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A Simulation Study of the Potential Effects of Healthy Food and Beverage Substitutions on Diet Quality and Total Energy Intake in Lower Mississippi Delta Adults[1,2,3]

Jessica L. Thomson[4,*], **Lisa M. Tussing-Humphreys**[4], **Stephen J. Onufrak**[5], **Jamie M. Zoellner**[6], **Carol L. Connell**[7], **Margaret L. Bogle**[8], and **Kathy Yadrick**[7]

[4]USDA Agricultural Research Service Southern Regional Research Center, Baton Rouge, LA 70803

[5]CDC National Center for Chronic Disease Prevention and Health Promotion, Atlanta, GA 30341-3717

[6]Virginia Tech Department of Human Nutrition, Foods and Exercise, Blacksburg, VA 24061

[7]University of Southern Mississippi Department of Nutrition and Food Systems, Hattiesburg, MS 39406

[8]USDA Agricultural Research Service Delta Obesity Prevention Research Unit, Little Rock, AR 72211

Abstract

The majority of adult diets in the United States, particularly the South, are of poor quality, putting these individuals at increased risk for chronic diseases. In this study, simulation modeling was used to determine the effects of substituting familiar, more healthful foods and beverages for less healthy ones on diet quality and total energy intake in Lower Mississippi Delta (LMD) adults. Dietary data collected in 2000 for 1,689 LMD adults who participated in the Foods of Our Delta Study were analyzed. The Healthy Eating Index-2005 (HEI-2005) was used to measure diet quality. The effects of substituting targeted foods and beverages with more healthful items on diet quality were simulated by replacing the targeted items' nutrient profile with their replacements' profile. For the single food and beverage groups, 100% replacement of grain desserts with juice-packed fruit cocktail and sugar-sweetened beverages with water resulted in the largest improvements in diet quality (4.0 and 3.8 points, respectively) and greatest decreases in total energy intake (98 and 215 kcal/d, respectively). The 100% substitution of all food and beverage groups combined resulted in a 12.0-point increase in HEI-2005 score and a decrease of 785 kcal/d

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[3]Supplemental Table 1 is available as Online Supporting Material with the online posting of this paper at http://jn.nutrition.org.

[*]Corresponding Author and Reprints: Jessica L. Thomson, USDA Agricultural Research Service, 284 Knapp Hall, Human Nutrition and Food, LSU AgCenter, Baton Rouge, LA 70803, Telephone: 225-892-3662, Fax: 225-578-4443, jessica.thomson@ars.usda.gov.

in total energy intake. Community interventions designed to improve the diet of LMD adults through the use of familiar, healthy food and beverage substitutions have the potential to improve diet quality and decrease energy intake of this health disparate population.

INTRODUCTION

Proper nutrition is essential for good health, yet the majority of adults in the US do not consume an adequate diet (1). Only 3–4% of American adults follow all the dietary recommendations of the DGA[9] (2). This is particularly true for subpopulations of the US, including the rural South (3–6). Cardiovascular disease, hypertension, dyslipidemia, T2DM, osteoporosis, obesity, and some cancers have all been linked to poor diet (7). In the US LMD region, half of the adults participating in the 2000 FOODS survey reported having at least one diet-related chronic health condition, including CVD, hypertension, T2DM, osteoporosis, and obesity (4). Hence, dietary interventions designed to address nutrition inadequacies and thereby improve diet quality could lower chronic disease risk in this region, particularly if such improvements led to a reduction in energy intake and subsequent weight loss.

Assessing a population's diet quality is a necessary step for determining nutrition inadequacies and subsequently designing effective dietary interventions which address these problems. The HEI-2005 is a tool that assesses diet quality in terms of adherence to the 2005 DGA. The 2005 DGA provides science-based advice to promote health and reduce the risk for major chronic diseases through diet and physical activity (7). Among the 2005 DGA key recommendations are food groups to encourage (fruits, vegetables, whole grains, and fat-free or low-fat milk), limitations for saturated fat and trans fat consumption, and reduction of added sugars and energy-containing sweeteners (7). These same recommendations are also emphasized in the recently released 2010 DGA (8). However, little is known about which of these recommendations has the greatest potential for improving diet quality. One practical approach to this problem is to simulate the impact of replacing less healthy foods and beverages with more healthful alternatives using an existing dietary data set. Recently, two studies reported the potential effects of replacing SSB with water on total energy intake (9, 10). Another study investigated the impact of simulating the substitution of canola oil for other vegetable oils in terms of compliance to dietary fat recommendations (11). Two other studies described dietary changes or food intake patterns needed to achieve nutritional recommendations for individuals or subgroups in a population using a mathematical optimization technique known as linear programming (12, 13). However, to the best of our knowledge, no studies have reported the potential impact of several different types of food and beverage substitutions, alone and in combination, on diet quality and total energy intake. Hence, the objectives of this study were to use simulation modeling to determine the effects of substituting familiar, more healthful foods and beverages for less healthy ones on diet quality and total energy intake in LMD adults. Determining food or beverage substitutions

[9]Abbreviations used: CVD, cardiovascular disease, DGA, Dietary Guidelines for Americans, DGOV&L, dark green and orange vegetables and legumes, FOODS, Foods of Our Delta Study, HEI-2005, Healthy Eating Index-2005, LMD, Lower Mississippi Delta, MPED, MyPyramid Equivalents Database, SoFAAS, solid fats, alcoholic beverages, and added sugars, SSB, sugar-sweetened beverages, T2DM, type 2 diabetes mellitus.

with the greatest potential for health improvement as well as the potential of several substitutions executed together is important for designing dietary interventions targeted for specific populations.

