USUAL DIETARY INTAKE OF CHILDREN AGES 2-5 YEARS IN A COMMUNITY AT HIGH RISK FOR OBESITY: COMPARISON TO AGE-MATCHED NHANES DATA, 2009-2012

by

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LIST OF ABBREVIATIONS

Abbreviation	Description
ASA24	Automated Self-administered 24-hour Recall
CDC	Centers for Disease Control and Prevention
DRI	Daily Recommended Intake
IOM	Institute of Medicine
ISUF	Iowa State University Foods
NCI	National Cancer Institute
NDSR	Nutrition Data System for Research 2013
NHANES	National Health and Nutrition Examination Survey
NRC	National Research Council
SE	Standard Error
UL	Tolerable Upper Limit
USDA	United States Department of Agriculture

I. LITERATURE REVIEW

Background

Rates of childhood obesity in the US are alarmingly high, and although the overall prevalence of obesity may be stabilizing, incidence of severe obesity among children continues to rise.[1,2] Among children 2-19 years, 32% are overweight, 17% are obese, and 8% are severely obese.[1] The national data do not reveal the true extent of the problem, as geographic disparities in childhood obesity rates exist across the US.[3] For example, in Texas, 36.6% of children are overweight or obese, but the prevalence of childhood obesity varies considerably within the state.[4,5] Specifically, in the capital city of Austin, adult and childhood obesity rates are among the lowest in the state. In contrast, in the city of San Marcos, only 30 miles south of Austin, children are at exceptional risk for overweight and obesity, as exhibited in FITNESSGRAM® data.[5,6] In fact, 52% of children in 3rd through 12th grade in San Marcos CISD were overweight or obese in 2013.

Childhood obesity has serious psychological and physiological ramifications. For example, obese children are more likely to suffer from depression, low self-esteem, attention deficit hyperactivity disorder, poor body image, bullying, social isolation, and discrimination.[7] Obese children are also more likely to develop asthma, poor dental health, and a myriad of metabolic diseases once considered conditions of middle age such as hypertension, fatty liver disease, type 2 diabetes, sleep apnea, and dyslipidemia.[8,9] Finally, overweight and obese children have a higher likelihood of becoming obese adults and experiencing premature mortality and physical morbidity.[10]

Developing Obesity Prevention Interventions

Causes of Obesity

Simplistically, obesity is sometimes viewed as an energy imbalance, which is in turn determined by both energy intake and energy expenditure.[11] This is an egregious generalization, however, as a multitude of other factors influence energy balance. Some factors, such as an individual's unique microbiome, genetic makeup, and hormonal milieu, play roles in energy balance that have yet to be fully characterized.[12–14] Currently, the best model for explaining how these factors collectively affect energy balance is the socio-ecological model of obesity from the Institute of Medicine (Figure 1).[15] The socio-ecological model illustrates how energy balance is influenced by (1) individual factors such as demographics, taste preferences, genetic makeup, gene-environment interactions, and psychosocial factors, (2) behavioral settings such as communities, school systems, worksites, child care facilities, and home environments, (3) large-scale sectors of influence such as the government, public health measures, health care systems, education, agriculture, media, and transportation systems, and (4) social norms and values. Consideration of the socio-ecological model provides a framework upon which interventions may be planned.

