MEASURING THE HEALTHFULNESS OF CHILDREN'S DIETS AND THE ROLE OF THE HOME FOOD ENVIRONMENT

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ABSTRACT

Amy Lynn Roberts: Measuring healthfulness of children's diets and the role of the home food environment
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Although diet is well recognized as key to good health in children, methods for assessing diet and an understanding of the environmental factors that influence children's diets are limited.. One widely used method to evaluate diet quality is HEI-2010, but the utility of this method has not been previously examined in children. In this study, we found that children with higher HEI-2010 scores were more likely to meet micronutrient requirements (mean micronutrient adequacy ratio 82.4±1.9 vs. 60.8±1.6) and less likely to over-consume energy (+2.1±4.7 % vs. +17.8±3.2%) compared to children with lower HEI scores. However, HEI-2010 did not adequately assess some components of diet in young children (ages 2 to 12). For example, children who received the maximum HEI score for the dairy component often consumed less than the recommended level of for calcium (-21%), vitamin D (-3%) and vitamin A (-11%) compared to children who met the dairy Dietary Guideline. Overall, HEI-2010 was an effective tool for assessing nutrient quality in the diets of older children, but had important flaws when used in younger children.

These findings led us to use the Dietary Guidelines rather than HEI-2010 to measure the association between the availability of foods in the home and child diet. We found that parents of African American children were less likely to report always having fruit (percent difference from reference,-12%) and low-fat milk(-10%), and more likely to report dark greens(+10%) in their homes compared to white children. Children who always vs. rarely, had a food in their homes were more likely to meet the dietary guideline for that food: OR (95% CI); Fruit: 2.61(1.01, 6.75), Dark greens: 3.33(0.76, 14.40), and low-fat milk: 1.44(1.04, 2.00). Children who always, compared to rarely, had soft drinks available were more likely to exceed the recommended empty calorie limit from calories in soft drinks: 1.92(1.34, 2.74). Many of the current dietary methods were first developed for adults and later applied to children. By thoroughly examining the utility of these tools for children, and, when necessary, developing child specific versions of tools, we can uncover important intervention targets, such as increasing the availability of healthy foods in the home.

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LIST OF ABBREVIATIONS

AI	Adequate Intakes
FPED	Food Patterns Equivalents Database
NCC	Nutrition Coordinating Center
NCI	National Cancer Institute
NDSR	Nutrition Data System for Research
NHANES	National Health and Nutrition Examination Survey
RDA	Recommended Dietary Allowance
SNAP	Supplemental Nutrition Assistance Program
SoFAAS	Solid Fats and Added Sugar
SSBs	Soft drinks or fruit flavored beverages
USDA	United States Department of Agriculture

Chapter 1. INTRODUCTION

A. Background

Childhood obesity in the US has more than doubled in the past 30 years[1, 2], and more than 40 million pre-school aged children worldwide are overweight or obese[1]. Obesity persists across the life course. At ages as young as two years, obese are at increased risk for adult obesity[3] and its associated comorbidities including type 2 diabetes and cancer[4]. Though children (2-18y) consume approximately 66% of their daily calories in the home[5], the mechanisms underlying the contribution of the home food environment to childhood obesity remain unclear. Previous research in this area has been limited by small regionally specific samples, which prevent generalizability to the American population. Given the importance of the home for shaping both the diet and health of children, and the urgent need for early intervention, it is imperative to have a better characterization of the home food environment and its effect on child diet and obesity.

We will use data from two studies: the NHANES 2007-2010, a nationally representative cross-sectional dataset, and the My Parenting SOS intervention on 324 parent/ child dyads, which contains high quality parenting questionnaires and dietary recalls in a higher income but racially diverse sample. Using these uniquely rich datasets we will: 1) improve researchers understanding of how to best capture dietary patterns in children and; 2) determine how the home environment is associated with child diet. Specifically, this project will include the following aims:

1. ***Aim 1***

Develop a method for calculating HEI-2010 using dietary data collected using the Nutrient Data System for Research (NDSR) from the University of Minnesota. Households (n=324) who participated in the My Parenting SOS study will be used in this analysis to test the HEI-2010 calculation method.

2. ***Aim 2***

Determine if the HEI-2010 is a valid measure of the USDA Dietary Guidelines for children 2-17 years of age. Using data from NHANES 2007-2010 we assess the diets of children (n=6,392) using one 24hour recall to calculate HEI-2010 component scores, and determine if children are meeting their Daily Guidelines for Americans.

Hypothesis: 1) HEI-2010 will not accurately capture children if young children are meeting their Daily Guidelines for Americans. 2) The age and sex adjusted the USDA recommendation for intake will be associated with children meeting their RDA or AI for 25 micro- and macronutrients more frequently than HEI-2010 component scores.

3. ***Aim 3.***

Determine the association of foods in the home with child dietary intake. Using one 24-hour recall from NHANES 2007-2010 we will determine the factors associated with food available in the homes of American children and adolescents. We will test if reported availability of fruits, dark green vegetables, low fat milk or sugar sweetened beverages available in the home increases the likelihood that children and adolescents will meet their USDA recommended dietary intake for that food. *Hypothesis: Children will be more likely to meet their recommended intake level when a food is always available in their home compared to rarely of never.*

Chapter 2. LITERATURE REVIEW

A. Diet Collection

1. *Overview*

Diet collection methods include a variety of tools including weighed food diaries, food frequency questionnaires, and dietary recalls. There has been extensive research on the validity and reliability of each of these methods, and each of the methods were found to have issues with bias and misreporting [6, 7]. As a result, there is no gold standard dietary collection method. However, the 24 hour recall has become one of the most commonly used dietary collection methods. Because it collects all of the foods eaten in the previous 24 hours, it is appropriate for all races and cultures, has a relatively low burden on the participant, especially when compared to weighed dietary records, and can be used to estimate usual intake when repeated on appropriate days [6, 7]. The methodological considerations of the 24-hour recall will be explored in this section.

2. *Dietary Recalls*

Dietary recalls are a method of dietary collection where an individual reports all the foods they have eaten within a stated time period. The 24-hour multi-pass recall method is a commonly used paradigm for dietary recalls. This method is typically administered by a trained researcher using a structured interview protocol aimed at capturing all dietary intake from the previous day. The four-stage multi-pass method refers to the process in which a researcher first captures a list the foods and beverages that were consumed. The second pass captures a detailed description of each item. The third stage aims to capture the servings or portions of each food and beverage. Often times the individual reporting their intake will have access to a visual representation of portions of various foods to use as a reference when estimating their intake. The final pass checks all the reported foods for accuracy[8]. Automated methods such as the Automated Self Administered -24 hour recall are also available[9].

The nutrient information for 24 hour recalls are based on a nutrient database such as the USDA database or the Nutrient Data System for Research. Due to the large variety of foods available as well as the rapidly changing composition of food products, especially consumer packaged foods, it is challenging for these databases to maintain up to-date information and thus they may not accurately reflect nutrients available in foods [10, 11]. This is a limitation of all data collection methods that link to nutrient information.

Extensive work has been done to determine the number of recalls that are required to assess usual intake. The protocol that captures three 24-hour dietary recalls on at least one weekend day is considered adequate to estimate usual intake in most populations[6, 7]. This method balances participant burden, measurement error, and measurement quality. A systematic review by Burrows et al. found that three 24-hour recalls, including a weekend day, captured using parents as proxy reporters was the most accurate method for children 4-11 years of age[12]. Studies using doubly labeled water have validated this method and found that energy intake is accurate for 15-18 year old children but may be underestimated in younger children (<9 years of age) [6].

Dietary recalls have advantages and disadvantages when compared with other dietary collection methods. Recalls have a relatively low participant burden compared to dietary diaries and some other methods. Interviewer led recalls do not require literacy, making them more appropriate for use in children. Because 24-hour recalls report past intake, reporters are less likely to alter their diet in response to the dietary collection method compared to food diaries. One of the key disadvantages of the recall method is that data collection relies on the participant's memory. There is evidence that weight status, age and gender may all affect what people report during 24-hour recalls[6, 7, 12]. Additionally, there is error with portion size estimates, as people have a difficult time estimating portion size. This method is also time consuming compared to some methods, such as quick fruit and vegetable screener, and expensive to administer. Tools such as the ASA-24[9] may reduce the cost of 24 hour recalls, but researcher time for data cleaning and analysis remains high.

3. *Diet Collection in Children*

Children present unique challenges for dietary collection. As children age, their developing cognitive ability directly impacts what and how they are able to report their diet. Issues of literacy and numeracy are key concerns for younger children. In general, children tend to over-estimate portion size[13], and have difficulty recalling meals from certain locations, such as home versus school meals[14]. Additionally, children often have a lower ability to focus on a task for long periods of time compared to adults. As a result, methods that are time consuming, such as the 24 hour recall, which often takes an hour or more to complete, may not be appropriate for children in when administered with the standard multi-pass method.. Some researchers use games or rewards to encourage complete data collection in children[12].

To ease the burden and fill in the cognitive gaps among children, caregiver reported and caregiver assisted methods are often used to capture dietary intake. For children under 9 years of age, caregiver reported 24 hour recalls are considered to be more accurate than child reported intake[12]. Evidence indicates that children between the ages of 4-8 years provide the most accurate data when assisted by a caregiver, and adult proxies are appropriate for younger children[14]. Although parents are reliable reporters of their child's intake when the child is with them, they are unreliable reporters of intake that takes place outside their care[12]. Based on this finding, some studies, such as My Parenting SOS[15] a study of preschool aged children (2-5 year old), choose to only assess intake when the child is in the presence of the primary caregiver. All of these methods have different biases that must be considered when the comparing diet among different ages of children.

4. *Dietary Patterns*

In diet research, dietary pattern analysis allows researchers to determine how the overall combination of foods and nutrients influence outcomes. Pattern analysis can include data driven methods, such as factor analysis, or scores and indexes, such as the Mediterranean Diet Index. Recent studies have demonstrated stronger associations with chronic diseases and dietary patterns, compared to studies looking at single nutrients [16-18].

There are a variety of methods of quantifying patterns of foods and food groups. Cluster analysis, factor analysis and dietary scores analysis are commonly used in dietary intake research [19]. *Cluster analysis* groups individuals with other people who have similar diets. Larger clusters would be comprised of individuals that consume food items that are common among many people. Small clusters would be comprised of outliers or people who eat foods that few others in the sample eat. Foods that are nearly universal among individuals do not contribute to cluster formation[19]. *Factor analysis* provides scores for each person based on their intake of foods that cluster together, referred to as factors. These values can be compared using quintile analysis for each factor. *Score analysis* ranks the individuals based on a score of diet quality. Individuals that have a given score, can represent a variety of exposures that result in a similar ranking. For example, a diet pattern that scored high on vegetables and low on sodium may have a similar score to a diet pattern that scored high on fruits and low on fat. Similar to factor analysis, quintiles are often used to compare groups[19].

A variety of indexes are available in the literature that are appropriate for different settings, including the Healthy Eating Index (HEI)[20], Alternative Healthy Eating Index[21], Diet Quality Index[22, 23], Recommended Food Score[24] and Alternative Mediterranean Diet Index[25, 26]. The HEI is designed to compare diet to Dietary Guidelines for Americans[27]. There are three versions available including HEI[28], HEI-2005[20], and the newly released HEI-2010[29]. Each version of the HEI represents the USDA's Dietary Guidelines for American's (DGA) recommendations for healthy eating at the time of the HEI release. Many of the other indexes are independent of the USDA recommendations, such as the Mediterranean Diet Index which is scored based on the median intakes of participants in a given study. A recent review by Marshall et al.[30] identified 80 diet quality indexes that have been used in children. 13 were designed for use in US children[21, 28, 31-41] and of these, seven are based on outdated guidelines or have been revised[28, 32-36, 40], one was designed for adults[21], one was designed for infants[31], and two are designed to reflect the Mediterranean diet pattern[38, 39]. Only the HEI-2010 was created to measure 2010 DGA in children. A comprehensive literature review (see Table 2.1) to identify the foods and food groups in the home that are the most predictive of childhood obesity was created.

5. Healthy Eating Index

a. Creation and use of HEI

The HEI was first created in 1995 as measure of the Dietary Guidelines of the time [28]. This early tool was then modified in 2005 and 2010 to match the updated dietary guidelines[36, 42]. The HEI-2010 is a flexible tool that is design for use in Americans 2 years of age or older who are not consuming infant milk or breast milk. This flexible score has been applied to individuals, populations, food environments and the US food supply[42].

The Healthy Eating Index-2010 is comprised of 12 component categories each with a maximum point value: fruits(5 points), whole fruits(5 points), vegetables(5 points), greens and beans(5 points), protein(5 points), seafood and plant protein(5 points), whole grain(10 points), dairy(10 points), fatty acids(10 points), sodium(10 points), refined grain(10 points), and empty calories(20 points).

The maximum total score is 100. For components where adequacy is assessed, e.g., fruits and vegetables, the maximum score is achieved by having an intake of at least the required amount. For moderation components (refined grains, sodium and empty calories) a maximum score is achieved by consuming less than the maximum limit. Full details on the composition and scoring of the HEI-2010 are available elsewhere[37].

b. Calculating HEI Scores

The National Cancer Institute (NCI) provides resources for researchers to calculate HEI-2010 using data compatible with the USDA database. These resources include a SAS macro to calculate the proportion of greens and beans that count towards the protein requirement and another SAS macro which calculates servings per 1000 kcal and component scores. Compatible data sources include dietary data from the National Health and Nutrition Examination Survey (NHANES) and data from the Automated Self Administered -24 hour recall [9]. However, many researchers use the University of Minnesota Nutrition Data System for Research (NDSR) requiring an alternate approach in order to calculate HEI-2010.

NDSR is often used by researchers to capture 24 hour recall data and detailed ingredient level nutrient data. The extensive dietary data produced by NDSR can be used for a variety of purposes including to calculate HEI-2010. However, the format of the data does not directly match the categorizations of food components that are used in HEI-2010, making the process of converting NDSR data into HEI compatible variables onerous and time consuming. Due to the extensive use of the NDSR system it is imperative that researchers have an efficient tool for applying the HEI-2010 to their data.

c. Validation of HEI

Previous versions of the HEI have been assessed for validity and reliability in a variety of populations, as well as, for measuring the association of diet quality with a variety of diet -related outcomes. For example, in an analysis of 58,717 adults on colorectal cancer risk, reduced risk was associated with the HEI-2005 scores in women (relative risk 0.80, 95%CI 0.64, 0.98) and in men (relative risk 0.72 95%CI 0.62, 0.83)[19]. Because of the relative newness of the HEI-2010, only 1 validation study is currently available. This validation study of HEI-2010 was conducted by NCI and assessed the construct validity and reliability of the instrument Overall they found the HEI-2010 to be a reliable and valid tool based on their assessment criteria, including scores that were independent of energy[42]. It is unclear from this validation studies if the HEI-2010 is an adequate tool for capturing dietary quality among children.

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Earlier versions of HEI have been assessed in children through comparisons with other dietary indices and scores designed for explicitly for children. The Youth Healthy Eating Index[35] and the Revised Child-Diet Quality Index (RC-DQI)[33] are two such measures. The Youth Healthy Eating Index was created for children 9-14 years of age with the aim of being more easily communicated to children. It additionally includes health-related behaviors such as multivitamin use and use of margarine or butter[35]. The RC-DQI is also measures the recommendations and health related behaviors. A recent paper compared HEI-2005 to RC-DQI in American children, both of which measure a version of the DGA for 2005, and found that the RC-DQI provided a larger distribution of scores while the HEI-2005 tended to create a bimodal distribution[43].For this reason, the authors recommende the use of the RC-DQI, instead of the HEI-2005, among children. Due to the changes in the 2010 Dietary Guidelines the utility of HEI-2010 in children needs to be reassessed.

B. Influences of Child Diet

1. *Overview*

Recently, there has been a growing interest in environmental influences of diet and obesity[44-47]. The home food environment is a unique micro-environment that has a large impact on the intake of household members. Young children's diets are particularly influenced by the home food environment especially, because these children are reliant on their caregivers for food and eat more of their meals at home than adults[48]. Even with increases in the number of meals eaten away from home between 1977 and 2006, approximately 66% of calories per day are consumed at home[49]. Additionally, dietary habits formed at a young age likely affect diet later in life, and obesity in early life has been linked with later obesity[3]. Due to the importance of early child diet and the large percentage of intake coming from the home among children, the home food environment is an important research area.

Prior research has shown that the home environment is a predictor of intake[50-53] and weight status[54, 55] among children. Home environment is comprised of two important components: the physical environment and the social environment. The physical environment includes: 1) foods that are available in the home, and; 2) the accessibility of those foods. While the social environment includes a variety of cultural and environmental factors. For children, the social environment is usually described in terms of the feeding styles and feeding practices of the caregivers in the home. Styles and practices have been linked to over all diet quality, and fruit and vegetable consumption among children[56-59].

2. *Physical Environment*

The physical environment includes the foods available in the home and the accessibility of those foods, whereas, availability refers to all the foods in the home including items stored in the pantry, refrigerator and freezer. Accessibility addresses the form of those items. Items are considered accessible if they are ready to eat and in sight. For example, bell peppers that have been washed, sliced and are stored in the fridge where the child can reach them are considered accessible, while the whole pepper would be considered less accessible. For this project, we will focus on availability of foods because it allows us to summarize a key aspect of the home and has relatively more standardized measurement methods compared to accessibility.

a. Impact of foods in the home on obesity and diet:

The physical food environment includes all foods available in the home at a given time. Having foods available in the home has a positive association on the likelihood of the consumption of that food for both children and adults[50-53, 73-78]. This is advantageous in the case of healthy items (fruits, vegetables, nutrient-dense foods, etc.), but detrimental for unhealthy items (snacks, sodas, desserts, energy-dense foods, etc.).

Researchers have repeatedly shown that increased availability of fruits and vegetables in the home is associated with increased intake of those items[74, 77, 79-84]. Similarly, the presence of high fat or low fat foods has also been linked to intake of those items[85]. (See Table 1) Few of these studies examined the impact of availability and accessibility in pre-school aged children[59, 84].

