Quality of Popular Diet Patterns in the United States: Evaluating the Effect of Substitutions for Foods High in Added Sugar, Sodium, Saturated Fat, and Refined Grains

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ABSTRACT

Background: Many Americans have adopted popular diet patterns for general health improvement that restrict specific foods, macronutrients, or eating time. However, there is limited evidence to characterize the quality of these diet patterns.

Objectives: This study *1*) evaluated the quality of popular diet patterns in the United States and *2*) modeled the effect of targeted food substitutions on diet quality.

Methods: Dietary data from 34,411 adults ≥20 y old were acquired from the NHANES, 2005–2018. Dietary intake was assessed using the National Cancer Institute's usual intake methodology, and the Healthy Eating Index-2015 was used to evaluate diet quality. A diet model was used to evaluate the effect of targeted food substitutions on diet quality.

Results: A pescatarian diet pattern had the highest diet quality (65.2; 95% CI: 64.0, 66.4), followed by vegetarian (63.0; 95% CI: 62.0, 64.0), low-grain (62.0; 95% CI: 61.6, 62.4), restricted-carbohydrate (56.9; 95% CI: 56.6, 57.3), time-restricted (55.2; 95% CI: 54.8, 55.5), and high-protein (51.8; 95% CI: 51.0, 62.7) diet patterns. Modeled replacement of ≤3 daily servings of foods highest in added sugar, sodium, saturated fat, and refined grains with alternative foods led to an increase in diet quality and a decrease in energy intake for most diet patterns.

Conclusions: Low diet quality was observed for all popular diet patterns evaluated in this study. Modeled dietary shifts that align with recommendations to choose foods lower in added sugar, sodium, saturated fat, and refined grains led to modest improvements in diet quality and larger reductions of energy intake. Greater efforts are needed to encourage the adoption of dietary patterns that emphasize consumption of a variety of high-quality food groups. *Curr Dev Nutr* 2022;6:nzac119.

Keywords: popular diet, fad diet, diet pattern, diet quality, Healthy Eating Index, restricted carbohydrate

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Supplemental Tables 1–4 are available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/cdn/.

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Abbreviations used: DGA, Dietary Guidelines for Americans; FNDDS, Food and Nutrient Database for Dietary Studies; FPED, Food Patterns Equivalents Database; HEI, Healthy Eating Index; NCI, National Cancer Institute; RDN, Registered Dietitian Nutritionist.

Introduction

Diet patterns are the combinations of foods and nutrients that individuals habitually consume that act synergistically to affect health outcomes (1). Nearly one-half of Americans adopted popular diet patterns in 2020, an increase of 5 percentage points over the previous year (2). These diet patterns include plant-based, low-carbohydrate, high-protein, and intermittent fasting, among others. Many people who report following these diet patterns report that general health improvement is their primary motivator for adopting them (2), yet there is limited scientific evidence on their comparative healthfulness (3). Given the rising popularity of these diet patterns and consumers' tendency to overestimate their own diet quality (2), greater research is needed to evaluate the quality of these diet patterns so that consumers have evidence-based information to make healthy food choices, and clinicians have the information needed for effective dietary counseling.

The healthfulness of diverse diet patterns can be quantified and compared using diet quality indexes (4). These tools compare actual or theoretical intakes of food groups and nutrients to recommended intakes, then scoring algorithms are applied to generate a summary score for the entire diet. Higher scores represent greater adherence to dietary guidance and are associated with better health outcomes (5, 6). The application of these indexes to evaluate actual intake of popular diet patterns has been limited to vegetarian diet patterns that exclude all or some types of animal-based foods (e.g., lacto-ovo vegetarian, pescatarian, vegan) and generally demonstrate greater diet quality than omnivorous diet patterns that include greater amounts of animal-based foods (7). Few studies have evaluated the diet quality of a broader range of popular diet patterns; and these have been limited to menu analyses of theoretical diet patterns, which demonstrate higher diet quality for diet patterns that limit animal-based foods (8) and some, but not all, higher-carbohydrate diet patterns (8, 9).

A recent analysis of several large US cohorts demonstrated wide variability of food intake within diet patterns, and that high diet quality can be achieved with different diet patterns, yet popular diet patterns (e.g., vegetarian, restricted-carbohydrate, high-protein) were not specifically evaluated (10). This raises questions regarding whether some popular diet patterns are healthier than others, and whether targeted food substitutions that align with consumers' preferred diet patterns can meaningfully improve diet quality. In keeping with the "small changes" approach (11), others have shown that even modest food substitutions can have meaningful impacts on nutrient adequacy (12), yet these analyses have not been used to evaluate popular diet patterns. More information on the comparative diet quality of actual rather than theoretical popular diet patterns, and the degree to which specific food substitutions can improve diet quality, is needed to help consumers make evidence-based food decisions to improve health outcomes.

To address these research gaps, the present study *1*) evaluated the diet quality of 5 popular diet patterns among a nationally representative US sample, and *2*) modeled the effect on diet quality if foods and beverages highest in added sugar, sodium, saturated fat, and refined grains were replaced by healthy alternatives, which directly addresses a key recommendation provided by the Dietary Guidelines for Americans (DGA) 2020–2025 (13).

