Poor adherence to U.S. dietary guidelines for children and adolescents in the NHANES population

Key words: diet quality, NHANES, childhood, adolescence, HEI

Word count: 3,245

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1 **Abstract**

2 **Background** Poor diet quality in childhood and adolescence is associated with adverse health
3 outcomes throughout life, yet the dietary habits of American children and how they change
4 across childhood and adolescence are unknown.

5 **Objectives** This study sought to describe diet quality among children and adolescents by
6 assessing adherence to the Dietary Guidelines for Americans (DGA) and to determine whether
7 any differences in adherence occurred across childhood.

8 **Design, Setting, and Participants** We employed a cross-sectional design using data from the
9 National Health and Nutrition Examination Survey (NHANES). Of 9,280 children ages 4-18
10 who participated in NHANES from 2005-2010, those with insufficient data on dietary recall
11 (n=852) or who were pregnant or lactating during the time of interview (n=38) were excluded
12 from the final study sample (n=8,390).

13 **Main Outcome Measures** We measured adherence to the DGA using the Healthy Eating Index
14 2010 (HEI-10) and stratified participants into three age groups (4-8, 9-13 and 14-18 years of
15 age). We analyzed each of twelve HEI-10 components, and total HEI-10 score.

16 **Results** The youngest children had the highest overall diet quality due to significantly greater
17 scores for total fruit, whole fruit, dairy, and whole grains. These children also had the highest
18 scores for sodium, refined grains, and empty calories. Total HEI-10 scores ranged from 43.59 to
19 52.11 out of 100, much lower than the minimum score of 80 thought to indicate a diet associated
20 with good health.

Conclusions Overall, children and adolescents are failing to meet the DGA and may be at an increased risk of chronic diseases throughout life. By analyzing which food groups show differences between age groups, we provide data which may inform the development of dietary interventions to promote specific food groups targeting specific ages, thus improving diet quality among children and adolescents.

Introduction

In countries where malnutrition is not a prevailing concern, poor dietary quality across childhood and adolescence is associated with adverse health outcomes including early puberty (a risk factor for hormone-related cancers), high diastolic blood pressure, and possibly central obesity, although the association of dietary quality with obesity in childhood is controversial.¹⁻³ Growing evidence that dietary habits developed during childhood often persist into adulthood both raises concern and creates opportunity for intervention because poor dietary quality is recognized as a risk factor for chronic diseases among adults including diabetes, cardiovascular disease, and cancer.^{4,5} However, we know relatively little about differences in the dietary quality of children at different ages in the developed world. Several indices exist to measure dietary quality and, although small differences exist, all focus on adherence to a diet that emphasizes vegetables, fruits, whole grains, low-fat dairy, fish, and unsaturated fatty acids.⁶ In recognition that overall ‘food pattern’ may be more beneficial for health than individual nutrients, the United States Department of Agriculture (USDA) releases the DGA, which are updated every five years. To assess adherence to the DGA, the USDA also develops the Healthy Eating Index (HEI), which is updated to reflect changes in the DGA with the most recent guidelines released in 2010 (HEI-10). The HEI-10 scores twelve component food groups. Total HEI-10 score, ranging from 0-100, is a sum of these components, with a high score reflecting greater adherence to the DGA. A small Canadian study used HEI scores to assess the dietary quality of 125 youths and found that 95% of participants had an HEI-10 score below 80, the recommended minimum HEI score for disease prevention.^{7,8} Only limited analyses have been done on adherence to the HEI among US children and adolescents. Of these, studies evaluating individual dietary components have shown that children and adolescents are not eating enough dairy, whole grain, fruits, vegetables, or fish

⁹⁻¹² and are consuming excessive empty calories in the form of soda and grain desserts.¹³

However, focusing on individual food components makes it difficult for clinicians and practitioners to assess food patterns and overall dietary quality. In addition, these results do not address whether dietary quality changes across childhood.