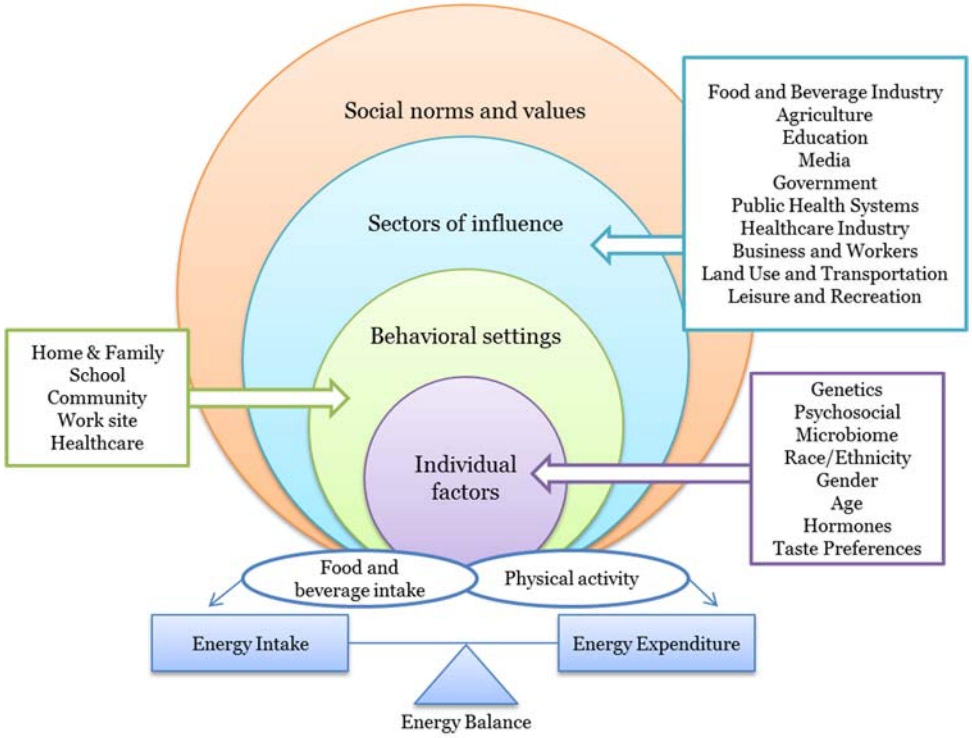

Figure 1. Socioecological Model of Obesity, Adapted from the Institutes of Medicine.[15]

While acknowledging that obesity is a complex, multifactorial issue, it remains true that a fundamental determinant of childhood obesity is excessive caloric intake.[16,17] Several dietary factors can contribute to excessive caloric intake. One of the most important factors is the consumption of energy-dense foods and beverages. Experimental evidence shows that consumption of energy-dense foods increases overall energy consumption in children and adults.[18] Further, research has demonstrated correlations between the increased consumption of energy-dense foods and beverages with the increased rates of childhood obesity over the past few decades.[17,19,20] Energy-dense foods commonly found in children's diets include cookies, candy, cold cereal, and sugar-sweetened beverages.[21] Because young children's nutrient needs are high relative to their energy requirements, there is little room in their diets for these low-nutrient, energy-dense foods.[22] Another dietary factor influencing excess caloric intake among children is insufficient consumption of fruits and vegetables. Fruits and vegetables are low in energy density, typically providing few calories while containing many important nutrients that are often lacking in young children's diets, such as potassium and dietary fiber.[23] Hence, displacing energy-dense foods with fruits and vegetables can support the maintenance of a healthy body weight.[24] The diets of children, in particular those of young children, are significantly influenced by their environments. For example, 61% of children under age 6 spend an average of 33 hours per week and consume up to two-thirds of their daily nutrition in childcare centers.[25,26] Many studies have reported unhealthful dietary practices in childcare centers, such as excessive reliance on refined, salty grain snacks and fruit juice.[27–29] However, in contrast, a study of Mexican-American children near the Texas-Mexico border showed that the food children received in childcare centers was more healthful than the food provided by their parents at home.[30] These discordant results suggest a need for further studies that compare the foods served in childcare centers with the foods provided to children at home. In summary, several common characteristics of the diets of US children, including a plethora of energy-dense foods and inadequate numbers of fruits and vegetables, appear to be important drivers of excessive caloric intake. Moreover, the diets of young children are heavily influenced by their environments, although the positively or negatively of that influence has yet to be fully characterized.

Obesity Interventions

Recently, it has become evident that interventions targeting young children before they enter kindergarten have the potential to have a profound effect, not only on childhood obesity rates, but also on the rates of obesity among adults. Overweight status in the years immediately preceding kindergarten is a major risk factor for becoming obese later in childhood and in adulthood. Children who are overweight when entering kindergarten have four times the risk of becoming obese by the age of 14.[31] Half of the incidence of childhood obesity in older children can be attributed to overweight status during preschool years; overweight preschoolers are five times more likely to become overweight or obese adults as compared to their normal-weight peers.[31,32] Furthermore, interventions with young children have the potential to shape food preferences that last into adulthood.[33,34] Research has shown that the number of different foods children like does not change significantly between the ages of 2-3 years to age 8, and that newly tasted foods are more likely to be accepted among children ages 2-3 years than among older children.[34] Consistently offering healthy foods such as fruits, vegetables, low-fat dairy products, and whole grains to young children can support the formation of healthy food preferences.[35,36] Unfortunately, the same holds true for foods associated with the development of obesity and chronic disease: exposing young children to sweets, salty snacks, and processed foods can increase a child's innate liking and consumption of these foods.[37] Finally, interventions targeting preschool children have potential for success because they are a relatively accessible population. Nearly three-quarters of children ages 3 to 6 years attend childcare, making them a captive audience for researchers and public health organizations.[38]