The evidence for an association between obesity and foods in the home is less consistent[50, 86, 87]. Arcan et al.[50] found an association with vegetable availability and overweight status among American Indian kindergarteners at baseline ($p = 0.051$) but the effect was attenuated longitudinally. The availability of other foods, such as in the fruits and milk, were not associated with weight status in this age group[50]. Using one of the only exhaustive home food inventories available, Byrd-Bredbenner et al. found that households with obese children were more likely to have a greater percent of calories from meat ($p<0.05$) and a greater percent of protein and carbohydrates from grains ($p<0.02$) than households with normal weight children[88]. Similar differences were found in households with overweight parents. The source of the inconsistent findings may be due to many of these studies using self-reported home food availability data that only captured a limited number of foods[89-91], and in some cases self-reported weight and height[64, 92].

b. Measuring food in the home:

A variety of methods have been used to collect data on the foods in the home. These methods can be broken into two categories: 1) Survey measurements, which include checklists and other measures intended to capture key items in the home and 2) Exhaustive methods, which use researchers or participants to itemize every item available at a given time.

Survey methods

The majority of studies on the home food environment have used survey methods to describe food availability. Checklist methods use a simple food list and ask the respondent to indicate if the food item was available in the home during a given time period. For example, a checklist item may list apples, and the respondent would select “yes” if the item was available in the home or “no” if the item was unavailable. Cullen et al.[89] created a 71-item checklist which captures the presence or absence of fruits, juices, vegetables, high-fat foods, and low-fat foods available in the home during the past week. A variety of other checklists, such as Patterson’s[91] 15-item high fat food list or Marsh’s[90] 48-item fruit and vegetable checklist are also available. Although these checklists vary in length and food items queried, they all capture the availability of a limited number of food items that are hypothesized to be important for obesity related outcomes.

Checklists are convenient and have a relatively low subject and researcher burden; however, they have a several key limitations that must be considered. First, while checklists are able to capture the variety of foods in the home, e.g. bananas or carrots, they typically fail to capture the quantity or preparation of food items. Second, these measurements rely on the subject to remember the items in their home, making them susceptible to memory related biases. Objectively collected measurements can reduce or eliminate many biases associated with questionnaires. Similar to issues with Food Frequency Questionnaires, the checklist must also be culturally relevant for the population being studied[93]. For example, in a Latino population, it may be necessary to include items such as plantains, or yucca, on the checklist to adequately capture the fruits and vegetables in the home. The foods available in the home may also vary by region. Without a culturally and regionally relevant food list, it is likely that researchers will underestimate the foods available in the home.

Other survey methods attempt to capture details about the home beyond the availability of certain food items. For example, the Gattshall[94] home environment survey is a 126-item questionnaire that queries 10 aspects of the home environment including the availability and accessibility of fruit, vegetables, fat and sweets, as well as social factors such as parental role modeling, and parental policies and support related to healthy eating. Similarly, the Healthy Home Survey created by Bryant et al.[95] prompted participants to estimate the quantity of foods available if they responded “yes” to the item being present. This type of survey provides a better picture of the overall home food environment, but is still limited by the biases that are inherent in self-report tools. These measures also have higher participant burden than the short checklist methods requiring numeracy and literacy. Depending on the research question and population of interest, the longer questionnaires may not be appropriate.

Exhaustive methods

Exhaustive measurements are traditionally paper based methods that require the researcher or participant to record details on every food item available in the home. These methods have been used for many decades and typically involve a researcher entering the home and recording each food item and the quantity available[86, 96-98].

Recently, researchers have used scanning technology to ease the burden of capturing all the food items in the home[97-99]. Scanners capture the Universal Product Code (UPC) on food packages and labels and can then been linked to product information, including package size and nutrient information. Food items without a UPC must still be captured manually. Scanning technology studies have demonstrated that this method is feasible, reliable and efficient, especially compared to paper based exhaustive inventories[97, 99, 100]. Scanners had an accuracy of 95.6% and produced a 31.8% time savings over the traditional line-item inventory approach[99]. Some researcher have argued that the UPC scanning is not a feasible given the cost and subject burden[101]; however, more recent studies have found them to be feasible and reliable methods[98, 100].

The primary advantage to exhaustive inventories, compared to survey methods, is that they capture all foods in the home rather than just a limited number of items, eliminating the need to have culturally or regionally specific tools. Exhaustive methods additionally capture the amount and preparation of each food item available in home, which are often important considerations when looking at diet and obesity outcomes. Unlike survey measurements, objectively collected exhaustive methods are not subject to social desirability biases, nor are they reliant on the memory of participants.

3. *Social Food Environment*

The social context in which foods are served and eaten is an important predictor of diet[56, 87, 102, 103]. In this project, we will focus on parental feeding styles. Feeding styles refer to the overall environment created by a combination of feeding practices. Caregivers generally fall into one of four categories of feeding styles: **Authoritarian, Authoritative, Indulgent, or Uninvolved**[57, 104].

a. Feeding Styles:

Feeding styles are determined by the caregiver's responsiveness to and demandingness during eating occasions. Parents with **authoritarian** styles often restrict certain foods while forcing children to eat others (highly demanding) with little regard to the child's preferences and desires (low responsiveness). Parents with **authoritative** styles encourage the child to eat, but rather than using the more overt actions of authoritarian parents, such as physically struggling or using rewards for eating, authoritative styles encourage eating by making foods more compelling and controlling the foods available in the home. This may include arranging food in interesting ways. This is both a demanding and a responsive style. Parent with **indulgent** (or **permissive**) styles allow the child to eat whatever they want in whatever quantity they desire. Children are limited only by availability in the indulgent style. The limited direction children receive is responsive. **Uninvolved** styles are similar to permissive, but the little direction children receive is unresponsive[59, 105, 106].

These feeding styles have been linked to diet behaviors and weight status of children. Authoritative feeding styles are associated with higher fruit and vegetable intake[56, 59], while authoritarian styles have been associated with lower intake[59]. Conversely, indulgent and uninvolved feeding styles are associated with lower diet quality, such as increased consumption of low-nutrient dense foods[56, 58]. Indulgent styles have also been linked to higher BMI levels in children[106]. These associations have been shown to vary by race and ethnic groups[60-63], but the underlying factors of this affect are not understood.

4. ***Socio-economic factors***

Feeding styles and practices have been shown to differ based on race and ethnicity[60-63] and other socio-economic factors. Food security has been associated with diet. Two tools are commonly used to capture food security. They are the USDA 18-item questionnaire, and the USDA 6-item short questionnaire (see appendix A)[108]. In the United States, food security has been consistently linked to overweight and obesity in adult women[64, 109, 110]. For American children the effects vary based on gender, age and race ethnicity. Girls, older children, and Hispanic children demonstrate positive associations with food insecurity and obesity, while other groups of children have a null or negative association with food security controlling for relevant covariates[83, 109-112]. Furthermore, the quality of foods available in the home[64, 68, 83, 113] and the diet[64-72] of household members is lower in food insecure homes. There is evidence that as the time since the last paycheck increases, these trends become more pronounced[114]. Many of the studies of food security have used sub-optimal methods, self-report weight or nonvalidated diet questionnaires. Given the sensitive nature of this topic, biases, such as the social disability bias, may be magnified.

C. Innovation

To understand the impact of food available in the home on the diet of American children, diet must be accurately described. We begin by exploring methodological issues around calculating HEI-2010 scores in a commonly used database, NDSR. We then determine if HEI-2010 is a valid measure of assessing whether children are meeting the Dietary Guidelines for American recommendations.. Finally, based on our findings, we assess the association of foods available in the home on children meeting the DGA recommendations. This is the first study to examine the utility of HEI-2010 for capturing adherence to the DGAs among children and to measure the association of food availability on the diets of children in the US using a nationally representative sample.

Figure 2.1. Conceptual model of the Home Food Environment

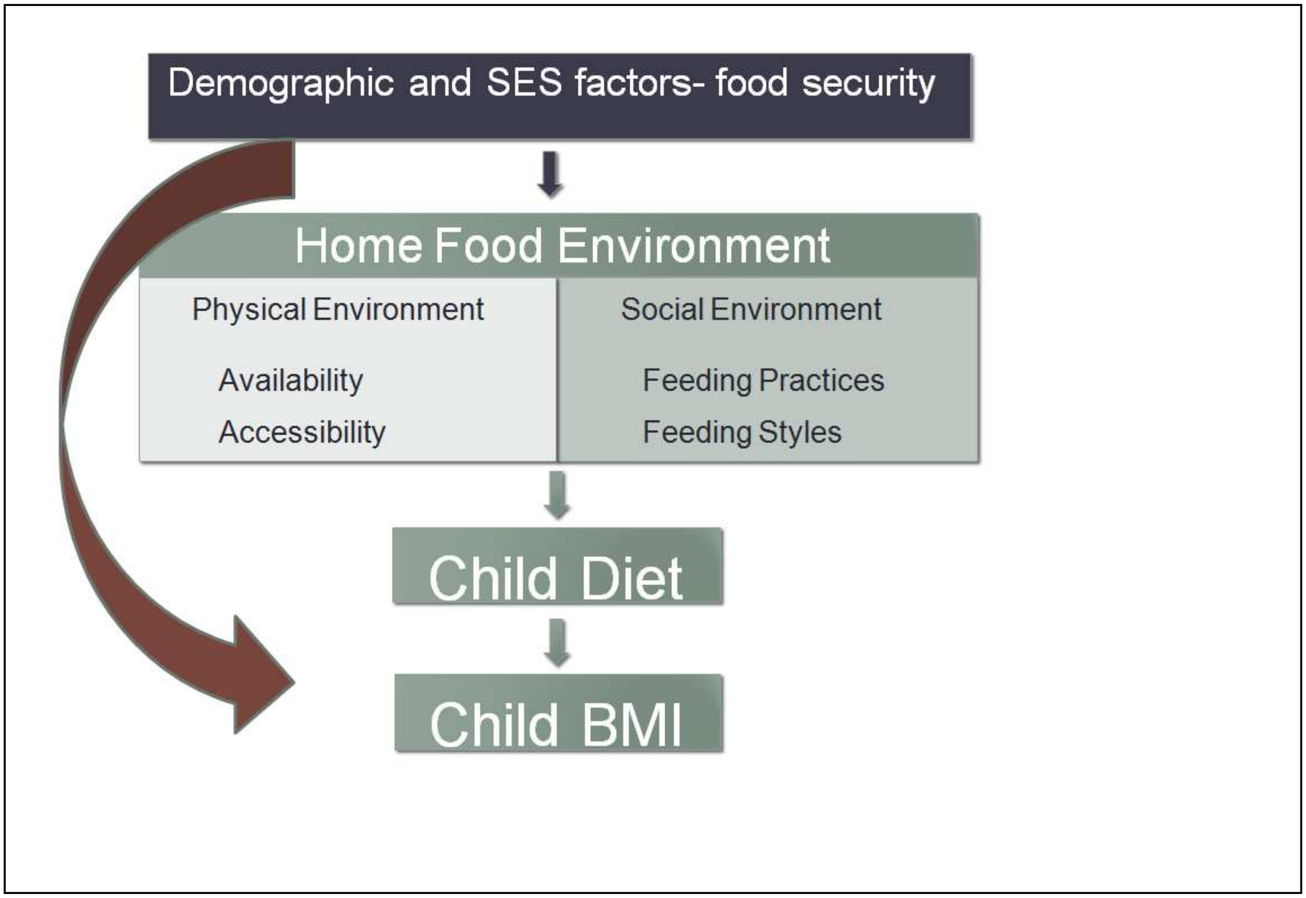


Table 2.1 Correlates of fruit and vegetable intake in 6-11y children (Adapted from Pearson, 2008[115])

Correlate	Fruit Consumption					Vegetable Consumption					Fruit, Fruit Juice and vegetable Consumption				
	Association (+/-)	No. of studies	Summary (n)			Association (+/-)	No. of studies	Summary (n)			Association (+/-)	No. of studies	Summary (n)		
			+	-	Null			+	-	Null			+	-	Null
Physical															
	+	6	5*	0	3	+	9	6	0	3	+	4	2	0	2
Accessibility	-	3	0	2	3	+	3	1	0	2	+	6	3	0	3
Social															
TV during meals[1]	Null	1	0	0	2	-	1	0	1	0					
Role Modeling	+	7	6	0	2	+	10	5	0	5	+	3	3	0	0
Parent intake	+	3	4	0	0	+	3	1	0	2	+	3	2	0	1
Parental control	+	1	1	0	1	Null	1	0	0	1	Null	1	0	0	1
Pressure to eat	Null	2	0	0	2	+	3	1	0	2					
Restriction	Null	3	3	0	0	Null	3	0	0	3	Null	1	0	0	1
Parental Encouragement	+	3	3	0	0	+	5	4	0	1	Null	1	0	0	1
Frequency of family breakfast	+	2	2	0	0	+	2	1	0	1	Null	1	0	0	1
Frequency of family dinner	+	3	1	0	3	+	3	1	0	2	Null	1	0	0	1
Demographic															
Household education	+	2	1	0	2	Null	2	0	0	2	Null	1	0	0	1
Household income	+	3	2	0	3	Null	3	0	0	3	-	2	0	1	1

* In one study, if a correlate is examined in relation to two outcomes (fruit and juice) and the results differ for the outcomes the study is counted once in the 'No of samples' and twice in the 'Summary'

[1]Not all correlates were available for all outcome

Chapter 3. NOVEL METHOD OF CALCULATING THE HEALTHY EATING INDEX-2010 BASED ON PARTIAL DAY INTAKE (FOODS CONSUMED AT HOME) AND FULL DAY HEI IN THEIR CAREGIVERS USING THE MINNESOTA NUTRITION DATA SYSTEM FOR RESEARCHERS

A. Abstract

Background

The Healthy Eating Index-2010 (HEI-2010) is a widely used tool for measuring dietary patterns. Previously, there was no readily available method for calculating HEI-2010 in the Nutrition Data System for Research (NDSR).

Objective

1) Develop a method for calculating HEI-2010 with NDSR dietary data. 2) Test our method in a population of caregivers and their preschool aged children.

Method

Using three NDSR food files, we created food categories to match each of the 12 the HEI-2010 components. For the empty calories component we calculated excess calories from fat in meats, and dairy. These calories were added to total calories from fat from butter, lard, cream, and other foods that are predominately comprised of fats, as well as calories from added sugars and alcoholic beverages. We converted NDSR servings into cup or ounce equivalents based on the conversion that was used in the Food Patterns Equivalents Database (FPED). Finally, we calculated HEI-2010 component and total scores for children and caregivers who participated in the baseline data collection for My Parenting SOS

intervention. HEI-2010 scores were also calculated using the NCI method for matching samples from NHANES 2007-2010.

Results

We successfully created a method to calculate HEI-2010 scores using NDSR dietary data. Our method differed from the NCC method on the inclusion of baby foods, the calculation of grains. The new version of NDSR includes a solid fat variable that should be used to calculate empty calories.

Conclusions

Our HEI-2010 method and associated SAS macros will greatly reduce the burden and help standardize the calculation of HEI-2010 using NDSR dietary data.

B. Introduction

The Healthy Eating Index-2010 (HEI-2010) is a method of measuring dietary patterns based on the 2010 Dietary Guidelines for Americans, and can be used in people 2 years or older who are have been fully weaned. Two previous versions of the score have been created to capture prior USDA dietary guidelines[28, 36]. HEI-2010 sums the scores from12 component foods and food groups, for a maximum score of 100. The National Cancer Institute (NCI) provides resources for researchers to calculate HEI-2010 using data compatible with the USDA database, such as dietary data from the National Health and Nutrition Examination Survey (NHANES) and data from the Automated Self Administered -24 hour recall[9]. However, many researchers use the University of Minnesota Nutrition Data System for Research (NDSR) requiring an alternate approach in order to calculate HEI-2010.

NDSR is used to capture 24 hour recall data and detailed ingredient level nutrient data. The extensive dietary data produced by NDSR can be used for a variety of purposes including calculating HEI-2010. However, the format of the data does not directly match the categorizations of food components that are used in HEI-2010, making the process of converting the NDSR data into HEI compatible variables onerous and time consuming. Due to the extensive use of the NDSR system it is imperative that researchers have an efficient tool for applying the HEI-2010 to their data.

Miller et al.[116] created a method to calculate HEI-2005 using NDSR data. This method outlines key considerations for converting NDSR data, including calculations to convert most foods to the appropriate cup or oz equivalents. The Miller method[116] and the accompanying SAS maco are extremely useful tools for calculating HEI-2005. However, HEI-2010 differs from the HEI-2005 in such a way the variables created by the Miller method are not suitable for use with the HEI-2010.

The HEI-2010 version modified four component categories. The categorization of vegetables from total vegetables and dark green or orange vegetables and legumes used in the HEI-2005 include only total vegetables (unchanged) and dark green vegetables and legumes. The 2005 classification of oils (≥12g/1,000kcal) has changed to the fatty acid component in HEI-2010, which is the sum of polyunsaturated fatty acids and monounsaturated fatty acids to saturated fatty acids. The updated HEI includes a seafood and plant protein component awarding points for eating at least 0.8 oz equivalents of seafood, nuts, seeds, soy or legumes. This is a change from the more general 2005 category of meats and beans. The empty calories category has changed the most significantly in the HEI-2010 compared to the calories from SoFAAS category that was used in 2005. The current empty calories definition includes excess calories from solid fats, calories from added sugars and alcoholic beverages that exceed the recommended limit.

We aim to develop a method of calculating HEI-2010 using NDSR dietary recall data that can be used by researchers. We will apply this method to at home dietary data for preschool aged children and their caregivers in the My Parenting SOS[15] study and compare HEI-2010 scores to dietary data from a matching NHANES sample. We selected the My Parenting SOS sample to evaluate this new method because it and allowed us to evaluate both parent and child dietary patterns and provides an opportunity to evaluate the utility of HEI for measuring the diet of children while under the care of their primary caregiver.

C. Methods

1. *My Parenting SOS Sample*

My Parenting SOS (conducted in 2009-2011) was a 35-week randomized, controlled intervention of families with preschool-aged children (n= 324 caregiver/child dyads) to promote parenting practices that lead to healthy eating and activity behaviors in children[117]. English speaking families having at least 1 child between 2-5 years old, and at least one parent with a BMI greater than 25 were eligible for this study. Participants who did not have at least one weekday and weekend day dietary recall were excluded from the analysis (parents n= 42, children n=42). The final analytic sample was 282 children and adult participant dyads.

Dietary intake was assessed using the standard multi-pass 24-hour recall method using the Minnesota Nutrition Data System for Research (NDSR) [118, 119]. After each measurement visit, caregivers completed three unannounced recalls, on two weekdays and one weekend day, over a four-week period. Caregivers only reported child diet if the child was with the caregiver at the time of the eating occasion. As a result, we do not have dietary data for children while they are in childcare or with another caregiver. We calculated at home meals for children based on the protocol that is described in detail elsewhere (Martin 2014- submitted). For all children, we calculated meals with caregivers as any weekday eating occasion that occurred prior to 9 am or after 5 pm inclusive and full day intake on weekends. To estimate mean caregiver supervised intake, we used the following algorithm: the mean of weekend day intake and the weekday intake defined as the mean of the two weekdays) (Weekday 1 Intake before 9 and after 5 and Weekday2 Intake before 9 and after 5). Full day recall data was used for parents.

