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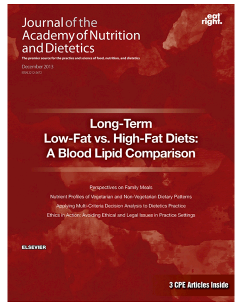

Incorporating Dietary Guidelines for Americans vegetable recommendations into the diet alters dietary intake patterns of other foods and improves diet quality in adults with overweight and obesity

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Research Snapshot

Research Question: How do people incorporate DGA recommended types and amounts of vegetables into their diet and how does this impact dietary intake patterns, diet quality, and body weight and composition?

Key Findings: In this community-based parallel, randomized controlled trial that included 51 adults with overweight or obesity increasing vegetable consumption to meet DGA recommendations for 8 weeks improved diet quality and decreased the energy density of the diet. With the increase in vegetable consumption there were decreases in the number of servings of total grains, protein foods, saturated fats and added sugars consumed. There was no change in energy intake or body weight and composition.

Incorporating Dietary Guidelines for Americans vegetable recommendations into the diet alters dietary intake patterns and improves diet quality in adults with overweight and obesity

Abstract

Background. Understanding how vegetables are incorporated into the diet, especially in the types and amounts recommended by the Dietary Guidelines for Americans (DGA), and how this alters dietary intake patterns is vital for developing targeted behavior change interventions.

Objective. To determine how a provision of vegetables was incorporated into the diet of adults with overweight and obesity, whether the provided vegetables displaced other foods and what, if any, effect this had on diet quality and body weight and composition.

Design. This study investigated secondary outcomes from the "Motivating Value of Vegetables Study", a community-based, randomized, parallel, non-blinded controlled trial. Participants were randomly assigned to a provided vegetable intervention or attention control group using a 1:1 allocation ratio.

Participants/setting. Men and women with self-reported low vegetable consumption, aged 18-65 years, with a body mass index ≥ 25 were recruited from Grand Forks, ND, between October 2015 and September 2017. Only participants randomized to the provided vegetable intervention group (n=51; attrition=8%) were included in this secondary analysis.

Intervention. DGA recommended types and amounts of vegetables were provided weekly for 8 weeks.

Main outcome measures. How the provided vegetables were incorporated into the diet was measured using daily self-report and 24-hour dietary recalls. Diet quality was assessed via the

Healthy Eating Index (HEI)-2015. Body weight and composition were measured before and after the intervention.

Statistical analyses performed. Data were assessed using generalized linear mixed models where phase (pre, post) was the within-subject factor and subject was the random effect.

Results. Participants self-reported using 29% of the provided vegetables as substitutes for other foods. With the increase in vegetable consumption there were decreases in total grains (mean difference ± standard deviation; -.97 ± 3.23 ounce-equivalents; $p = .02$), protein foods (-1.24 ± 3.86 ounce-equivalents; $p = .01$), saturated fats (-6.44 ± 19.63 g; $p = .02$) and added sugars (-2.44 ± 6.78 teaspoon-equivalents; $p = .02$) consumed. Total HEI-2015 scores increased (+4.48 ± 9.63; $p = .001$) and dietary energy density decreased (-.44 ± .52 kcals/g; $p < .0001$). There was no change in total energy intake or body weight and composition.

Conclusions. Increasing vegetable consumption to meet DGA recommendations alters dietary intake patterns, improving diet quality and energy density. These findings highlight the importance of characterizing how individuals incorporate DGA recommendations into their diet.

Incorporating Dietary Guidelines for Americans vegetable recommendations into the diet alters dietary intake patterns and improves diet quality in adults with overweight and obesity

Introduction

The health benefits of eating vegetables are well known, yet consumption continues to be below recommended amounts set forth by the Dietary Guidelines for Americans (DGA) for all vegetable groups across all age groups with few exceptions.[1, 2] A variety of interventions can increase vegetable consumption;[3, 4] however, upon cessation of the intervention, vegetable consumption either returns to pre-study consumption amounts[5] or remains only marginally greater (less than 80 g per day).[6] When attempting to incorporate vegetables into the diet, individuals may add them without reducing the consumption of other foods or, alternatively, they may substitute them into the diet by displacing other foods. DGA recommendations state that a healthy eating pattern requires not only an increase in vegetable consumption from all vegetable groups but that these nutrient-dense foods replace more energy-dense foods.[1] However, there is a dearth of evidence on how interventions focused on increasing vegetable consumption alter dietary intake patterns. Understanding how vegetables are incorporated into the diet, especially in the types and amounts recommended by the DGA, and how this alters dietary intake patterns is vital for developing targeted behavior change interventions that improve long-term adherence to DGA recommendations.[4]

The relationship between vegetable consumption, energy intake, and weight management has long been a topic of interest. Nonetheless, research into these relationships has provided mixed results[2, 7-12] that may be explained by how the vegetables are incorporated into the diet. DGA recommendations are based on energy needs.[1] Accordingly, when striving to increase vegetable consumption simply adding vegetables to the diet could result in an increase in energy intake whereas the substitution of vegetables could result in no change or a decrease in energy intake. This is especially important for individuals with overweight and obesity. Therefore, the aims of this study were threefold: 1) to determine how the provision of vegetables in the types and amounts recommended by the DGA was incorporated into the diet; 2) to determine whether the provided vegetables displaced other foods and what, if any, effect this had on diet quality; 3) to determine whether incorporation of vegetables was associated with changes in body weight (BW) and adiposity (percent body fat; %BF). The hypotheses were that participants would substitute the provided vegetables into the diet, displacing energy-dense foods, resulting in lower energy intake, better diet quality and decreased BW and %BF.