Methods

Data acquisition

Data on individual-level food intake, nutrient intake from foods and supplements, and sociodemographic status were acquired from the NHANES, 2005–2018. The NHANES uses a clustered, stratified, multistage sampling design. Trained staff use in-person surveys, physical examinations, and laboratory tests to collect data from ∼5000 noninstitutionalized participants per year. Reliability and precision for subgroup analysis are increased by oversampling some population groups (14). Data are released in 2-y cycles (15). Dietary data are collected by trained interviewers using the computer-assisted Automated Multiple-Pass Method to minimize respondent burden and increase reliability and validity (16, 17). Approximately 80% of the sample completes a subsequent recall administered by telephone 3–10 d later (18). The salt adjustment was appropriately removed from dietary data collected from 2005–2008 to standardize measurement of sodium intake across all data years (19). In most cases, individuals report consuming mixed dishes that represent multiple food groups, so the Food Patterns Equivalents Database (FPED) was used to convert each NHANES food into ≥1 food groups that align with those included in the DGA (20). The present study is a secondary analysis of publicly available and de-identified data and was deemed exempt from human studies ethical review by the Institutional Review Board at William & Mary. Preregistration for this study can be found elsewhere (21).

Current (baseline) dietary intake

Current (baseline) dietary intake of kilocalories, nutrients, and Healthy Eating Index (HEI)-2015 components was estimated using the National Cancer Institute's (NCI's) usual intake methodology, which uses data from two 24-h recalls collected from most participants to estimate within-person variation of the entire sample (22). Individual-level predicted intake was estimated using the SAS macros MIXTRAN (version 2.21) and INDIVINT (version 2.3). For nutrients consumed episodically, the probability of consumption was assumed to be correlated to the amount consumed (23). Nutrient densities (e.g., % energy from protein) were estimated using the NLMIXED_UNIVARIATE (version 1.2), NLMIXED_BIVARIATE (version 1.2), and PREDICT_INTAKE_DENSITY (version 1.2) macros (24–26).

Diet pattern categorization

Data on food and nutrient intake were used to categorize the diet patterns for each participant into food group–restricted (vegetarian, pescatarian, low-grain), macronutrient-restricted (high-protein, restricted-carbohydrate), and time-restricted. The operationalization of these categories was informed by published literature (2, 3, 27–29) and is described in **Supplemental Table 1**. Food group–restricted diets were categorized using data on daily intake of food groups from the FPED, and NHANES daily nutrient intake files were used to categorize macronutrient-restricted diets. The time-restricted diet was categorized using NHANES individual food files which provide data on the amount of time between each eating occasion for each participant. Diet patterns were not mutually exclusive so it was possible for participants to be categorized into multiple diet patterns. Because the NCI methodology only predicts nonzero intake, participants that did not consume any amount of a given food group on both days of recall were assumed to be nonconsumers.

Food categories and serving sizes

Each food and beverage reported consumed by participants on the first day of NHANES dietary recall was categorized into 1 of 89 food and beverage categories (hereafter, food categories) based on the categorization scheme used in the Food and Nutrient Database for Dietary Studies (FNDDS) (30) and FPED (20). For example, yeast breads were identified using the FNDDS and were further disaggregated into whole-grain and refined-grain breads using the FPED (**Supplemental Table 2**). NHANES files provide data on the gram weight of each food consumed as well as their caloric and nutrient content, and FPED files provide data on the amount of each HEI-2015 component present in each food. These data were used to estimate average serving sizes of each food component as well as the average amounts of kilocalories, added sugar, sodium, saturated fat, refined grains, and each HEI-2015 component present per serving of each food category, as described in what follows.

Serving sizes for each food category were computed as the mean gram weight of all foods consumed within each category at each eating occasion for the entire sample. For example, there were 189 types of refined-grain yeast breads that were consumed on 24,746 occasions, and the average amount (in grams) of refined-grain yeast breads consumed at each eating occasion was used as the serving size for this food category. All estimated serving sizes for packaged foods and beverages were comparable with serving size recommendations provided on the Nutrition Facts Panel of these products (31), and the estimated serving sizes for nonpackaged foods were comparable with serving size estimates provided by FPED documentation (32). The amounts of kilocalories, added sugar, sodium, saturated fat, refined grains, and each HEI-2015 component present per gram of each food were averaged across all foods within each food category, and the resultant value was multiplied by the average serving size (in gram weight) of each food category to estimate the amounts of kilocalories, nutrients, and HEI-2015 components per serving of each food category.

Target foods and alternative foods

The contribution of each food category to daily intake of added sugar, sodium, saturated fat, and refined grains was estimated for each diet pattern (i.e., at the diet pattern level, not the individual level), and those highest in these components were identified as food categories to be removed from each diet pattern during modeling (target foods). Alternative food categories were identified based on 3 conditions: *1*) adhered to the principles of each diet pattern (e.g., meat was not used as an alternative food for the vegetarian diet pattern); *2*) represented a reasonable dietary substitution that an individual may make, as determined through consultation and consensus with multiple Registered Dietitian Nutritionists (RDNs; e.g., dishes were replaced with dishes, beverages with beverages, snacks with snacks, and desserts with desserts); and *3*) of the remaining options it was consumed in the greatest quantity.

Diet modeling

A diet model was constructed to estimate the effects on diet quality if food categories highest in added sugar, sodium, saturated fat, and refined grains (target foods) were replaced with alternative foods, which aligns with a key recommendation in the DGA 2020–2025 to choose foods lower in these components (13). All replacements were made on a serving-per-serving basis to account for the units in which individuals typically consume foods and beverages (i.e., servings rather than mass quantity or kcal). Individual-level intakes of kilocalories, nutrients, and HEI-2015 components were estimated at baseline using the SAS macros from the NCI method discussed previously and were recalculated after each modeled substitution. As discussed in what follows, this information was used to estimate energy-adjusted (1000 kcal) HEI-2015 scores at baseline (i.e., current intake), and the energy-adjusted scores were recalculated after each modeled substitution.

