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Candidate measures of whole plant food intake are related to biomarkers of nutrition and health in the US population (National Health and Nutrition Examination Survey 1999-2002)

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ABSTRACT

Indices of overall dietary patterns are used in epidemiologic research to examine the relationship between nutrition and health. The objective of this study was to develop and validate an interpretable summary measure of dietary intake of whole plant foods (WPF; whole grains, vegetables, whole fruit, legumes, nuts, seeds) because of their similar nutritional characteristics and health effects. Six candidate WPF measures were calculated using data from subjects (age ≥6 years) participating in the 1999-2000 and 2001-2002 National Health and Nutrition Examination Survey. Measures differed by the inclusion or exclusion of potatoes and whether they were expressed as total intake or as a proportion of energy (4180 kJ) or mass (kg) consumed. Both standard and nontruncated (allowed to vary proportionally with intake) Healthy Eating Index-2005 (HEI-2005) scores were calculated. Regression analysis examined the associations between WPF and HEI-2005 measures, and between all diet measures and serum carotenoid concentration, serum lipids, fasting glucose, insulin, C-peptide, and C-reactive protein. Mean total WPF intake was 3.6 cup/oz equivalents, or 1.7 cup/oz equivalents per 4180 kJ and per kg. The largest R^2 between WPF and HEI-2005 measures was found for energy-adjusted WPF including potatoes and nontruncated HEI-2005 (R^2 = 0.50). All diet measures were positively related to serum carotenoids (P <.001) and were similarly related to health indicators (R^2 range from 0.003 to 0.16, P <.045 for regressions, indicating significant associations between WPF measures and health indicators). Whole plant food measures are interpretable indicators of dietary intake that are significantly related to nutrition and health biomarkers and may be of public health use.

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1. Introduction

In pursuit of understanding the relationship between diet and health, researchers have developed a number of indices to indicate the quality of dietary intake, created on the basis of a priori knowledge of the importance of various dietary components to health outcomes [1]. Indices have been constructed to reflect dietary guidance, patterns, and/or

Abbreviations: A1c, glycohemoglobin; CRP, C-reactive protein; HDL-C, high-density lipoprotein cholesterol; HEI-2005, Healthy Eating Index-2005; HEI2005_NT, nontruncated HEI-2005; HEI2005_ST, standard, truncated HEI-2005; LDL-C, low-density lipoprotein cholesterol; NHANES, National Health and Nutrition Examination Survey; TC, total cholesterol; TGs, triglycerides; WPF, whole plant food; WPFNP_TOT, total whole plant food intake, excluding potatoes; WPFP_KJ, energy-adjusted whole plant food intake, including potatoes; WPFP_TOT, total whole plant food intake, including potatoes.

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nutrient content and represent an alternative approach for classifying dietary exposure, rather than focusing on specific foods or nutrients in isolation [1–3]. Measures of diet quality or patterns are intended to give a more realistic measure of dietary behavior, given that nutrients and foods are not consumed in isolation, as well as to address the interrelationships among nutrients of dietary components [2,4]. The use of such measures may be evaluated with respect to their relationships with other indicators of dietary intake and health status, their interpretability, and their potential applications for research and policy.

The Healthy Eating Index-2005 (HEI-2005) [5] is an index of overall dietary quality that was developed in 2008 by a governmental interagency working group to assess adherence to the 2005 Dietary Guidelines for Americans (DGA). The HEI-2005 total score comprises 12 component scores, which are calculated from dietary intakes of various foods or nutrients per 4180 kJ (1000 kcal) consumed and represent different elements of the 2005 DGA. Total scores resulting from the summation of the 12 components range from 0 to 100, with higher scores indicating better adherence to dietary guidelines. The primary improvement in this index over its predecessors is that scores are determined on the basis of intake standardized to 4180 kJ (1000 kcal), allowing for comparisons across individuals with different energy requirements. Previous studies have reported relationships between the HEI-2005 and health biomarkers [6] as well as with long-term health outcomes [7]. However, the complexity of the index's calculation limits the measure's implementation in many research settings and the interpretation of any observed associations with outcomes. Because the HEI-2005 overall score reflects a variety of dietary components with differential nutritional profiles and health effects, relations observed between the overall score and outcomes related to nutrition and health are difficult to interpret [1,2]. Conversely, using the individual components of the HEI-2005 as the exposure may limit the ability to detect relationships with diet and health outcomes because multiple food groups with similar nutritional characteristics and health effects would be examined individually rather than collectively [1,2].