Materials and Methods

This study investigated a secondary outcome of a larger parent study.[5, 13] The parent study was conducted in accordance with CONSORT between October 2015 and January 2018 at the Grand Forks Human Nutrition Research Center (GFHNRC). The trial was approved by the University of North Dakota Institutional Review Board and is registered on ClinicalTrials.gov as NCT02585102 (Motivating Value of Vegetables Study). All participants were recruited from the Greater Grand Forks area through posted flyers and newspaper advertisements and provided written informed consent prior to enrollment into the study. Detailed information on the study design, participant selection, and procedures has been published.[5, 13] Briefly, participants were men and women aged 18-65 years with a body mass index (BMI) $\geq$ 25 kg/m^2 who self-reported low habitual vegetable consumption ($\leq$1 serving per day – excluding fried potatoes).[5, 13] Habitual vegetable consumption was established by asking participants during their initial visit “About how many cups of vegetables (excluding fried potatoes) do you eat each day?” Responses were none, ½ cup or less, ½ to 1 cup, 1-2 cups, 2-3 cups, 3-4 cups, 4 cups or more. Habitual vegetable consumption was then confirmed by having participants complete three non-consecutive 24-hour dietary recalls prior to starting the intervention. Participants exceeding the predefined cutoff of ≤1 serving per day (excluding fried potatoes) were excluded from participation.

The parent study was a 16-week community-based randomized controlled trial designed to determine the impact of increasing daily vegetable consumption to meet DGA recommendations on the sensitization of vegetable reinforcement.[5] The parent study consisted of two study arms – an attention control group (n = 55; age: 40 ± 14 years; BMI: 35 ± 7 kg/m^2) who received no vegetables and an intervention group (n = 55; age: 40 ± 16 years; BMI: 34 ± 7 kg/m^2) who were provided with DGA-recommended types and amounts of vegetables for 8 weeks.[5] Both groups were then followed for another 8 weeks to ascertain the impact of the repeated exposure to increased vegetable consumption beyond the 8-week intervention.[5] **Figure 1** shows the flow of participants through this study including reasons for losses and exclusions. Due to the nature of the intervention blinding was not possible for this study. Participants assigned to the intervention group who completed all study requirements during the intervention phase when all vegetables were provided (n = 51; age: 41 ± 16 years; BMI: 34 ± 7 kg/m^2) are the focus of this report. Participants completed a demographics questionnaire, and their demographic characteristics are presented in **Table 1**. All participants received monetary reimbursement for their participation.

Vegetable Intervention

The types and amount of vegetables provided during the 8-week intervention phase of the parent study were based on the recommendations set forth by the DGA 2010-2015 USDA Food Patterns.[14] Energy requirements were calculated using indirect calorimetry and adjusted for physical activity level using the Stanford 7-day recall.[15] As previously reported, mean estimated energy requirement for the participants assigned to the intervention group was 3140 ± 830 kcal/day and as such they were provided with a mean amount of 3.7 ± 0.41 cup equivalents (approximately 270 g supplying about 300 kcals) of vegetables daily.[5] Each week participants completed an order form consisting of 31 vegetable and 3 vegetable juice options representing each vegetable group (**Table 2**). Participants were required to pick the DGA recommended number of servings for each vegetable group based on their energy needs and were limited to no more than 4 juice servings per week. Participants came to the GFHNRC twice each week to pick up their pre-packaged, minimally processed fresh or frozen vegetables and were given a booklet with recipes and preparation instructions for those vegetables. Participants were instructed to eat everything given to them but were free to choose how to prepare and consume their vegetables. Compliance with the vegetable intervention was determined via weekly skin carotenoid scans using resonance Raman spectroscopy (RRS).[5, 13] Mean RRS intensities in the vegetable intervention group increased weekly throughout the intervention as previously reported.[5]

Vegetable incorporation into the diet

Determination of how the provided vegetables were incorporated into the diet was measured by a paper-pencil questionnaire and 24-hour dietary recalls. For the paper-pencil questionnaire, participants were given a consumption log at each twice-weekly visit in which they recorded whether the provided vegetables were substituted for another food item. The consumption log was returned at the next visit. For each vegetable received, the participant answered the following questions:

1. Did you substitute for another food? Y or N
2. If substituted, what food would you normally have eaten? _______________

Dietary intake was collected and analyzed using the Automated Self-Administered 24-hour (ASA24®) Dietary Assessment Tool, versions 2014 and 2016, developed by the National Cancer Institute, Bethesda, MD.[16] Participants completed their first 24-hour dietary recall at the GFHNRC under the instruction of a Registered Dietitian and then completed two more 24-hour dietary recalls before their baseline visit.[13] Thereafter, participants completed three non-consecutive 24-hour dietary recalls during each 4-week study period.[13] The days of the recalls were randomly scheduled at least three days apart and included both weekdays and weekends. Energy density of the diet was calculated for all energy containing food and beverage items consumed based on the nutritional composition. The 24-hour dietary recalls for each participant were averaged to represent dietary intake and energy density before (Pre) and in response to the vegetable intervention (Post).

Diet quality

The Healthy Eating Index (HEI) is a measure of diet quality in terms of adherence to DGA recommendations. The HEI-2015 consists of 13 components and the scoring method is described in full at https://epi.grants.cancer.gov/hei.[17] Briefly, the simple HEI scoring algorithm method was used to calculate the HEI total and component scores per individual across all 24-hour dietary recalls collected before (Pre) and in response to the vegetable intervention (Post). The HEI component score was calculated as follows:

$$\sum total\ amount\ of\ HEI\ component\ over \times days\ \div \sum total\ energy\ over \times days$$

The calculated ratio for each component was then compared with the applicable HEI standard per 1000 kcal to determine each HEI component score.[17] There are nine adequacy components for which greater consumption corresponds to a greater score – total vegetables, greens and beans, total fruits, whole fruits, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acids (defined as the ratio of polyunsaturated and monounsaturated fatty acids to saturated fatty acids). For each of the adequacy components the score ranges from 0 to 5 points, except for whole grains, dairy, and fatty acids which have a maximum score of 10 points. In all cases, a greater score represents greater consumption and better adherence to DGA recommendations. There are four moderation components for which lower consumption corresponds to a greater score – refined grains, sodium, added sugars, and saturated fats. For each of the moderation components the score ranges from 0 to 10 points, where a greater score represents lower consumption and better adherence to DGA recommendations. Therefore, an individual's total HEI-2015 score which is calculated by summing the component scores can range from 0 (absolute nonadherence) to 100 (perfect adherence).