Multiple scenarios of food replacement were modeled to represent a variety of ways that individuals may modify their diet pattern to comply with dietary guidance. Some people may find it more achievable and sustainable to focus on limiting a single food/beverage component at a time (i.e., added sugar, sodium, saturated fat, or refined grains) rather than limiting all 4 simultaneously. This study evaluated incrementally greater replacement levels for each of these 4 components, on a serving-by-serving basis, with ≤3 serving replacements. For example, for each diet pattern, 1 serving of a target food was replaced by 1 serving of an alternative food, and this was performed iteratively for 2- and 3-serving replacement levels. For each replacement, the amount of kilocalories, nutrients, and HEI-2015 components present in each serving of the target food was removed from the diet pattern of each participant, and the amount of kilocalories, nutrients, and HEI-2015 components present in each serving of the alternative food was added to the diet pattern of each participant. The replacement levels were progressive, so that if a participant consumed less than the replacement level, the preceding replacement level was used as the default. For example, under the 3-serving replacement scenario, if a participant consumed 2.9 servings of the target food only 2 servings would be replaced; and if that participant consumed 3.1 servings of the target food only 3 servings would be replaced. This modeling structure thus allowed for discretionary intake of these food/beverage components rather than eliminating them entirely from the diet, because the former may increase achievability for some individuals. This study also modeled the effects on diet quality if individuals simultaneously replaced foods highest in added sugar, sodium, saturated fat, and refined grains rather than focusing on 1 of these at a time.

Diet quality

Although multiple diet quality indexes have been developed and validated (4), the HEI is best suited to address the objectives of the present study because it measures compliance with the DGA (33). The HEI has been updated several times since its inception in 1995, and it is recommended to use a single version when measuring diet quality across different years (34). The most recent version is HEI-2015, which includes 9 components to encourage (total fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and the ratio of unsaturated to saturated fats) and 4 components to limit (refined grains, sodium, added sugars, and saturated fats) (34, 35). Intake of most components is energy-adjusted to 1000 kcal. Intake of each component is evaluated against a prespecified standard that awards a minimum and maximum number of points and intermediate intakes are scored proportionally. Some components are scored 0–5 and others are scored 0–10, with higher scores being more favorable. All component scores are summed to estimate a total score for each participant out of a maximum score of 100 (33). The simple scoring algorithm was used to calculate HEI-2015 scores using individual-level dietary data estimated from the NCI method (MIXTRAN and INDIVINT macros) (33).

Statistical analyses

Diet quality was evaluated before (i.e., current intake) and after each modeled replacement. NHANES survey weights and design variables were used to account for the multistage probability sampling design and to produce nationally representative estimates. SAS version 9.4 (SAS Institute) was used to estimate usual intakes using the NCI macros, and Stata version 16.1 (StataCorp.) was used for data management and final analyses.

TABLE 1 Current and modeled diet quality after replacing foods and beverages high in added sugar with alternative foods, 2005–2018[1]

Diet pattern	Replacements			
	Current[2]	1 serving	2 servings	3 servings
General population[3]				
HEI-2015	57.1 (56.9, 57.4)	57.7 (57.5, 57.9)	57.8 (57.6, 58.0)	57.8 (57.5, 58.0)
kcal	2094 (2083, 2104)	2066 (2055, 2076)	2042 (2031, 2052)	2026 (2015, 2037)
Vegetarian[4]				
HEI-2015	63.0 (62.0, 64.0)	63.8 (62.9, 64.7)	63.9 (63.0, 64.8)	63.9 (63.0, 64.8)
kcal	1839 (1783, 1895)	1836 (1780, 1892)	1833 (1777, 1889)	1832 (1776, 1888)
Pescatarian[5]				
HEI-2015	65.2 (64.0, 66.4)	65.6 (64.4, 66.8)	65.8 (64.5, 67.0)	65.8 (64.5, 67.0)
kcal	1856 (1807, 1905)	1838 (1791, 1885)	1821 (1775, 1867)	1808 (1762, 1855)
Low-grain[6]				
HEI-2015	62.0 (61.6, 62.4)	63.4 (63.0, 63.8)	63.7 (63.3, 64.1)	63.7 (63.3, 64.1)
kcal	1587 (1568, 1605)	1580 (1561, 1599)	1575 (1557, 1594)	1572 (1553, 1591)
High-protein[7]				
HEI-2015	51.8 (51.0, 52.7)	56.8 (56.0, 57.6)	59.1 (58.1, 60.0)	59.3 (58.3, 60.2)
kcal	3651 (3615, 3687)	3628 (3592, 3664)	3598 (3562, 3634)	3570 (3534, 3607)
Restricted-carbohydrate[8]				
HEI-2015	56.9 (56.6, 57.3)	57.2 (56.9, 57.5)	57.2 (56.9, 57.5)	57.2 (56.9, 57.5)
kcal	2147 (2129, 2165)	2134 (2117, 2152)	2127 (2110, 2145)	2124 (2107, 2141)
Time-restricted[9]				
HEI-2015	55.2 (54.8, 55.5)	56.0 (55.6, 56.3)	56.1 (55.7, 56.4)	56.1 (55.7, 56.4)
kcal	1819 (1796, 1842)	1784 (1761, 1807)	1756 (1732, 1779)	1736 (1712, 1761)

[1] $n = 34{,}411$. Values are means (95% CIs). HEI scores were energy-adjusted to 1000 kcal/d. The diet model replaces the food highest in added sugar (target food) with 1, 2, or 3 servings of alternative food. HEI-2015, Healthy Eating Index-2015.
[2] Based on usual intake estimated from two 24-h recalls using the National Cancer Institute method.
[3] All participants that met the inclusion criteria, including those in each diet category as well as those not categorized into diet categories.
[4] Zero intake of meat, poultry, and seafood.
[5] Zero intake of meat and poultry and >0 ounce-equivalents of seafood.
[6] ≤10th percentile of total grain intake.
[7] ≥30th percentile of total protein intake.
[8] <45th percentile of total carbohydrate intake.
[9] ≥12 h food and beverage fast.