METHODS

Study sample

Analyses were performed using data from FOODS, a cross-sectional telephone survey of residents in a 36-county LMD region that was conducted from January to June 2000 (14). A two-stage stratified cluster sampling plan with list-assisted random-digit dialing was used in FOODS. Demographic information was collected during an initial interview. Dietary intake data was collected using the USDA 24-h dietary recall multiple pass methodology at an unscheduled follow-up telephone interview with the assistance of a foods measurement guide that had been mailed to survey participants. Dietary intake data was collected for 1,751 adults (participants 18 y of age and older) using a single 24-h recall. A more detailed description of the FOODS methodology has been published (14). The procedures followed in FOODS were in accordance with ethical standards and approval was obtained from the Institutional Review Board of Westat, Rockville, MD. For this study, only plausible 24-h recalls were used in the analyses. Dietary intake plausibility was based on the following criterion: $500 \leq$ intake kcal ≤ 6000 (15).

Diet quality assessment

The HEI-2005 is a scoring method designed to measure adherence to the 2005 DGA and diet quality (16). The HEI-2005 is composed of 12 components corresponding to total fruit (including 100% fruit juice); whole fruit; total vegetables; DGOV&L; total grains; whole grains; milk; meat and beans; oils; saturated fat; sodium; and kcal from SoFAAS. The total score, calculated as the sum of the component scores, has a maximum value of 100. Component scores are calculated using a density approach per 1,000 kcal or as a percent of energy and range from 0–5 for fruit, vegetables, and grains components; 0–10 for milk, meat and beans, saturated fat, and oils components; and 0–20 for the SoFAAS component. For each component, higher scores reflect better adherence to DGA recommendations corresponding to that component. For fruit, vegetables, grains, meat and beans, and milk components, each score is based upon MyPyramid equivalents consumed per 1,000 kcal. Oils and sodium component scores are calculated based upon grams consumed per 1,000 kcal. Saturated fat and SoFAAS component scores are calculated based upon percent of energy intake attributed to these energy sources. MyPyramid equivalents contributing to HEI-2005 index were derived using version 1.0 of the MPED which provides equivalents per 100 grams for each unique USDA eight digit food code (17).

Food and beverage substitutions

Selection of foods and beverages targeted for replacement was guided by the 2005 DGA recommendations, identification as a major food or beverage source for total grains or SoFAAS in the LMD adult population (18), and judgment of investigators experienced with the cultural dietary practices of the LMD population (Supplemental Table 1). In most cases, substitutions for a particular food code were made only if consumption frequency was greater than or equal to 20 occurrences in the data set. Exceptions occurred for the grain dessert and SSB groups due to the programmatic ease of replacing entire food subgroups, regardless of consumption frequency, with a single substitution food or beverage.

Foods and beverages chosen as more healthful substitutions were typically whole grain, lower fat, or lower sugar versions of the original items (Supplemental Table 1). In some cases, when a healthier version of the targeted food was not available, the selection of a replacement food was based upon the judgment of the investigators (e.g. fruit cocktail packed in juice for grain desserts). All foods and beverages selected as substitutions were deemed familiar foods and beverages based upon their inclusion in the FOODS data set. Briefly, white breads, rolls, biscuits, and spaghetti were replaced with their whole wheat counterparts, while white rice was replaced with brown rice. Whole and reduced fat white and chocolate milk were replaced with their nonfat counterparts. Regular fat cheeses were replaced with their reduced fat counterparts. The majority of white potato preparations (baked, boiled, mashed, fresh deep-fried French fries, and frozen baked French fries) were replaced with baked sweet potatoes, a culturally acceptable and popular orange vegetable in the LMD region (19). However, the majority of frozen deep-fried French fries and tater tots were consumed outside the home, presumably at fast food restaurants. Hence, they were replaced with a lettuce salad and reduced energy fat-free Italian dressing. The majority of fast food restaurants do include ‘side salads’ on their menu but not baked sweet potatoes, making this a suitable replacement. White potato chips and grain snacks were replaced with air-popped popcorn. Higher fat meats, poultry, and seafood were replaced with their leaner counterparts (e.g. regular ground beef with lean, fried catfish with baked). All grain desserts (cakes, cookies, pies, and pastries), regardless of consumption amount, were replaced with 119 g (½ cup) of fruit cocktail packed in juice. This was done because the consumption amounts (e.g. 5 g [½] of a cookie to 327 g [½] of a cake) in this food group were extremely varied making it difficult to determine a suitable substitution scheme for fruit cocktail amounts. Sugar-sweetened beverages were replaced with tap water. Beverages were identified as sugar sweetened based on the categorization scheme of Wang et al. (10). For the LMD population, SSB included: sweetened tea, carbonated soft drinks, fruit drinks, and non-carbonated beverages (e.g. fruit flavored drinks). Coffee, unsweetened tea, and unsweetened or sugar-free soft drinks were not included as SSB in the analyses. An example of a substitution algorithm may be found in Supplemental Table 1. Foods and beverages chosen for substitution and their corresponding replacements were identified using USDA eight digit food codes (20). To simulate the effects of substituting 25%, 50%, and 100% of targeted foods and beverages with their replacements on HEI-2005 total and component scores, the targeted items’ nutrient profiles were reduced by the respective amounts for the analyses while the replacement items’ nutrient profiles were inserted at the corresponding levels. Only five nutrient variables (grams, energy, carbohydrates, saturated fat, and sodium) required modification or insertion because the FOODS data set was linked to the MPED which only required these five variables to calculate MyPyramid equivalents. Because the gram weights of the targeted foods and beverages and their respective substitutions were often not equivalent, the substituted amount of the replacement items (in grams) was adjusted using the ratio of their typical serving size weight to the targeted items’ typical serving size weight. These weighted amounts were then used to calculate the amount of the five nutrient variables to insert for the substitutions. The nutrient profiles for the replacement foods were extracted from the FOODS data set.