Trained researchers measured anthropometric data for both children and their caregivers. Standing height was measured to the nearest 1/8 inch using a Shorr or Seca infant/Child/adult measuring board (Shorr Productions, Olney, MC; Seca Corporations, Columbia, MD). Weight was measured to the neareast 0.1 lb with a Seca model 770 portable electronic scale (Seca corporation, Columbia, MD). Children additionally had triceps and subscapular skinfold thickness, measured to the 1.0 mm using Lange calipers (Beta Technology, Inc. Cambridge MD); and waist circumference, measured to the nearest 0.1 cm using a Gulick II measuring tape, measurements.

2. *NHANES 2007-2010 Sample*

We created a sample that matched the SOS sample by age, and gender (adults only) in order to compare the SOS HEI scores with an American population of the same age. The matched sample additionally allowed us to validate the partial day HEI-2010 score in children. Children 2-5 years of age who participated in NHANES 2007-2010 were eligible for inclusion in this study (n=1898) and adult women between with a BMI >25 with at least one child, were including in this sample. HEI-2010 was designed for children 2 years and older who are not breastfeeding or consuming infant formula, therefore children were excluded from this analysis if they consumed breast milk (n=5), or infant formula (n=5). The final analytic sample included 1679 children and 2846 adults.

Child diet was measured using one 24-hour recall reported by an adult caregiver. Adults reported their own diet [120, 121]. Servings of each food component were calculated using the Food Patterns Equivalents Database (FPED) for 2007-2008 and 2009-2010[121]. FPED calculated the servings reported for each food based on the intake of whole foods and the component parts of mixed dishes. We calculated the servings from each individual food consumed during the relevant time period to create totals for the at home food HEI. Regardless of the time period, if a participant does not meet their protein requirement from meat sources servings of beans and legumes counted first towards the protein requirement. Once that requirement was met, any additional servings were counted as vegetable servings. HEI-2010 scores were calculated using the National Cancer Institute SAS macro [122].

Anthropometrics were measured and questionnaires were administered using standardized procedures by trained research staff in mobile examination centers[120, 121, 123] Weight was measured to nearest 0.1 kilogram in an examination gown without shoes, and standing height without shoes was measured to the nearest 0.1 centimeter using a stadiometer with fixed vertical backboard and adjustable head piece. BMI percentile was calculated using the CDC growth curve macro[124].

3. *Calculating HEI-2010 using NDSR Dietary Data*

NDSR data requires extensive data manipulation and formatting before being used to calculate HEI-2010. There is no exact match between the categories that are used in FPED requiring some decisions to be made in the definition of the food categories. We based many of decisions on the method used by Miller et al to calculate HEI-2005 with NDSR data. We will describe the creation of each of the 12 component categories using four NDSR files (the components/ingredient file (File 01), the meal file (File 03), the intake properties totals file (File 04) and the serving count total file (File 09). Finally, the foods text file matching the version of NDSR used, e.g., Foods2009.txt, is required to link the foods in the component file to the USDA food codes and the NDSR servings files. A SAS macro is provided (Supplement 1) to calculate the empty calories category and to the remaining categories for use with the SAS macros provided by NCI to calculate beans and greens component and total HEI score.

a. Variables created from serving count total file (NDSR File 09)

Total fruit and **whole fruit** are calculated using the serving count total file (File 09). Whole fruit includes citrus fruit (FRU0300), other fruit (FRU0400), avocados (FRU0500) and fried fruit (FRU0600). Total fruit additionally includes citrus and fruit juices (FRU0100 and FRU0200) and fruit based snacks (FRU0700). According to the DGA for Americans, such that one medium apple, banana, orange or pear, ½ cup of chopped, cooked or canned fruit or ¼ a cup of juice are equivalent to 1 serving of fruit(NDSR manual 2009). We divide servings by two to calculate cup equivalents (1 servings = 0.5 cup equivalents). Cup equivalents are required for the NCI HEI SAS macro.

Whole grains and r**efined grains** were calculated using 3 NDSR categories: whole grain, some whole grain and refined grain. All servings of whole grain foods (GRW0100-GRW1200) and half of the servings of some whole grain foods (GRS0100-GRS1000) were counted as whole grains. Refined grains included servings of refined grains (GRR0100- GRR1000) and the remaining half of the some whole grain foods. The servings were converted to cup equivalents such that 1 serving = 0.5 cup equivalents.

Total vegetable include all sources of vegetables and any legumes that do not count toward the protein requirement (VEG0100-VEG0900, FMC0100). This includes juices, and fried vegetables such as potato chips and French fries. **Greens and beans** include all dark green vegetables (VEG0100), and legumes (VEG0700) that do not count towards the protein requirement. (1 serving = 0.5 cup equivalents).

Seafood and plant proteins include seafood (MFF0100, MFL0100, MFF0200, MSL0100, MSF0100), nuts and seeds (MOF0500, MOF0600), soy (MOF0700) and legumes that count towards the protein requirement (VEG0700).

Total proteins include all items in the seafood and plant categories and all remaining meats including beef, poultry, pork, game, and processed meats and sausages (MRF0100-MRF0500, MRL0100-MRL0400, MCF0200, MCL0200, MPF0100, MPF0200, MPL0100, MCF0100, MCL0100, MOF0100, MOF0300, MOF0400), where 1 serving = 1 ounce equivalent.

The NCI greens and beans macro[122] is used to determine the number of servings of legumes that contribute toward the protein and vegetable components. If a person does not meet their protein requirement from meat sources, such as with vegetarians, protein from legumes first count towards the total protein requirement and seafood and plant proteins (1 serving of legumes = 2 lean meat ounce equivalents). Any remaining legume intake counts towards the total vegetable and greens and beans category (1 serving = 0.5 cup equivalents).

b. Variables created from the intake properties totals file (File 04)

Fatty Acids are calculated as the ratio of the sum of monounsaturated fatty acids and polyunsaturated acids by saturated fatty acids intake. Total grams of each of the types of fatty acids are reported in the intake properties totals files. **Sodium** is the total mg of intake is converted to grams of intake (intake in mg/1000), and is also reported in this file.

Two components of the **empty calories** category (added sugars and alcohol intake) are calculated form the intake properties file. Added sugars in grams are converted to calories with a ratio of 3.87 kcal per gram based on the USDA nutrient database[125]. Similarly grams of alcohol are converted to calories by multiplying the grams of intake by a factor of 7 kcal/gram[125]. If a participant is over 21 years of age, only alcohol that exceeds 13 g per day contributes to the empty calories total. Only alcoholic beverages, not trace alcohols in foods, are counted towards the empty calories total.

c. Variables created from the components/ingredient file (File 01)

In order to calculate cup equivalents for each type of **dairy** (e.g., milk, processed cheese, soft cheese and fortified soy beverages), we applied USDA food codes because they provided more precise food categories than the NDSR food serving categories. Milks, soymilks and yogurts (fresh and frozen) were converted as 1 serving per cup equivalent (USDA code: 111, 113-115). Natural cheeses (USDA code 141) were converted as 1.5 ounce (42.5 g) per cup equivalent, while processed cheeses (USDA code 144) were converted as 2 ounces (56.7 g) per cup equivalent. Cottage cheeses (USDA code 142) had a 4.5 oz (127.6 g) per cup equivalent ratio. Dry milk (USDA code 118) was 25g per cup equivalent and condensed milks (USDA code 112) had a 125 g per cup equivalent ratio. The sum of cup of equivalents of dairy create the **dairy** component variable.

Empty calories are calculated by summing the calories from added sugars and alcohol (calculated from the intake properties file) with excess calories from fat. Excess calories from fat are defined as fat from dairy beyond 1.5 g per cup equivalent, fat from meat beyond 9.28g per 100g of meat[37, 126]. Total trans and saturated fatty acids from cream, butter, salad dressings, mayonnaise, oil based condiments, and oil based snack foods count toward the excess fat total. These ratios selected are the ones used by MPED in the calculation of these items[126]. The grams of fat are converted to calories by multiplying 9 kcals/gram of fat.

d. Calculating the HEI score

For the My Parenting SOS, we used file 4 from NDSR to link the time of the intake from each of these components and calculated the mean at home intake (as previously described). The total at home intake for each component food was used in calculating the HEI score. We used the NCI HEI-2010 SAS macro[122] to calculated component and total HEI scores for our sample.

4. *Analysis*

Mean HEI-2010 scores were calculated for both the NHANES (PROC SURVEYMEANS) and My Parenting SOS (PROC MEANS) samples. We did not conduct statistical tests comparing the NHANES and SOS samples. However, the NHANES sample did provide validation for the partial day HEI-2010 scores in children. For the NHANES sample HEI components amounts were calculated for the full day using the total intake file and for at home intake using time-matched intake (foods file). HEI scores were calculated using the NCI HEI macro[122] and survey weighted mean scores were calculated both full and at home intake. Mean HEI scores were calculated for the My Parenting SOS sample. Associations with demographic variables and parental feeding style and HEI scores were calculated (PROC REG and PROC LOGISTIC). All analysis were completed in SAS (SAS/STAT®9.3, SAS Institute Cary, North Carolina, USA) using survey weights and procedures when necessary.

D. Results

Table 1a and 1b provide an overview of the NDSR files and unit conversions needed in order to calculate HEI scores using NDSR data. In August 2014, NCC released a document[127] that outlines calculating HEI-2010. Our method is similar to the NCC method with the differences noted in Table 1.

Demographic information on the NHANES and My Parenting SOS samples are reported in **Table 2.** The SOS sample of preschool aged children tended to have higher income households and had a different distribution of race and ethnicity compared to the children in NHANES. The adults in the My Parenting SOS sample were additionally more highly educated than the NHANES sample.

At home intake HEI and full day HEI in children 2-5y were similar (**Table 3**). Total score was not different between the two samples, with at home intake HEI being 53 (95% CI 51, 54) and full day being 54 (95% CI 53, 55). Small differences were observed for total fruit, whole fruit and seafood and plant proteins with the largest difference being 0.9 points for whole fruit.

As also shown in **Table 3**, HEI-2010 intake for My Parenting SOS was higher than the NHANES sample with At-Home Intake with an total score of 58.0 (95% CI 56.6, 59.4). Children in the SOS sample had higher scores for total and whole fruit, greens and beans, whole grains, and empty calories, and lower scores for refined grains, and seafood and plant proteins. **Table 4** indicates that adult women in My Parenting SOS had total HEI-2010 scores 10 points higher than women in NHANES.

Two SAS macros are provided for use by researchers in the supplementary materials. The first macro calculates empty calories and uses the component ingredient file for NDSR. The second macro prepares the NDSR dataset for use with the NCI beans and green and HEI macros.

E. Discussion

We succeeded in creating a method for calculating HEI-2010 using 24-hour recall data collected with the NDSR system. Using our method, we calculated mean HEI-2010 in adult women and at home food in preschool aged children. We compared these results to the HEI-2010 scores of matching populations in NHANES using the Food Patterns Equivalents Database. Some differences were observed in HEI-2010 scores between the My Parenting SOS dataset and NHANES data for children and for adults. We found that the population mean for the total score did not differ between full day and partial day (caregiver supervised meals) among children in the NHANES sample. There were no differences in either NHANES or SOS for children of different weight statuses or those who were exposed to responsive feeding styles, compared to non-responsive.

The NCC method for calculating HEI-2010 scores differed from my method in a few ways. First, NCC includes baby foods (grains, meats, etc.), but this study excluded baby foods since HEI-2010 is not intended for children who are weaning[37]. However, due to the low intake of these foods among the population intended for use with HEI-2010, the difference between our method and the NCC method did not have a major impact on HEI scores.

Second, the NCC method includes all grains with some whole grain (i.e., those with GRS prefix) in the refined grain category. Similar to the method used by Miller et al.[116] we made the assumption that half of the grains in the some whole grain counted towards whole grains and the remaining half counted toward refined grains. This difference will result in higher whole grain and refined grain scores than would be observed with the NCC method.

The final difference between the current method and the NCC method is in the calculation of empty calories, which are comprised of calories from solid fats, added sugars, and excess grams of alcohol. For alcohol, we count any alcohol as “excess” for children less than 21 years of age, while NCC does not make a distinction based on age, such that any alcohol intake below 13g/1000kcal is not counted towards the empty calorie category.

In 2014, NDSR began providing a variable for solid fat. We strongly recommend that researchers update their data and use this variable for calculating solid fat. Our method is based on the older versions of NDSR that requires an estimate of solid fat. Because previous versions of NDSR did not fully disaggregate the component fats of all foods, the older method relies on assumptions about the composition of some food items. The new solid fat variable provides a more reliable calculation of solid fat that does not rely on ad hoc assumptions of food composition. The NCC method advises that researchers use this variable for calculating the empty calories component of HEI-2010 and we agree that it should be used whenever possible. NCC, provides instructions on uploading previously collected data into the new software version to generate the solid fat variable. Therefore, it is strongly recommended that researchers use this approach for calculating solid fat even when using older diet data.

Methods in dietary analysis have shifted away from focusing on single nutrients and foods toward capturing the full dietary pattern[19, 30].. There are two strategies to capturing dietary patterns: 1) data driven approaches, and; 2) score based methods. While data driven methods offer the advantage of capturing previously undiscovered patterns, score based methods are advantageous because they can be used across samples to compare diet patterns in a large variety of settings. The HEI-2010 is currently the only score, to our knowledge, that was designed to capture the USDA Dietary Guidelines for Americans in children. However, the utility of the HEI-2010 for assessing the Dietary Guidelines among children had not been previously determined.

In our work on American children, we found that as HEI-2010 scores increased micronutrient profiles improved, and overconsumption of energy decreased (Chapter IV). Although it is not a perfect measure of DGA in children, is applicable to both children and adults. As such, it has been used to set policy goals, including the goal of improving the dietary quality of children in American as part of Healthy People 2020[128] ---The current goal is to raise the mean HEI-2010 score among children in the US from the 50s to the 80s. Although the NDSR system is widely used in dietary research, until now it was extremely difficult to calculate HEI-2010 scores using this database. Our method and improvements in the NDSR software will extend the settings in which HEI-2010 can be applied.

1. *Limitations*

Dietary scores such as HEI-2010 have numerous applications and advantages. However, it is important to understand the measurement error issues that are associated with using a score such as HEI-2010. The most import consideration is the quality of the dietary data that was collected. Research protocols should strive to capture complete, repeated dietary recalls whenever possible[6]. If researchers are interested in estimating population distributions, complex analytic methods may be required to capture usual HEI-2010 scores[129].

All of our analysis was collected in cross-sectional samples. My Parenting SOS does not have complete dietary data for children due to time in child care. As a result, we calculated an "at-home" HEI-2010 score. A complete description of our method for calculating at-home time is available elsewhere (Chantel 2014, submitted). Additionally, among adults, we only calculated HEI-2010 scores for adult caregivers. These two groups provide examples on how to apply our method in using the NDSR to calculate HEI-2010 scores. Further work is necessary to describe the dietary patterns among these special populations.

2. *Conclusions*

Numerous researchers use NDSR to capture nutrient information from research participant. Due to the onerous nature of calculating HEI-2010 scores from NDSR data, few have examined this diet pattern score in their study populations. This is a lost opportunity to both use and evaluate the utility of the HEI-2010 in a wide variety of populations. One of the greatest benefits of using a diet score to measure dietary patterns, rather than a data driven method such as cluster analysis, is that a score allows for comparisons across samples. Our method, combined with the updated variable available in NDSR address this burden by providing a tool that researchers can use to calculate HEI-2010 in their own populations.

Table 3.1a. Method to calculate HEI 2010 in NDSR

HEI-2010 component	NDSR File	Units		Conversion	Requirements	Differences with NDSR method
		NDSR	HEI			
Total Fruit	File 09	Servings	Cup eq.	1 serving = 0.5 cup eq		None
Whole Fruit	File 09	Servings	Cup eq.	1 serving = 0.5 cup eq		None
Total Vegetables	File 09	Servings	Cup eq.	1 serving = 0.5 cup eq		None
Greens and beans	File 09	Servings	Cup eq.	1 serving = 0.5 cup eq	Only legumes counted as vegetables	None
Whole grains	File 09	Servings	Cup eq.	1 serving = 1 oz eq	All of whole grains and ½ of some whole grains components	NDSR additionally includes grains from baby foods[1] NDSR does not include whole grain component of some whole grains
Dairy	File 01	Servings	Cup eq.	1 cup equivalent = 1 cup milk yogurt , 1.5 natural cheese, 2 oz processed cheese, 2 cups cottage cheese, 0.5 cup evaporated milk	Conversion done in Empty calories program	Different approach, no difference in values calculated

Table 3.1b. Method to calculate HEI 2010 in NDSR

HEI-2010 component	NDSR File	Units		Conversion	Requirements	Differences with NDSR method
		NDSR	HEI			
Total Protein foods	File 09	Servings	Oz eq.	1 serving = 1 cup eq	Including protein legumes	Baby foods are excluded, plant proteins are counted using bean and green macro
Seafood and Plant protein	File 09	Servings	Oz eq.	1 serving = 1 cup eq	Including protein legumes	None
Fatty Acids	File 04	Grams	Grams		PUFA+MUFA/SFA	None
Refined Grains	File 09	Servings	Oz eq.	1 serving = 1 oz eq		NDSR counts all of the some whole grains towards refined grains
Sodium	File 04	Grams	Grams	N/A		None
Empty Calories	File 01, File 04	kcal	kcal		Empty calories program	Different approach[2]

[1]Because HEI-2010 was designed for children who are fully weaned, baby foods were excluded from intake calculations in this study

[2]Versions of NDSR starting with 2014 include a variable for solid fats. Older versions require a calculation with assumptions based on the composition of food. NDSR does not provide guidelines for this method. Our assumptions are described in the methods section.