Results

Participant characteristics

A total of 61,682 participants provided dietary data from 2005–2018. Exclusion criteria were being <20 y old ($n = 26{,}375$) and provided incomplete or unreliable dietary information as determined by NHANES staff or were pregnant or breastfeeding ($n = 896$). The final sample included 34,411 participants. Approximately 56% of the sample did not follow any of the diet patterns evaluated in this study, 35% followed 1 diet pattern, 8% followed 2 diet patterns, and 1% followed ≥3 diet patterns (data not shown). The prevalence of food group–restricted diet patterns was 1.7% for pescatarian, 2.6% for vegetarian, and 10% for low-grain (**Supplemental Table 3**). Participants that followed food group–restricted diet patterns were 45–50 y old. Most were female and non-Hispanic white with at least some college education and income-to-poverty ratios ≥ 2.8. Participants who followed a vegetarian diet pattern had the lowest proportion of non-Hispanic blacks (5.3%) and the highest proportion of other races/ethnicities (34%).

Among macronutrient-restricted diet patterns (Supplemental Table 3), the prevalence of a high-protein diet pattern was 2.7% and the prevalence of a restricted-carbohydrate diet pattern was 29%. Compared with participants that followed a high-protein diet pattern, those that followed a restricted-carbohydrate diet pattern were older (48 y compared with 40 y), had higher income-to-poverty ratios (3.3 compared with 2.6), and were more educated (66% completed some college compared with 56%). The majority of participants that consumed a high-protein diet pattern were male (93%) compared with 56% of participants that followed a restricted-carbohydrate diet pattern. Over 9% of participants followed a time-restricted diet pattern; approximately half were male (48%), completed at least some college (48%), and were non-Hispanic white (53%), and they had lower income-to-poverty ratios (2.4).

Foods and beverages highest in added sugar, sodium, saturated fat, and refined grains

Soft drinks with added sugar were the largest contributor to daily added sugar intake for most diet patterns, ranging from 16% in the vegetarian diet pattern to 36% in the time-restricted diet pattern (**Supplemental Table 4**). Poultry dishes accounted for the greatest daily intake of sodium in the general population (7.3%) as well as in the restricted-carbohydrate (8.5%), time-restricted (8.6%), and low-grain (9.5%) diet patterns; and refined-grain pizza was the largest contributor of sodium intake in the vegetarian (7.4%) and high-protein (10%) diet patterns. In the pescatarian diet pattern, the greatest daily intake of sodium came from seafood dishes (18%), but these were ineligible as a target food because removing them did not adhere to the diet's principles; therefore, the next greatest contributor, refined-grain rice dishes (6.1%), was used as the target food. Cheese accounted for the largest daily intake of saturated fat for most diet patterns, ranging from 8.7% in the low-grain diet

TABLE 2 Current and modeled diet quality after replacing foods high in sodium with alternative foods, 2005–2018[1]

Diet pattern	Current[2]	Replacements 1 serving	2 servings	3 servings
General population[3]				
HEI-2015	57.1 (56.9, 57.4)	56.7 (56.5, 57.0)	56.4 (56.1, 56.6)	56.2 (56.0, 56.5)
kcal	2094 (2083, 2104)	2078 (2067, 2088)	2066 (2056, 2077)	2060 (2049, 2071)
Vegetarian[4]				
HEI-2015	63.0 (62.0, 64.0)	64.2 (63.2, 65.2)	64.3 (63.3, 65.3)	64.3 (63.3, 65.2)
kcal	1839 (1783, 1895)	1810 (1754, 1865)	1793 (1738, 1849)	1788 (1733, 1844)
Pescatarian[5]				
HEI-2015	65.2 (64.0, 66.4)	66.1 (64.9, 67.3)	66.3 (65.1, 67.5)	66.2 (65.0, 67.4)
kcal	1856 (1807, 1905)	1852 (1803, 1901)	1850 (1801, 1899)	1849 (1800, 1898)
Low-grain[6]				
HEI-2015	62.0 (61.6, 62.4)	61.7 (61.3, 62.1)	61.4 (61.0, 61.9)	61.3 (60.9, 61.8)
kcal	1587 (1568, 1605)	1574 (1555, 1593)	1566 (1547, 1584)	1561 (1542, 1580)
High-protein[7]				
HEI-2015	51.8 (51.0, 52.7)	53.8 (53.0, 54.5)	55.5 (54.7, 56.3)	54.7 (53.8, 55.5)
kcal	3651 (3615, 3687)	3578 (3540, 3616)	3480 (3432, 3527)	3403 (3347, 3459)
Restricted-carbohydrate[8]				
HEI-2015	56.9 (56.6, 57.3)	56.5 (56.1, 56.8)	56.1 (55.7, 56.4)	55.8 (55.5, 56.2)
kcal	2147 (2129, 2165)	2127 (2109, 2144)	2111 (2093, 2129)	2102 (2085, 2120)
Time-restricted[9]				
HEI-2015	55.2 (54.8, 55.5)	55.4 (55.1, 55.8)	55.4 (55.1, 55.7)	55.4 (55.1, 55.8)
kcal	1819 (1796, 1842)	1812 (1789, 1835)	1807 (1784, 1830)	1804 (1781, 1828)