Assessing Usual Dietary Intake

To maximize potential for success, an obesity prevention intervention should be tailored to the specific needs of the targeted community. For this reason, interventions should begin with a needs assessment. An important component of a comprehensive needs assessment is the determination of usual dietary intake, which is the long-term average daily intake of a population.[39] To date, only two nationally representative studies have assessed the dietary intake of children 2-5 years: the National Health and Nutrition Examination Survey (NHANES) and the 2008 Nestlé Feeding Infants and Toddlers Study (FITS).[40,41] Data from these national studies reveal inadequate intake of fiber, potassium, and vitamin E among children 2-5 years.[23,42] Inadequate intake of calcium was found among children ages 4-5 years.[42] These national studies also revealed intakes of energy, saturated fat, sodium, synthetic folate, zinc, and preformed vitamin A at levels above recommended levels.[23,42]

While data from large-scale studies are useful from a national perspective, they cannot adequately inform researchers about regional dietary patterns. Just as obesity incidence varies considerably across the US, nutrient intake differs from region to region. For example, although data from national studies suggest that infants and toddlers consume adequate amounts of vitamin D, an assessment of usual intake among infants and toddlers enrolled in the Central Texas Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) revealed inadequate consumption of Vitamin D among children ages 4-24 months.[43] Inadequate intake of vitamin D, iron, and zinc have also been found in low-income populations in Atlanta, GA and Minneapolis, MN.[44–46] Furthermore, determination of usual intake among populations with high incidences of obesity has revealed that obesity can mask nutrient deficiencies and associated ramifications such as stunting, as seen in Hispanic children in the US.[47] In short, to fully understand and address the issue of childhood nutrition in a particular community, it is imperative to determine the usual intake of the specific population in question.

24-Hour Recalls

There are four primary instruments for collecting data on dietary intake: food frequency questionnaires, food records, diet histories, and 24-hour recalls (Table 1). However, the 24-hour recall is the most widely used tool in population studies that require quantitative analysis of food and nutrient intake over a long period of time.[48,49] Indeed, the 24-hour recall is the primary method for national nutrition monitoring and is used to set the national dietary reference intakes against which usual intake is compared.[48,49] Briefly, a 24-hour recall entails asking the participant to remember and report all foods and beverages consumed during the previous day. Recalls can be conducted in person or via telephone.[50,51] When collecting dietary data of young children, parents or other caregivers are used as proxies, as they are considered to be the best source of information of dietary intake for children younger than 8 years.[52,53] The interview is structured, with specific probes designed to help respondents remember all foods and beverages consumed during the previous day. The benefits and limitations of the 24-hour recall are described in Table 1. The primary advantages of the 24-hour recall is that participant burden is relatively low, participant literacy is not required, and due to the short recall period (24 hours), the participant is generally able to recall most of the dietary data required.[54]

Table 1. Strengths and limitations of tools used to assess usual dietary intake.[48,49,55]

Tool	Method	Usual use	Benefits	Limitations
Food Records	Subjects weigh, measure, or estimate, and record all foods consumed over a 3 to 7 day period of time	Studies or clinical settings that require estimates of the food and nutrient intake of individual respondents	Because parents or caregivers keep the records, they are relatively inexpensive to administer.	Sample bias based on the higher degree of literacy required as compared to other Respondents more likely to change their feeding / eating behavior Higher burden on respondent relative to other methods
Diet History	Questionnaires are used to collect descriptive detail and amount information about individual foods or food groups.	Individual counseling and epidemiology studies	Relatively easy and inexpensive. Can be collected in person, via telephone, or be self-administered on hard copy or on the Internet.	Precision is sacrificed to obtain data covering the longer time interval
Food Frequency Questionnaires	Questionnaires are used to collect data on specific food consumption for a specific period of time	Individual counseling and for epidemiology studies	Relatively inexpensive May reflect typical diet when weekly consumption is considered	Portion size is usually not captured which means no specific nutrient information or estimates of absolute intake can be determined Respondents often have difficulty accurately estimating the frequency of consumption or adding single foods together to respond to a question about a series of foods or food group
24-Hour Recall	Trained interviewers collect information on all food and beverages consumed during a defined 24-hour period, usually the previous day between the hours of midnight to midnight	Used in population studies requiring quantitative intake of foods and nutrients, national nutrition monitoring, and used to set dietary reference intakes.	Standardized methodology Automated software Relatively small participant burden Low systemic error relative to FFQ	Parents tend to over-report food intake of their children Labor intensive for researchers, who must receive training, interview respondents, and review and resolve issues that arise with coding the recalls. More difficult if obtaining intake from multiple respondents who may have cared for the child on a given day

