key recommendations found in the Guidelines can be summarized as follows: (1) limit total fat, saturated fat, cholesterol, and *trans* fat and (2) emphasize sources of polyunsaturated and monounsaturated fat, such as vegetable oils, fish, and nuts. Although several different types of fat are mentioned, limiting saturated fat is considered the most important because current intake of saturated fat is more excessive than that of *trans* fat or cholesterol (HHS & USDA, 2005). Separate components for total fat and cholesterol are not needed in the HEI-2005 because intakes of both are significantly correlated with saturated fat (.92 and .59, respectively). The HEI-2005 also captures solid fats, which include hydrogenated vegetable oils. Solid fats are important sources of both *trans* fatty acids and cholesterol. It would be very difficult to monitor intake of *trans* fats because the food industry is working to reduce their levels in the U.S. food supply (Hunter, 2005). The HEI does capture the important sources of polyunsaturated and monounsaturated fats in the Oils component.

The HEI-2005 was not designed to capture weight management, physical activity, or food safety. Although these are included in the 2005 Dietary Guidelines, the HEI does not address them because it was developed to be a measure of the nutritional quality of the diet *per se*. It is, after all, a healthy *eating* index.

Differences Between the HEI-2005 and the Original HEI

The HEI-2005 differs from the original in several ways: assessing the quality of the diet on a density basis and introducing new components for Oils, for Calories from SoFAAS, and three subgroups of foods—whole fruit, dark green and orange vegetables and legumes, and whole grains. Like the 2005 Dietary Guidelines and MyPyramid, the HEI-2005 recognizes that some fats are more desirable than others. Oils are recommended in MyPyramid, hence are included in the HEI-2005 because they are excellent sources of essential fatty acids and vitamin E, which is in short supply in the diets of Americans (Moshfegh, Goldman, & Cleveland, 2005). It is also more specific in its assessment of dietary variety.

Just as the Dietary Guidelines have evolved to specify the types of variety that are most advantageous, the HEI has become more specific. Variety is no longer a separate component. Rather, new components were constructed to capture the types of variety believed to be most beneficial. An optimal score on all components requires balanced intake across all the food groups and sufficient consumption of specific types of vegetables that are generally consumed in less-than-recommend amounts. Optimum scores also preclude reliance on refined grains rather than whole grains and fruit juices rather than whole fruit.

While original HEI population scores had included pregnant and lactating women, the scores for 1994-96 and 1999-2000 excluded them “because of their special dietary needs.” Pregnant and breastfeeding women are now included once again because MyPyramid dietary patterns were evaluated recently by CNPP and found to meet their nutritional needs.

Differences Between the HEI-2005 and Other Indexes

In addition to the HEI, several other diet quality measures have been developed. These index-based tools all use a similar approach, adding the scores of multiple components (nutrients and/or foods) to create a total score to reflect a level of diet quality based on predefined dietary standards.

The earliest dietary scoring systems, for example, the Mean Adequacy Ratio and the Index of Nutritional Quality, used only nutrients (Guthrie & Scheer, 1981; Sorenson, Wyse, Wittwer, & Hansen, 1976). The Diet Quality Index (Patterson, Haines, & Popkin, 1994) was the first attempt at a more comprehensive assessment of diet quality, including foods as well as nutrients. The revised Diet Quality Index (DQI-R) (Haines, Siega-Riz, & Popkin, 1999) and the original HEI have been modified for use with different populations, including pregnant women (Bodnar & Siega-Riz, 2002), children and adolescents (Feskanich, Rockett, & Colditz, 2004; Kranz, Hartman, Siega-Riz, & Herring, 2006), and people living in China (Kim, Haines, Siega-Riz, & Popkin, 2003). The Alternate Healthy Eating Index (AHEI) (McCullough et al., 2002) and the Mediterranean Diet Score (Trichopoulou, Costacou, Bamia, & Trichopoulos, 2003) were developed based on other food guidance systems, Harvard’s Healthy Eating Pyramid and the Mediterranean diet, respectively. More recently, a Dietary Guidelines for Americans Adherence Index was published (Fogli-Cawley et al., 2006). The HEI-2005 differs from all of these indexes in the use of a density approach and the choice of components. Those unique to the HEI-2005 are discretionary, non-nutrient-dense sources of energy (Calories from SoFAAS), oils, and whole fruit.