Table 3.2. Demographic characteristics of the NHANES 2007-2010 and My Parenting SOS (2009-2011) sample

	Child (2-5y)		Adult (19y and older)	
	NHANES N= 1679	SOS N=282	NHANES N=2,846	SOS N=282
Gender				
Female	780 (47%)	147 (52%)	2846(100%)	240 (93%)
Male	899 (53%)	134 (48%)	n/a	19 (7%)
Age	3.4±0.04	3.5±0.8	43.2±0.03	34.8±6.3
Race				
Black	328 (14%)	112 (40%)	656 (16%)	112 (39.7%)
White	596 (55%)	126 (45%)	1071 (63%)	126 (44.7%)
Other	755 (32%)	44 (15%)	1119 (21%)	44 (15.6%)
BMI Percentile/BMI	57.8±1.2	59.1±28.5	32.5±0.2	30.2±7.2
Household Income				
Lower income	978 (48%)[1]	100 (35%)[2]	1478 (44%)	100 (35%)
Higher income	584 (52%)	182 (65%)	1129 (56%)	182 (65%)
Parental Education				
High School grad or Some college	NA	66 (23%)	2344 (77%)	66 (23%)
College grad or advanced degree	NA	216 (77%)	500 (23%)	216 (77%)

[1]NHANES lower income is <$45,000/year and higher income is >$45,000/year
[2]SOS lower income is <$50,000/year and higher income is >$50,000/year

Table 3.3. Mean HEI score by component part for preschool aged children (2-5y) for either the full day or for at home time (prior to 9am and after 5pm inclusive) in NHANES 2007-2010

	NHANES 2007-2010				SOS	
	Full Day (n=1679)		At Home Time (n= 1679)		At Home Time (n=287)	
Component (max score)	Mean	95%CI	Mean	95%CI	Mean	95% CI
Total Fruit (5)	**3.6**	**3.5, 3.7**	**3.0**	**2.8, 3.1**	3.8	3.6, 4.0*
Whole Fruit (5)	**3.1**	**2.9, 3.3**	**2.2**	**2.0, 2.4**	3.4	3.1, 3.6*
Total Vegetables (5)	2.1	2.0, 2.2	2.0	1.9, 2.1	2.1	2.0, 2.3
Greens and Beans (5)	0.9	0.7, 1.0	0.8	0.6, 0.9	1.3	1.1, 1.5*
Whole Grain (10)	2.5	2.3, 2.7	2.7	2.4, 2.9	5.0	4.6, 5.4*
Dairy (10)	8.2	7.9, 8.4	7.9	7.7, 8.1	8.2	7.9, 8.5
Total Protein (5)	3.4	3.3, 3.5	3.1	3.0, 3.3	3.5	3.3, 3.7
Seafood Plant Proteins (5)	**3.7**	**3.6, 3.8**	**4.3**	**4.2, 4.4**	1.7	1.4, 1.9
Fatty Acids (10)	3.2	2.9, 3.5	3.0	2.7, 3.3	3.4	3.0, 3.8
Refined Grains (10)	5.2	4.9, 5.5	5.4	5.1, 5.7	4.5	4.1, 4.9*
Sodium (10)	5.8	5.5, 6.0	5.8	5.6, 6.0	6.0	5.6, 6.4
Empty Calories (20)	12.7	12.3, 13.0	12.5	12.2, 12.9	15.2	14.6, 15.8*
Total Score (100)	54.2	53.1, 55.3	52.7	51.8, 53.7	58.0	56.6, 59.4

Table 3.4. Mean HEI score by component part for adult women participating in My Parenting SOS 2009-2011 and those participating in NHANES 2007-2010

	NHANES 2007-2010		SOS	
Component (max score)	Mean	95% CI	Mean	95% CI
Total Fruit (5)	2.2	2.1, 2.3	2.5	2.2, 2.7
Whole Fruit (5)	2.2	2.0, 2.3	2.7	2.5, 2.9
Total Vegetables (5)	3.1	3.0, 3.2	3.5	3.4, 3.7
Greens and Beans (5)	1.5	1.3, 1.6	2.5	2.2, 2.7
Whole Grain (10)	2.4	2.2, 2.6	5.3	4.9, 5.7
Dairy (10)	5.4	5.2, 5.6	4.3	4.0, 4.6
Total Protein (5)	4.1	4.1, 4.2	4.5	4.4, 4.6
Seafood Plant Proteins (5)	2.2	2.0, 2.3	2.6	2.3, 2.8
Fatty Acids (10)	4.9	4.7, 5.1	4.4	4.0, 4.7
Sodium (10)	4.3	4.1, 4.6	4.2	3.8, 4.6
Refined Grains (10)	5.0	4.8, 5.2	4.0	3.6, 4.3
Empty Calories (20)	11.8	11.3, 12.2	18.2	17.7, 18.7
Total Score (100)	49.0	47.8, 50.3	58.6	57.2, 59.9

Chapter 4. THE HEALTHY EATING INDEX-2010 DOES NOT FULLY CAPTURE COMPLIANCE WITH THE 2010 DIETARY GUIDELINES FOR AMERICANS IN CHILDREN

A. Abstract

Background:

Healthy Eating Index-2010 (HEI-2010) is a widely used tool for capturing dietary patterns, however, there is little work on the validity of this method in children.

Objective:

Determine if the HEI-2010 is a valid tool for assessing adherence to 2010 Dietary Guidelines for Americans in children (2-17y).

Methods:

A cross-sectional, nationally representative sample of 5,592 American children aged 2-17y (1679 preschoolers 2-5y; 2194 school-aged 6-11y and 1719 adolescents 12-17y) from NHANES 2007-2010 was used to examine the utility of the HEI-2010 for compliance with the Dietary Guidelines. Using one 24-hour recall, population survey weighted means were calculated for HEI-2010 scores, Dietary Guidelines, and nutrient intakes.

Results:

Children with high HEI scores were more likely to meet the USDA nutrient recommendations compared to children with lower HEI scores (mean micronutrient adequacy ratio 82.4±1.9 vs. 60.8±1.6). Children with HEI scores <=25 over-consumed calories by 17% compared to 2% of children with HEI scores >75. HEI

scores differed by age group, with preschool aged children receiving the highest total score compared to adolescents who received the lowest scores (54.2±0.6 vs. 48.2±0.4). School-aged children with the maximum possible HEI-2010 score for dairy were approximately one serving below the Dietary Guideline for dairy, resulting in a lower percentage of children meeting the recommendations for calcium (-21%), vitamin D (-3%) and vitamin A (-11%), compared to children who met the dairy Dietary Guideline. No significant differences in HEI scores were observed among children by BMI category; however, children who were overweight did have a significantly lower mean micronutrient adequacy ratio for multiple micronutrients compared to normal weight children (67.2±1.3 vs. 71.8±0.7).

Conclusion:

The HEI-2010 score does not detect differences observed for dairy, whole grains and empty calories that are observed with direct measurement of the Dietary Guidelines for preschool (2-5y) and school aged (6-11y) children.

B. INTRODUCTION

Improving the diet quality of children is a priority of policy makers and researchers. Several goals of Healthy People 2020[128],a policy initiative for Americans, address diet quality and aim to increase intake of fruit, vegetables and whole grains and decrease intake of solid fats, added sugars and sodium as measured by Healthy Eating Index 2010. The Healthy Eating Index 2010 (HEI-2010) is a score to assess compliance with the 2010 Dietary Guidelines for Americans[37]. It was intended for use in both children and adults, as well as in environmental applications, such as assessment of the health of the national food supply.

The Dietary Guidelines are based on the Recommended Dietary Allowance (RDA) and Adequate Intakes (AI) levels for nutrients that are customized to the age and gender of the individual[68]. Daily and weekly recommendations for food groups and dietary components, such as dairy, and protein, were determined by the Dietary Guideline for energy intake. It is difficult to evaluate intake adequacy based on the Dietary Guidelines alone because there are recommendations for 17 individual components, with no summary score.

The HEI-2010 simplifies the analysis of Dietary Guidelines by providing general cut points for a smaller, representative set of food components and an overall score. The HEI was created in 1995[28], and was updated to improve performance and to reflect changing Dietary Guidelines in 2005[36] and in 2010[37]. The current version is intended for use in American populations over the age of 2 who are not consuming breast milk or infant formula.

The HEI-2010 score is the sum of 12 component food categories and has a maximum score of 100. The score is standardized per 1000 kcal consumed to limit correlation with energy intake. Americans often do not meet all of the Dietary Guidelines and strict application of fully meeting a guideline in order to obtain all the points assigned to a relevant component in the HEI could result in having very few individuals placed in the highest category of the score for that component. Therefore, HEI cut points were set to give maximum points for a component food category if an individual meets or is close to meeting the guideline for that category [42]. Accordingly, the cut point used to assign the maximum possible points to a component food group score was based on the lowest (i.e., easiest to meet) recommended intake for foods and nutrients within the 1,200-2,400 calorie patterns [37].

In cases where the recommendation limits a food or nutrient, such as sodium, the maximum score is achieved by eating less than the maximum intake limit. Points are subtracted if the individual exceeds the recommended limit. The only published validation study of HEI-2010 found the tool to be a valid and reliable measure of 2010 Dietary Guidelines for the overall population and for food environments[42]. The validity of the HEI as an assessment of compliance to the Dietary Guidelines in children has not been evaluated.

This study aims to determine if the HEI-2010 identifies children aged 2-17 who meet the Dietary Guidelines. We will examine the nutrient intake profiles of children by HEI-2010 total score, and compare the micro- and macro-nutrient intakes of children who meet the Dietary Guidelines to those who received the maximum HEI-2010 score by separate components. Finally, we examine the utility of these methods for identifying food group and nutrient deficiencies in children of different age and weight status categories.

C. METHODS

Subjects

Data from children 2-17 years of age who participated in the National Health and Nutrition Examination Survey (NHANES) 2007-2010 were used for this study (n=6,392). Children were excluded from the analysis if they consumed breast milk (n=5) or infant formula (n=8) because the USDA does not provide Dietary Guidelines for these children. We excluded children if their dietary recall status was “not reliable or did not meet the minimum criteria", or was "not done" (n=346)[120, 121]. Children who were on a special diet for weight or other health reasons (n= 441) were also excluded. The final analytic sample included 5,592 total children of whom 1,679 were 2-5 years of age, 2,194 were 6-11 years of age and 1,719 were 12-17 years of age (unweighted Ns).

1. *Demographic and Anthropometric measurements*

Height and weight were measured and questionnaires were administered using standardized procedures by trained research staff in mobile examination centers[123]. Height was measured without shoes to the nearest 0.1 centimeter using a stadiometer with fixed vertical backboard and adjustable head piece, and weight was measured to the nearest 0.1 kilogram without shoes and in an examination gown. BMI percentile was calculated using the CDC growth curve macro[124].

2. *Diet Measurement*

Diet was assessed using 24-hour recalls as part of the dietary component of NHANES. As a sensitivity analysis we additionally calculated intake and HEI scores using the 2nd day dietary recall available in NHANES. For children under 6 years of age, caregivers reported the child's dietary intake. Children 6-11 years of age completed the interview with the assistance of an adult familiar with their diet, and children over 12 years old completed the dietary interview without caregiver assistance[72, 121].

Dietary guidelines pattern servings and HEI scores

The Dietary Guidelines provided energy intake recommendations for children based on gender, age and activity level. For this analysis, moderate activity levels were used for all children to determine the appropriate USDA daily caloric guideline. This cut point was chosen because it provided a calorie value in the middle of the range for children at each year of age and over 70% of children in NHANES reported moderate activity[130].

Intakes of each food component were calculated using NHANES 2007-2008[131] and 2009-2010[131] dietary recall data, and their corresponding Food Patterns Equivalents Database (FPED) for 2007-2008 and 2009-2010[121]. The method used by FPED to calculate intake amount has been described in detail elsewhere[132]. Briefly, intake amounts were calculated based on reported intake of whole foods and the component parts of mixed dishes. If a participant did not meet their protein requirement from meat sources, a situation that arises frequently with vegetarians, beans and legumes were counted first towards the protein requirement. Once that requirement was met, any additional intake was counted as vegetable servings. HEI scores were calculated from cup or ounce equivalents using the National Cancer Institute SAS macro[122]. In order to compare the cut points used by Dietary Guidelines and HEI-2010, we matched selected Dietary Guidelines food categories to the HEI-2010 components[37].

Nutrient Intake

We selected nutrients that are important for growth and development in children to compare the Dietary Guidelines and HEI-2010. Because children of different developmental stages have different nutrient recommendations, we used the nutrient adequacy ratio (NAR) to assess if children were meeting the recommended intake of energy and each nutrient according to the Dietary Guideline. NAR was calculated as the ratio of intake for a given nutrient divided by the recommended intake for that nutrient. We calculated NAR values for the micronutrients calcium, fiber, iron, magnesium, vitamin A, vitamin C, vitamin D, and for macronutrients. The mean adequacy ratio (MAR) was calculated as the mean of all the micronutrient NAR values (maximum value per NAR is capped at 100%) to provide a summary score of overall micronutrient intake.

Because of day-to-day variability in intakes, children may not meet their full RDA for nutrients each day, but may on average consume adequate amounts of the nutrient. The HEI was designed to capture 85% of the recommendations for nutrients[28]. Therefore, in addition to calculating the number of children who met the full recommendation, we calculated the survey weighted percentage of children who met at least 85% of their RDA for nutrients if they had received the maximum HEI score or met the Dietary Guidelines for that food component.

3. *Analysis*

Mean HEI-2010 component and total scores were calculated for children by age category: preschool (2-5y), school aged (6-11y), and adolescent (12-17y) (PROC SURVEYMEANS). We identified any differences between intake amount recommended by the age and gender specific Dietary Guidelines patterns and the amount needed for a maximum HEI-2010 component by subtracting the amounts required by each method. We calculated mean intake levels for micro- and macronutrients by HEI score (0-25, 26-50, 51-75, 76-100) (PROC SURVEY MEANS). We compared the survey weighted percent of children who met RDA values for each of micro- and macro nutrients among children who met the Dietary Guidelines and those who scored the maximum on the HEI-2010 for a given food group. We stratified by age category (preschool, school aged, and adolescent) for each of these analyses (PROC SURVEYFREQ). All analyses were conducted in SAS (SAS/STAT®9.3, SAS Institute Cary, North Carolina, USA).

D. RESULTS

1. *Overall and component HEI-2010 scores*

Table 1 presents the survey weighted mean HEI-2010 total and 12 component scores for children 2-17 years of age. The overall mean HEI-2010 score was 48.2±0.4 (mean±SE). Preschool children had the highest overall score while adolescents had the lowest overall score. The dairy and protein groups had the highest component score, standardized by the maximum points available by category, with scores ranging from 6.4±0.1 for adolescents to 8.2±0.1 for preschool aged children out of a possible score of 10 for dairy and a mean score of 3.6 out of 5 for protein. With a mean score of 0.8±0.0 out of 5 possible points, greens and beans had the lowest mean score among children.

We conducted a sensitivity analysis that used 2 days of dietary recalls to calculate the HEI-2010 scores (n=2347). All components and total HEI-2010 scores varied by less than 1 point compared to HEI-2010 scores calculated with 1 day of dietary recall, e.g., the total HEI score for all children was 48.2±0.4 for 1 day compared to 48.0±0.5 for 2 day recalls. The one exception was for seafood and plant proteins which tended to be 1.5 points lower when calculated with the 2 days of recall (1.8±0.1) compared to the 1 day of recall (3.3±0.0). These results were consistent across all age groups.

2. *HEI scores vs. nutrient intake adequacy overall and in vulnerable groups*

The population mean nutrient intake by HEI-2010 scores are presented in **Table 2.** Children who had a HEI-2010 total score between 0-50 consumed 250 kilocalories more than children who received higher HEI scores. Overeating, as indicated by an energy intake NAR above 100, was associated with lower HEI scores. Children who had an HEI score ≤25 had an energy intake NAR of 117.8±3.2 while children with an HEI score ≥76 or higher had a NAR of 102.1±4.7. Children with low HEI scores had higher reported intakes of carbohydrates, fat, protein, and iron. The NAR for micronutrients generally increased with higher HEI scores, but this was not observed for iron. Overall, the MAR for micronutrients increased as HEI scores increased, with the highest observed MAR values being 82.4±1.9 for children receiving an HEI score greater than 75.

Supplementary Table 2 shows that HEI-2010 scores are less sensitive at distinguishing between children who are normal, overweight or obese in NHANES compare to the Dietary Guidelines. Although we observed a trend for lower HEI scores among children who were overweight or obese compared to normal weight children, there were no significant differences among these groups. A sensitivity analysis that used HEI scores from both dietary recall days available in NHANES showed similar results. In contrast, children who were normal weight had a significantly higher MAR values of 71.8 (95% CI 70.3, 73.3) compared to overweight (67.2 (64.5, 69.9)) and obese children (68.0 (95%CI 66.2, 69.8)).

3. *HEI scores vs. USDA recommended food and nutrient intakes*

There were differences between the amount of intake required to receive the HEI-2010 maximum score and the USDA guidelines for children in different age and gender groups for fruit, whole fruit, greens and beans, and seafood and plant proteins and the servings recommended by the Dietary Guidelines **(Figure 1 and supplementary table 1)**. The dairy and protein components showed the largest difference between the amounts required for HEI and the Dietary Guidelines. The HEI cut point for dairy (1.3 cups per 1000 kcals) is 35% lower than the USDA recommended 2 cups of dairy for the 1000 kcal pattern that applies to 2y old children. Children 6-8 years old who can receive the maximum HEI score while failing to meet their dairy requirement by nearly 1 serving. This relationship changes direction for 16 and 17 year old boys must over-consume dairy by a mean of 0.64 servings in order to receive the maximum HEI score for this component.

Similarly, the number of empty calories allowed with the HEI-2010 component was 53-183 calories higher than the Dietary Guidelines. That is because the HEI scores are based on a constant percentage of empty calories (<20% of energy) while the USDA recommendation ranges from 8-19% of energy based on the number of calories remaining after all the other recommendations are met.

The number of children who met the minimum RDA for nutrients did not differ significantly between HEI-2010 and the Dietary Guidelines for greens and beans, seafood and plant proteins, total fruit, total protein, vegetables, whole fruit. (Data not shown) For the dairy, whole grains, sodium and empty calories components there were differences between how well the two diet measurements predicted adequacy of key nutrient intakes. The comparison for dairy is shown in Figure 2 and supplementary Figure 1 (other components not shown). A lower percentage of children met the RDA for calcium (70% vs. 91%), vitamin D (5% vs. 8%), and vitamin A (88% vs. 96%) when they received the maximum HEI score compared to children who met the Dietary Recommendations (supplementary Figure 1). Differences were attenuated but remained when we examined the proportion of children who consumed at least 85% of their RDA (Figure 2).