Food, Attitudes and Behaviors (FAB) Survey

To explore potential factors associated with the incorporation of vegetables into the diet, participants completed a questionnaire adapted from the Food Attitudes and Behaviors (FAB) Survey developed by the National Cancer Institute, Bethesda, MD.[18] The FAB survey measures factors related to social support, perceived barriers, perceived benefits, motivation, and self-efficacy of vegetable consumption and was administered prior to and again at the end of the intervention.

Body weight and body composition

Body weight was assessed once immediately before and then again once at the end of the 8-week intervention in the morning after an overnight fast using a digital scale (Health-O-Meter Professional digital scale) without shoes and wearing light street clothing to the nearest 0.1 kg. Body composition was assessed immediately before and at the end of the 8-week intervention in the morning after an overnight fast via whole-body Dual Energy X-ray absorptiometry (iDXA with enCORE software Version 13.60.033; GE Lunar, Madison, WI).

Statistical Analysis

For this secondary outcome of a larger randomized intervention study (n = 110) only participants assigned to the intervention group who completed all study requirements (n = 51) are included in the analysis and reported here. Sample size calculation, power analysis and randomization for the larger parent study have been reported.[5, 13] Dietary intake data were analyzed using SAS® software, version 9.4 (SAS Institute, Inc., Cary, NC, USA)[19] using generalized linear mixed models (GLIMMIX) where phase (pre, post) was a within-subject factor and subject was a random effect. The Gaussian distribution was used with the Identity link function. Tukey-Kramer contrast were used for post-hoc pairwise comparison of means. The FAB survey was analyzed with IBM SPSS Statistics®, version 27.0 (IBM Corp., Armonk, NY, USA)[20] using a generalized linear model (GLM) model where phase (pre, post) was a within-subject factor. Significance was set at a p-value < 0.05. Data are reported as means ± standard deviations (SD) unless otherwise noted.

Results

ASA24® dietary recalls

Participants completed 306 (67%) weekday and 148 (33%) weekend day 24-hour dietary recalls – completing 99% of the 459 total number of recalls that were scheduled throughout the study. Prior to starting the study participants completed 151 recalls (102 weekday and 49 weekend day), two participants had recalls coded as incomplete or having items with no amounts and these recalls were not used in the data analyses. During the vegetable intervention participants completed 303 recalls (204 weekday and 99 weekend day), three participants had recalls coded as incomplete or having items with no amounts and these recalls were not used in the data analyses. Participants reported that the amount of food they consumed on each of the days they recorded their dietary intake represented their usual daily intake 71% of the time, was much less than their usual intake 12% of the time and was much more than their usual intake 17% of the time. There was no effect of the vegetable intervention on factors related to vegetable consumption as measured by the FAB survey (data not shown).

Vegetable incorporation into the diet

From the paper-pencil questionnaire of vegetable incorporation, 29% of the total amount of provided vegetables were reported as being used as a substitute for another food item. The substitution rate (percent frequency distribution) for each vegetable group was: 28% for dark green vegetables, 33% for red and orange vegetables, 28% for starchy vegetables, 29% for legumes, and 25% for other vegetables. Of the 29% of total vegetables reported being used as a substitute, the majority were reported as replacing a main meal (44%), meaning that the vegetables were combined to make a salad or a stir fry that was then consumed as a meal. **Figure 2** presents all the food items participants reported substituting the provided vegetables for and the percent frequency distribution that vegetables replaced those food items.

Changes in energy intake and dietary intake patterns in response to the vegetable intervention

Dietary intake before (Pre) and in response to the vegetable intervention (Post) is presented in **Table 3**. Energy intake did not change in response to the intervention (-69 ± 602 kcals; $p = 0.3838$); however, the energy density of the diet decreased (-0.44 ± 0.52 kcals/g; $p < 0.0001$). Changes in the relative composition of the diet were also observed. There was an increase in the percentage of energy (E%) consumed from carbohydrates (+3.1 ± 6.6 E%; $p = 0.0015$). This change in carbohydrate intake was accompanied by a decrease in the E% from fat (-1.7 ± 5.3 E%; $p = 0.0337$). There was no change in E% from protein (-0.5 ± 3.9 E%; $p =$

0.3442). Total vegetable consumption increased by 2.43 ± 1.38 cup-equivalents ($p < 0.0001$), as did consumption of all the vegetable subgroups (**Table 3**), as expected by study design. With the increase in vegetable consumption there were decreases in consumption of total grains (-0.97 ± 3.23 ounce-equivalents; $p = 0.0240$), protein foods (-1.24 ± 3.86 ounce-equivalents; $p = 0.0094$), saturated fats (-6.44 ± 19.63 grams; $p = 0.0156$) and added sugars (-2.44 ± 6.78 teaspoon-equivalents; $p = 0.0154$).

Changes in diet quality in response to the vegetable intervention

Overall diet quality as measured by total HEI-2015 scores increased ($p = 0.0013$) from 52 ± 10 at baseline to 57 ± 9 in response to the 8-week vegetable intervention (**Figure 3**). As expected by study design, there was an increase in total vegetables scores (3.3 ± 1.2 vs 5.0 ± 0.0; $p < 0.0001$) as well as greens and beans scores (2.5 ± 2.0 vs 4.6 ± 0.8; $p < 0.0001$) and seafood and plant proteins scores (2.9 ± 2.1 vs 4.1 ± 1.4; $p = 0.0002$). There was a decrease in whole fruits scores (2.5 ± 1.9 vs 1.7 ± 1.6; $p = 0.0022$) in response to increasing vegetable consumption to meet DGA recommendations. There were no changes in scores for the other five dietary components that focus on adequacy (dietary components to increase). Interestingly, there were significant changes in three of the four dietary components that focus on moderation (dietary components to decrease). For these dietary components greater scores correspond with lower intake whereas lower scores correspond with greater intake. There was an increase in scores for both refined grains (6.5 ± 2.9 vs 7.9 ± 2.4; $p = 0.0064$) and saturated fats (4.5 ± 3.2 vs 5.5 ± 2.8; $p = 0.0074$) but there was a decrease in sodium scores (2.7 ± 2.6 vs 1.2 ± 1.7; $p < 0.0001$). The change in added sugars scores did not reach significance (7.2 ± 2.6 vs 7.7 ± 2.6; $p = 0.0687$).