Applications and Conclusions

Using the HEI-2005 to Assess Diets of Groups and Individuals

Original HEI scoring system. The methodology used with the original HEI for assessing diets of the U.S. population and sub-populations calculated HEI scores first for each individual's 1-day diet as reported in the national dietary surveys. Using the Total Grains component as an example component, an individual's score was computed as follows:

$$TG_{individual} \rightarrow \text{Assign Score}_{individual}$$

where TG = Total Grain Intake for the Day.

The component scores were then summed to get the individual's total HEI score for the day. The 1-day component and total scores were averaged to get the population component and total scores. Thus, the population total HEI scores were the average 1-day HEI scores.

Development of the HEI-2005 scoring system for groups. It is preferable, however, to calculate HEI scores based on a population's *usual* intake, estimated from 1-day intake data, in line with the IOM's emphasis on assessing usual diets. Both the IOM and the *Dietary Guidelines for Americans 2005* point out that recommendations are to be met over the long term (IOM, Food and Nutrition Board, 2000; HHS & USDA, 2005). Thus, assessments should not be based on only 1 day, but rather should be based on *usual*, or long-term, intake. When only 1 day of data is available, as is the case in NHANES 01-02, the usual intake of an individual cannot be estimated because of large day-to-day variation in dietary intake; however, the mean usual intake of a group of individuals can be estimated if the individual days reported, provided that all seasons of the year and all days of the week are represented in the sample.

Because the HEI-2005 scores are based on ratios, the scores may be calculated several ways. A simulation study of three potential methods for calculating HEI-2005 component scores was conducted to determine which one would be the best to use (data not shown). The methods investigated were: (1) HEI-2005 scoring system applied to each individual's 1-day intake and the mean score calculated (i.e., the method used with the original HEI); (2) scoring system applied to the mean of the individuals' 1-day ratios of food group (or nutrient) intake to energy intake; and (3) scoring system applied to the ratio of the population's mean food group (or nutrient) intake to the population's mean energy intake. We refer to the first method as the "mean score," the second method as the "score of the mean ratio," and the third method as the "score of the population ratio." The conclusion reached was that the score of the population ratio should be used if the individual days cover all days of the week and seasons of the year.

Applying the HEI-2005 scoring system for groups. Continuing with total grains as the example, when making estimates for the total population or comparisons among subpopulations, the average score for each HEI component will be computed as follows:

$$\frac{\Sigma\,(TG)_{individual}}{\Sigma\,(E)_{individual}} \rightarrow \text{Assign Score}_{population}$$

where TG = Total Grain Intake for an individual
E = Energy Intake for an individual

Thus, the scoring system is applied at the population level, not at the individual level. The total HEI score for the population is the sum of the population component scores. This method will result in a more accurate reflection of the differences in diet quality between groups or by the same group over time.

Applying the HEI-2005 scoring system to diets of individuals. When individual-level scores are needed, several days of intake data should be used to calculate the HEI-2005 because day-to-day variation in dietary intake is large for most people. When calculating HEI-2005 scores for use with individuals, we recommend that the component scores be calculated by dividing the total food-group or nutrient intake over several days by the total energy intake over those same days. The scoring system should then be applied to this ratio. This is the method used for the exemplary menu analysis, described on page 11, where multiple days of dietary information were available. Users of such scores should be cautioned that the scores apply only to the days reported and not necessarily to the longer term diet. Note, however, that the data analyses presented in this report, except for the menu analysis, were conducted using 1-day individual-level scores because we were interested in looking at the spread of scores and relationship among components. Individual-level data were necessary for those purposes, and only 1 day per person was available.