Therefore, the utility of the HEI-2010 for measuring the Dietary Guidelines varied by age. Preschool and school aged children had the greatest differences between HEI and the Dietary Guidelines. By adolescence both the HEI component score and the Dietary Guidelines preformed in a similar manner. For the dairy component, 17% more preschool children, and 21% more school-aged children met their calcium requirement with the USDA cut point compared to the maximum HEI component score. In contrast, there was only a 3% difference between scores for adolescents. Overall, the HEI and RDA were most similar for adolescent children, and most disparate for preschool and school aged children (**Figure 2**).

E. DISCUSSION

The HEI-2010 was designed to measure compliance with the Dietary Guidelines, and we found that for most dietary components the HEI-2010 did adequately reflect the guidelines for children 2-17 years of age. However, the HEI-2010 scores for the dairy, empty calories, and whole grains categories did not reflect compliance with the Dietary Guidelines for preschool and school aged children. In addition, children in different BMI categories showed substantial differences in nutrient intake adequacy that were not captured by the HEI. These findings indicate that an alternate tool or index such as age-specific versions may be necessary to fully capture Dietary Guideline compliance in children.

HEI-2010 has been used to evaluate the quality of food environments and to assess government food assistance programs[28, 37, 42, 133]. The design factors that help make HEI-2010 a useful tool across a wide range of settings precludes it from being tailored to the nutrient needs of individual subpopulations, such as children. For example, the calorie patterns used for the HEI-2010 creation (1200-2400kcal) are outside the range recommended for preschool and adolescent children[134]. Many preschool aged children have an energy intake recommendation of 1000kcal per day, while adolescent boys have a recommended intake of 2800kcal-3200kcal depending on their age and activity level. As a result, HEI-2010 scores do not reflect the dietary recommendations for these different age groups (**Figure 1 and Supplementary table 1**).

At the time of writing, the only study assessing the construct validity and reliability of HEI-2010 was conducted by Guenther et al.[42]. They found that HEI-2010 produced score variation between individuals, a finding that we also observed in our sample for most dietary components (**Table 1**). Vegetables and dark greens were one exception to this finding due to extremely low overall intake, with scores often less than 1 out of 5 possible points. Additionally, the average dairy component score in our sample was high, with a mean score of 7.1±0.1 out of a maximum of 10 points. Children who received the maximum score for this component had a wide range of intakes from 1 cup equivalent below the Dietary Guideline to an intake that exceed the Dietary Guideline.

Many nutrients are directly correlated with energy intake, such that an individual who consumes more calories consumes more of that nutrient as well[68]. HEI-2010 adjusted for density to account for this factor. Guenther et al.[42] found HEI-2010 to be independent of energy intake with the strongest observed correlations with energy and component scores being for the empty calories and total fruit. In our sample, children with higher HEI scores were less likely to overeat compared to children with lower HEI scores. Thus, the HEI-2010 preformed as expected in children for this construct.

The study by Guenther et al.[42] also found distinct patterns in HEI-2010 scores among groups of adults with known differences in dietary intake. Similarly, we hypothesized that children who were overweight or obese would have lower scores than children in the normal weight category. We found that although HEI tended to be lower in overweight and obese children compared to normal weight children the differences were not significant. This result is similar to our study of 324 preschool aged children, in which we found that obese children (62.9, 95%CI 58.0, 67.8) had higher HEI scores for home meals than normal weight children (57.7, 95%CI 56.0, 59.4) (Roberts 2014 to be submitted). By contrast, we were able to detect nutrient differences by weight status in these children, with children who were normal weight having a higher MAR than overweight or obese children. Thus, there were nutrient differences observed among children that were not detected by HEI-2010 and an alternate score may be required.

Although many alternate dietary indices have been developed, none measure compliance with the current Dietary Guidelines. A review by Marshall et al.[30] identified 80 diet quality indexes that have been used in children. 13 were designed for use in US children[21, 28, 31-41] and of these, seven were based on outdated guidelines or have been revised[28, 32-36, 40], one was designed for adults[21], one was designed for infants[31], and two were designed to reflect the Mediterranean diet pattern[38, 39]. Only the HEI-2010 was intended to measure compliance with 2010 Dietary Guidelines. However, alternate tools are available to measure compliance with the 2005 Dietary Guidelines, such as the Youth Healthy Eating Index[35] and the Revised Child-Diet Quality Index (RC-DQI)[33]. The Youth Healthy Eating Index was created for children 9-14 years of age with the aim of being more easily calculated and communicated to target populations. It additionally included health related behaviors such as multivitamin supplement use and use of margarine or butter[35]. The RC-DQI also measured the 2005 Dietary Guidelines and health related behaviors.

Currently, there are no comparisons of HEI-2010 to a child specific dietary score; however, a recent study compared HEI-2005 to RC-DQI in American children, both of which measure a version of the Dietary Guidelines for 2005. This study found that the RC-DQI provided a more normal distribution of scores while the HEI-2005 had a bimodal distribution with children either receiving 0 points or 5 points for the components included in the study thus limiting the precision[43]. Our study indicated that this issue may remain in the HEI-2010, particularly for the dairy and the vegetable categories as the majority of scores tended to be clustered high or low respectively. More research is needed to determine the impact of this effect on the utility of HEI-2010 and to determine if a child-specific dietary score that assesses the 2010 Dietary Guidelines needs to be created.

1. *Implications for diet quality research*

The HEI-2010 can be used for comparisons across studies and groups of individuals using only diet data and is suitable for many research applications requiring a simple score that summarizes compliance to Dietary Guidelines. Although there are advantages of having a general score that can be used in both children and adults, HEI has important limitations that must be considered in order to determine if it is appropriate for a specific research application. Our study found that 30% of school aged and 20% preschool aged children who received the maximum HEI score for dairy did not meet the calcium RDA compared with 7% of school aged and 3% and preschool aged children met the USDA recommendation. Additionally, HEI-2010 did not differentiate between children of different weight status despite detectable disparities in nutrient adequacy ratios. This finding is of particular concern for interventions involved in obesity prevention and treatment for children. Researchers may prefer to use the Dietary Guidelines directly; however, this method does not provide a concise summary score. An age-specific HEI-2010 that uses cut points such that the maximum score is achieved only when children meet the 2010 Dietary Guidelines would improve utility of HEI among children while still providing the advantages of a summary score.

2. *Limitations*

The diet data used in the survey is from only one dietary recall. For population level means this is adequate[135] but one recall does not assess usual intake as some foods are consumed episodically. Previous studies have found that there are 5 episodically consumed components of the HEI-2010: total fruit, whole fruit, greens and beans, whole grains, and seafood and plant proteins[42]. Additionally, certain micronutrients require multiple dietary recalls or an additional Food Frequency Questionnaire in order to assess usual intake[7, 136]. Both the HEI-2010 in comparison to Dietary Guidelines should be affected in a similar way by this bias. We completed a sensitivity analysis using two day 24 hour recalls and observed no differences by BMI category for either method of calculating HEI, however, we were able to detect differences by weight status for nutrients with the MAR method.

We followed the analysis guidelines for dietary data provided by NHANES[120, 121], but we considered using the NCI multivariate method[129] to estimate HEI scores based on estimated usual intake, as used by Guenther et al.[42]. However, we decided not to use the NCI approach because we believe the method of estimating usual episodic food consumption in children has inappropriate assumptions. The NCI method assumes that the majority of people consume all the food components at some point in time, an assumption that is likely not true of children[137, 138]. In fact, documentation for the method states that it does not allow for “the possibility that some people never, ever consume an episodically consumed dietary component”[129]. The authors also indicated that the current iteration of the NCI multivariate method is “a first step, and not a last step” and that “it would be extremely interesting to make the model more general [to groups such as non-consumers].” We decided the NCI multivariate method was not suited to the objectives of the current study[129, 139-143] and look forward to the development of alternative methods.

3. *Conclusion*

It is imperative that we have accurate tools to monitor policy and intervention outcomes and the HEI-2010 has made a strong contribution toward that goal. Nevertheless, the limitations described in this study highlight areas in which improvements would be useful. For young children, additional work will be needed to create and test indices that more accurately reflect compliance with all components of the 2010 Dietary Guidelines for Americans.

Table 4.1. Mean energy intake and Healthy Eating Index 2010 scores for American children

Component (maximum score)	Preschool[1] (n=1679)	School aged[2] (n=2194)	Adolescent[3] (n=1719)	Total (n=5592)
Total Energy in kcal	1533±18	1899±17	2121±34	1887±17
HEI-2010				
Total Fruit (5)	3.6±0.1	2.7±0.1	1.9±0.1	2.6±0.1
Whole Fruit (5)	3.1±0.1	2.5±0.1	1.8±0.1	2.4±0.1
Total Vegetables (5)	2.1±0.0	2.0±0.1	2.3±0.1	2.1±0 .0
Greens and Beans (5)	0.9±0.1	0.7±0.1	0.9±0.1	0.8±0 .0
Whole Grain (10)	2.5±0.1	2.0±0.1	1.8±0.1	2.1±0.1
Dairy (10)	8.2±0.1	7.1±0.1	6.4±0.1	7.1±0.1
Total Protein (5)	3.4±0.1	3.6±0.0	3.7±0.1	3.6±0.0
Seafood and Plant Proteins (5)	3.7±0.0	3.2±0.0	3.0±0.1	3.3±0.0
Fatty Acids (10)	3.2±0.1	3.9±0.1	4.0±0.1	3.8±0.1
Refined Grains (10)	5.2±0.1	4.0±0.1	4.0±0.1	4.3±0. 1
Sodium (10)	5.8±0.1	5.2±0.1	4.6±0.1	5.1±0.1
Empty Calories (20)	12.7±0.2	10.7±0.2	10.3±0.2	11. 1±0.1
Total Score (100)	54.2±0.6	47.5±0.4	44.6±0.5	48.2±0.4

1Children 2-5 years of age, **2** Children 6-11 years of age, **3** Children 12-17 years of age

Table 4.2. Mean micro- and macronutrient intake by quartile of HEI-2010 scores for children 2-17 years old.

	HEI Score Range			
	0-25 (n=154) Mean±SE	26-50 (n=3064) Mean±SE	51-75 (n= 2290) Mean±SE	76-100 (n=84) Mean±SE
Micronutrients				
Calcium (mg)	905.3±56.1	1032.7±17.1	1018.5±19.6	1008.7±43.1
Calcium NAR%*	67.5±3.4	72.6±0.7	78.7±0.7	86.2±2.6
Fiber (g)	10.7±0.3	12.0±0.2	14.7±0.3	17.3±1.5
Fiber NAR%	46.0±1.9	52.1±0.7	67.7±0.8	79.9±3.3
Iron (mg)	15.2±0.8	13.8±0.2	13.2±0.2	12.5±0.9
Iron NAR%	93.8±1.1	89.8±0.4	90.1±0.5	86.0±3.5
Magnesium (mg)	206.2±13.9	217.6±2.8	242.1±3.9	260.1±13.7
Magnesium NAR%	75.3±3.2	79.7±0.6	90.9±0.5	95.3±2.2
Vitamin A (mcg RAE)	437.0±23.8	580.4±11.9	622.1±19.5	628.2±47.2
Vitamin A NAR%	62.4±2.7	74.5±0.6	82.7±0.8	90.0±3.0
Vitamin C (mg)	59.6±11.3	64.6±2.2	103.6±3.3	97.4±11.0
Vitamin C NAR%	59.2±4.6	70.2±1.1	90.1±0.8	94.6±2.6
Vitamin D (mcg)	3.2±0.3	5.4±0.1	6.3±0.1	6.8±0.6
Vitamin D NAR%	21.6±2.2	34.7±0.6	40.4±0.9	44.8±3.7
MAR**	60.8±1.6	67.7±0.4	77.2±0.5	82.4±1.9
Macronutrients				
Carbohydrate (g)	298.9±9.8	267.1±2.9	236.3±3.2	207.4±9.9
Carbohydrate NAR%	99.3±0.4	98.3±0.2	98.8±0.2	99.0±0.6
Fat (g)	91.4±4.5	75.7±1.0	59.6±1.1	46.0±3.2
Fat NAR%	99.2±0.4	98.5±0.2	96.5±0.4	91.0±2.6
Protein (g)	70.3±5.0	69.3±0.9	64.1±0.9	57.8±3.1
Protein NAR%	95.8±1.2	96.3±0.3	98.3±0.3	98.3±0.6
Total energy (kcal)	2284.6±88.7	2009.5±20.8	1711.5±22.6	1439.2±71.9
Total energy NAR%	117.8±3.2	109.8±1.1	106.7±1.1	102.1±4.7

*NAR is the ratio of the intake of a nutrient and the recommended nutrient intake.

** MAR is the mean of NARs (maximum 1) for calcium, fiber, iron, magnesium, vitamin A, vitamin C, vitamin D

Figure 4.1. Differences between servings required to receive a maximum HEI score compared to Dietary Guidelines for vegetables, protein and dairy in American children.

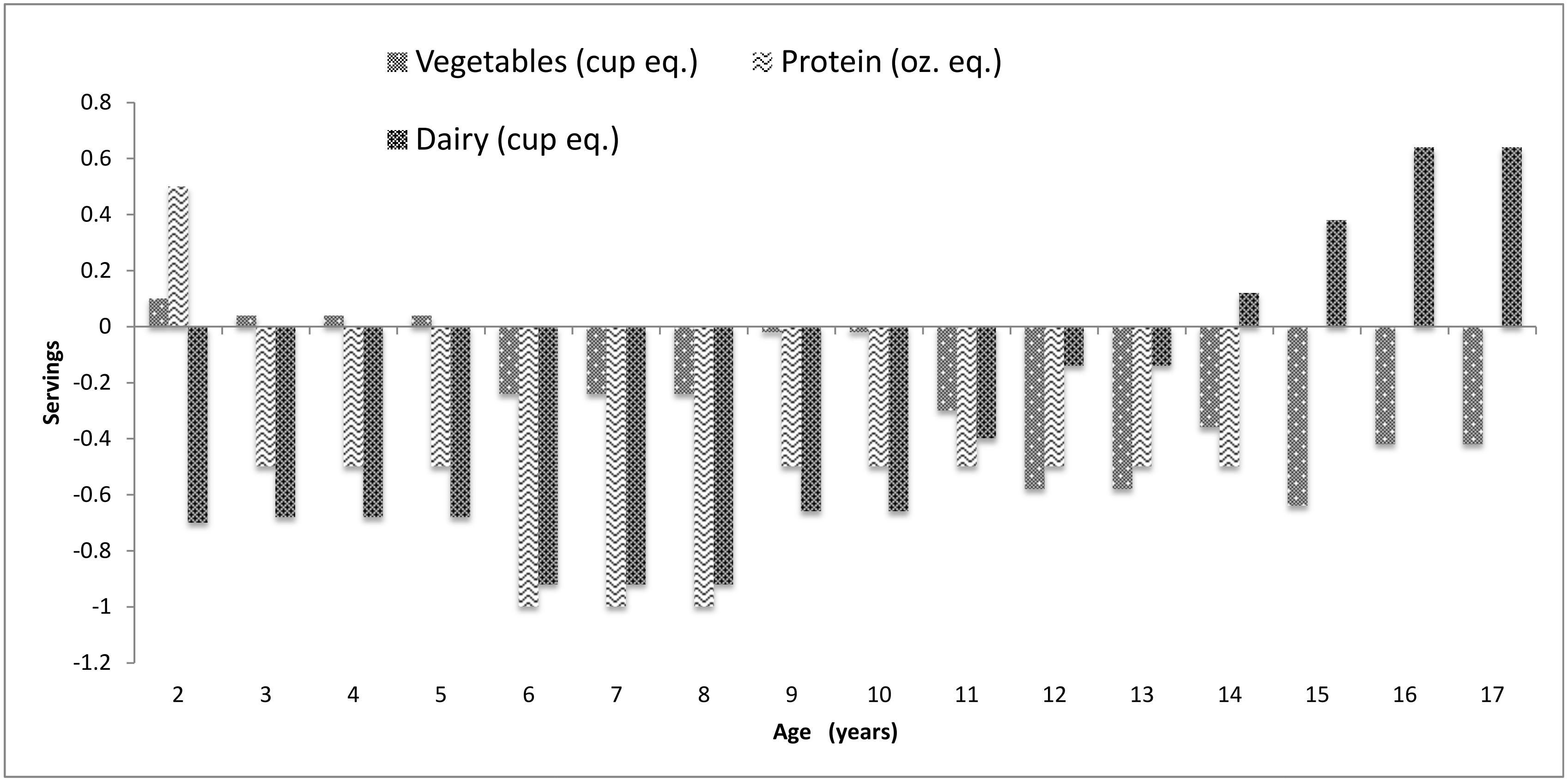
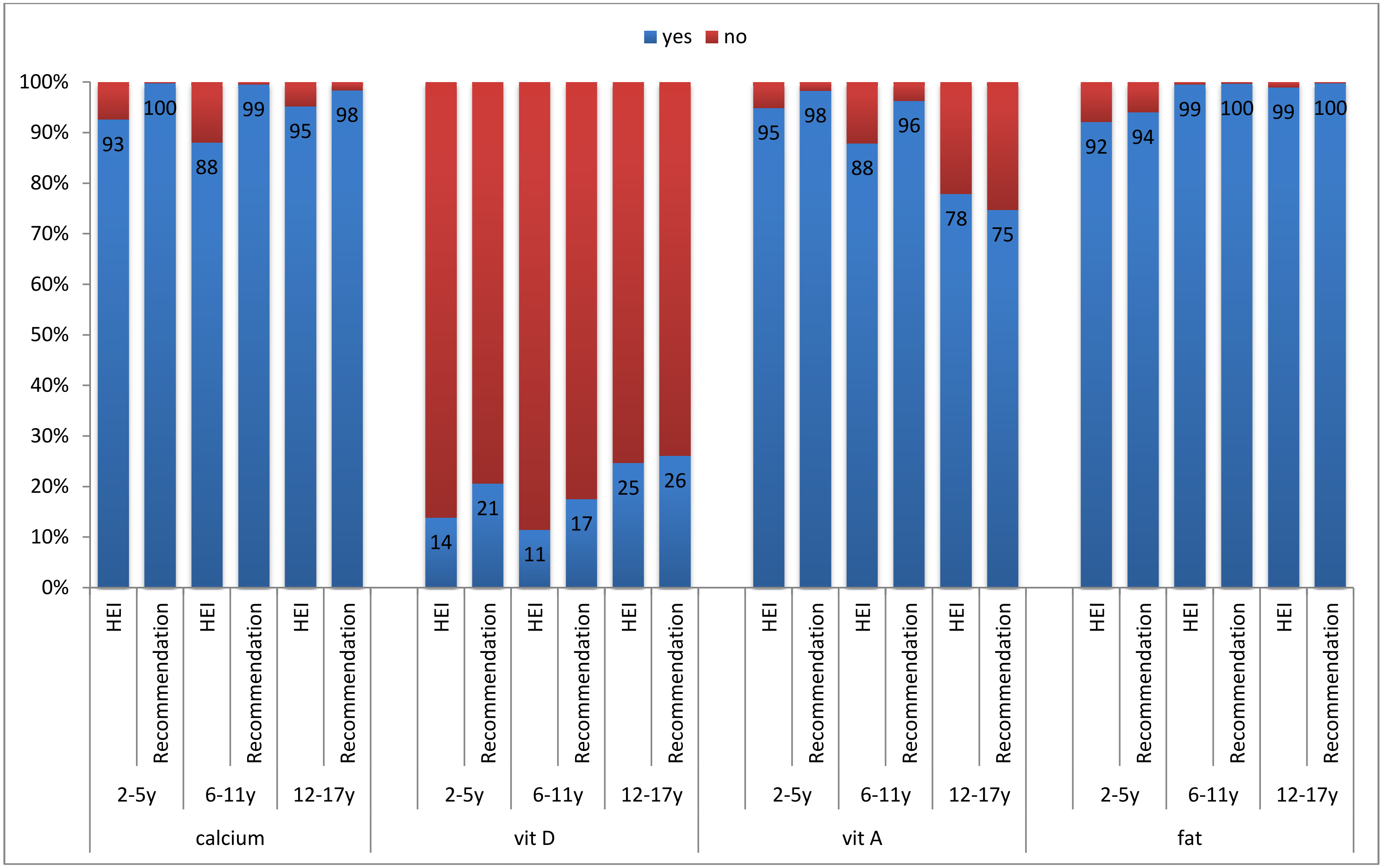


Figure 4.2. Percent of children who met at least 85% of the RDAs for selected nutrients who received the maximum HEI-2010 score for the dairy component compared to children who met the dairy Dietary Guidelines.