Dietary quality is influenced by several stable factors, including socioeconomic status (SES), gender, and ethnic background.¹⁴⁻¹⁹ However, modifiable factors such as beverage patterns, TV watching patterns, and meal skipping have also been shown to associate with dietary quality, making it plausible that dietary quality can change across childhood and adolescence.²⁰⁻²² This notion is supported by a cross-sectional study of adolescents in Brazil that used an early iteration of the HEI and 24-hour recalls.²³ The authors found that overall HEI scores were lower from ages 12 to 20, but did not report which HEI components contributed to this change.¹⁹ NHANES is a large, nationally representative sample that includes analytic methods for reducing bias in parent- and self- report nutrition data in the study method.²⁴ This allows researchers to accrue large samples needed to accurately analyze national trends, while minimizing issues surrounding self-report nutrition data. In order to provide insight into food categories that may need special attention at different ages, to improve overall diet quality and contribute to chronic disease prevention efforts, the goals of the current analysis are to describe the diet of US children in relation to the DGA using the HEI and to evaluate whether there are differences in adherence to specific dietary components across childhood and adolescence (4-18 years) using data from the National Health and Nutrition Examination Survey (NHANES).

Methods

Population

NHANES uses interviews and physical examinations to determine the health and nutrition status of a representative population of children and adults living in 15 different counties across the United States.²⁵ Certain groups, such as those over 60 and Hispanics, are oversampled to ensure that the data reflects current population trends.²⁵ Three cycles of NHANES data were included in the current study (2005-2006, 2007-2008, and 2009-2010) using information from participants ages 4-18. Of the children and adolescents eligible for the study (N=9,280), those with missing dietary data, those with incomplete dietary recall information (N=852) and girls who were pregnant or lactating at the time of interview (N=38) were excluded, leaving a final study sample of 8,390. This was a secondary data analysis with de-identified data; therefore, this study was exempted from full review by the MD Anderson Institutional Review Board. This study was deemed exempt under federal regulation 45 46.101 (b) CFR.

Measures

Dietary intake was collected from all three cycles using two 24-hour dietary recalls. We used the population ratio approach to control for the likelihood that participants underreported dietary intake (see analyses section), which, when using HEI-10 data, necessitates that only the first day 24-hr recall be used.²⁴ The first 24-hour recall interview was conducted at a Mobile Examination Center using a standard set of measuring guides to assist in estimating portion sizes.²⁶ Adults completed the dietary recall by proxy for children aged 2-5, though information for those aged 2-3 was not used for this study.²⁷ Children aged 6-11 completed the interview with help from an adult and adolescents aged 12-18 independently completed the recall interview.²⁷

Dietary intake was assessed using the HEI-10, which assesses dietary quality using the 2010 DGA.²⁸ We chose the HEI-10 score since this has more relevance to nutritional assessments for health used by dietitians today.

Dietary quality Total HEI-10 score was used as a measure of dietary quality. Total HEI-10 score was created from 12 dietary components, which mirrors aspects of the Dietary Guidelines for Americans 2010.²⁹ These 12 components are: total fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, fatty acids, refined grains, sodium and empty calories. Each component has a minimum score of zero and a maximum score between five and 20. Each component is scored such that a higher value indicates better adherence to dietary guidelines. To create the total HEI-10 score, each component ratio score was summed. Thus, the total-HEI and each component are represented by a score indicating intake per 1,000 kcal which is taken forward to analysis, rather than an estimation of absolute intake. The total HEI score ranges from 0 to 100, with higher scores indicating higher diet quality. Further details on the HEI-10 are available elsewhere.³⁰

Daily total energy intake (kcal) Daily total energy intake (kcal) is provided by the Centers for Disease Control within the NHANES data and used to calculate HEI scores when using the population ratio approach. Total intake was calculated by converting reported food intake into macronutrient intake values for each food using the reported serving size and the USDA's Food and Nutrient Database for Dietary Studies. The macronutrients were converted to energy using the following conversion factors: 4 kcals/gram for protein and carbohydrate and 9 kcals/gram for total fat and saturated fat.