Types of Applications

The HEI-2005 can be used for a variety of purposes, including population monitoring; nutrition education; evaluation of nutrition interventions; epidemiologic research; economic research; and other types of research. USDA's major application is to monitor the diet quality of the U.S. general and low-income populations (USDA, 2006). CNPP plans to include the HEI-2005 in a future update of MyPyramid Tracker, the Center's dietary assessment and nutrition education tool (USDA, CNPP, 2006a).

Other measures of interest may be used in conjunction with the HEI-2005 for research purposes. Anthropometric measures, such as BMI and waist circumference, may be used to evaluate the appropriateness of the level of longer term energy intake and to provide a more complete picture of nutritional status. The HEI-2005 could also be used in conjunction with physical activity measures and other covariates of interest. For example, the HEI-2005, as a measure of diet quality that is not confounded with diet quantity, can be helpful in measuring the effect of dietary patterns apart from weight status.

SAS® Code

The documented SAS® code that created the HEI-2005 scores used in this report may be downloaded from the CNPP website (http://www.cnpp.usda.gov/HealthyEatingIndex-2005report.htm). Researchers who create the HEI-2005 using other dietary data sets should carefully consider the accuracy and precision of the intake data when interpreting their results. The evaluations presented here used 24-hour recall data, collected and coded using very high quality, standardized procedures developed by the USDA Agricultural Research Service (Raper, Perloff, Ingwersen, Steinfeldt, & Anand, 2004) as well as a database that carefully breaks food mixtures down into their ingredients (Friday & Bowman, 2006).

Conclusions

We have met our objectives for the revision of the HEI. We have constructed a tool that reflects the 2005 Dietary Guidelines and is suitable for a variety of purposes. In addition, we have developed a method for calculating HEI scores for groups that is based on the group's dietary usual intake. The psychometric analyses confirm that the individual components of the HEI provide additional insight to that of the total score. The HEI-2005 has several types of construct validity, as demonstrated by the ability to distinguish between groups with known differences in diet quality, the independence of diet quality and diet quantity as measured by energy intake, and the ability to detect differences among individuals as shown by the distributions of scores. Most important, the HEI-2005 has content validity, including face validity. It is a valid reflection of the key recommendations of the 2005 Dietary Guidelines for Americans.

Appendix 1. Foods Included in Components of the Healthy Eating Index-2005

The following lists are foods reported in NHANES 01-02, grouped into HEI components, which are based on the food groups used in the MyPyramid Equivalents Database. Other foods or ingredients may be categorized into HEI-2005 components by using this list as a guide.

Total Fruit includes acerola, apple, apricot, Asian pear, avocado, banana, blackberries, blueberries, boysenberries, calamondin, cantaloupe, casaba melon, cherries, cranberries, currants, dates, dewberries, elderberries, figs, genip, gooseberries, grapefruit, grapes, guava, honeydew melon, huckleberries, jackfruit, japanese pear, jobo, June berries, kiwifruit, kumquat, lemon, lime, loganberries, loquats, lychee, mamey (mamea apple), mandarin oranges, mango, mulberries, nectarine, oranges, papaya, passion fruit, peach, pear, persimmon, plantain, pineapple, plum, pomegranate, prickly pear, prunes, raisins, raspberries, red banana, rhubarb, sapodilla, soursop (guanabana), star fruit quince, strawberries, sweetsop, tamarind, tangelo, tangerine, ugli fruit, watermelon, watermelon rind, wi-apple, youngberries (carambola), and juices made from these fruits.

Whole Fruit excludes the juice forms of the fruits listed above. To create the Whole Fruit component, CNPP separated the Total Fruit group found in the MyPyramid Equivalents Database into two subgroups, whole fruit and fruit juice. This was done by first looking at the food code description and then the recipe for that food code, found in the Food and Nutrient Database for Dietary Studies, version 1.0, if necessary. If the recipe revealed that the Total Fruit group contained both whole fruit and juice, then the entire amount was designated as either whole fruit or fruit juice, according to whichever amount was greater in the recipe. The fruit juice subgroup is not used in the HEI-2005.