Note: the USDA recommendations are not intended to provide adequate vitamin D intake.

Table 4.3.1. Difference between the servings of major food categories required for a maximum HEI score compared to number of servings required to meet the USDA Recommendations (HEI - Recommendation) for boys ages 2-17 years.

Age	Fruit (cup eq.)	Whole Fruit (cup eq.)	Veggies (cup eq.)	Greens and beans (cup eq.)	Protein (oz. eq.)	Seafood and Plants (oz eq.)	Dairy (cup eq.)	Empty Calories (kCal)
				Boys				
2	-0.20	-0.10	0.10	0.06	**0.50**	0.23	**-0.70**	53
3	-0.38	-0.19	0.04	0.07	**-0.50**	-0.17	**-0.68**	145
4	-0.38	-0.19	0.04	0.07	**-0.50**	-0.17	**-0.68**	145
5	-0.38	-0.19	0.04	0.07	**-0.50**	-0.17	**-0.68**	145
6	-0.22	-0.11	-0.24	-0.04	**-1.00**	-0.43	**-0.92**	183
7	-0.22	-0.11	-0.24	-0.04	**-1.00**	-0.43	**-0.92**	183
8	-0.22	-0.11	-0.24	-0.04	**-1.00**	-0.43	**-0.92**	183
9	-0.06	-0.03	-0.02	-0.07	**-0.50**	-0.27	**-0.66**	181
10	-0.06	-0.03	-0.02	-0.07	**-0.50**	-0.27	**-0.66**	181
11	-0.40	-0.20	-0.30	-0.03	**-0.50**	-0.11	-0.40	122
12	-0.24	-0.12	**-0.58**	-0.13	**-0.50**	-0.10	-0.14	152
13	-0.24	-0.12	**-0.58**	-0.13	**-0.50**	-0.10	-0.14	152
14	-0.08	-0.04	-0.36	-0.09	**-0.50**	-0.22	0.12	126
15	0.08	0.04	**-0.64**	-0.19	0.00	-0.06	0.38	132
16	-0.26	-0.13	-0.42	-0.15	0.00	-0.05	**0.64**	137
17	-0.26	-0.13	-0.42	-0.15	0.00	-0.05	**0.64**	137

Table 4.3.2. Difference between the servings of major food categories required for a maximum HEI score compared to number of servings required to meet the USDA Recommendations (HEI - Recommendation) for girls ages 2-17 years.

Age	Fruit (cup eq.)	Whole Fruit (cup eq.)	Veggies (cup eq.)	Greens and beans (cup eq.)	Protein (oz. eq.)	Seafood and Plants (oz eq.)	Dairy (cup eq.)	Empty Calories (kCal)
				Girls				
2	-0.20	-0.10	0.10	0.06	**0.50**	0.23	**-0.70**	53
3	-0.04	-0.02	-0.18	0.03	0.00	-0.04	**-0.94**	107
4	-0.38	-0.19	0.04	0.07	**-0.50**	-0.17	**-0.68**	145
5	-0.38	-0.19	0.04	0.07	**-0.50**	-0.17	**-0.68**	145
6	-0.38	-0.19	0.04	0.07	**-0.50**	-0.17	**-0.68**	145
7	-0.22	-0.11	-0.24	-0.04	**-1.00**	-0.43	**-0.92**	183
8	-0.22	-0.11	-0.24	-0.04	**-1.00**	-0.43	**-0.92**	183
9	-0.22	-0.11	-0.24	-0.04	**-1.00**	-0.43	**-0.92**	183
10	-0.06	-0.03	-0.02	-0.07	**-0.50**	-0.27	**-0.66**	181
11	-0.06	-0.03	-0.02	-0.07	**-0.50**	-0.27	**-0.66**	181
12	-0.40	-0.20	-0.30	-0.03	**-0.50**	-0.11	-0.40	122
13	-0.40	-0.20	-0.30	-0.03	**-0.50**	-0.11	-0.40	122
14	-0.40	-0.20	-0.30	-0.03	**-0.50**	-0.11	-0.40	122
15	-0.40	-0.20	-0.30	-0.03	**-0.50**	-0.11	-0.40	122
16	-0.40	-0.20	-0.30	-0.03	**-0.50**	-0.11	-0.40	122
17	-0.40	-0.20	-0.30	-0.03	**-0.50**	-0.11	-0.40	122

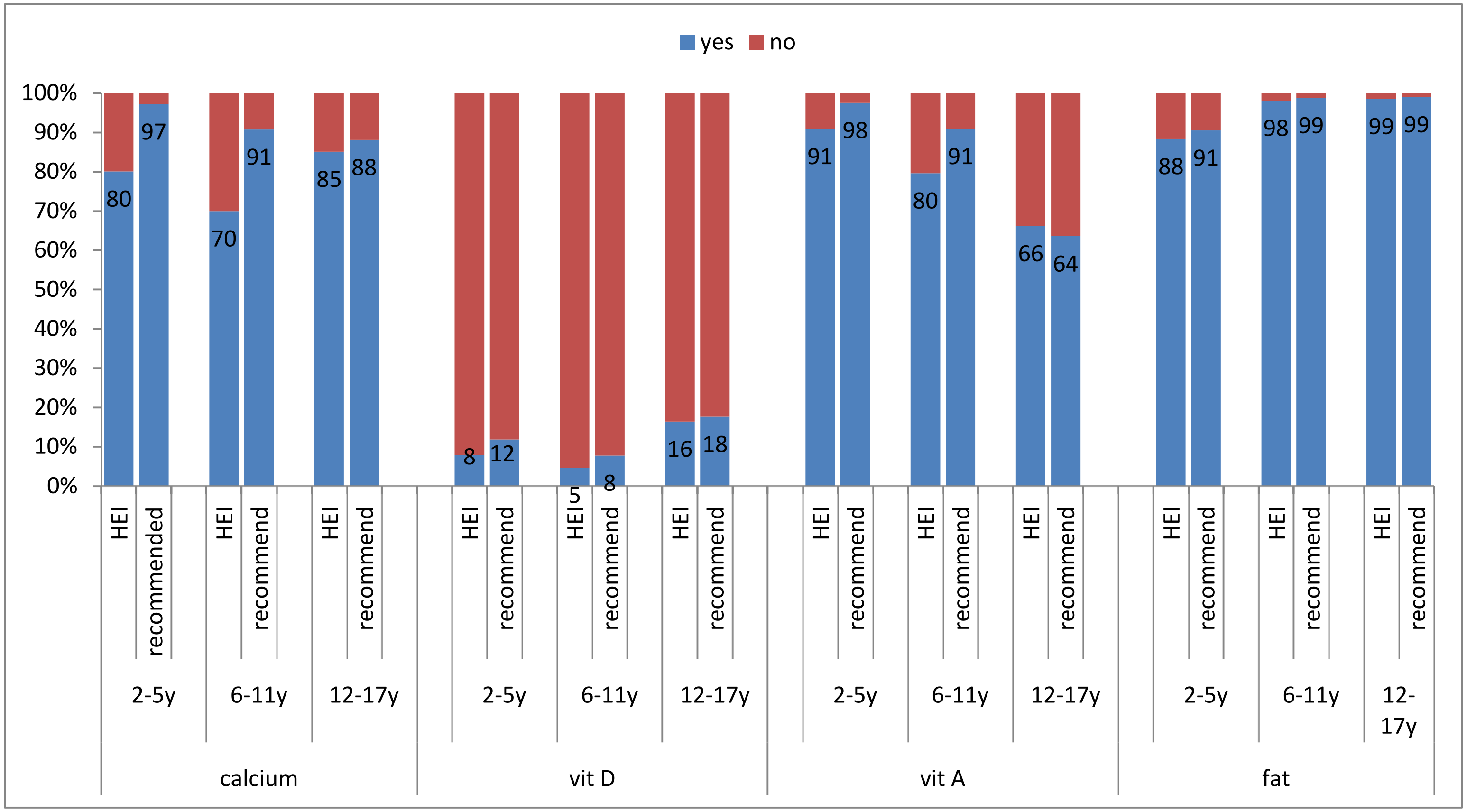
*Bolded values indicate a 0.5 a serving difference or greater. Where negative numbers indicate a the HEI maximum value is less than the USDA Recommended intake level.

Table 4.4. Survey weighted mean HEI scores for American children 2-17 years of age by weight status

	Weight Status[1] Mean (95% Confidence Interval)			
	Under weight 1 day recall n=174, 2 day recall n=68	**Normal weight** 1 day recall n=3587, 2 day recall n=1516	**Over weight** 1 day recall n=851, 2 day recall n=348	**Obese** 1 day recall n=973, 2 day recall n=415
HEI 2010 total score				
1 day recall	46.6 (43.7, 49.4)	47.5 (46.5, 48.5)	45.8 (44.6, 47.0)	46.1 (44.8, 47.4)
2 days of recalls	49.8 (46.0, 53.5)	48.6 (47.6, 49.7)	46.9 (44.5, 49.2)	46.1 (44.1, 48.2)
MAR[2]	70.6 (64.2, 76.9)	71.8 (70.3, 73.3)	67.2 (64.5, 69.9)	68.0 (66.2, 69.8)

1 Weight Status is based on CDC growth curves such that a BMI Percentile <5 is underweight, <85 is normal weight, <95 is overweight, and >95 is obese. 2 Mean Adequacy Ratio (MAR) for calcium, fiber, iron, magnesium, vitamin A, vitamin C, vitamin D. The MAR is calculated from the 1 day recall.

Figure 4.3. Percent of children who met RDAs for selected nutrients who received the maximum HEI-2010 score for the dairy component compared to children who met the dairy Dietary Guidelines.



Note: the USDA recommendations are not intended to provide adequate vitamin D intake.

Chapter 5. Home food availability associated with children and adolescents meeting dietary recommendations in NHANES 2007-2010.

A. Abstract

Background

Food from the home is the primary source of energy for American children. It is important to understand the factors that influence foods available in the home and how food availability affects child diet.

Objectives

Determine if having a food available in the home increases the likelihood that children and adolescents will meet the USDA recommended dietary intake for that food.

Design

A cross-sectional, nationally representative sample of 4,944 American children and adolescents aged 2-15y (NHANES 2007-2010) was used to examine the survey weighted associations.

Results

Parents report that having fruit (73.1±1.6%), dark greens(58.9±1.4%), low-fat milk (34.3±1.6), and sugar sweetened beverages(SSBs) (41.5±1.8%) always available in their homes. African American children were less likely to always have fruit (percent difference from reference)(-12%) and low-fat milk(-10%), and more likely to have dark greens (+10%) in their homes compared to white households.

Households with low food security were less likely to have fruit (-28%), dark greens (-10%), and low-fat milk (-26%) compared to other homes. Children who always vs. rarely, had a food in their homes were more likely to meet the dietary recommendation for that food: OR (95% CI); Fruit: 2.61(1.01, 6.75), Dark greens: 3.33(0.76, 14.40), and low-fat milk: 1.44(1.04, 2.00). Children who always, compared to rarely, had SSBs available were more likely to exceed the recommended empty calorie limit from SSBs calories alone: 1.92(1.34, 2.74). Compared to older children, the strongest associations were observed in 2-5y children.

Conclusion

The food available in the home differs by ethnicity and socio-economic factors. The food available in the home is associated with child diet and may be an important intervention area for improving the diet quality of children.

B. Introduction

The United States Department of Agriculture (USDA) provides Dietary Guideline for Americans for a healthy balanced diet. These guidelines give recommended minimum intakes for food groups and limits for excess empty calories from solid fats and added sugars (SoFAAS)[144]. Less than 30% of American children and adolescents meet these recommendations for most food groups and less than 1% meet their recommended intake of vegetables[145]. This is a concern because poor diet quality during youth adversely impacts growth and development and increases risk of obesity and obesity related diseases[146, 147]. Policymakers and researchers are working to improve the diets of American children and adolescents; however, more effective intervention strategies are needed that address this vulnerable age group.

Environmental factors are associated with dietary intake and are sometime modifiable, making them promising targets for intervention. The home food environment is one of the most promising environments because Americans eat 65-72% of their calories per day from food in the home[148]. Previous studies have found that the food available in the home is associated with dietary intake[50-53] and weight status[54, 55] of household members, and there is some evidence that improving the quality of foods in the home may improve the diet quality of children**.**

Much of the previous work on the food available in the home has been in relatively small, homogenous samples[52, 54, 79, 149-152] that limit the ability to compare across different demographic and economic characteristics. These studies indicate that household level factors such as the number of people living in the home, household food security and poverty level all may affect the type or amount of food available in the home. Individual factors, including the age and race of the child, may also affect the relationship between the food in the home and the diet quality of children[74, 153, 154]. The majority of studies examining the impact of home food availability on child diet have been on older school aged children and adolescents(8, 10, 12-16). Fewer studies have examined the impact of foods available in the home on the dietary intake of pre-school aged children[59, 84] and none, to our knowledge, have been able to compare the associations across age groups from preschool to adolescence. Compared to older adolescents, young children are more reliant on their caregivers for access to food[48]. Older children purchase and eat more food away from the home[155], leading to shifts in their overall dietary pattern[156]. Therefore, we would expect the influence of the food available in the home on diet to decline as children age.

This study examines the foods that are available in the homes of American children using NHANES, a large racially and economically diverse population that is representative of United States children and adolescents. We will determine if socioeconomic factors are related to which foods are in the home. We will also test if frequently having a food item available in the home is associated with children meeting their USDA recommended intake level for that food, and if that association differs for preschool, school aged and adolescent children.

C. Methods

1. *Subjects*

Children between 2-15 years of age who participated in the NHANES 2007-2010 were eligible for inclusion in this study (n=5,712). Children were excluded from this analysis if they were missing home food availability data (n=69), if their dietary recall status was “not reliable”, “did not meet the minimum criteria”, was not completed, or if they reported consuming breast milk (n=512). Children who were on a special diet for weight or other health reasons (n= 187) were also excluded. The final analytic sample included 4,944 total children comprised of 1,662 preschool children 2-5 years old, 2,177 school aged children from 6-11 years old and 1,105 adolescents from 12-15 years old (unweighted sample sizes). The age ranges were selected based on the data collection methods used for the dietary recall and Consumer Behavior Questionnaire.

2. *Home Availability*

For children under 16 years of age, one adult from each household responded to the Consumer Behavior Questionnaire in NHANES. This survey queries the availability of fruits, dark green vegetables, low-fat or fat-free milk, snack foods and SSBs in the home. Because there is no USDA recommendation for snack foods, this category of food was not included in this analysis. For each food item, respondents indicated if the food was available in their home “always”, “most of the time”, “sometimes, “rarely”, or “never”. For this analysis the “rarely” and “never” categories were combined due to small sample sizes. NHANES has provided specific definitions for the foods included as part of the food availability questions. Fresh, dried, canned, and frozen preparations of fruits and dark green vegetables are included. Dark green vegetables do not include iceberg, butterhead, Boston, or manoa lettuce. SSBs availability includes soft drinks, fruit-flavored drinks, and fruit punch, but not sports drinks, diet soft drinks or 100% fruit juice.

3. *Dietary Intake*

NHANES day 1 dietary recall data were used to calculate children’s intake of fruits, dark green vegetables, milk, and SSBs. Due to the lower response for the second day of recalls, it was not used. NHANES uses adult proxies to capture the dietary intake of children under 6 years old. For children 6-11 years old, the interviews were conducted with the child assisted by an adult familiar with the child’s diet. Children 12 years and older completed the dietary interview without the assistance of an adult.

We used standard definitions provided by the USDA for categorizing the servings of each food item. Fruit servings included fruit from all sources including fruit juices. Dark green vegetables included leafy greens such as spinach, kale, and collard greens, as well as broccoli. We also examined total vegetable servings, which included vegetables from all sources including starchy vegetables, such as French fried potatoes. We matched low-fat milk and milk in the home to the recommended dairy servings that included all milks, yogurts and cheeses. Each child's intake of these foods was calculated using the Food Patterns Equivalents Database for 2007-2008 and 2009-2010. Servings for each food were based on the reported intake of whole foods (e.g. apple) and the component parts of mixed dishes (e.g. dark greens in a pasta dish)[121]. Calories from SSBs were calculated using USDA category codes for soft drinks and fruit drinks. Using these codes 20 soft drinks and 58 fruit drinks (78 total beverages) were matched to the definition of SSBs in the Consumer Behavior Questionnaire. Total energy intake from any of these SSBs was calculated for each child. We classified children and adolescents as consumers of SSBs if they had any intake greater than 0 kCal.