135

136 *Analyses*

137 Sample-weighted data were used and all analyses were performed using SAS 9.3 (SAS Institute,
138 Cary, NC 2010) to adjust the variance for the complex sample design. A 6-year weight variable
139 was calculated and used in analyses of all data. The SAS code used to calculate HEI-10 scores
140 was downloaded from the National Cancer Institute website
141 (<http://appliedresearch.cancer.gov/hej/tools.html>). In order to account for the underreporting
142 associated with self-report nutrition data, nutrient density models residualize reported intake to
143 energy-adjusted intake and give nutrient scores which are independent of the methodological
144 influence of underreporting.³¹ For group comparisons, nutrient density models have been adapted
145 in the population ratio approach, which we used to describe HEI component scores. Compared to
146 using the mean of individual scores or the score of the mean of individual ratios, the population
147 ratio approach produces HEI component scores that are closest to the true observed component
148 scores.²⁴ Using this approach, the population's total score for a specific HEI component (e.g.,
149 dairy) was calculated as a ratio of the population's total energy intake. Total HEI-10 score was
150 calculated by summing all twelve component scores to produce a score out of a possible 100
151 points. The population ratio approach necessitates univariate analyses, and so intergroup
152 comparisons were then performed using three separate two-sample t-tests. We applied a false
153 discovery rate correction to the P-values generated from these t-tests in order to correct for
154 multiple comparisons, and present corrected Q-values.³²

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Results

The demographic characteristics of the NHANES sample show that age groups did not differ by gender or parental education level (Table 1). There was a significant difference in poverty-income ratio ($P<0.0001$ -.02; Table 1) and mean family size ($P<0.001$; Table 1) between some age groups, which is likely explained by the ethnicity differences between the groups ($P<0.01$ -.06; Table 1).

Trends in dietary quality across childhood

HEI-10 scores were lower for older age groups for total fruit, whole fruit, dairy, and whole grains (Table 2). Total fruit scores were significantly different in age group comparisons, with the 4-8 year age group eating significantly more than the 9-13 year age group ($Q=0.002$; Table 2) and the 9-13 year age group eating significantly more than the 14-18 year age group ($Q=0.002$; Table 2). A similar pattern was seen with whole fruit scores, which included all aspects of the total fruit component except fruit juice. The 4-8 year age group had a significantly greater score than the 9-13 year age group ($Q=0.002$; Table 2) and the 9-13 year age group had a significantly greater score than the 14-18 year age group ($Q=0.002$; Table 2). Dairy scores mirrored these trends; the 4-8 year age group had significantly greater scores when compared to both the 9-13 and 14-18 year age groups ($Q=0.002$ for both groups; Table 2). The 9-13 year age group also had a significantly greater dairy score when compared to the 14-18 year age group ($Q=0.010$; Table 2). Whole grain scores were different between age groups, though overall scores were notably low, and was significantly higher among the 4-8 and 9-13 year age groups when compared to the 14-18 year age group ($Q=0.002$ for both groups; Table 2). In addition, the 4-8 year age group

178 reported significantly higher whole grain scores than the 9-13 year age group ($Q=0.010$; Table
179 2).

180 Conversely, protein scores were high across childhood (Table 2) and was the only food group
181 that was significantly higher in older age groups (all $Q<0.04$; Table 2). Total vegetable scores
182 were not as high but similarly was higher in the older age groups (Table 2), with a significant
183 difference in scores between the 4-8 and 14-18 year age groups ($Q=0.002$; Table 2). Fatty acid
184 scores were also greater among older age groups; the fatty acid score was highest among the 14-
185 18 year age group and a significant difference between scores was observed between the 4-8 and
186 14-18 year age groups ($Q=0.002$; Table 2).

187 Seafood and plant protein was the only component for which the greatest adherence was
188 observed among the 9-13 year olds (Table 2). There was a significant difference in seafood and
189 plant protein scores between the 4-8 and 9-13 year age groups ($Q=0.041$; Table 2), with no
190 significant difference observed in any other group comparisons.