[1] n = 34,411. Values are means (95% CIs). HEI scores were energy-adjusted to 1000 kcal/d. The diet model replaces the food highest in sodium (target food) with 1, 2, or 3 servings of alternative food. HEI-2015, Healthy Eating Index-2015.
[2] Based on usual intake estimated from two 24-h recalls using the National Cancer Institute method.
[3] All participants that met the inclusion criteria, including those in each diet category as well as those not categorized into diet categories.
[4] Zero intake of meat, poultry, and seafood.
[5] Zero intake of meat and poultry and >0 ounce-equivalents of seafood.
[6] ≤10th percentile of total grain intake.
[7] ≥30th percentile of total protein intake.
[8] <45th percentile of total carbohydrate intake.
[9] ≥12 h food and beverage fast.

pattern to 12% in the vegetarian and pescatarian diet patterns. Refined-grain yeast bread accounted for the greatest daily intake of refined grains in all diet patterns, ranging from 20% in the high-protein diet pattern to 25% in the low-grain and refined-carbohydrate diet patterns.

Current diet quality

The pescatarian diet pattern had the highest diet quality (65.2; 95% CI: 64.0, 66.4), followed by vegetarian (63.0; 95% CI: 62.0, 64.0) and low-grain (62.0; 95% CI: 61.6, 62.4), all of which were higher than the diet quality of the general population (57.1; 95% CI: 56.9, 57.4) (**Table 1**). The restricted-carbohydrate (56.9; 95% CI: 56.6, 57.3), time-restricted (55.2; 95% CI: 54.8, 55.5), and high-protein diet patterns (51.8; 95% CI: 51.0, 62.7) had diet quality scores lower than that of the general population.

Modeled changes in diet quality

Modeled replacement of foods and beverages highest in added sugar with alternative foods and beverages (Table 1) increased diet quality for all diet patterns at each replacement level (1, 2, and 3 servings replacement). Diet quality improved by a maximum of 1.7 points for all diet patterns except for the high-protein diet pattern, which increased by 7.5 points at the 3-serving replacement level, thereby surpassing the diet quality of the general population. Daily energy intake decreased for all diet patterns at all replacement levels.

Modeled replacement of foods highest in sodium with alternative foods (**Table 2**) at the 1- and 2-serving replacement levels led to an increase in diet quality of ≤1.3 points for the vegetarian, pescatarian, and time-restricted diet patterns, and ≤2.6 points for the high-protein diet pattern. Diet quality decreased modestly at the 3-serving replacement level for most diet patterns because HEI-2015 is energy adjusted using the density method, and the decrease in energy intake was larger than the decrease in sodium intake without a meaningful change in consumption of other HEI-2015 components. All replacement levels led to a reduction in energy intake for all diet patterns, from 4 kcal in the pescatarian diet pattern to 248 kcal in the high-protein diet pattern.

Modeled replacement of foods highest in saturated fat with alternative foods (**Table 3**) at the 1- and 2-serving replacement levels led to an increase in diet quality of ≤1 point for most diet patterns, with larger increases for the restricted-carbohydrate (1.7 points) and high-protein diet patterns (3.7 points). The diet quality of the low-carbohydrate diet pattern surpassed the diet quality of the general population at all replacement levels. Diet quality decreased at the 3-serving replacement level for the high-protein diet pattern owing to energy adjustment. All replacement levels led to a reduction in energy intake for all diet patterns, from 10 kcal for the low-grain and time-restricted diet patterns to 248 kcal for the high-protein diet pattern. Modeled replacement of foods highest in refined grains with alternative foods led to an increase in diet quality of ≤3.1 points for all diet patterns at all replacement levels

TABLE 3 Current and modeled diet quality after replacing foods high in saturated fat with alternative foods, 2005–2018[1]

Diet pattern	Current[2]	Replacements 1 serving	2 servings	3 servings
General population[3]				
HEI-2015	57.1 (56.9, 57.4)	57.8 (57.5, 58.0)	58.2 (57.9, 58.4)	58.3 (58.0, 58.5)
kcal	2094 (2083, 2104)	2089 (2079, 2099)	2085 (2074, 2095)	2081 (2071, 2091)
Vegetarian[4]				
HEI-2015	63.0 (62.0, 64.0)	63.7 (62.6, 64.7)	63.9 (62.9, 64.9)	64.0 (62.9, 65.0)
kcal	1839 (1783, 1895)	1834 (1778, 1890)	1829 (1773, 1885)	1824 (1768, 1881)
Pescatarian[5]				
HEI-2015	65.2 (64.0, 66.4)	65.7 (64.5, 66.9)	65.9 (64.7, 67.1)	65.9 (64.7, 67.1)
kcal	1856 (1807, 1905)	1851 (1803, 1900)	1847 (1798, 1895)	1843 (1795, 1892)
Low-grain[6]				
HEI-2015	62.0 (61.6, 62.4)	62.4 (62.0, 62.8)	62.6 (62.2, 63.0)	62.6 (62.2, 63.0)
kcal	1587 (1568, 1605)	1583 (1565, 1602)	1580 (1562, 1599)	1577 (1558, 1596)
High-protein[7]				
HEI-2015	51.8 (51.0, 52.7)	53.8 (53.0, 54.5)	55.5 (54.7, 56.3)	54.7 (53.8, 55.5)
kcal	3651 (3615, 3687)	3578 (3540, 3616)	3480 (3432, 3527)	3403 (3347, 3459)
Restricted-carbohydrate[8]				
HEI-2015	56.9 (56.6, 57.3)	58.0 (57.7, 58.4)	58.6 (58.3, 59.0)	58.7 (58.4, 59.1)
kcal	2147 (2129, 2165)	2140 (2122, 2158)	2134 (2116, 2152)	2128 (2110, 2146)
Time-restricted[9]				
HEI-2015	55.2 (54.8, 55.5)	55.8 (55.5, 56.2)	56.2 (55.8, 56.5)	56.3 (55.9, 56.6)
kcal	1819 (1796, 1842)	1815 (1792, 1839)	1812 (1789, 1836)	1810 (1786, 1833)