USDA Food Patterns guidelines are available for children over 2 years of age who are not consuming breast milk. The recommended energy intake level in kCal for boys and girls at each year of age is based on their typical physical activity level (sedentary, moderate or vigorous)[157]. NHANES queries physical activity levels with a questionnaire that is completed by a proxy reporter (home caregiver and, if appropriate, child care provider) for children. Self- and proxy-reported physical activity data have been demonstrated to have low to moderate validity[130]. We assumed a moderate physical activity level for all children in this sample to determine their recommended energy intake levels.

Using the recommended energy intake, we determined the recommended servings (cup/equivalents) of fruits, dark green vegetables, vegetables, dairy and recommend limit (kCals) of SoFAAS for each child. Children were classified dichotomously as having met vs. not met their recommended dietary level if they ate at least the amount of each food, or consumed kCals below the SoFAAS limit, specified for their age and gender group for children with a moderate physical activity level. The recommendation for dark green vegetables is for a week long period. For this analysis we divided the recommended weekly amount by 7 days to determine the daily recommended level. The USDA determines the empty calories or SoFAAS limit based on the calories remaining after all the other recommendations have been met. SoFAAS limits range from 8 to 19% of total recommended calories. Calories from SSBs are included in this total. Thus any additional calories beyond the USDA recommended limit is classified as exceeding the SoFAAS limit.

4. *Covariates*

Demographic and socioeconomic factors that influence the foods available in the home were analyzed as potential covariates. The child's gender and age in years were collected at the NHANES screening interview. Race and ethnicity were categorized here as non-Hispanic white, African American or other[131].

Socio-economic variables used in this analysis were self-reported by questionnaire. The ratio of the family income to the poverty index (family income divided by the relevant poverty guideline) was based on the Department of Health and Human Services yearly poverty index that accounts for family size and state of residence. Household food security is based on responses to the 18-item US Food Security Survey Module that was scored to rank households as having “full”, “marginal”, “low”, or “very low” food security[158]. Households were considered to have received food aid if anyone in the home received Women, Infants and Children (WIC) program benefits or Supplemental Nutrition Assistance Program (SNAP) benefits during the previous 12 months.

Our analysis included other factors we have hypothesized to impact the food available in the home and were captured by self-reported questionnaires: 1) family size, 2) frequency of grocery shopping and 3) number of meals eaten together and cooked at home in a typical week. Family size was a count of individuals living in the household. Questionnaire respondents indicated the frequency of major food shopping trips as “More than once per week”, “once a week”, “once a month or less”, “rarely make any major shopping trips” or “rarely shop for food”. For this analysis, the last three categories were collapsed into one category “less than once a month” due to small sample sizes. Similarly, families who reported eating 8 or more meals together during a week were combined into one category.

5. *Statistical analysis*

Standard NHANES protocols and survey weighting were used[131]. All analyses were completed in SAS (SAS/STAT®9.3, SAS Institute Cary, North Carolina, USA).

Weighted percentages and standard errors of food available in homes were calculated using weighted frequencies (PROC SURVEYFREQ). Odds ratios were calculated using logistic regression models with survey weights (PROC SURVEYLOGISTIC) to estimate the odds of meeting the age and gender adjusted serving recommendation levels of a food when that food was reported as always available in home compared to rarely or never available in the home. This analysis was performed for fruits, vegetables, dark green vegetables, and milk. For SSBs the odds of consuming any of those beverages and the odds of exceeding the SoFAAS recommendation were calculated.

Regression models were used to examine associations between foods in the home and foods consumed. Covariates examine included gender, race, household food security, ratio of family income to poverty guidelines, household size, the number of family meals prepared at home and eaten together, and frequency of large food shopping trips. Gender, race, household food security, and household availability variables were analyzed as class variables and all others were analyzed as continuous variables.

Analysis was conducted in the overall population and stratified by age groups. The Consumer Behavior Questionnaire is self-reported for children 16 years and older; therefore, we restricted our analysis to 2-15 year old children who all had parent reported home food availability data.

D. Results

1. *Dietary Recommendations*

Fewer than 10% of children in all age groups met their total vegetable, or dark green vegetable recommendation (**Table S1**). The one exception was that 13% of preschool aged children met their total vegetable requirement, which includes starchy vegetables such as corn and peas. Only 6% of school aged children and adolescents met their recommendation for dark greens or vegetables. Adolescents ate the most total vegetables with a mean of 1.02 cup equivalents (0.92, 1.13), however, this amount was still below their recommended intake. Preschool children ate a little over a half of cup of all vegetables with a mean of 0.69 cup equivalents (0.65, 0.73). Dark greens had the lowest overall intake amounts, despite relatively high frequency of availability in some homes. The mean intake in the full population was 0.04 cup equivalents (0.03, 0.05) with all age groups having a mean intake of less than 0.06 cup equivalents (approximately one tablespoon).

2. *Availability of foods in the home*

The reported data from an adult in the household indicated that over 50% of households of children and adolescents had fruits (73.1±1.8%), and dark green vegetables (58.9±1.4%) available in the home at all times (Table 1). Only 1.54± 0.4% and 5.2±0.8% of households rarely or never had fruit or dark green vegetables available respectively. Low-fat milk was less commonly available with 34.4±1.7% of households reporting always having low-fat milk available and 58.4±1.6% of households reporting rarely or never having low-fat milk available. SSBs were the commonly available with approximately 56% of homes having them available always or most of the time (Table 2).

The availability of foods in the home varied widely among race/ethnic groups, and by socio-economic factors (Table 1-2). Dark green vegetables were more commonly available in the homes of African American children and adolescents, while fruit and low-fat milk were more commonly available in the homes of white youth. Over 70% of households of children and adolescents from African American or other racial groups rarely or never had low-fat or non-fat milk available. A lower percentage of households with marginal or low household food security always had fruits, dark greens or milk available compared to households with full food security. SSBs were commonly available in households from all the demographic and socio-economic groups in this study. The foods available in the home did not vary by child gender, child age, frequency of family meals, household size, and frequency of large grocery shopping trips.

3. *Food Availability and Recommended Intakes*

Children 2-15 years old categorized as always having a food item in the home were more likely to meet their recommendation for that food item compared to children categorized as rarely or never having the item available in their home (Figures 1 and 2). Overall, children and adolescents who always have fruit in their homes were 2.82 (1.05, 7.56) times as likely to meet their recommended intake of fruit compared to children who rarely or never had fruit in their home (unadjusted).

Similar, but not statistically significant results were observed for dark green vegetables (OR 4.107 (0.89, 18.97) (Supplemental Table 2)). Children who always had low-fat milk in the home were 1.56 (1.16, 2.09) times as likely to meet their dairy recommendation compared to children who rarely or never had low-fat milk in the home. Children who always had soft drinks or fruit flavored beverages in their homes were more likely to both be consumers of these beverages and to exceed their SoFAAS recommended calorie limit from the beverages alone (Figures 1 and 2, Supplemental table 3).

4. *Age differences in influence of home availability on intake*

Preschool aged children had a strong association between having fruit and SSB available in their home and meeting their dietary recommendations related to these foods. This association was strongest for fruits and preschool aged children were 6.88 (2.24, 21.18) times as likely to meet their recommendation for fruit when fruit was always in the home compared to rarely, or never in the home (unadjusted). This effect was attenuated in older children and was null for adolescents 0.63 (0.16, 2.56). Always having SSBs in the home was associated with preschool aged children being 3 times as likely to consume these beverages and to exceed their recommended SoFAAS limit from SSBs alone compared to children who rarely or never had these drinks in their homes (Table S2, Figure 2). Similar results were observed for exceeding the SoFAAS limit from all foods when SSBs were always in the home.

A stronger association was observed between low-fat milk availability and meeting the diary recommendation for this food among adolescents (OR 2.57 (1.19-

5.56)) compared to preschool (OR 1.37 (0.94-2.00)) and school aged (OR 1.43 (0.83- 2.45)) children. Only 11% of adolescents met their overall diary recommendation, compared to 25% of preschool aged children.

The impact of always having dark green vegetables available in the home on adequate intake of this food group was lowest for preschool aged children 4.1 (0.9, 19.0) (Supplemental table 1). Although the odds ratios for each group were large and were significant for school aged children and adolescents, the confidence intervals were extreme broad. This is likely due to the very low numbers of children who met their dark green vegetable recommendation.

E. Discussion

We found that having a food available in the home was associated with increased intake of that food, especially among young children. This finding is consistent with previous studies on home food availability that have found availability to be associated with intake[50-53]. Very few children meet their USDA recommended intake levels; however, when children had a food available in their homes they were far more likely to meet their recommend intake levels for that food. Always having SSBs in the home was associated with increased likelihood that children would consume those beverages and an increased likelihood that they would exceed their recommended intake of SoFAAS limit from all foods and from the SSBs alone.

95% children exceeded the SoFAAS recommendation from any dietary source. This finding is consistent with other studies that reported preschool aged children having a mean intake of 91 kcals from SSB, with 44% of the calories coming from fruit drinks and 27% coming from soda[159]. The low variability of SoFAAS intake in our population may have prevented us from observing a statistically significant association between food availability and intake. We found no significant associations between most examined items including snack foods, and the SoFAAS recommendation (data not shown). However, we found a strong association between exceeding the overall SoFAAS recommendation and always have SSB beverages at home for school aged children. Of children who exceeded their SoFAAS limit, those who did so with SSBs alone were 1.9 times as likely to always have those beverages in their home compared to rarely or never. The SoFAAS limit for preschool aged children is below 140 kCal[144]. SSBs were ubiquitous among American households, and were SSB the only category of foods that did not vary by race/ethnicity or poverty level.

Food security is known to be associated with the home food environment[64, 70, 83, 160, 161]. We found that as food security decreased the availability of healthy foods decreased significantly. Similarly, fruits and low-fat milk were less frequently available in households that received food assistance than in households that had not received food assistance in the last 12 months. This finding is consistent with Masters et al.[162] who examined differences by income and race/ethnicity in an older sample of NHANES 2007-2010 children (6-19y). That study found that children who were below 130% of the poverty income ratio compared to those above 350% were less likely to always have fruit (56.7± 2.0 vs. 75.4 ±2.4), dark greens (54.8 ± 1.7 vs. 60.1± 2.8), low-fat milk (15.1 ± 1.4 vs. 38.4 ± 2.1) and more likely to have SSBs (43.6±2.1 vs. 36.4±2.3)[162]. Food assistance aims to provide additional food for households with low food security. SSBs are currently included in SNAP benefits, policy changes aimed at reducing this benefit and increasing benefits for healthier items such as fruits, vegetables and milk, may help children from low-income households meet their dietary recommendations[163].

The food available in African American and other race/ethnic households differed from White households. Our findings are consistent with previous literature[153, 162]. Using an exhaustive home availability measurement, the report of Schefske et al. found both African American and Mexican American households had less calcium available in their homes compared to white households[153]. The availability of SSBs in the home did not vary significantly among race or ethnic groups in our population.

The types of foods that were available in the home were consistent across age groups for the four food categories we studied. Nonetheless, the strength of association between having fruits and SSBs available in the home and children meeting their dietary recommendations decreased as children aged. Few studies have examined the effect of foods available in the home on the diets of preschool aged children. A study by Bryant et al. found that young children ate 60.8g more fruit if they lived in a home in the highest tertile of availability compared to the lowest tertile of availability[79]. More work is needed to understand how the home food environment impacts child diet and the best ways to encourage the formation of life-long healthy habits.

As children age their diets evolve and foods available in the home are less likely to affect their diets. However, it is possible that exposure to healthy foods in the home at a young age may create healthier diet choices at older ages. Several studies have shown that young children develop dietary tastes and habits that persist into adulthood[3, 164]. The Avon Longitudinal Study of Parent and Children tracked 7,866 children over 7 years and found that children who were given fruits and vegetables at 6 months were more likely to eat fruits and vegetables at 7 years[113]. Another study of Finnish children (3-18y) repeated dietary recalls 21 years after baseline and found that dietary patterns tracked into adulthood. 41% of children in the highest quintile of the unhealthy pattern remained in the highest quintile of unhealthy intake 21 years later. Similarly, 38% of children remained in the same quintile for the healthy pattern[165]. This finding indicates that dietary patterns established as young children are critically important to long-term healthy habits. We found that for preschool aged children the foods available in the home had a strong association meeting their dietary recommendations. This is a promising area for intervention as increasing the availability of healthy foods, such as fruits, and limiting the availability unhealthy items, such as SSBs, in the homes of young could improve the long-term dietary quality of children.

1. *Limitations*

NHANES uses a brief parent reported food availability questionnaire. Repeated objectively collected, exhaustive household food inventories are the best available method for assessing the food available in the home, however, due to participant and researcher burden and increased expense they are not feasible in large studies such as NHANES. Most household availability checklists[95, 98] that have been in smaller samples are more extensive than the questions used in

NHANES, such as the 126-item checklist[94]. The NHANES questionnaire only captures 5 items limiting the ability to provide a full picture of the home food environment.

In this study child diet was measured with one dietary recall. One dietary recall does not adequately capture episodically consumed foods. This issue is of particular concern for dark green vegetables that have a weekly, instead of a daily, recommended intake level. Because of the large, representative sample available in NHANES the mean dietary estimates for the population remain valid; however, for episodic foods it is important to consider this limitation when interrupting the results. The differences we observed across age groups may be due in part to reporting differences; however, the proxy methods used by NHANES are the most appropriate measurements for children at each stage of a cognitive development[166].

2. *Conclusion*

The home is a critical and modifiable food environment that is associated with child diet. NHANES provided an opportunity to determine the association of foods in the home in a large racially and economically diverse population that is representative of American children from 2-15 years of age. In this study we found that children and adolescents of different races or ethnicities have different home availability pattern for fruits, dark green vegetables, and low-fat milk. Children who come from homes with low food security or have received food assistance reported having fruits, dark green vegetables, and low-fat milk in their homes less frequently that children with higher food security or who did not receive food assistance. Additionally, our study is the first to show the association of food in the home on children meeting their dietary recommendations varies by age in a nationally representative sample. These findings provide promising evidence that interventions targeted at improving the quality of food in the home may improve the dietary quality of children.

Table 5.1.a. Availability of fruits and dark green vegetables in the homes of American children and adolescents (2-15 years old) by demographic characteristics and socioeconomic status.

	N[1]	Availability of Fruits Weighted Percent ±Standard Error[2]				Availability of Dark Green Vegetables Weighted Percent ±Standard Error[2]			
		Always	Most of the time	Some of the time	Rarely or Never	Always	Most of the time	Some of the time	Rarely or Never
Full Sample	4944	73.1±1.6	18.3±1.1	7.1±0.7	1.5±0.4	58.9±1.4	22.5±1.2	13.4±1.2	5.2±0.8
Gender									
Male (ref[3])	2565	74.1±1.9	17.1±1.4	7.6±0.8	1.3±0.3	59.2±1.6	22.4±1.4	13.1±1.3	5.3±0.7
Female	2378	72.1±1.8	19.6±1.3	6.6±0.9	1.8±0.7	58.5±1.8	22.6±1.5	13.7±1.5	5.1±1.1
Race									
White (ref)	1645	76.1±2.7	17.2±1.7	5.7±1.0	1.0±0.7	57.8±1.8	23.1±1.9	13.3±2.0	5.8±1.2
Black	1088	**64.1±2.3**	21.9±1.8	10.9±1.6	3.1±0.9	**67.8±2.4**	22.5±2.1	8.3±1.3	1.4±0.7
Other	2210	71.3±2.5	18.8±1.9	8.1±1.2	1.8±0.5	56.6±2.3	21.4±1.6	16.1±1.3	5.9±1.0
Age									
Preschool (2-5y)(ref)	1661	75.9±2.3	16.3±1.9	6.4±0.8	1.4±0.4	60.7±2.5	21.9±1.8	12.3±1.1	5.1±0.7
School Aged (6-11y)	2176	73.0±2.0	18.8±1.2	6.6±1.0	1.5±0.7	60.0±1.8	21.2±1.5	13.9±1.8	4.9±0.8
Adolescent (12-15y)	1105	70.1±2.2	19.7±1.9	8.5±1.4	1.7±0.5	55.2±2.0	25.2±2.3	13.8±1.7	5.8±1.7
Food Assistance[4]									
Yes (ref)	1253	66.1±2.4	21.4±1.8	10.3±1.3	2.2±0.6	57.3±2.1	21.8±1.6	16.7±0.9	4.1±0.8
No	3603	**76.9±1.6**	16.3±1.2	**5.6±0.8**	1.3±0.4	59.6±1.6	22.9±1.6	11.9±1.7	5.6±1.0

Table 5.1.b. Availability of fruits and dark green vegetables in the homes of American children and adolescents (2-15 years old) by demographic characteristics and socioeconomic status.

	N[1]	Availability of Fruits Weighted Percent ±Standard Error[2]				Availability of Dark Green Vegetables Weighted Percent ±Standard Error[2]			
		Always	Most of the time	Some of the time	Rarely or Never	Always	Most of the time	Some of the time	Rarely or Never
Full (ref)	2930	79.2±1.7	15.7±1.2	4.1±0.8	1.0±0.4	**61.6±1.4**	22.4±1.6	11.2±1.7	4.7±1.1
Marginal	727	**67.1±2.5**	21.5±2.1	**10.2±1.8**	1.1±0.5	**53.6±4.0**	23.1±3.8	18.1±2.2	5.2±1.0
Low	874	**51.3±3.9**	**28.0±3.0**	**16.7±2.0**	4.1±1.4	**50.9±3.5**	23.9±2.8	16.7±2.4	8.5±2.2
Very Low	406	**57.2±5.0**	23.5±3.9	**16.3±3.1**	3.0±1.2	50.7±4.7	20.8±3.3	24.3±3.8	4.2±1.8

Estimates that are significantly different from reference category ($p<0.05$) are bolded.

[1] Unweighted sample size

[2] Survey weighted percent and standard error

[3]REF= reference category for statistical comparison

[4] Participated in the Women's Infants and Children's supplemental food program or the Supplemental Nutrition Assistance Program in the last year

[5] Household food security as measured by the 18-item US Food Security Survey Module

Table 5.2.a. Availability of Low-fat or Non-fat milk and soft drinks and fruit flavored beverages in the homes of American children and adolescents (2-15 years old) by demographic characteristics and socioeconomic status.