191 Sodium, empty calories, and refined grains are categorized by the FDA as dietary components
192 that should be consumed in moderation. HEI component scoring for these groups was such that a
193 higher score indicates more moderate consumption. The 4-8 year age group had lower a sodium
194 score than the 9-13 and 14-18 year age groups ($Q=0.002$ for both groups; Table 2). The
195 difference in refined grain scores between the 4-8 year age group and the two other age groups
196 was significant, with higher scores in the older age groups ($Q=0.002$; Table 2). Similarly, scores
197 for empty calories were different by age group (Table 2), with a significant difference in scores
198 between the 4-8 and 14-18 year age groups ($Q=0.009$; Table 2). There was, however, no

significant difference in scores between the 9-13 year age group and the younger and older groups ($Q=0.248$, $Q=0.126$; Table 2).

When overall HEI-10 score was assessed, the score was lower in the older groups (Table 2). The 4-8 year age group had the highest mean total HEI-10 score, which was significantly higher than both the 9-13 ($Q=0.002$; Table 2) and 14-18 year age group mean HEI-10 scores ($Q=0.002$; Table 2), and the 9-13 year age group had a significantly higher mean score than that of the 14-18 year age group ($Q=0.002$; Table 2).

Discussion

The goal of this study was to assess the dietary quality of children and adolescents in the US and ascertain whether changes in adherence to specific components of the US dietary guidelines occurred across age groups. To our knowledge, this is the first study to compare adherence to individual dietary components of the HEI, and to compare across age groups. We report that overall dietary quality was low for all age groups and overall dietary quality scores were lower in older age groups. We also observed differences in adherence to specific dietary components, which highlight the need for dietary interventions to be tailored by age group.

We report that US children, across all age and ethnic groups, are far from meeting the minimum federal guideline for good health, which is an HEI score of at least 80.⁸ Total mean HEI-10 scores for all age groups were approximately 50, indicating diet in childhood is an important target for the prevention of diet-related adult chronic diseases. The observed lowered total HEI score in older groups was consistent with previous research that found an inverse relationship between age and dietary quality.^{7,19} However, these studies were conducted using information

gathered from youth populations outside the U.S. Confirmation of our results within the U.S. could have important public health implications, encouraging the development of age-specific dietary interventions aimed at increasing diet quality.

Total vegetables, greens and beans, whole grains, and fatty acids are component categories in which children are not meeting even half the recommended intake per 1000 calories; although greens and beans were reported to have the lowest scores, all component categories could benefit from efforts to increase consumption. This concurs with previous research that has reported that children and adolescents do not consume enough whole grains³³ but is at odds with research reporting that children and adolescents are not consuming enough dairy.⁹ While dairy scores were not at a maximum, they did generally meet 80% of the maximum requirement indicated for good health. Previous data have reported that fruit consumption is too low¹¹ and our present analysis extends these findings by showing that in 4-8 year olds whole fruit scores are high, with an average score of 4.5 out of 5, but that fruit intake per 1000 calories is lower in older age groups, with an average score of 2.5 among 14-18 year olds which is just half the recommended intake. Consistent results across all studies suggest that inadequate consumption in most food groups remains a problem in the U.S., although dairy and whole fruit consumption are high in early childhood. Thus, interventions aimed at improving dietary quality may include age-specific components to have maximum efficacy.