It should be noted that for many substitutions, some HEI-2005 component scores that would not have been expected to change (e.g. fruit, vegetables, grains, and saturated fat for SSB substitutions) can increase or decrease depending on the substitution and component. Because component scores are based on the number of MyPyramid equivalents, kcal, or grams consumed per 1,000 kcal, substitutions that reduce the number of kcal results in increased densities. This increase in density can raise component scores for which a greater density is favorable (fruits, vegetables, grains, milk, meat and beans, and oils), but at the same time, lower component scores for which a greater density is unfavorable (saturated fat, sodium, and SoFAAS).

Data Analysis

All statistical analyses were performed using SAS® software (version 9.2, SAS Institute, Inc., Cary, NC) and SUDAAN® software (version 10.0.1, Research Triangle Institute, Research Triangle Park, NC). SAS survey and SUDAAN procedures were used to compute frequencies, means, and their associated 95% CI. These procedures are tailored to account for the complex sampling design used in FOODS. Hence the results are weighted and should be considered representative of the LMD adult population. The population ratio method was used to compute mean HEI-2005 scores and corresponding 95% CI using jackknife variances for the overall population. This method computes scores using the ratio of the weighted sum of MyPyramid equivalent servings for the relevant HEI-2005 component to the weighted sum of energy intake for the entire population. It is the least biased way to estimate a mean HEI-2005 score for a population (21).

The potential impact of the substitutions on daily total energy intake was estimated for single food and beverage groups at the 100% level and for the combined group at the 25%, 50%, and 100% levels. Changes in daily total energy intake were estimated by subtracting the population’s mean total energy intake corresponding to a given substitution scheme from the population’s actual mean total energy intake.

RESULTS

Sixty-two of the 1,751 LMD respondents were excluded due to implausible dietary records, resulting in a total sample size of 1,689 adults. The sample was composed of 47.5% males, 42.8% African Americans, 20.7% less than 30 years of age, and 23.3% greater than 60 years of age (Table 1). Approximately one fourth of the sample’s household income was less than $15,000 per year and 23.2% of the sample had less than a high school education (Table 1). Almost one-fourth (24.4%) of the respondents were current smokers, while 18.0% were former smokers (Table 1). Based on self-reported heights and weights, almost two thirds of the sample was either overweight [$25.0 \le BMI \le 29.9$] or obese ($30.0 \le BMI \le 39.9$), and 4.2% had extreme obesity ($BMI \ge 40.0$) (Table 1). The mean daily energy intake for the LMD adult respondents was 2,010 kcal (Table 1).

The HEI-2005 total score for the LMD population was 54.5 (Table 2). Only those HEI-2005 components that changed by at least 0.2 points (considered a meaningful change) for the 100% substitution level are presented (Table 2) with the exception of the combined substitutions which included all components. While all three substitution levels, 25%, 50%, and 100% are reported (Table 2), only the 100% substitutions of single food and beverage groups were highlighted within the results section in the interest of brevity. Similarly, while all substitutions resulted in improvements in associated component scores (e.g. total grains component score increased for refined grain substitutions with whole grains), only the HEI-2005 total score changes were highlighted within this section. Simulating 100% substitution of refined grains (white bread, spaghetti, and rice) with whole grains (whole wheat bread and spaghetti, and brown rice) resulted in a 1.9-point increase in total score. Simulating 100% substitution of higher fat milk and cheese with reduced fat or nonfat versions, higher fat grain snacks with air-popped popcorn, and higher fat meat with low or reduced fat versions resulted in 2.8-, 0.7- and 0.6-point increases in total score, respectively. Simulating 100% substitution of white potatoes with sweet potatoes, lettuce salad, or air-popped popcorn (depending on preparation method) resulted in a 1.0-point increase in total score. Simulating 100% substitution of grain desserts with juice-packed fruit cocktail and SSB with water resulted in 4.0- and 3.8-point increases in total score, respectively. When all simulated substitutions were performed collectively (combined), eight of the 12 HEI-2005 component scores increased by at least 0.5 points and the total score increased by 5.4 points at the 50% substitution level. Similarly, for the combined substitutions at the 100% level, eight of the 12 HEI-2005 component scores increased by at least 1.2 points and the total score increased by 12 points.

All the simulated food and beverage substitutions at the 100% level resulted in total energy intake decreases except for one food group substitution (Table 3). Substituting refined grains with whole grains resulted in a 15-kcal/d (0.7%) daily energy increase. All other targeted single group substitutions resulted in total energy intake decreases ranging from 27 (1.3%) to 215 kcal/d (10.7%). For the combined substitution, 25%, 50%, and 100% replacement resulted in total energy intake decreases of 196 (9.7%), 393 (19.5%), and 785 kcal/d (39.0%), respectively.

DISCUSSION

To the best of our knowledge, this is the first study to report the simulated effects of several different food and beverage substitutions, alone and in combination, on diet quality and total energy intake. Of the seven single food and beverage group substitutions, the replacement of SSB with water and grain desserts with juice-packed fruit cocktail had the largest impact on diet quality as measured by HEI-2005, and total energy intake. The relatively large effects of these two substitutions are likely due to the high rate of SSB consumption in this population and the high solid fat and added sugar content of grain desserts. At the 50% replacement level, the combined substitutions' improvement in HEI-2005 total score and reduction in total energy intake exceeded all seven of the single groups' improvements and reductions at the 100% level. Hence, while some of the single food and beverage group substitutions resulted in impressive improvements in diet quality and projected reductions in total energy intake at 100% substitution, none were as impressive as the combined substitutions at the

50% level. These results suggest that a more comprehensive approach encompassing simultaneous change within several food and beverage groups at a relatively realistic substitution level of 50% may be more effective at improving diet quality and decreasing energy intake than any single food or beverage substitution.