Changes in body weight and composition in response to the vegetable intervention

Body weight and body composition measures can be found in **Table 4**. There was no change in body weight (-0.23 ± 1.97 kg; $p = 0.4022$), fat mass (+0.10 ± 1.27 kg; $p = 0.5725$), fat free mass (-0.06 ± 1.47 kg; $p = 0.7817$), or %BF (+0.22 ± 1.62%; $p = 0.3284$) in response to the 8-week vegetable intervention.

Discussion

To develop successful interventions targeted at increasing the healthfulness of the American diet, such as increasing vegetable consumption, it is essential to understand how dietary intake patterns change as DGA recommendations are incorporated into the diet. The provision of vegetables during an intervention offers a unique opportunity to understand how people incorporate vegetables into their diet and how this influences dietary intake patterns and diet quality. To our knowledge, this is the first study to directly ascertain how adults with overweight and obesity incorporated a provision of DGA recommended types and amounts of vegetables into their diet and how this impacted dietary intake patterns and diet quality. There were noteworthy alterations in the consumption of other dietary components and improvements in diet quality and energy density. Increasing vegetable consumption to meet DGA recommendations reduced the consumption of total grains, protein foods, saturated fats and added sugars. Comparing dietary intakes to those recommended by the DGA, increasing vegetable consumption resulted in increases in HEI-2015 component scores for refined grains and saturated fats; however, the observed decreases for whole fruit and sodium scores are areas of concern. These results highlight the complexity in helping Americans meet DGA recommendations.

Increasing fruit intake is another goal of the DGA, yet these results suggest that increasing both vegetable and fruit consumption to meet DGA recommendations may prove to be difficult. One potential explanation for this result may stem from the fact that fruits and vegetables are typically considered and promoted together as a single food category. This is most evident by the well-known public health campaign "5-a-day" (other countries have similar promotion campaigns[21]). However, there exists a lack of understanding and clarity of the details encompassing the message.[22, 23] This is demonstrated by the fact that fruit and vegetable consumption fell slightly during the "5-a-day" public health campaign in the U.S.[24] The need to include a *variety of both* fruits and vegetables has been reported as a main point of misunderstanding.[23] Therefore, it is foreseeable that the seemingly large quantity of vegetables that was provided to the habitual low-vegetable consumers who participated in the current study may have unintentionally offset fruit consumption. Distinguishing fruits and vegetables as separate food categories in public health campaigns may improve adherence to dietary guidelines. Following the "Go for 2 & 5" public health campaign in Australia that focused on consuming 2 fruits and 5 vegetables each day there was an increase, albeit modest, in both fruit and vegetable consumption.[25] In analyzing fruits and vegetables separately, there was a greater increase in vegetable consumption compared to fruit consumption (0.6 and 0.2 servings/day, respectively).[25] Taken together with the findings from the current study, targeting fruits and vegetables separately may be beneficial to achieving better adherence to dietary guidance. However, this requires further research as public health campaigns continue to adjust messaging (such as the Fruits and Veggies-More Matters® campaign in the U.S.[24]) to increase fruit and vegetable consumption and improve diet quality.

Increasing vegetable consumption in these self-reported low vegetable consumers resulted in a decrease in HEI-2015 sodium scores (representing an increase in consumption). This effect of increasing vegetable consumption on sodium intake may be reflective of the more common consumption of vegetables in cooked forms[4] and salt's ability to improve the positive sensory attributes of foods.[26] The addition of salt suppresses the sensory perception of naturally bitter compounds, typically found in vegetables, and can boost the sweetness of a food.[26] This attribute of salt can therefore mask the unpleasant taste of vegetables reported by some individuals, especially those who have a greater propensity to experience bitterness (6-*n*-propylthiouracil (PROP) medium- and super-tasters).[27] As previously reported, a larger percentage of the participants in the current study were classified as either medium- (38%) or super-tasters (16%), as opposed to non-tasters (46%).[5] Collectively, these results may explain the observed increase in sodium intake in response to increasing vegetable consumption. Further investigation on this relationship is needed.

Dietary guidance emphasizes consuming of a variety of vegetables to increase consumption.[1] A recent epidemiological study demonstrated that a greater variety of vegetables and fruits was associated not only with greater consumption but also greater energy intake.[2] Compared to individuals who consumed a limited variety of vegetables and fruits (1-2 different items), energy intake was 261 kcal greater in those who consumed a moderate variety (3-4 different items) and 385 kcal greater in those who consumed a large variety (≥5 different items) as part of their habitual diet.[2] Contrary to this finding, when vegetable consumption is analyzed separately from that of fruit there appears to be a negative association between the variety of vegetables consumed and energy intake.[7] The findings from the present study, which was based on the variety of vegetables recommended by the DGA, demonstrated no impact of consuming a greater variety of vegetables on energy intake, even though the vegetable provision contributed approximately 300 additional calories. Remarkably, 71% of the provided vegetables were not reported as being used as a substitute leading to the assumption that they were added to the diet. If indeed these vegetables were simply added to the diet, energy intake would have increased by about 213 kcal/day resulting in a body weight gain. However, no change in body weight was observed in the current study.