Our analysis revealed a more positive message for protein consumption, with a high scores in early childhood, which still less than nearly the maximum recommended score by adolescence. This higher total protein score in older groups was mirrored by a trend towards higher score in total vegetables. This finding was unexpected, as previous research has shown that children consume fewer vegetables as they age.¹¹ While this difference may be due to a number of

factors, we suspect that can be attributed to the classification of white potatoes as vegetables in the HEI-10. Therefore, higher intake fried white potato (e.g., potato chips, French fries) would contribute to an higher total vegetable component score but may have deleterious effects on overall health.³⁴

Along with encouraging intake of healthful foods, DGA recommends limiting consumption of less healthful dietary components, including empty calories, sodium and refined grains. Previous studies have shown that nearly 40% of daily energy consumed by children and adolescents comes from empty calories (i.e., calories with little to no nutritional value).¹³ Empty calorie scores were around 10 out of a maximum score of 20 (higher score indicates lower consumption per 1000 kcal consumed), for most age groups. Empty calorie scores were significantly lower in the 4-8 year olds compared to the 14-18 year olds. The observed difference in empty calorie scores may have also contributed to higher sodium scores across childhood, as empty calorie sources often contain elevated amounts of sodium.³⁵ The higher sodium score in older groups is consistent with previous literature. Specifically, our findings are in agreement with the results of one study which reported that nearly all adolescents consume more than twice the recommended daily intake (per 1000 calories) of sodium.³⁶ Similarly, our finding of higher refined grain scores in older groups is consistent with previous reports that less than 1% of adolescents are consuming the recommended amount of whole-grain foods and are instead eating refined grains.^{12,33} Thus, the use of current NHANES data in our study verified previous results indicating that consumption of these components is too high in U.S. children; we extend these findings by revealing that they differ between age groups. Compliance with HEI-10 moderation categories needs to be addressed among all children, and future research into the causes of and precursors to declining dietary quality may enable design of more effective interventions.

To survey a large, representative sample of the US population, NHANES data relies on dietary recall, which may be subject to underreporting. Although our analytical methods reduced the effect this may have had on our conclusions, the use of objective validation of self-reported intake is a key future direction. Due to the use of NHANES data, this study is limited to children within the US and it is not clear how these findings will generalize to other countries. The use of proxy interviews and adult assistance for those ages 4-11 may have led to inaccurate recall and it is not clear if this had an effect on the data. We did not employ a longitudinal design, and made inferences based on age groups. It is possible that there were population differences such as year of birth between the age groups which could account for the differing scores across age-groups. However, analyzing data across several NHANES cycles helps to minimize this possibility. In addition, we have controlled for any potential confounding effects on data collection year, which can affect longitudinal samples. Our analysis did not include reasons for lower dietary quality as children age, and a key future direction would be to examine causal factors of dietary change across childhood. Our analysis suggests that several variables could be targeted to prevent a decrease lower dietary quality in older children.

Conclusion

This study showed that overall diet quality was poor among all age groups and significantly declined for older age groups. Our data suggest that interventions tailored for food groups or at age groups may promote the continuation of high adherence to dairy, total fruits, and whole fruits observed in childhood or seek to increase vegetable and greens and beans consumption across all age groups. It is clear, however, that there is an urgent need to devise and implement effective dietary quality interventions early on in life, in order to significantly reduce overall risk of chronic diseases like diabetes, cardiovascular disease, and cancer.

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Table 1. Demographic information of NHANES 2005-2010 population ages 4-18 (N=8390). Means are reported with standard deviations.

	Sample size	Age Group			P-values		
		4-8 yrs (x)	9-13 yrs (y)	14-18 yrs (z)	xy	xz	yz
Age (years) , mean $\pm$ SD	8390	5.97 $\pm$ 1.42	11.02 $\pm$ 2.30	15.92 $\pm$ 1.60	< 0.0001*	< 0.0001*	< 0.0001*
BMI-Z Score, mean $\pm$ SD	8334	0.41 $\pm$ 1.84	0.62 $\pm$ 2.02	0.64 $\pm$ 2.00	0.0047*	0.0020*	0.7239
Race, %					0.0555	0.0072*	0.0098*
Non-Hispanic White	2552	57.07	57.57	63.17			
Non-Hispanic Black	2216	13.78	14.78	14.1			
Mexican American	2420	15.48	13.79	11.32			
Other Hispanic	719	5.96	5.42	5.42			
Others/Multi-Racial	483	7.72	8.44	5.99			
Sex, %					0.4527	0.6259	0.8708
Male	4266	51.74	50.7	50.94			
Female	4124	48.26	49.3	49.06			
Poverty Income Ratio, %					0.0183*	< 0.0001*	0.0974
≤ 1.3	3351	33.5	29.68	27.06			
>1.3 to ≤ 3.5	2844	39.04	37.14	36.41			
>3.5	1660	27.46	33.18	36.53			
Missing	535						
Family Size, mean $\pm$ SD	8390	4.54 $\pm$ 1.89	4.51 $\pm$ 2.30	4.16 $\pm$ 2.13	0.4382	< 0.0001*	< 0.0001*
Attending School, %					0.3589	< 0.0001*	< 0.0001*
In School	5100	73.41	75.55	70.25			
On Vacation	1232	25.84	24.14	21.81			
Neither	260	0.75	0.31	7.94			