A higher quality diet, as measured by HEI-2005, has been associated with a number of positive health outcomes in adults. In low income postpartum women, HEI-2005 total scores were negatively associated with BMI, postpartum weight retention, LDL cholesterol, and total cholesterol, and positively associated with HDL cholesterol (22). The authors concluded that the strong relationship observed between HEI-2005 total scores and lipid profiles suggested that higher scores may translate to reduced risk for CVD in low income women, independent of BMI. In two studies, inverse relationships were found between HEI-2005 total scores and colorectal cancer in men and women, suggesting that adherence to DGA is associated with reduced risk of colorectal cancer (23, 24). Although these studies did find significant positive relationships between HEI-2005 total scores and specific health outcomes, caution should be used when translating these results to the current study's population because differences in demographic characteristics exist. Hence, more studies assessing the link between diet quality and chronic disease risk in diverse populations are needed. Further, the determination of barriers to dietary guidance compliance across ethnicities, socio-demographic groups, and geographic areas is warranted since only a small percentage of US adults follow all the DGA recommendations (25).

The improvement in diet quality as reflected by increases in HEI-2005 scores observed in this study are sufficient to warrant assessment of the feasibility and impact of nutrition interventions involving these food and beverage substitutions in the LMD adult population. Furthermore, the theoretical decrease in total energy consumed and potential for weight reduction in this population, given that the estimated rate of obesity (based on self-reported heights and weights) is approximately 34%, is just as compelling. Two intervention studies investigated the impact of adhering to a diet based on one or more components of the 2005 DGA on weight status and adiposity. In overweight and obese women, diets designed to reduce fat intake alone or coupled with increased fruit and vegetable intake led to one-year weight losses between 4.3 and 7.9 kg (26, 27). In observational studies, increases in fruits and vegetables and elimination of sweets from the diet (similar to the present study's grain dessert substitutions) were strategies associated with less weight gain over a 4-year period in US adults (28). However, when educating the general public, emphasis needs to be placed on substituting less healthy foods and beverages with more healthful ones and not simply adding healthy items to an unhealthy diet. For example, findings from a study designed to test for associations between whole and refined grain intakes and body fat suggested that the inclusion of whole grains in a diet already high in refined grains may not translate to lower abdominal adiposity (29). Clearly, a randomized controlled trial assessing the impact of the proposed dietary substitutions on weight status is warranted in the overweight and obese LMD adult population.

The results of this study suggest that potentially substantial reductions in total energy intake may be achieved using familiar, but more healthful food and beverage substitutions. While the reported improvements in diet quality may seem surprisingly small, a 12-point increase in HEI-2005 total score is sufficient to move an individual from the 20^{th} to the 50^{th} percentile or from the 70^{th} to the 90^{th} percentile for HEI-2005 total score in US adults (30). Thus, given the distribution of HEI-2005 scores in the American population, the improvements found in this study should be considered substantial. Further, if the artificial decreases which occurred for the saturated fat and sodium scores due to the decrease in total energy intake could somehow be accounted for, the improvements in HEI-2005 scores would likely have been larger. However, the ubiquitous presence of SoFAAS in the American food supply may also be partially responsible for the seemingly small improvements in HEI-2005 scores. Only 11 of the 165 food and beverage groups in the FOODS data set did not contribute energy to the SoFAAS component score (data not shown). Hence efforts are needed to reduce Americans' consumption of foods high in SoFAAS and the food industry could contribute significantly to these efforts by producing healthier food and beverage products.

A major strength of this study is the use of the FOODS data set. To the best of our knowledge, this is the only data set containing dietary intake measures on a representative sample of LMD adult residents. Because the FOODS sampling plan was designed to be representative of the LMD region, these results are generalizable to the entire LMD adult population. However, this study does have limitations. The data were collected in 2000 and may not completely represent the current dietary intake or demographic profile of LMD adults. A single 24-h dietary recall is not an accurate measure of an individual's usual intake due to large day-to-day variability in food intake. However, at the group or population level, the mean of a single day of intake is highly reproducible (31) and can therefore be representative of a population's usual intake. Additionally, self-reported dietary assessment methods, such as 24-h dietary recalls, are prone to intake underreporting (15). It is likely that underreporting occurred in FOODS. If underreporting had not occurred, improvements resulting from the targeted food and beverage substitutions may have been even larger. Further, for some substitutions, the serving size was not equivalent between the targeted food and its replacement due to complexities involved in programming the substitutions. For example, all slices of white bread (regular, thin, and thick) were substituted with regular slices of whole wheat bread. In all such cases, the size of the substituted item was equivalent to the most frequently occurring size of the targeted food. In most cases, such replacements resulted in conservative estimates of the substitution effects since the serving size of the substitution food was equal to or larger than that of the targeted food. Also, the substitutions were based on 2005 DGA recommendations because the most current 2010 DGA recommendations were not available when the analyses were conducted. Finally, the theoretical energy reductions reported in this study are likely not realistic and may over-estimate the expected decrease in energy resulting from the proposed dietary substitutions as individuals may compensate for the reduction in energy intake with other food and beverage items.

Future directions for this research include testing the feasibility and effectiveness of implementing the food and beverage substitutions simulated in this study in the LMD adult population. While care was taken to substitute targeted foods and beverages with more healthful, but familiar items (as evidenced by their inclusion in the FOODS data set), there is no assurance that these substitutions will be adopted by a large proportion of the LMD adult population. Implementing dietary interventions in regions designated as food deserts, such as the LMD, can be challenging. The low availabilities of supermarkets and healthy foods in this region have been highlighted in previous research as possible determinants of diet quality (32, 33). Hence, culturally sensitive interventions designed to encourage the replacement of less healthy food and beverages with more healthful ones are suggested. Such interventions may be the most efficacious approach for conveying potentially substantial health benefits in this and similar disadvantaged regions of the US where cultural dynamics have an immense influence on food choices and health practices (34).