Total Vegetables includes the dark green and orange vegetables and legumes listed below and algae, aloe vera juice, artichoke, asparagus, balsam-pear pods, bamboo shoots, bean and alfalfa sprouts, beets, black-eyed peas (not dried), breadfruit, broccoflower, Brussels sprouts, buckwheat sprouts, burdock, cabbage (green and red), cactus, capers, casabe, cassava, cauliflower, celeriac, celery, celery juice, chayote, Chinese cabbage, chives, christophine, chrysanthemum, coriander, corn, cowpeas (not dried), cucumber, dasheen, eggplant, fern shoots, garlic, ginger root, green beans, green peas, hominy, horseradish, jicama, jute (potherb), kohlrabi, leek, lettuce, lima beans (immature), lotus root, luffa (Chinese okra), mushrooms, nopales, okra, olives, onions (mature and green), oriental parsnips, palm hearts, peppers (green, red, hot, banana), pigeon peas, pimiento, poi, pumpkin flowers, radicchio, radishes, rutabaga, salsify, sauerkraut, seaweed, sequin (Portugese cabbage), snow peas, summer squash, string beans (yellow), swamp cabbage, tannier, taro, tomatillo, tomato, tomato juice, tree fern, turnips, water chestnuts, wax beans, waxgourd, white potato, winter melon, yambean, and zucchini.

Dark Green and Orange Vegetables and Legumes includes dark green vegetables: arugula, balsam-pear tips, beet greens, bitter melon leaves, broccoli, chard, chicory, cilantro, collard greens, cress, dandelion greens, endive, escarole, grape leaves, kale, lambsquarters, mustard greens, mustard cabbage, parsley, poke greens, pumpkin leaves, romaine lettuce, spinach, sweet potato leaves, taro leaves, turnip greens, and watercress; orange vegetables: calabaza, carrots, carrot juice, pumpkin, sweetpotato, winter squash, and yams; and legumes: bayo beans, black beans, blackeyed peas, broadbeans, calico beans, chickpeas (garbanzos), cowpeas, fava beans, kidney beans, lentils, lima beans (mature), mongo beans, mung beans, navy beans, pinto beans, pink beans, red Mexican beans, split peas, soybeans (mature), and white beans. Infant formulas are not included. Legumes count as a vegetable only after the Meat and Bean standard is met as explained on page 10.

Total Grains includes yeast breads and rolls, quick breads, such as muffins, biscuits, pancakes, and tortillas; rice; pasta; breakfast cereals; grain-based snacks, such as crackers, pretzels, popcorn, and corn chips; and baked goods made from grain flour, such as cakes, cookies, croissants, doughnuts, pastries, and pie crust.

Whole Grains contain the entire grain kernel (bran, germ, and endosperm). Examples include whole-wheat flour, bulgur (cracked wheat), oatmeal, whole cornmeal, and brown rice. Some examples of refined grain products, which are included in Total Grains but not in Whole Grains are white flour, degermed cornmeal, white bread, pearled barley, bran, and white rice.

Milk includes all products made from cow's and goat's milk and soy beverages. Excluded are infant formulas and those products that are primarily fat, namely butter, cream, sour cream, and cream cheese.

Meat and Beans includes beef, pork, lamb, veal, game, poultry, fish, shellfish, frankfurters, sausages, bacon, luncheon meats, organ meats; eggs; nuts; seeds; and soy-based products such as tofu/soybean curd, soy flour, and meat analogs, for example, soy burgers. Legumes can also count in this group as explained on page 10.

Oils are fats that are liquid at room temperature, such as vegetable oils used in cooking. Foods that are mainly oil include mayonnaise, some salad dressings, and soft tub or squeeze margarine. A fat is assigned to the Oil component if it was from a plant source and not described as "hydrogenated" or "shortening," from a fish source, from nuts and seeds, or a margarine described as a "tub" or "liquid." If the form (stick/tub/liquid) of a margarine is not specified, it is classified as oil if the recipe ingredient was classified as oil or if the fat content was less than 80 percent.