Given that there is a limit on how much food an individual can comfortably consume, it is understandable that there was a reduction in the consumption of other foods. However, most of the alterations to the diet appeared to have happened outside of conscious effort, and this lack of awareness may explain the slight mismatch between the food items reported as being replaced by the vegetables, the dietary recall data, and the HEI component scores. Eating behavior is predisposed to cognitive biases and environmental cues.[28-30] Accordingly, the provision of vegetables may have been an efficacious environmental cue that coaxed participants toward healthier food choices resulting in a modest, but significant, increase in the healthfulness of the diet (9% increase in total HEI score and 19% decrease in the energy density of the diet). This substitution effect preserved individual freedom of choice[28-30] as no other dietary restraints were placed on the participants and they were free to choose how to incorporate the vegetables into their diet. Further research is needed to elucidate the impact of vegetable provisions and the potential of greater vegetable availability in the home environment to alter dietary intake patterns and potentially ‘nudge’ people toward a healthier diet.

The present study had some strengths that bear mentioning. First, the experimental design, DGA-recommended amounts and types of vegetables were provided for 8 weeks which removed any barriers to vegetable procurement. Second, the inclusion of self-reported low vegetable consumers with overweight and obesity. Currently 73% of U.S. adults are classified as having overweight or obesity[31] and consume on average 1.1 cups of vegetables (excluding fried potatoes) in a typical day.[24] Perhaps the greatest limitation of this study was that the majority of participants were woman (75%) who self-identified as White (98%), limiting generalizability to men and other racial/ethnic groups. Due to the nature of the intervention participants had to live within driving distance from the research facility and therefore, are representative of the local area. Second, the provision of vegetables, while a strength of the study, limits 'real-world application' where barriers to vegetable procurement exist. Third, the overall small sample size, which may prevent the findings from being extrapolated to the larger population. There are also well-recognized methodological challenges associated with 24-hour dietary recalls.[32] Lastly, we did not collect information on whether the provided vegetables were consumed raw or cooked and if so, how the vegetables were cooked (i.e., sautéed with butter and salt). This limited the ability to determine how this may have impacted some of the other dietary components.

Conclusion

The results presented here further the knowledge about how habitual low-vegetable consumers with overweight and obesity incorporate vegetables into their diet and how this influences dietary intake patterns. When providing vegetables in the amounts and types recommended by the DGA there appears to be a substitution effect that results in an improvement in overall diet quality, albeit modest. Outside of the vegetable provision, the improvement in diet quality was the result of alterations in dietary moderation components. These findings highlight the importance of characterizing how individuals incorporate DGA recommendations into their diet, providing valuable information that can be used to develop targeted behavior change interventions. Future research could determine which food group(s) to reduce to increase vegetable consumption most effectively while not reducing whole fruit consumption or to simultaneously increase consumption of both vegetables and fruits to meet DGA recommendations. Future work could also investigate the amount of vegetable consumption where fruit consumption begins to wane or the effect of consuming DGA recommended types and amounts of fruits on dietary intake patterns, energy intake and diet quality. Future research should also include more diverse populations to determine potential cultural differences when trying to increase vegetable consumption to meet DGA recommendations.

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Figure Legend

Figure 1: Flow diagram of participants through an 8-week randomized controlled vegetable intervention trial (enrollment, intervention allocation, follow-up, and data analysis), including reasons for losses and exclusions, conducted from October 2015 to January 2018 in Grand Forks, ND.

Figure 2: Food items that were self-reportedly substituted for with the provided vegetables during an 8-week intervention (Motivating Value of Vegetables Study). Participants reported using 29% of the provided vegetables as a substitute for other food items. The food item main meal was reported to represent that the vegetables were combined to make a salad or a stir fry that was then consumed as a meal. The food item snack food was reported to represent any food item that was consumed outside of a main meal. Data are expressed as the percent frequency distribution in which the reported food items were replaced with the provided vegetables.

Figure 3: Healthy Eating Index (HEI)-2015 component scores before (Pre) and in response (Post) to an 8-week vegetable intervention (Motivating Value of Vegetables Study). HEI-2015 component scores increased for total vegetables, greens and beans, seafood and plant protein, refined grains, and saturated fats. HEI-2015 component scores decreased for whole fruits and sodium. Data were analyzed using generalized linear mixed models where phase (pre, post) was a within-subject factor and subject was a random effect. $**P < .01$, $***P < .001$.

Table 1. Demographic characteristics of the 51 men and women assigned to the vegetable intervention group of the Motivating Value of Vegetables Study conducted from October 2015 to January 2018 in Grand Forks, ND.

Characteristic	Mean ± standard deviation	n	%
Age (y)	41 ± 16		
BMI[a] (kg/m^2)	34 ± 7		
Sex			
Men		13	25
Women		38	75
Race			
White		50	98
Asian		1	2
Ethnicity			
Not Hispanic or Latino		50	98
No Response		1	2
Annual Income ($)			
<25,000		12	24
25,000-49,999		11	22
50,000-74,999		9	18
75,000-99,999		5	10
100,000-124,999		8	16
≥125,000		2	4
No response		3	6
Employment			
Working full time		38	76
Working part time		8	16
Unemployed		3	6
Retired		1	2
Education			

High school graduate/GED[b]	2	4
Some college or associate degree	7	14
Current college student	9	18
College graduate	17	34
Postgraduate education	15	30

[a] BMI = Body Mass Index
[b] GED = General Educational Development

Table 2: Minimally processed vegetable options that were provided during the 8-week vegetable intervention of the Motivating Value of Vegetables Study conducted from October 2015 to January 2018 in Grand Forks, ND. Participants freely chose from the list but were required to pick the recommended number of servings from each subgroup based on their individual energy needs according to the Dietary Guidelines for American. Choices were provided in half cup increments with the exception of leafy vegetables which were provided in one cup increments.