Additionally, it is important to determine if different diet modeling methods used to demonstrate the impact of dietary changes on diet quality, such as linear programming, would yield similar findings as the simulation approach used in the current study. Linear programming is a mathematical optimization technique that has been used to design nutritionally adequate diets and simulate the effects of improving adherence to nutrient based recommendations (12, 13). In the present study, simulated dietary changes were based on food or food group guidelines and used a food-based dietary assessment rather than a nutrient-based assessment. It would be interesting to compare a nutritionally adequate diet designed for the LMD adult population using linear programming with the simulated dietary modifications identified in the current study. However, while the simulation methods used in the current study are not complicated and can be programmed by a statistician, epidemiologist, or nutrition researcher with statistical software experience, it appears that linear programming may involve the use of specialized software (e.g. Operational Research package of SAS) and somewhat specific expertise for implementation. Thus each technique may have applications to which it is better suited.

In conclusion, poor diet is associated with increased risk of many chronic diseases including CVD, T2DM, hypertension, and obesity, which are all prevalent in the LMD adult population. Simulating the substitution of more healthful but familiar foods and beverages for less healthy ones commonly consumed by a representative sample of LMD adults resulted in considerable improvement in diet quality as assessed by HEI-2005. These simulated substitutions also resulted in decreased energy intake which could potentially translate to reductions in body weight for this population. While some single food and beverage group substitutions resulted in relatively large improvements in diet quality and reductions in energy intake, the combined substitutions involving all food and beverage groups were most effective. This simulation modeling provides promising evidence for the capacity of community interventions involving familiar, healthy food and beverage substitutions to improve diet quality and decrease energy intake with the potential for weight reduction in a health disparate population. Efforts to help individuals improve the quality of their diet may include implementing policy and environmental changes which make more nutritious food and beverage choices the easier choice.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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References

1. Moshfegh, A.; Goldman, J.; Ahuja, J.; Rhodes, D.; LaComb, R. What We Eat in America, NHANES 2005–2006: Usual nutrient intakes from food and water compared to 1997 dietary reference intakes for vitamin D, calcium, phosporus, and magnesium. USDA Agricultural Research Service; 2009.
2. Kohatsu ND, Robinson JG, Torner JC. Evidence-based public health: an evolving concept. Am J Prev Med. 2004; 27:417–21. [PubMed: 15556743]
3. Asirvatham J. Examining diet quality and body mass index in rural areas using a quantile regression framework. The Review of Regional Studies. 2009; 39:149–69.
4. McCabe-Sellers BJ, Bowman S, Stuff JE, Champagne CM, Simpson PM, Bogle ML. Assessment of the diet quality of US adults in the Lower Mississippi Delta. Am J Clin Nutr. 2007; 86:697–706. [PubMed: 17823435]
5. Savoca MR, Arcury TA, Leng X, Bell RA, Chen H, Anderson A, et al. The diet quality of rural older adults in the South as measured by healthy eating index-2005 varies by ethnicity. J Am Diet Assoc. 2009; 109:2063–7. [PubMed: 19942025]
6. Vitolins MZ, Tooze JA, Golden SL, Arcury TA, Bell RA, Davis C, et al. Older adults in the rural South are not meeting healthful eating guidelines. J Am Diet Assoc. 2007; 107:265–72. [PubMed: 17258963]
7. Dietary Guidelines for Americans 2005. Washington, DC: US Department of Health and Human Services, US Department of Agriculture; 2005.
8. Dietary Guidelines for Americans 2010. Washington, DC: US Department of Health and Human Services, US Department of Agriculture; 2010.
9. Stookey JD, Constant F, Gardner CD, Popkin BM. Replacing sweetened caloric beverages with drinking water is associated with lower energy intake. Obesity (Silver Spring). 2007; 15:3013–22. [PubMed: 18198310]
10. Wang YC, Ludwig DS, Sonneville K, Gortmaker SL. Impact of change in sweetened caloric beverage consumption on energy intake among children and adolescents. Arch Pediatr Adolesc Med. 2009; 163:336–43. [PubMed: 19349562]
11. Johnson GH, Keast DR, Kris-Etherton PM. Dietary modeling shows that the substitution of canola oil for fats commonly used in the United States would increase compliance with dietary recommendations for fatty acids. J Am Diet Assoc. 2007; 107:1726–34. [PubMed: 17904932]
12. Maillot M, Drewnowski A. Energy allowances for solid fats and added sugars in nutritionally adequate U.S. diets estimated at 17–33% by a linear programming model. J Nutr. 2011; 141:333–40. [PubMed: 21178090]
13. Maillot M, Vieux F, Amiot MJ, Darmon N. Individual diet modeling translates nutrient recommendations into realistic and individual-specific food choices. Am J Clin Nutr. 2010; 91:421–30. [PubMed: 19939986]
14. Champagne CM, Bogle ML, McGee BB, Yadrick K, Allen HR, Kramer TR, et al. Dietary intake in the lower Mississippi delta region: results from the Foods of our Delta Study. J Am Diet Assoc. 2004; 104:199–207. [PubMed: 14760567]
15. Willett, W. Nutritional epidemiology. New York, NY: Oxford University Press; 1998.
16. Guenther PM, Reedy J, Krebs-Smith SM. Development of the Healthy Eating Index-2005. J Am Diet Assoc. 2008; 108:1896–901. [PubMed: 18954580]
17. Friday, JE.; Bowman, SA. MyPyramid Equivalents Database for USDA Survey Food Codes, 1994–2002 Version 1.0. [Online]. Beltsville, MD: USDA, Agricultural Research Service, Beltsville Human Nutrition Research Center, Community Nutrition Research Group; 2006.