	N[1]	Availability of Low-Fat or Non-Fat Milk Weighted Percent ±Standard Error[2]				Availability of Soft Drinks Weighted Percent ±Standard Error[2]			
		Always	Most of the time	Some of the time	Rarely or Never	Always	Most of the time	Some of the time	Rarely or Never
Full Sample	4944	34.3±1.6	2.7±0.4	4.6±0.5	58.4±1.6	41.5±1.8	14.9±0.8	19.3±1.2	24.4±1.1
Gender									
Male (ref[3])	2565	34.1±1.9	2.8±0.7	4.3±0.6	58.8±1.9	41.5±2.1	14.4±1.0	19.6±1.3	24.5±1.4
Female	2378	34.6±2.0	2.5±0.4	4.9±0.7	58.0±2.2	41.4±2.2	15.4±1.0	19.0±1.5	24.2±1.4
Race									
White (ref)	1645	46.2±3.0	2.0±0.5	3.3±0.7	48.5±3.1	43.6±2.9	14.0±1.1	16.1±1.8	26.3±1.6
Black	1088	**13.1±1.9**	5.8±1.3	6.9±1.4	**74.2±2.4**	45.6±3.3	17.9±1.4	20.4±2.9	16.1±1.9
Other	2210	**20.3±1.3**	2.6±0.6	6.1±0.8	**71.1±1.6**	34.9±1.6	15.2±1.7	25.5±1.7	24.5±1.6
Age									
Preschool (2-5y)(ref)	1661	33.3±1.9	2.6±0.7	4.9±0.7	59.2±1.9	38.9±1.6	15.0±1.6	18.0±1.3	28.0±1.8
School Aged (6-11y)	2176	34.3±2.1	3.0±0.5	4.7±0.7	58.0±2.1	42.7±2.1	14.4±1.1	20.0±1.6	22.9±1.4
Adolescent (12-15y)	1105	35.5±2.5	2.3±0.5	4.0±0.7	58.1±2.5	42.3±2.6	15.5±1.6	19.5±2.4	22.7±1.5
Food Assistance[4]									
Yes (ref)	1253	18.5±1.9	3.4±0.8	4.9±0.8	73.2±1.8	42.9±2.2	17.9±1.6	19.9±1.4	19.3±1.6
No	3603	**41.6±2.0**	2.4±0.4	4.5±0.7	**51.4±2.1**	40.06±2.5	13.7±0.9	18.8±1.6	**26.8±1.6**

Table 5.2.b. Availability of Low-fat or Non-fat milk and soft drinks and fruit flavored beverages in the homes of American children and adolescents (2-15 years old) by demographic characteristics and socioeconomic status.

	N[1]	Availability of Low-Fat or Non-Fat Milk Weighted Percent ±Standard Error[2]	Availability of Soft Drinks Weighted Percent ±Standard Error[2]

		Always	Most of the time	Some of the time	Rarely or Never	Always	Most of the time	Some of the time	Rarely or Never
Food Security[5]									
Full (ref)	2930	42.2±2.2	2.4±0.4	4.3±0.6	51.0±2.2	42.0±2.3	14.0±0.8	18.5±1.4	25.6±1.4
Marginal	727	**16.7±2.3**	2.2±0.6	4.0±0.9	**77.1±2.4**	39.7±4.1	15.8±2.6	19.7±2.4	24.8±3.6
Low	874	**15.8±2.7**	4.2±1.1	5.1±1.0	**74.8±2.8**	41.6±3.0	16.3±2.2	22.5±2.8	19.6±2.4
Very Low	406	**13.3±3.6**	3.6±2.1	7.3±2.6	**75.8±4.8**	38.9±4.9	21.1±4.5	20.6±3.1	19.4±4.5

Estimates that are significantly different from reference category ($p<0.05$) are bolded.

[1] Unweighted sample size

[2] Survey weighted percent and standard error

[3] REF= reference category for statistical comparison

[4] Participated in the Women's Infants and Children's supplemental food program or the Food Stamp program in the last year

[5] Household food security as measured by the 18-item US Food Security Survey Module

Figure 5.1. Crude odds of meeting fruit, dairy, dark green vegetables or SoFAAS recommendation when fruit, dark green vegetables, low-fat or non- fat milk, or SSBs are always available in the home compared to never available in the home.

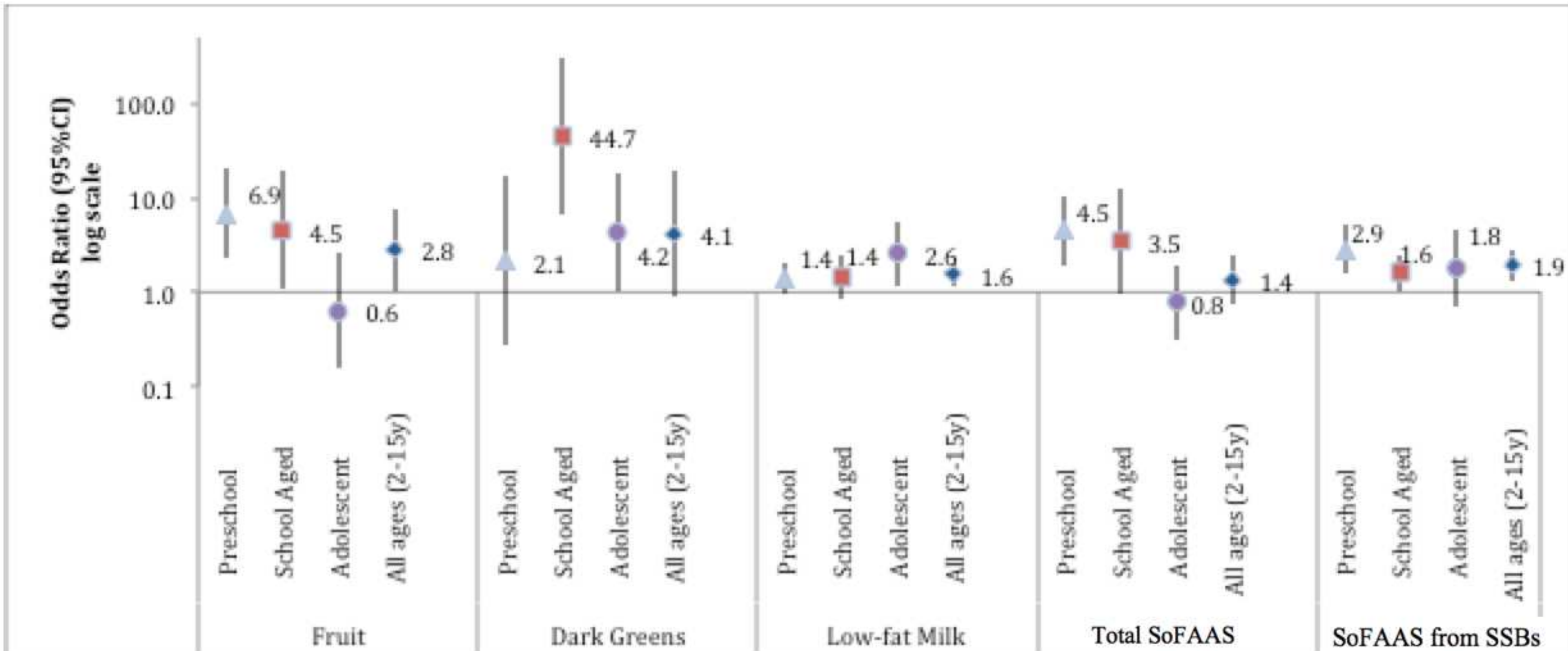
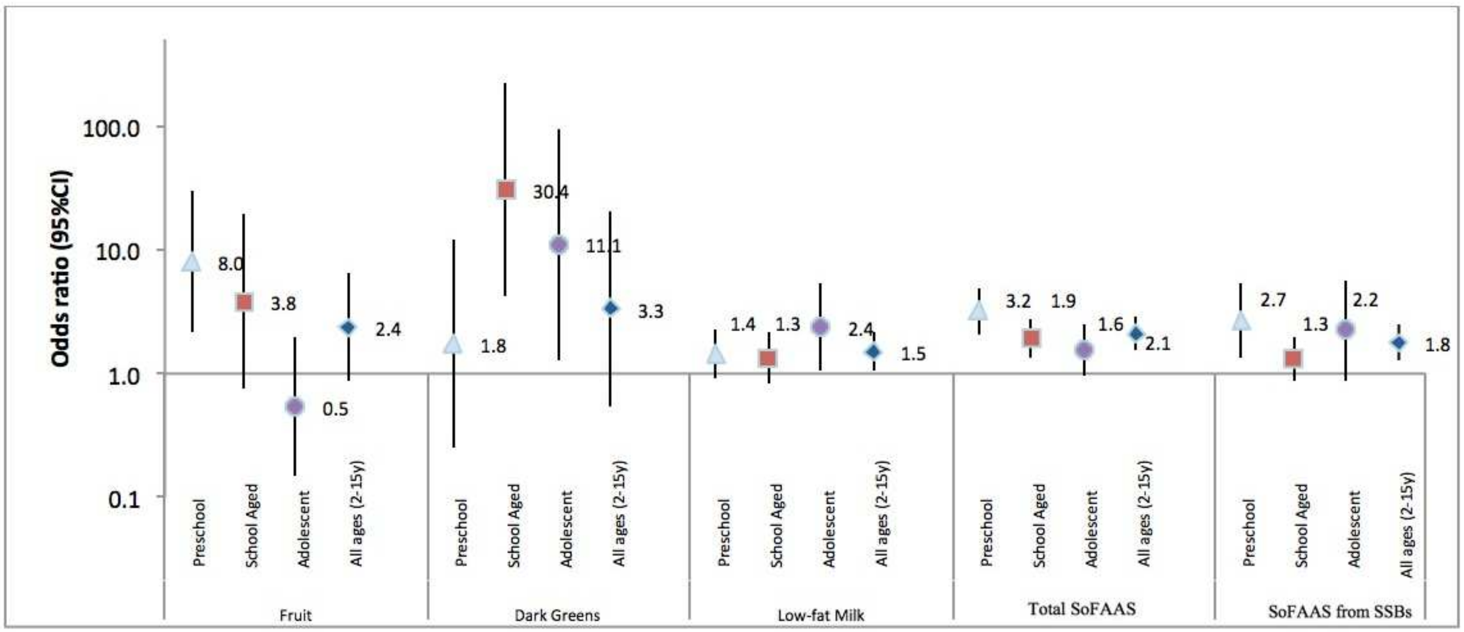


Figure 5.2. Fully adjusted1 odds of meeting fruit, dairy, dark green vegetables or SoFAAS recommendation when fruit, dark green vegetables, low-fat or non- fat milk, or SSBs are always available in the home compared to never available in the home.



Chapter 6. SYNTHESIS

A. Summary

This work focused on measuring the healthfulness of children's diets and the role of the home food environment. Our first aim was to extend the settings in which HEI-2010 scores can be applied by developing a method for calculating HEI-2010 scores using the NDSR database. Prior to the development of our method and the NCC method, it was prohibitively onerous to calculate HEI-2010 scores with the NDSR database. Our second aim was to determine if the HEI-2010 score was a valid measure of the Dietary Guidelines for Americans. After finding that the HEI-2010 did not fully capture the dietary guidelines of children under 12 years of age, we used a direct measure of the dietary guidelines to assess the association between having a food available in the home on children meeting the dietary recommendation for that food (Aim 3).

Aims one and two used the HEI-2010, a widely used tool that has been used measure policy incentives such as Healthy People 2020[128]. At the time of this work, only one validation study had been completed on the HEI-2010.[133] For our second aim, we assessed the utility of the HEI-2010 for children. We found that the HEI-2010 was an effective tool for assessing nutrient quality in the diets of older children (12-17 years). As HEI-2010 scores increased more children met the micronutrient requirements. Children with higher HEI scores were also less likely to over consume energy compared to children with lower HEI scores. However, the

HEI-2010 does have limitations when used in children. It does not adequately assess dairy intake in children, and thus children who receive a perfect HEI score for the dairy component may still be below their recommended intakes for calcium, vitamin D, and vitamin A. Because of these findings, we recommend that researchers modify the HEI-2010 for children under 12 years of age to use the age specific dietary guidelines (scaled 1000kcal) for setting the maximum HEI score cut points. Alternatively, researchers may prefer to use the age specific guidelines directly as we did in Aim 3.

Our third aim measured the association of reported home food availability and children meeting the Dietary Guidelines for Americans. Children consume nearly 70% of their calories each day from foods available in the home[5]. This makes the home one of the most important food environments for children. We found that the foods that are available in the home vary widely based on race and ethnic groups, and on socio-economic factors. We also found a strong association between children always having a food group in their home and meeting their recommendation for that food. Given the number of interventions that have tried and failed to improve childhood obesity in recent years, it is of critical importance that we identify interventions that may have a high impact for a relatively low cost. Improving the availability of healthy foods and reducing the availability of sugar-sweetened beverages is a promising target for improving the dietary patterns of children.

Exhaustive food inventories provide a complete and objective assessment of the environment reducing the biases that are inherent in checklist or questionnaire based methods. However, exhaustive methods are not typically feasible for large epidemiological studies; therefore, self-reported questionnaires and checklist are commonly used.

The assessment tool used in NHANES was an abbreviated questionnaire that captured 5 varieties of foods: fruit, dark green vegetables, low fat or non-fat milk, soft drinks and fruit flavored beverages and snack foods. This abbreviated home food availability questionnaire was not adequate to fully assess the foods that are available in the homes of American children. For example, dairy, regardless of fat content, availability is hypothesized to be important for children. However, some households may only consume high fat milk products and would have the same score as households with no dairy availability with the current NHANES questionnaire. Nevertheless, we did find that even with this abbreviated questionnaire the food environment was associated with children meeting the dietary guidelines. This finding indicates that the home food environment should be a key consideration in the efforts to improve child dietary patterns.

B. Advances in diet collection

High quality diet measurement tools are of critical importance to public health. Obesity, one of the most prevalent and far reaching diseases of our time, is largely impacted by dietary patterns. Without high quality diet measurement tools we cannot adequately assess and improve our food environments and diets. This finding is particularly important for children, who form dietary habits that continue through their adult lives.

However, diet measurement is biased and often full of error. Measurement error can be due to using tools that are inappropriate or inadequate to assess diet in a given population. Bias may also arise from making inappropriate analysis assumptions about the usual intake of an individual. Additionally, errors can result from using outdated databases for nutrient values.

The commonly used dietary tools, include food frequency questionnaires, 24 hour recalls, food diaries, direct observation, and technology based versions of these tools. Each of these tools is biased in its own way[6]. Tools such as direct observation and food dairies can cause the participant to alter their diet in response to having their diet monitored[136]. This bias prevents researchers from understanding the participants' usual intake in a meaningful way. Other tools that focus on intake that has happened in the past, are less susceptible to this bias, but are affected by the ability of the participant to accurately recall their intake. To assist in this process, researchers may use pictures or models to help participants jog their memories and to estimate portion sizes. Some researchers have used combination methods, such as diaries collected in an electronic format, such as smartphone or camera phone, in an attempt to improve these methods[6, 7]. Additionally, researchers will often use interview techniques to limit the effect of social desirability biases and other reporting errors. This increases the cost of diet collection, as it is requires highly trained staff to accurately collect this data. Despite all of these efforts, the biases are never completely eliminated. However, as long as the errors are not systematic these biases are not a concern in certain analyses.

Because children develop dietary preferences and weight trajectories that persist into adulthood[63], children are an extremely important group for dietary research. All of the issues that are present with diet data collection in adults are present in children with additional biases arising from limited cognitive ability to complete tasks, and biases related to proxy reporters. Many researchers are working to find ways to improve data collection in this group with tools that turn the recall into a game[12] or reward children for each meal or recall they complete. These motivational tools are necessary to keep children engaged in a tedious and sometimes long task of dietary recalls. Technology based methods may help improve engagement among children as well, improving the quality of the dietary data collected.

The shift towards technology based methods has already been observed. NCI recently released the ASA-24, an automated 24 hour recall that can be used in large epidemiological studies[9]. Tools such as EPIC-Soft have been used internationally[131]. Similar work has been done for children in interventions. Other groups have created animated versions of the recalls or frequency questionnaires in effort to improve participation among children[167-169]. As we develop these new methods it is imperative that we consider not only the scientific rigor of the data collection, but also the user experience. We will be able to collect more complete and higher quality data if we make the data collection process pleasant and, if possible, fun for participants. User experience designers and psychologists in the field of human and computer interaction have a wealth of knowledge on these topics and should be included in the design of future dietary tools.

In addition to new dietary collection methods, the nutrient databases and analytic methods for diet data collection need to be improved. Groups are working to use image processing to capture diets[170, 171]. Others are tackling the issues with databases and working to provide up to date nutrient information on consumer packaged goods[10]. NCI are working on analytic techniques to limit the biases that are inherent with the diet data, providing methods to estimate episodically consumed foods[129].

Database limitations are often an overlooked contributor to diet data collection measurement error. The foods available to consumers are numerous and quickly changing. Consumer packaged goods are particularly difficult to track as manufacturers may alter their formulations relatively frequently due to the cost of raw ingredients, consumer preferences and many other factors. Maintaining nutrient databases that accurately capture the nutritive value of foods is an extremely large and time consuming endeavor that cannot keep pace with the rapidly changing food marketplace. The USDA prioritizes certain food groups for each update of their databases, but some foods have not been updated in decades and do not reflect changes in formulations, husbandry, farming practices, etc. that can all lead to an altered nutrient profile. Efforts are being made to improve nutrient databases, but more awareness and resources are needed to improve our nutrient databases.

New analytic methods are also resulting in movement towards improving the quality of our dietary data. Groups such as NCI, have created methods to estimate usual dietary intake[129]. Although these methods address many of the key issues with diet data, they rely on assumptions that may not be appropriate for all populations and are computationally intensive. As the analytic methods improve for dietary data we will begin to see more wide spread use of the sophisticated statistically modeling and better estimations of usual dietary intake.

In order to create a gold standard dietary data collection method, researchers must address all of these issues from multiple fronts. We need better collection tools, dietary databases that are complete and up to date, and analytic methods that address the underlying biases that will remain in all tools. Innovation in this field will come from a coordinated, trans-disciplinary effort. Ideas such as open science, a movement to increase the spread of ideas and technology, will facilitate these efforts, but will require collaboration among industry and academic leaders.

New technologies and greater focus on the diet make this an exciting and important time in dietary research. We have the opportunity to improve research methodology to allow greater understanding of the impact of diet on important groups, such as children, and to identify intervention points where we can make the most impact on the obesity epidemic. However, we cannot make progress in this field if we do not address the underlying measurement errors that are currently inherent in diet data. We must find ways to improve the collection and analysis of this important component of human life so that we can make progress and impact public health in clinically meaningful ways.

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