Vegetable group	**Vegetable Option**
Dark Greens	Broccoli
	Green Leafy Lettuce[a]
	Romaine Lettuce[a]
	Spinach[a]
	Healthy Greens Juice[b]
	Kale[a]
Red and Orange	Carrots
	Red Pepper
	Sweet Potato
	Tomato
	Tomato Juice[b]
	Mango Carrot Juice[b]
Starchy	Corn
	Peas
	Potato
	Water Chestnuts
Beans	Black
	Garbanzo
	Kidney
	Pinto
Other	Asparagus
	Cabbage[a]
	Cauliflower
	Celery
	Cucumber
	Green Beans
	Green Pepper

	Iceberg Lettuce[a]
	Mushrooms
	Onions
	Zucchini

[a] Provided in one cup increments

[b] Limited to 4 servings a week

Table 3: Daily dietary intake of the 51 men and women assigned to the vegetable intervention group of the Motivating Value of Vegetables Study conducted from October 2015 to January 2018 in Grand Forks, ND.

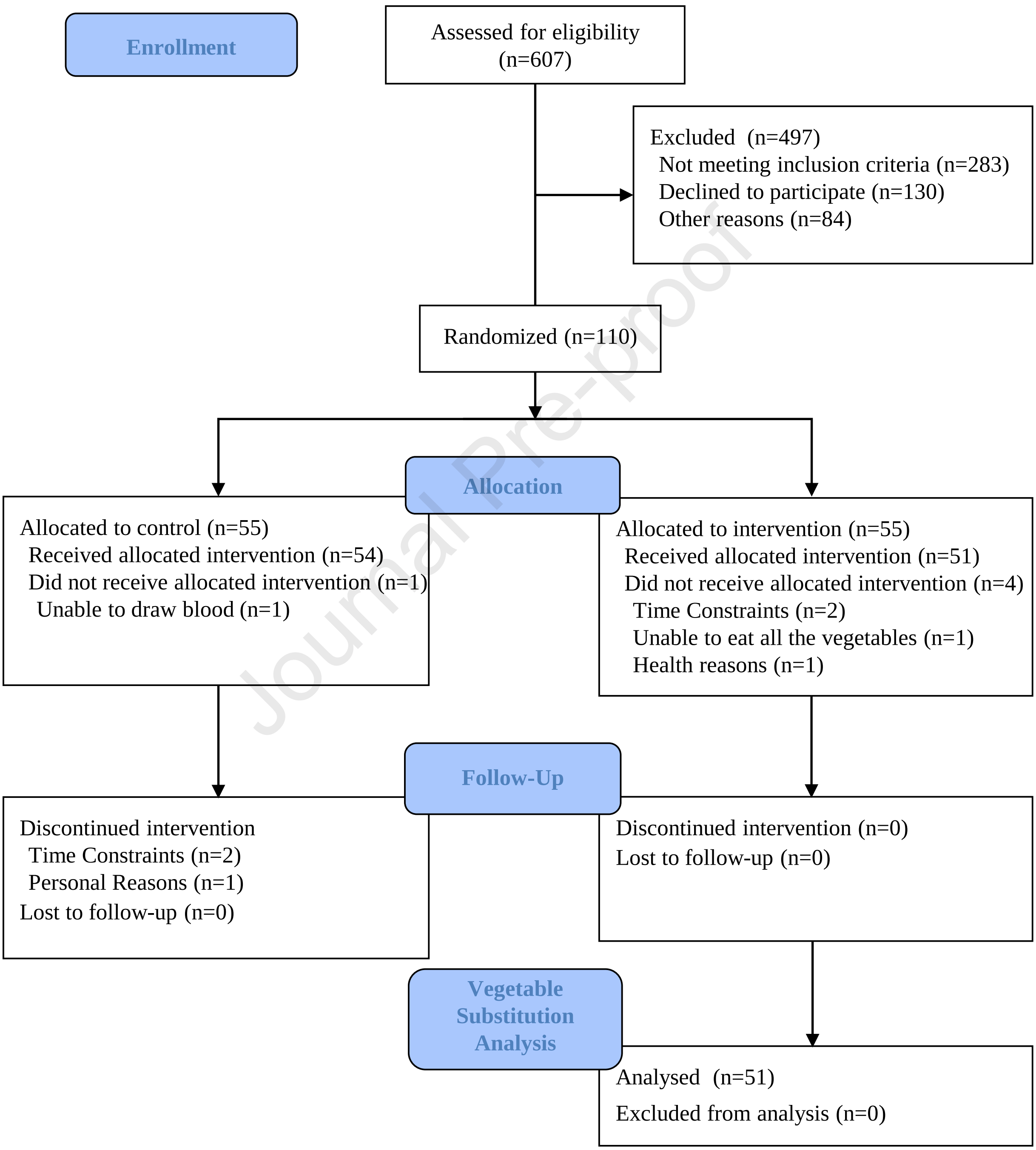
Dietary Component	**PRE**	**POST**	***P*-value[a]**
	mean ± SD		
Total energy, *kcals*	2068 ± 810	1998 ± 894	0.3838
Energy density, *kcals/g*	2.26 ± 0.54	1.82 ± 0.49	**<0.0001**
Carbohydrates, *g*	237 ± 130	247 ± 140	0.2892
Protein, *g*	86 ± 38	79 ± 29	0.1125
Fat, *g*	85 ± 39	78 ± 34	0.1184
Total Vegetables, *cup-equivalents*	1.49 ± 0.72	3.92 ± 1.23	**<0.0001**
Dark Green	0.21 ± 0.27	0.39 ± 0.28	**0.0004**
Red and Orange	0.37 ± 0.26	1.33 ± 0.59	**<0.0001**
Starchy	0.39 ± 0.34	0.97 ± 0.46	**<0.0001**
Legumes (Beans and Peas)	0.36 ± 0.72	1.46 ± 1.41	**<0.0001**
Other	0.52 ± 0.43	1.23 ± 0.54	**<0.0001**
Total Fruits, *cup-equivalents*	0.69 ± 0.72	0.51 ± 0.60	0.0645
Citrus, Melons, Berries	0.18 ± 0.33	0.07 ± 0.14	**0.0499**
Other	0.41 ± 0.51	0.27 ± 0.46	**0.0149**
Juice	0.10 ± 0.24	0.17 ± 0.31	0.1204
Total Grains, *ounce-equivalents*	6.23 ± 2.83	5.26 ± 3.38	**0.0240**
Whole Grains	0.85 ± 0.84	0.66 ± 0.70	0.0994
Refined Grains	5.38 ± 2.59	4.61 ± 3.35	0.0597
Total Protein Foods, *ounce-equivalents*	6.21 ± 4.34	4.97 ± 2.31	**0.0094**
Meat	1.99 ± 2.25	1.69 ± 1.51	0.3254
Poultry	1.60 ± 2.75	1.11 ± 1.05	0.1418
Eggs	0.58 ± 0.77	0.53 ± 0.53	0.5497
Seafood	0.40 ± 0.90	0.24 ± 0.51	0.2463
Soy	0.06 ± 0.24	0.07 ± 0.18	0.7204
Nuts and Seeds	0.69 ± 1.15	0.49 ± 0.60	0.1746
Total Dairy, *cup-equivalents*	1.73 ± 0.96	1.56 ± 1.03	0.2114
Milk	0.61 ± 0.49	0.58 ± 0.52	0.7567
Yogurt	0.09 ± 0.17	0.05 ± 0.12	0.1132
Cheese	1.00 ± 0.84	0.91 ± 0.85	0.3912
Saturated Fats, *g*	38.84 ± 21.77	32.40 ± 17.26	**0.0156**
Added Sugars, *teaspoon-equivalents*	16.51 ± 17.75	14.07 ± 15.90	**0.0154**