18. Thomson JL, Onufrak SJ, Connell CL, Zoellner JM, Tussing-Humphreys LM, Bogle ML, et al. Food and beverage choices contributing to dietary guidelines adherence in the Lower Mississippi Delta Public Health Nutr. In press. 10.1017/S1368980011001443
19. Tucker KL, Maras J, Champagne C, Connell C, Goolsby S, Weber J, et al. A regional food-frequency questionnaire for the US Mississippi Delta. Public Health Nutr. 2005; 8:87–96. [PubMed: 15705249]
20. USDA Food and Nutrition Database for Dietary Studies, 1.0. Beltsville, MD: Agricultural Research Service, Food Surveys Research Group; 2004.
21. Freedman LS, Guenther PM, Krebs-Smith SM, Kott PS. A population's mean Healthy Eating Index-2005 scores are best estimated by the score of the population ratio when one 24-hour recall is available. J Nutr. 2008; 138:1725–9. [PubMed: 18716176]
22. Shah BS, Freeland-Graves JH, Cahill JM, Lu H, Graves GR. Diet quality as measured by the healthy eating index and the association with lipid profile in low-income women in early postpartum. J Am Diet Assoc. 2010; 110:274–9. [PubMed: 20102856]
23. Miller PE, Lazarus P, Lesko SM, Muscat JE, Harper G, Cross AJ, et al. Diet index-based and empirically derived dietary patterns are associated with colorectal cancer risk. J Nutr. 2010; 140:1267–73. [PubMed: 20444952]
24. Reedy J, Mitrou PN, Krebs-Smith SM, Wirfalt E, Flood A, Kipnis V, et al. Index-based dietary patterns and risk of colorectal cancer: the NIH-AARP Diet and Health Study. Am J Epidemiol. 2008; 168:38–48. [PubMed: 18525082]
25. King JC. An evidence-based approach for establishing dietary guidelines. J Nutr. 2007; 137:480–3. [PubMed: 17237331]
26. Ello-Martin JA, Roe LS, Ledikwe JH, Beach AM, Rolls BJ. Dietary energy density in the treatment of obesity: a year-long trial comparing 2 weight-loss diets. Am J Clin Nutr. 2007; 85:1465–77. [PubMed: 17556681]
27. Psota, T. Development, implementation, and evaluation of a weight-management program based on the "2005 Dietary Guidelines for Americans". Department of Nutritional Sciences; University Park: Pennsylvania State University; 2009. p. 183
28. French SA, Jeffery RW, Murray D. Is dieting good for you?: Prevalence, duration and associated weight and behaviour changes for specific weight loss strategies over four years in US adults. Int J Obes Relat Metab Disord. 1999; 23:320–7. [PubMed: 10193879]
29. McKeown NM, Troy LM, Jacques PF, Hoffmann U, O'Donnell CJ, Fox CS. Whole- and refined-grain intakes are differentially associated with abdominal visceral and subcutaneous adiposity in healthy adults: the Framingham Heart Study. Am J Clin Nutr. 2010; 92:1165–71. [PubMed: 20881074]
30. Guenther, PM.; Reedy, J.; Krebs-Smith, SM.; Reeve, BB.; Basiotis, PP. Development and evaluation of the Healthy Eating Index-2005: technical report. Center for Nutrition Policy and Promotion, U.S. Department of Agriculture; 2007.
31. Gersovitz M, Madden JP, Smiciklas-Wright H. Validity of the 24-hour dietary recall and seven-day record for group comparisons. J Am Diet Assoc. 1978; 73:48–55. [PubMed: 659761]
32. Blanchard T, Lyson T. Food availability and food deserts in the nonmetropolitan South. 2006. Food Assistance and Needs in the South's Vulnerable Population.
33. Connell CL, Yadrick MK, Simpson P, Gossett J, McGee BB, Bogle ML. Food supply adequacy in the Lower Mississippi Delta. J Nutr Educ Behav. 2007; 39:77–83. [PubMed: 17346655]
34. Zoellner J, Bounds W, Connell C, Yadrick K, Crook L. Meaningful messages: adults in the Lower Mississippi Delta provide cultural insight into strategies for promoting the MyPyramid. J Nutr Educ Behav. 2010; 42:41–50. [PubMed: 19910255]

Table 1

Demographic characteristics for Lower Mississippi Delta adults[1]

Characteristic	*n*	%
Total	1689	
Sex		
Male	641	47.5 (46.7, 48.2)
Female	1048	52.5 (51.8, 53.3)
Age Group, *y*		
18–29	306	20.7 (18.4, 23.1)
30–39	321	19.1 (17.3, 20.8)
40–59	605	36.9 (34.6, 39.2)
≥60	456	23.3 (21.5, 25.1)
Unknown	1	0.0 (0.0, 0.1)
Race		
White	827	53.8 (53.1, 54.4)
African American	812	42.8 (41.7, 43.9)
Other	34	2.5 (1.5, 3.5)
Unknown	16	0.9 (0.5, 1.4)
Income Level		
<$15,000	465	23.1 (20.9, 25.4)
$15,000–$29,999	417	24.8 (22.3, 27.3)
≥$30,000	612	40.0 (37.2, 42.8)
Unknown	195	12.1 (10.4, 13.8)
Education Level		
<High School	407	23.2 (20.9, 25.5)
High School	568	36.8 (34.5, 39.1)
>High School	691	38.5 (36.1, 40.9)
Unknown	23	1.5 (0.7, 2.2)
Smoking Status[2]		
Current Smoker	388	24.4 (22.0, 26.8)
Former Smoker	302	18.0 (16.1, 19.8)
Non-smoker	984	56.5 (53.9, 59.1)
Unknown	15	1.2 (0.5, 1.8)
Weight Status		
Healthy Weight (18.5 ≤ BMI ≤ 24.9)	536	31.3 (28.8, 33.9)
Overweight (25.0 ≤ BMI ≤ 29.9)	548	33.3 (30.6, 36.0)
Obese (30.0 ≤ BMI ≤ 39.9)	494	29.6 (27.1, 32.1)
Extreme Obesity (BMI ≥ 40.0)	84	4.2 (3.1, 5.3)
Unknown	27	1.6 (0.8, 2.3)
Total Energy Intake, *kcal/d*	1689	2010 (1960, 2060)

[1]Values are mean (95% CI).