Calories from Solid Fat, Alcohol, and Added Sugar (SoFAAS)

The recommendations found in MyPyramid are presented as food patterns, which are amounts of food groups to consume at 12 energy intake levels plus a discretionary calorie allowance (Britten et al., 2006). The foods in the food groups are in their most nutrient-dense forms; that is, they are either in a fat-free or lowest fat form and contain no added sugar (or salt), and the number of discretionary calories recommended assumes that food items in each food group are selected in such forms. Therefore, calories from solid fat and added sugar always are counted as part of the discretionary calorie allowance. Although alcoholic beverages are not explicitly mentioned in MyPyramid, the implication is that calories from alcoholic beverages are also always counted as discretionary.

To create the Calories from SoFAAS component, CNPP used data from the MyPyramid Equivalents Database (MPED), version 1.0, and the NHANES 01-02 nutrient intake data files. From the MPED, we used Solid Fats, which is expressed in grams, and Added Sugar, which is expressed in teaspoon equivalents. From the nutrient database, we used alcohol (grams of ethanol) from alcoholic beverages and carbohydrate (grams) from beer and wine. Carbohydrate contributes about one-third of the calories in beer and one-tenth of the calories in wine. We did not use the Alcohol food group from the MPED because it is expressed as number of drinks, which is not easily converted to calories.

The Calories from SoFAAS component represents the Calories from Solid Fat + Calories from Alcohol + Calories from Added Sugar. Alcohol is defined as the beverages beer, wine, and distilled spirits, consumed separately or as an ingredient in a mixed drink. The steps used in the calculation are as follows:

(1) Solid Fat calories = Solid Fat (g) x 9 calories/g
(2) Added Sugar calories = Added Sugar (tsp) x 4 grams/tsp of granulated sugar x 4 cal/gram of granulated sugar
(3) Alcohol calories = Ethanol (g) x 7 cal/g + carbohydrate in beer and wine (g) x 4 cal/g

Solid Fat includes all excess fat from the Milk and Meat and Beans components beyond what would be consumed if only the lowest fat forms were eaten and solid fats added to foods in preparation or at the table, including cream, butter, stick margarine, regular or low-fat cream cheese, lard, meat drippings, cocoa, and chocolate.

Added Sugar includes all sugars used as ingredients in processed and prepared foods, such as breads, cakes, other grain-based desserts, soft drinks, jams, jellies, candies, ice cream, and sugars reported separately or added to foods at the table.

Appendix 2: Sample 1-Day Diets Examined to Assess Face Validity and to Compare Original HEI and HEI-2005 Scores

SEQN=19306

Food Name	*Amount in Grams (Units)*	
Milk, cow's, fluid, 2% fat	457.50	(~1 3/4 cups)
Milk, cow's, fluid, 2% fat	122.00	(1/2 cup)
Beef, roast, roasted, lean only eaten	51.00	(~1/2 cups)
Croissant	126.00	(3 small croissants)
Biscuit, baking powder or buttermilk type, made from refrig	58.00	(2 large biscuits)
Cake, white, standard-type mix (egg whites and water added)	45.00	(1 small piece)
Cookie, brownie, without icing	89.10	(1 three-inch brownie)
Soup, mostly noodles	466.00	(2 cups)
Apple juice	124.00	(1/2 cup)
White potato, from fresh, mashed, made with milk and fat	78.75	(~2 1/2 cups)
White potato, from dry, mashed, made with milk and fat	78.75	(~2 1/2 cups)
Beans, string, green, cooked, from canned, fat not added	67.50	(2 cups)
Sugar, brown	6.88	(~2 tsp)
Snow cone, slurps	233.44	(~3/4 cup)
Caramel, chocolate-flavored roll	13.00	(2 pieces)
Chewing gum, sugared	4.00	(1 piece)
Orange breakfast drink	187.50	(1 1/3 cups)