*=Significant comparison (P<.05)

SD: (standard deviation)

N is estimated without the use of weighting variables, while **mean $\pm$ SD, and p-value** are estimated with the weighting variables.

P-values for categorical variables were drawn from chi-square test and p-values for continuous variables were from ANOVA.

Reference for BMI z-score: <http://www.cdc.gov/nccdphp/dnpao/growthcharts/resources/sas.htm>

Table 2. Mean HEI-2010 component and total scores, expressed as absolute scores (n=8390) for the NHANES 2005-10 population ages 4-18 years.

	4-8 yrs (x)	9-13 yrs (y)	14-18 yrs (z)	Multiple comparison Q-values		
Component (maximum score)	Mean score $\pm$ Standard deviation			xy	xz	yz
Total Vegetables (5)	1.93 $\pm$ 2.48	2.08 $\pm$ 3.60	2.28 $\pm$ 4.39	0.116	0.002*	0.099
Greens and Beans (5)	0.55 $\pm$ 3.49	0.48 $\pm$ 2.55	0.54 $\pm$ 3.76	0.401	0.932	0.488
Total Fruit (5)	4.48 $\pm$ 8.89	3.17 $\pm$ 4.96	2.49 $\pm$ 6.25	0.002*	0.002*	0.002*
Whole Fruit (5)	4.95 $\pm$ 5.31	3.89 $\pm$ 8.81	2.81 $\pm$ 10.94	0.002*	0.002*	0.002*
Whole Grains (10)	2.14 $\pm$ 5.07	1.80 $\pm$ 4.74	1.32 $\pm$ 3.12	0.017*	0.002*	0.002*
Dairy (10)	9.33 $\pm$ 8.25	7.86 $\pm$ 10.52	7.05 $\pm$ 10.25	0.002*	0.002*	0.010*
Total Protein Foods (5)	3.83 $\pm$ 4.60	4.40 $\pm$ 5.48	4.74 $\pm$ 5.31	0.002*	0.002*	0.039*
Seafood and Plant Proteins (5)	2.33 $\pm$ 8.12	2.85 $\pm$ 8.98	2.49 $\pm$ 9.84	0.041*	0.546	0.204
Fatty Acids (10)	2.75 $\pm$ 6.16	3.10 $\pm$ 7.01	3.42 $\pm$ 7.94	0.084	0.002*	0.150
Sodium (10)	5.64 $\pm$ 6.00	4.63 $\pm$ 8.63	4.20 $\pm$ 12.97	0.002*	0.002*	0.200
Refined Grains (10)	4.92 $\pm$ 6.99	3.75 $\pm$ 9.14	3.97 $\pm$ 10.54	0.002*	0.002*	0.467
Empty Calories (20)	9.25 $\pm$ 10.94	8.85 $\pm$ 11.92	8.26 $\pm$ 13.23	0.248	0.009*	0.122
Total Score (100)	52.11 $\pm$ 29.68	46.85 $\pm$ 34.93	43.59 $\pm$ 36.65	0.002*	0.002*	0.002*

*=Significant comparison (Q-value<0.05)