[2]Current smoker = smoked at least 100 cigarettes and now smoking; former smoker = smoked at least 100 cigarettes and not smoking; non-smoker = did not smoke at least 100 cigarettes.

Table 2

Healthy Eating Index-2005 (HEI-2005) total and component scores for food and beverage substitutions with more healthful foods and beverages in Lower Mississippi Delta adults[1] (n=1689)

HEI-2005 Component	Substitution Level				Change[2]
	None	25%	50%	100%	
	Refined Grains (White Bread, Spaghetti, and Rice)				
Whole Grains	0.8 (0.7, 0.9)	1.4 (1.3, 1.5)	2.0 (1.9, 2.1)	3.3 (3.1, 3.4)	2.5
Oils	7.3 (7.6, 7.2)	7.2 (6.9, 7.5)	7.1 (6.8, 7.5)	7.0 (6.6, 7.3)	−0.3
Sodium	6.7 (6.5, 6.9)	6.8 (6.6, 7.0)	6.8 (6.6, 7.1)	6.9 (6.7, 7.2)	0.2
SoFAAS	5.8 (5.3, 6.3)	5.7 (5.2, 6.2)	5.6 (5.0, 6.1)	5.3 (4.8, 5.8)	−0.5
Total	54.5 (52.0, 57.1)	55.0 (52.4, 57.5)	55.5 (52.8, 58.0)	56.4 (53.7, 58.9)	1.9
	Milk and Cheese				
Saturated Fat	5.8 (5.4, 6.2)	6.2 (5.9, 6.6)	6.7 (6.3, 7.0)	7.5 (7.2, 7.9)	1.7
Sodium	6.7 (6.5, 6.9)	6.6 (6.4, 6.9)	6.6 (6.3, 6.8)	6.4 (6.2, 6.7)	−0.3
SoFAAS	5.8 (5.3, 6.3)	6.0 (5.5, 6.6)	6.3 (5.7, 6.8)	6.7 (6.2, 7.2)	0.9
Total	54.5 (52.0, 57.1)	55.2 (52.6, 57.8)	55.9 (53.3, 58.4)	57.3 (54.7, 59.8)	2.8
	White Potatoes				
DGOV&L	1.2 (1.0, 1.3)	1.3 (1.1, 1.5)	1.5 (1.3, 1.6)	1.8 (1.6, 2.0)	0.6
Oils	7.3 (7.0, 7.6)	7.2 (6.9, 7.6)	7.2 (6.8, 7.5)	7.0 (6.7, 7.4)	−0.3
Saturated Fat	5.8 (5.4, 6.2)	5.9 (5.5, 6.3)	6.0 (5.6, 6.4)	6.2 (5.8, 6.6)	0.4
Sodium	6.7 (6.5, 6.9)	6.6 (6.4, 6.8)	6.5 (6.3, 6.7)	6.3 (6.1, 6.5)	−0.4
Total	54.5 (52.0, 57.1)	54.8 (52.2, 57.3)	55.1 (52.5, 57.6)	55.6 (53.0, 58.1)	1.0
	Grain Snacks				
Oils	7.3 (7.0, 7.6)	7.1, (6.8, 7.4)	6.9 (6.6, 7.2)	6.5 (6.2, 6.8)	−0.8
SoFAAS	5.8 (5.3, 6.3)	5.7 (5.2, 6.3)	5.6 (5.1, 6.2)	5.4 (4.9, 6.0)	−0.4
Total	54.5 (52.0, 57.1)	54.4 (51.8, 57.0)	54.2 (51.6, 56.8)	53.8 (51.2, 56.4)	−0.7
	Meat (Beef, Pork, Poultry and Seafood)				
Saturated Fat	5.8 (5.4, 6.2)	5.9 (5.6, 6.3)	6.1 (5.7, 6.4)	6.3 (5.9, 6.7)	0.5
Sodium	6.7 (6.5, 6.9)	6.7 (6.4, 6.9)	6.6 (6.4, 6.8)	6.5 (6.2, 6.7)	−0.2
SoFAAS	5.8 (5.3, 6.3)	5.9 (5.4, 6.4)	6.0 (5.4, 6.5)	6.1 (5.5, 6.6)	0.3
Total	54.5 (52.0, 57.1)	54.7 (52.1, 57.3)	54.8 (52.2, 57.4)	55.1 (52.4, 57.7)	0.6