[1] $n = 34{,}411$. Values are means (95% CIs). HEI scores were energy-adjusted to 1000 kcal/d. The diet model replaces the food highest in saturated fat (target food) with 1, 2, or 3 servings of alternative food. HEI-2015, Healthy Eating Index-2015.
[2] Based on usual intake estimated from two 24-h recalls using the National Cancer Institute method.
[3] All participants that met the inclusion criteria, including those in each diet category as well as those not categorized into diet categories.
[4] Zero intake of meat, poultry, and seafood.
[5] Zero intake of meat and poultry and >0 ounce-equivalents of seafood.
[6] ≤10th percentile of total grain intake.
[7] ≥30th percentile of total protein intake.
[8] <45th percentile of total carbohydrate intake.
[9] ≥12 h food and beverage fast.

(**Table 4**), and all replacement levels led to a reduction in energy intake for all diet patterns of ≤8 kcal.

Figure 1 displays modeled changes in diet quality when foods and beverages highest in added sugar, sodium, saturated fat, and refined grains were simultaneously replaced with alternative foods and beverages (1 serving each, 4 servings total). The greatest increase in diet quality was observed for the high-protein diet pattern (9.8 points), which surpassed the diet quality of the general population, followed by the vegetarian (3.9 points), time-restricted (3.1 points), pescatarian (3 points), restricted-carbohydrate (2.4 points), and low-grain (2 points) diet patterns. Daily energy intake decreased by ≤171 kcal for all diet patterns.

Discussion

This nationally representative study of nearly 35,000 adults from 2005–2018 demonstrated that the diet quality of popular diet patterns was far below optimal. The pescatarian diet pattern had the highest diet quality, followed by the vegetarian and low-grain diet patterns, all of which were higher than the diet quality of the general population. The diet quality of the restricted-carbohydrate, time-restricted, and high-protein diet patterns was below the diet quality of the general population. Modeled replacement of ≤3 daily servings of foods highest in either added sugar, sodium, saturated fat, or refined grains with alternative foods led to modest improvements in diet quality. Greater changes in diet quality were observed when foods highest in added sugar, sodium, saturated fat, and refined grains were simultaneously replaced with alternative foods, although diet quality remained far from optimal.

To the best of our knowledge, no prior studies have evaluated the diet quality of popular diet patterns among a nationally representative US sample, with the exception of vegetarian diet patterns (36). Data from NHANES 2007–2012 showed greater diet quality among participants that consumed vegetarian diet patterns than among those that did not consume vegetarian diet patterns (36), which is consistent with studies conducted in other higher-income countries and those using different study designs (7, 8). Others have evaluated the diet quality of a broader range of popular diet patterns, but these have been limited to menu analyses of theoretical diet patterns rather than observed diet patterns and have generally (but not always) shown greater diet quality for higher-carbohydrate diet patterns (8, 9). This is consistent with post hoc analyses in the present study, which demonstrated a modest positive association between total carbohydrate intake as a percentage of kilocalories and HEI-2015 scores (0.6-point increase in HEI-2015 score for every 10-percentage-point increase in carbohydrate intake, $P < 0.001$). However, follow-up data from NHANES demonstrated that carbohydrate quality, rather than total carbohydrate intake, is a stronger predictor of chronic disease outcomes (37), which emphasizes the need for consumers to refocus their efforts on achieving optimal dietary patterns rather than adopt a singular focus on individual nutrients.

TABLE 4 Current and modeled diet quality after replacing foods high in refined grains with alternative foods, 2005–2018[1]

Diet pattern	Replacements			
	Current[2]	1 serving	2 servings	3 servings
General population[3]				
HEI-2015	57.1 (56.9, 57.4)	58.8 (58.5, 59.0)	59.3 (59.0, 59.5)	59.3 (59.0, 59.5)
kcal	2094 (2083, 2104)	2092 (2082, 2102)	2091 (2080, 2101)	2090 (2080, 2100)
Vegetarian[4]				
HEI-2015	63.0 (62.0, 64.0)	64.4 (63.3, 65.4)	64.7 (63.7, 65.7)	64.7 (63.7, 65.7)
kcal	1839 (1783, 1895)	1838 (1782, 1894)	1837 (1781, 1893)	1836 (1780, 1892)
Pescatarian[5]				
HEI-2015	65.2 (64.0, 66.4)	66.4 (65.1, 67.6)	66.6 (65.3, 67.8)	66.6 (65.3, 67.8)
kcal	1856 (1807, 1905)	1854 (1805, 1904)	1854 (1805, 1903)	1853 (1804, 1902)
Low-grain[6]				
HEI-2015	62.0 (61.6, 62.4)	62.5 (62.1, 63.0)	62.6 (62.1, 63.0)	62.6 (62.1, 63.0)
kcal	1587 (1568, 1605)	1586 (1567, 1605)	1586 (1567, 1605)	1586 (1567, 1605)
High-protein[7]				
HEI-2015	51.8 (51.0, 52.7)	53.4 (52.5, 54.2)	54.8 (53.9, 55.7)	54.9 (54.0, 55.9)
kcal	3651 (3615, 3687)	3648 (3612, 3684)	3645 (3609, 3681)	3643 (3607, 3678)
Restricted-carbohydrate[8]				
HEI-2015	56.9 (56.6, 57.3)	58.5 (58.2, 58.8)	58.9 (58.6, 59.2)	58.9 (58.6, 59.3)
kcal	2147 (2129, 2165)	2145 (2127, 2163)	2144 (2126, 2162)	2143 (2126, 2161)
Time-restricted[9]				
HEI-2015	55.2 (54.8, 55.5)	56.6 (56.3, 57.0)	57.0 (56.6, 57.4)	57.0 (56.7, 57.4)
kcal	1819 (1796, 1842)	1818 (1794, 1841)	1817 (1794, 1840)	1816 (1793, 1839)