Findings from numerous studies have indicated the primary health importance of dietary intake of whole plant foods (WPF) including whole fruit, vegetables, whole grains, legumes, nuts, and seeds. Shared nutritional characteristics of WPF include their low-energy and high-micronutrient and fiber content [8], as well as the absence of added sugars, animal fats, sodium, and other chemicals, preservatives, and additives associated with food processing (eg, juicing and refining). Foods with these nutritional attributes have been associated with health benefits including prevention of type 2 diabetes [9–12], improvement in glycemic control and cardiovascular disease risk factors and events [13–18], and reduced cancer risk [19–21] and overall mortality [22]. However, we are not aware of the existence of any measure representing this aspect of dietary quality, which may complement and enhance analytic methods for studying the relationship between diet and health.

The objective of this study was to develop and evaluate a measure of WPF intake. Validity was assessed by examining the associations with the HEI-2005 as well as with biomarkers of dietary intake and health status. The candidate measures were designed for simplicity of calculation to facilitate application in a variety of settings and interpretability to assist translation from research to policy and practice. We used the data from the National Health and Nutrition Examination Survey (NHANES) to evaluate alternative measures of WPF intake in a proof-of-concept manner.

2. Methods and materials

2.1. *Sample*

This study used data from individuals 6 years and older with a complete and reliable dietary recall (n = 7794) participating in the 1999-2000 and 2001-2002 NHANES. Data from these 2 release cycles were used to provide a sufficient sample size for addressing the stated research objectives. Preschool-aged children were excluded due to the increased difficulty associated with assessing dietary intake in this age group [23]. The survey is a multistage stratified probability sample of the noninstitutionalized, civilian population in the United States at least 2 months of age [24]. Information on smoking, physical activity, supplement use, alcohol use, age, sex, and race/ethnicity (non-Hispanic white, non-Hispanic black, Mexican American, other including multiracial, other Hispanic) was obtained during subject interviews. Exclusions were made for women who were pregnant (n = 623) or breastfeeding (n = 72). Details on the study design, procedures, and methods are described elsewhere [25].

2.2. *Dietary data collection*

Dietary information was obtained using a single interviewer-assisted 24-hour dietary recall during an examination in a mobile examination center. Dietary data for children 6 to 11 years of age were assisted by an adult. Descriptions of the dietary interview methods, including pictures of the Computer-Assisted Dietary Interview system screens, measurement guides, and medical records used to collect dietary information, are provided in the NHANES Dietary Interviewer's Training Manual [26].

2.3. *Healthy Eating Index-2005*

The HEI-2005 total score was calculated based on the instructions provided by the US Department of Agriculture [27] using the MyPyramid Equivalents Database for US Department of Agriculture Survey Food Codes, version 1, and the Center for Nutrition Policy and Promotion MyPyramid Equivalents Database for Whole Fruit and Fruit Juice, version 1, which enable calculation of intakes for the food group components of the HEI-2005 for NHANES data collected up to 2002 [28]. The HEI-2005 total score comprises 12 dietary components (total fruit, whole fruit, total vegetables, dark green/orange vegetables and legumes, total grains, whole grains, milk, meat and beans, oils, saturated fat, sodium, and solid fat/alcohol/added sugars) reflecting the recommendations of the 2005 DGA [5]. The index is calculated on a scale of 0 to 100, such that scores are truncated once intakes exceed