HEI-2005 Component	Substitution Level				
	None	25%	50%	100%	Change[2]
	Grain Desserts				
Total Fruit	2.4 (2.3, 2.6)	2.7 (2.5, 2.8)	2.9 (2.7, 3.1)	3.3 (3.1, 3.5)	0.9
Whole Fruit	2.3 (2.1, 2.5)	2.7 (2.5, 2.9)	3.1 (2.9, 3.3)	3.9 (3.7, 4.2)	1.6
Total Grains	4.9 (4.7, 5.0)	4.8 (4.7, 5.0)	4.8 (4.6, 4.9)	4.6 (4.5, 4.8)	−0.3
Milk	4.1 (3.9, 4.4)	4.1 (3.9, 4.4)	4.2 (3.9, 4.5)	4.3 (4.0, 4.6)	0.2
SoFAAS	5.8 (5.3, 6.3)	6.1 (5.6, 6.7)	6.4 (5.9, 7.0)	7.1 (6.5, 7.7)	1.3
Total	54.5 (52.0, 57.1)	55.5 (52.9, 58.1)	56.5 (53.8, 59.2)	58.5 (55.7, 61.3)	4.0
	Sugar-sweetened Beverages				
Total Fruit	2.4 (2.3, 2.6)	2.5 (2.3, 2.7)	2.5 (2.3, 2.7)	2.6 (2.4, 2.8)	0.2
Whole Fruit	2.3 (2.1, 2.5)	2.4 (2.2, 2.6)	2.5 (2.3, 2.7)	2.6 (2.4, 2.8)	0.3
Total Vegetables	3.2 (3.0, 3.3)	3.3 (3.1, 3.4)	3.4 (3.2, 3.5)	3.6 (3.4, 3.7)	0.4
Milk	4.1 (3.9, 4.4)	4.2 (4.0, 4.5)	4.3 (4.1, 4.6)	4.6 (4.3, 4.9)	0.5
Oils	7.3 (7.0, 7.6)	7.5 (7.2, 7.8)	7.7 (7.4, 8.1)	8.2 (7.8, 8.5)	0.9
Saturated Fat	5.8 (5.4, 6.2)	5.3 (4.9, 5.7)	4.8 (4.4, 5.2)	3.6 (3.2, 4.1)	−2.2
Sodium	6.7 (6.5, 6.9)	6.5 (6.2, 6.7)	6.2 (6.0, 6.4)	5.6 (5.4, 5.8)	−1.1
SoFAAS	5.8 (5.3, 6.3)	6.8 (6.3, 7.3)	7.9 (7.4, 8.4)	10.2 (9.7, 10.7)	4.4
Total	54.5 (52.0, 57.1)	55.5 (52.9, 58.0)	56.4 (53.8, 58.9)	58.3 (55.6, 60.9)	3.8
	Combined (All Substitutions Together)				
Total Fruit	2.4 (2.3, 2.6)	2.9 (2.7, 3.1)	3.4 (3.2, 3.6)	5.0 (4.6, 5.0)	2.6
Whole Fruit	2.3 (2.1, 2.5)	3.0 (2.7, 3.2)	3.8 (3.5, 4.1)	5.0 (5.0, 5.0)	2.7
Total Vegetables	3.2 (3.0, 3.3)	3.5 (3.4, 3.7)	3.9 (3.8, 4.1)	5.0 (5.0, 5.0)	1.8
DGOV&L	1.2 (1.0, 1.3)	1.5 (1.3, 1.6)	1.9 (1.7, 2.1)	3.0 (2.7, 3.3)	1.8
Total Grains	4.9 (4.7, 5.0)	5.0 (5.0, 5.0)	5.0 (5.0, 5.0)	5.0 (5.0, 5.0)	0.1
Whole Grains	0.8 (0.7, 0.9)	1.6 (1.5, 1.7)	2.7 (2.5, 2.8)	5.0 (5.0, 5.0)	4.2
Milk	4.1 (3.9, 4.4)	4.5 (4.2, 4.8)	5.0 (4.7, 5.3)	6.5 (6.1, 7.0)	2.4
Meat and Beans	10.0 (10.0, 10.0)	10.0 (10.0, 10.0)	10.0 (10.0, 10.0)	10.0 (10.0, 10.0)	0.0
Oils	7.3 (7.0, 7.6)	7.5 (7.2, 7.8)	7.8 (7.4, 8.1)	8.5 (8.0, 9.0)	1.2
Saturated Fat	5.8 (5.4, 6.2)	5.6 (5.2, 6.0)	5.4 (5.0, 5.8)	4.6 (4.1, 5.1)	−1.2
Sodium	6.7 (6.5, 6.9)	5.8 (5.6, 6.1)	4.7 (4.4, 5.0)	1.4 (1.0, 1.9)	−5.3
SoFAAS	5.8 (5.3, 6.3)	6.1 (5.6, 6.6)	6.4 (5.9, 7.0)	7.4 (6.7, 8.1)	1.6

HEI-2005 Component	Substitution Level				
	None	25%	50%	100%	Change[2]
Total	54.5 (52.0, 57.1)	57.0 (54.4, 59.6)	59.9 (57.0, 62.9)	66.5 (63.3, 69.3)	12.0

SoFAAS, solid fats, alcoholic beverages, and added sugars; DGOV&L, dark green and orange vegetables and legumes.

[1] Values are mean (95% CI).

[2] Change = 100% substitution - no substitution; only HEI-2005 components with changes ≥ 0.2 units were included for single food and beverage group substitutions.

Table 3

Healthy Eating Index (HEI-2005) total score, total energy intake, and body weight changes for food and beverage substitutions with more healthful foods and beverages in Lower Mississippi Delta adults (*n*=1689)

Food/Beverage Group Substitution (Level)	HEI-2005 Total Score Change	Total Energy Intake Change[1]		Body Weight Change[2]
		kcal/d	*%*	*kg/y*
Refined Grains[3] (100%)	1.9	15	0.7	0.7
Milk & Cheese (100%)	2.8	−39	−1.9	−1.9
White Potatoes (100%)	1.0	−59	−2.9	−2.8
Grain Snacks (100%)	−0.7	−32	−1.6	−1.5
Meat[4] (100%)	0.6	−27	−1.3	−1.3
Grain Desserts (100%)	4.0	−98	−4.9	−4.6
SSB (100%)	3.8	−215	−10.7	−10.2
Combined[5]				
25% Substitution	2.5	−196	−9.7	−9.3
50% Substitution	5.4	−393	−19.5	−18.6
100% Substitution	12.0	−785	−39.0	−37.2

SSB, sugar-sweetened beverages.

[1]Percentage change based on mean daily intake of 2,010 kcal.

[2]Yearly body weight change in kg = (daily kcal change in total energy intake x 365 d/y)/7700 kcal/kg of fat.

[3]Refined Grains = white bread, spaghetti, and rice.

[4]Meat = beef, pork, poultry, and seafood.

[5]Combined = all substitutions together.