[1] $n = 34,411$. Values are means (95% CIs). HEI scores were energy-adjusted to 1000 kcal/d. The diet model replaces the food highest in refined grains (target food) with 1, 2, or 3 servings of alternative food. HEI-2015, Healthy Eating Index-2015.
[2] Based on usual intake estimated from two 24-h recalls using the National Cancer Institute method.
[3] All participants that met the inclusion criteria, including those in each diet category as well as those not categorized into diet categories.
[4] Zero intake of meat, poultry, and seafood.
[5] Zero intake of meat and poultry and >0 ounce-equivalents of seafood.
[6] ≤10th percentile of total grain intake.
[7] ≥30th percentile of total protein intake.
[8] <45th percentile of total carbohydrate intake.
[9] ≥12 h food and beverage fast.

Evidence has continued to accumulate that adherence to healthy dietary patterns, which are defined by the totality of their constituent foods and nutrients, is strongly associated with reduced risk of major chronic disease outcomes (5, 38, 39). Accordingly, dietary patterns have appropriately become the major focus of recent dietary guidance (1, 39), and diet quality indexes have been developed to measure adherence to these dietary recommendations (4). Although a singular focus on specific foods or nutrients may be appealing to many consumers who place primary value on actionable nutrition guidance, it can obscure important dietary principles that are needed to achieve long-term success and improve self-efficacy. Greater efforts are needed to encourage the adoption of dietary approaches that optimize overall diet quality rather than

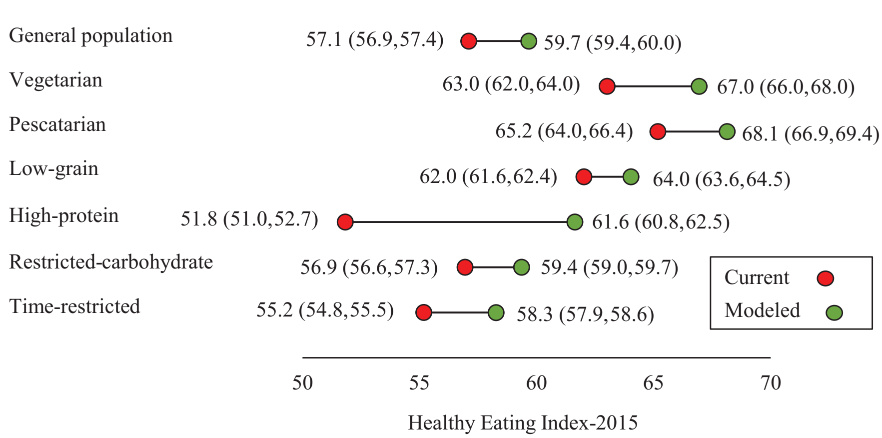

FIGURE 1 Current and modeled diet quality after replacing 1 serving of foods high in added sugar, sodium, saturated fat, and refined grains with alternative foods, 2005–2018. $n = 34,411$. Values adjacent to markers are means (95% CIs).

a singular focus on individual nutrients and foods, which can help improve health outcomes, build self-efficacy, and achieve long-term adherence.

Consumers may be more likely to initiate and sustain moderate diet and lifestyle changes than more comprehensive modifications, which is known as the "small changes" approach (40, 41). One way to implement this approach is to make targeted food replacements rather than adopt an entirely new diet pattern (12). The present study modeled this approach for 5 popular diets by replacing ≤3 servings of each food or beverage highest in added sugar, sodium, saturated fat, or refined grains with an alternative food or beverage, which is consistent with key dietary recommendations (13). For most diet patterns, 1-serving replacements increased HEI-2015 scores by 0.25–1.42 points, which may not be sufficient to lower risk of chronic disease (38, 42). Greater improvements in diet quality were demonstrated for the 2-serving (0.23–1.82) and 3-serving replacement levels (0.24–2.18), as well as when foods highest in added sugar, sodium, saturated fat, and refined grains were replaced simultaneously (2.01–3.93), but these changes were small and remain unlikely to yield meaningful health gains. The exception was the high-protein diet pattern, which had the lowest baseline diet quality (52 out of 100) but had the greatest increase after modeled replacements (≤9.81 points) that surpassed the diet quality of the general population but still left room for improvement. For other diet patterns with HEI-2015 scores below the general population at baseline (restricted-carbohydrate and time-restricted diet patterns), modeled food substitutions improved diet quality by ≤3.1 points, which was modestly higher than the improvement for the general population (≤2.6 points), but the HEI-2015 scores for these diet patterns remained lower than the score for the general population after modeled replacements. Even for diet patterns with HEI-2015 scores greater than that of the general population at baseline (pescatarian, vegetarian, and low-grain diet patterns), improvements were modest (≤3.9 points) and HEI-2015 scores did not exceed 68 out of 100.