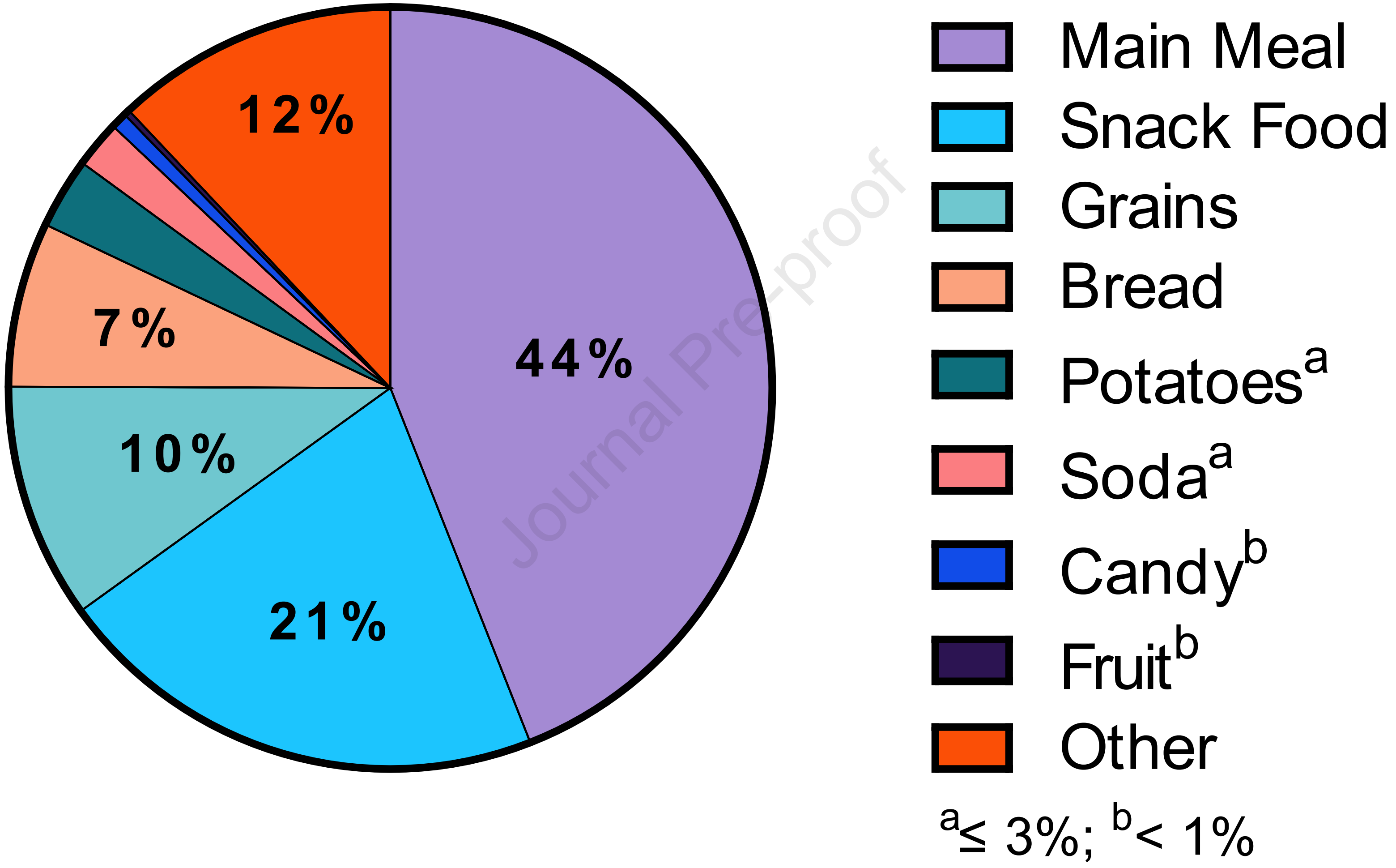
[a] Statistical analysis performed using generalized linear mixed models (GLIMMIX) where phase (PRE, POST) was a within-subject factor and subject was a random effect