Kcal=2606

HEI-2005 Total=29
Total Fruit=1.3
Whole Fruit=0
Total Vegetables=2.2
Dark Green and Orange Vegetables and Legumes=0
Total Grains=5.0
Whole Grains=0
Milk=7.4
Meat and Beans=3.1
Oils=0.7
Saturated Fat=4.1
Sodium=4.5
Calories from SoFAAS=0.6

Original HEI Total=72
Total Fruit=2.6
Total Vegetables=6.9
Total Grains=10
Milk=10
Meat (and beans)=3.4
Sodium=3.8
Saturated Fat=5.2
Total Fat=10
Cholesterol=10
Variety=10

SEQN=19027

Food Name	*Amount in Grams (Units)*	
Ground beef, regular, cooked	41.00	(~1 1/2 oz)
Hamburger, with tomato and/or catsup, on bun	111.00	(1 hamburger)
Corn dog (frankfurter or hot dog with cornbread coating)	88.00	(1 corn dog)
Egg omelet or scrambled egg, fat not added in cooking	60.00	(1 egg)
Bread, white	26.00	(1 slice of bread)
Crackers, graham	26.00	(~2 graham crackers)
Grits, cooked, corn or hominy, regular, fat not added in cooking	317.63	(~1 1/3 cups)
White potato, french fries, from frozen, deep fried	42.50	(~1/2 order small fries)
Tomato catsup	2.50	(1/2 tsp)
Fruit drink	1627.50	(~6 1/2 glasses)

Kcal=2017

HEI-2005 Total=37
Total Fruit=2.2
Whole Fruit=0
Total Vegetables=1.2
Dark Green and Orange Vegetables and Legumes=0
Total Grains=5.0
Whole Grains=0.8
Milk=0.3
Meat and Beans=8.9
Oils=1.0
Saturated Fat=9.5
Sodium=8.4
Calories from SoFAAS=0.0

Original HEI Total=87
Total Fruit=7.1
Total Vegetables=10
Total Grains=10
Milk=0.3
Meat (and beans)=10
Sodium=10
Saturated Fat=10
Total Fat=10
Cholesterol=9.3
Variety=10

SEQN=19634

Food Name	*Amount in Grams (Units)*	
Milk, cow's, fluid, whole	198.25	(~3/4 cup)
Milk, cow's, fluid, whole	198.25	(~3/4 cup)
Cheese, processed, American or Cheddar type	21.00	(1 slice)
Turkey, light meat, roasted, skin not eaten	63.75	(~3 oz)
Hamburger, plain, on bun	99.00	(1 small hamburger)
Bread, white, toasted	23.00	(1 slice)
Pie, sweetpotato	25.38	(~1/5 of a slice)
Breakfast tart	52.00	(1 pop tart)
Apple Jacks	39.38	(~1 1/3 cups)
Apple juice	201.50	(~3/4 cup)
White potato, french fries, from frozen, deep fried	85.00	(1 order small fries)
Tomato catsup	9.00	(1 Tbsp)
Corn, yellow, cooked, from canned, fat added in cooking	56.33	(1/3 cup)
Caramel, chocolate-flavored roll	35.00	(5 pieces)
Hard candy	14.00	(~2 pieces)
Soft drink, fruit-flavored, caffeine free	199.55	(~3/4 cup)
Soft drink, fruit-flavored, caffeine free	368.00	(~1 1/2 cups)
Fruit juice drink, NFS	201.50	(~3/4 cup)
Fruit juice drink, NFS	201.50	(~3/4 cup)

Kcal=2274

HEI-2005 Total=47
Total Fruit=4.9
Whole Fruit=0
Total Vegetables=2.0
Dark Green and Orange Vegetables and Legumes=0.3
Total Grains=4.8
Whole Grains=0
Milk=7.1
Meat and Beans=6.2
Oils=1.7
Saturated Fat=9.1
Sodium=9.0
Calories from SoFAAS=2.0

Original HEI Total=100
Total Fruit=10
Total Vegetables=10
Total Grains=10
Milk=10
Meat (and beans)=10
Sodium=10
Saturated Fat=10
Total Fat=10
Cholesterol=10
Variety=10

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