Kirkpatrick et al. (42) suggested that a 5- to 6-point difference may be considered meaningful, yet others have demonstrated that larger differences may be needed to reach clinical significance (38). Although there is no standardized cutoff to define a low-quality diet pattern using the HEI-2015, a graded approach where D corresponds to 60–69 points and F corresponds to 0–59 points has been proposed (34). By this measure, the diet quality of all popular diet patterns assessed in this study corresponded to a grade of D or F, which can be considered low quality. These findings suggest that more comprehensive modifications to diet patterns may be needed to realize meaningful health gains for individuals following most types of popular diet patterns, even though some exceeded the diet quality of the general population. However, small dietary changes can improve self-efficacy to make other healthy lifestyle changes and, if sustained, can accumulate and lead to a reduction in chronic disease risk over time.

This study modeled the effect on diet quality of targeted food substitutions on a serving-for-serving basis, yet other approaches to dietary improvement are available for consumers. For calorie control, consumers can choose lower-calorie food options, perhaps targeting the highest-calorie foods in each food group they consume; or focus on reducing portion sizes. Some may also find it helpful to focus on replacing ultra-processed foods with minimally processed foods that may contain fewer calories and less added sugar and sodium. Future modeling approaches could investigate the comparative advantages of these varied approaches on improving diet quality.

This study has several strengths. To our knowledge, this is the first study to evaluate the diet quality of a diverse suite of actual popular diet patterns among a nationally representative US sample, rather than menu analyses of theoretical diet patterns. These findings provide useful information about what people actually consume, which has direct relevance to subsequent health outcomes. Data were collected over a 14-y time period from nearly 35,000 participants, which provided a sufficiently large sample to evaluate diets with low prevalence of consumption among the US population. The findings from this study also provide direct relevance to specific DGA 2020–2025 recommendations that encourage consumers to make food choices lower in added sugar, sodium, saturated fat, and refined grains. In addition, several features of the diet model were designed to reflect consumer decision making in real-world conditions. Alternative foods and beverages were identified based on multiple criteria, which included adherence to the principles of each diet pattern, reasonable substitutions that consumers may make based on discussion and consensus with multiple RDNs, and greatest consumption amount. Replacements were made on the basis of observed serving sizes rather than mass quantity (i.e., gram-for-gram). Finally, the diet model allowed for discretionary intake of target foods rather than modeling their complete removal.

This study also has several limitations. Participants were categorized into specific diet patterns according to reported dietary intake rather than self-identification with these diets, so some participants may have been categorized into diet patterns that they did not intend to follow. For example, NHANES collects data on participants' intention to follow a low-carbohydrate diet, and in post hoc analyses we estimated that fewer than one-half of participants with this intention actually consumed a restricted-carbohydrate diet (<45% energy) based on repeated 24-h recalls, which suggests that many people do not adhere to the diet they are intending to follow. Others have reported that self-identified vegetarians often indicate meat intake on dietary assessments (7). Although an analysis of intended compared with actual dietary patterns is an interesting area for future research exploration, this study evaluated actual dietary patterns which have greater relevance to health outcomes. Self-reported dietary data may be subject to measurement error from social desirability bias, which can occur when participants alter their reporting of food and beverage intake based on their perceived healthfulness, and this may also have led to misclassification bias. For example, some participants may have over-reported consumption of fruits and vegetables and under-reported their consumption of foods high in added sugar, sodium, saturated fat, and refined grains, which could have influenced the modeling analysis. However, unlike energy intake, there is no objective method to measure intake of every food and beverage among all participants in large samples, so self-reported dietary data are needed to evaluate diet quality and to compare dietary patterns between groups (43). It is possible that other food and beverage replacements may produce different results. It is also possible that isometric (i.e., gram-for-gram) or isocaloric replacements would produce different results. Finally, sample sizes were too small to evaluate other popular diet patterns of interest, including vegan, grain-free, Paleo, keto, and others, although some evidence suggests that the prevalence of self-reported adherence to these diets is increasing (2).

In conclusion, this large, nationally representative study demonstrated poor diet quality for popular diet patterns in the United States from 2005–2018. The pescatarian diet pattern had the greatest diet quality, followed by vegetarian and low-grain diet patterns, all of which were higher than the diet quality of the general population. The diet quality of the restricted-carbohydrate, time-restricted, and high-protein diet patterns was below the diet quality of the general population. Modeled dietary shifts that align with dietary recommendations to choose foods lower in added sugar, sodium, saturated fat, and refined grains modestly improved diet quality and also decreased energy intake for most diet patterns. It is possible that sustained dietary improvements, however small, can accumulate and lead to a reduction in chronic disease risk over time. Ultimately, more comprehensive dietary shifts will be needed to improve diet quality and decrease chronic disease risk for individuals following popular diet patterns in the United States. Greater efforts are needed to encourage consumer adoption of dietary patterns that emphasize consumption of a variety of high-quality food groups rather than a singular focus on individual nutrients or foods.

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Data Availability

Data described in this article, code book, and analytic code will be made publicly and freely available without restriction at https://archive.org/details/osf-registrations-z3fme-v1. This study was preregistered at the Center for Open Science, Open Science Framework at https://archive.org/details/osf-registrations-z3fme-v1.

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