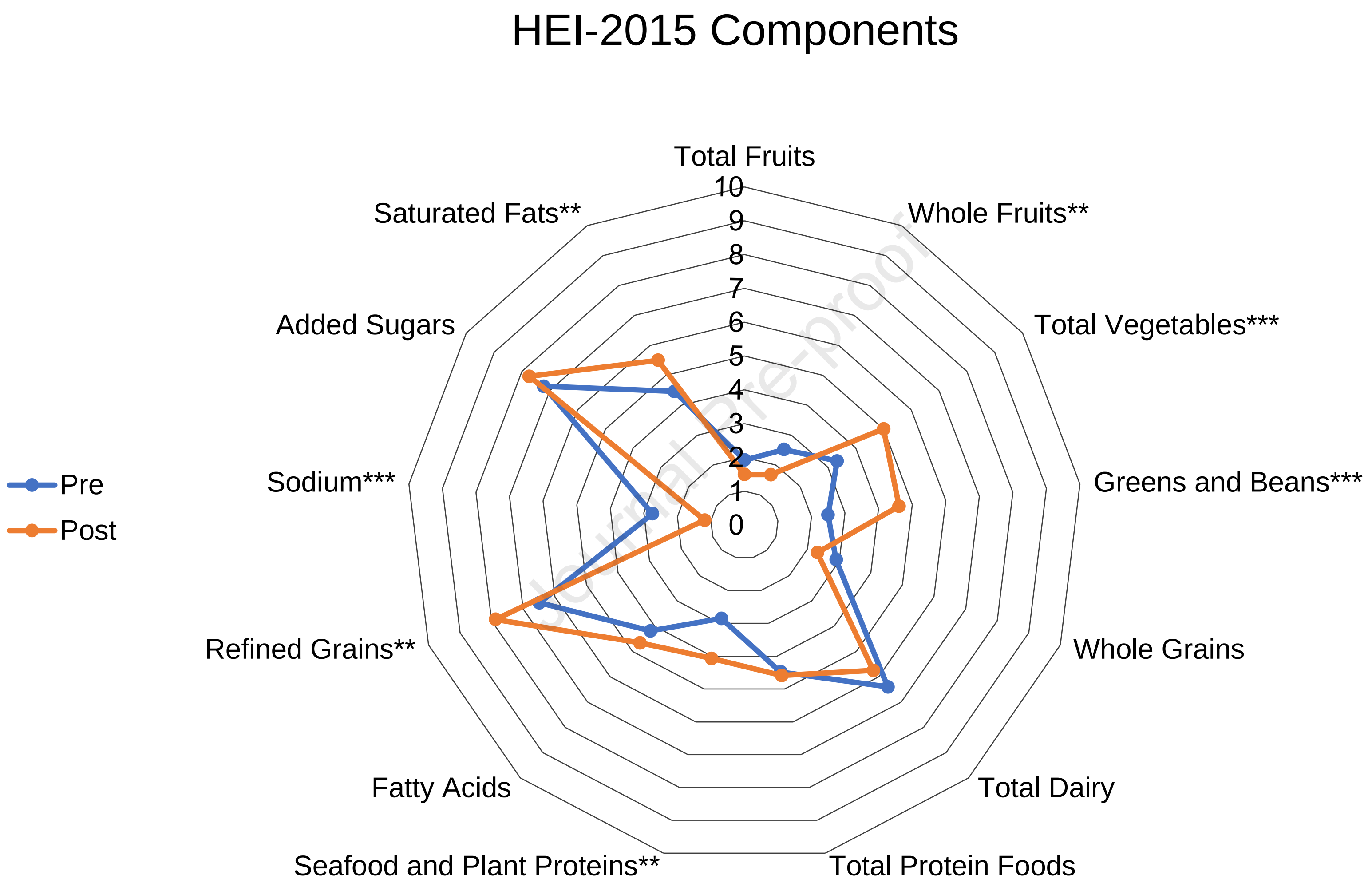
Table 4: Body composition of the 51 men and women assigned to the vegetable intervention group of the Motivating Value of Vegetables Study conducted from October 2015 to January 2018 in Grand Forks, ND.

Component	**PRE**	**POST**	***P*-value**[a]
	mean ± *SD*		
Body weight, *kg*	99.10 ± 20.91	98.86 ± 20.72	0.4022
Fat Free Mass, *kg*	51.89 ± 10.26	51.84 ± 10.59	0.7817
Fat Mass, *kg*	42.96 ± 15.08	43.06 ± 15.36	0.5725
Body Fat, *%*	42.64 ± 8.92	42.87 ± 9.10	0.3284

[a] Statistical analysis performed using generalized linear mixed models (GLIMMIX) where phase (PRE, POST) was a within-subject factor and subject was a random effect


Enrollment
Assessed for eligibility (n=607)
Excluded (n=497)
Not meeting inclusion criteria (n=283)
Declined to participate (n=130)
Other reasons (n=84)
Randomized (n=110)
Allocation
Allocated to control (n=55)
Received allocated intervention (n=54)
Did not receive allocated intervention (n=1)
Unable to draw blood (n=1)
Allocated to intervention (n=55)
Received allocated intervention (n=51)
Did not receive allocated intervention (n=4)
Time Constraints (n=2)
Unable to eat all the vegetables (n=1)
Health reasons (n=1)
Follow-Up
Discontinued intervention
Time Constraints (n=2)
Personal Reasons (n=1)
Lost to follow-up (n=0)
Discontinued intervention (n=0)
Lost to follow-up (n=0)
Vegetable Substitution Analysis
Analysed (n=51)
Excluded from analysis (n=0)


12%
7%
10%
21%
44%
Main Meal
Snack Food
Grains
Bread
Potatoes[a]
Soda[a]
Candy[b]
Fruit[b]
Other
[a]≤ 3%; [b]< 1%


HEI-2015 Components
Total Fruits
Whole Fruits**
Total Vegetables***
Greens and Beans***
Whole Grains
Total Dairy
Total Protein Foods
Seafood and Plant Proteins**
Fatty Acids
Refined Grains**
Sodium***
Added Sugars
Saturated Fats**
0
1
2
3
4
5
6
7
8
9
10
Pre
Post