Although the 24-hour recall is the gold standard for determining usual dietary intake, the collection and analysis is prone to measurement error, which can be both random (non-systemic) and biased (systemic).[56] Random error occurs because individuals tend to eat more on some days than on other days, resulting in 24-hour recalls reflecting intakes that are greater-than-usual or less-than-usual. Random error can also occur when standard nutrient values in nutrition databases are somewhat lower or higher than the actual amounts in the foods consumed.[57] Because some random errors positively affect the data while others negatively affect the data, they generally do not affect the mean of the sample (Figure 2). In contrast, bias, or systemic error, has potentially more serious effects because they do affect the mean of the sample. Specifically, in 24-hour recalls, there is a generalized bias towards under-reporting intake of some foods while over-reporting others.[54] This bias is not evenly distributed across the population. For example, individuals who are overweight tend to under-report to a greater degree than persons of normal weight, while individuals who are underweight tend to over-report intake.[58]

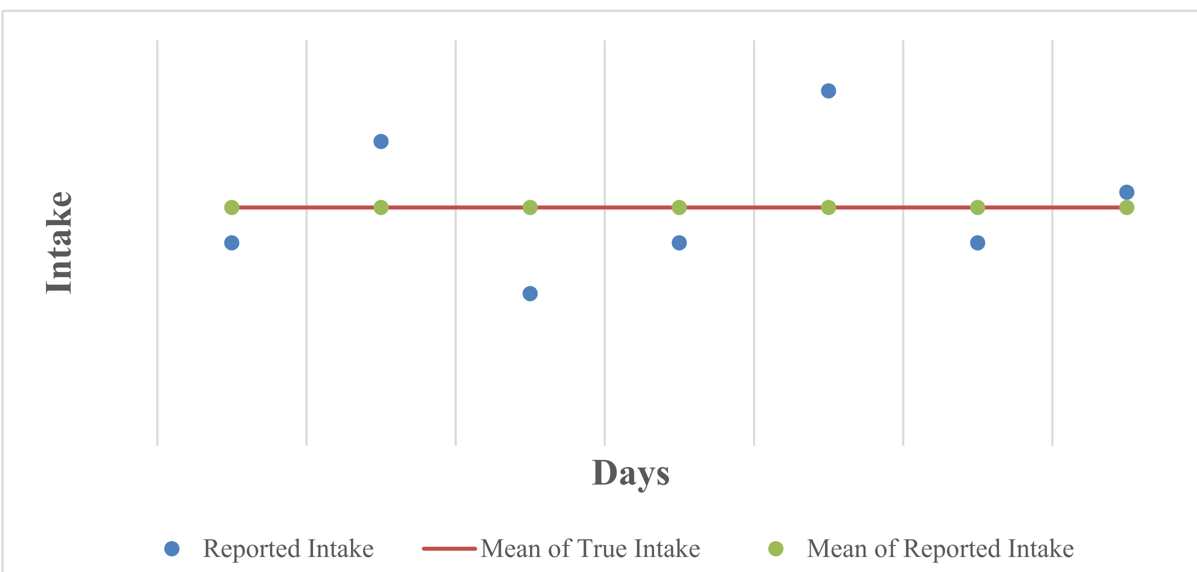

Figure 2. Random errors in a 24-hour recall average zero, and therefore do not affect mean dietary intake.

Measurement errors associated with 24-hour recalls have several practical implications that impact the determination of usual dietary intake. If left uncorrected, random error can result in dietary distributions that are wider than true intake distributions; the days of high intake pull the curve to the right while the days of low intake pull the curve to the left. Thus, while random error does not affect the means of usual dietary intake, it can lead to overestimation of the tail probabilities (e.g. the probability of being above or below some value such as the Daily Recommend Intake [DRI]). Random error can be addressed by using statistical adjustments. In contrast, systemic error does affect calculated mean intake, and there is currently no standard adjustment available to correct it. Nonetheless, the 24-hour recall and the statistical methods associated with it are the best methods available by which usual dietary intake is estimated.[57]

Because random error does not affect the mean of dietary distributions, it is possible to assess and compare the mean intake of foods and nutrients using standard, traditional statistical methods and software. However, in order to determine the percentage of the population that is meeting or exceeding some goal (e.g. DRIs), random error must be addressed using statistical methods of adjustment. One way to correct random error is to conduct many 24-hour recalls for each study participant on nonconsecutive days and to use the average; however, this method can create undue participant burden and prohibitively increase research costs. A more feasible way to adjust for random error is to use statistical modeling to estimate and remove the effects of within-person variability.[56] There are currently several statistical methods available to mitigate random error in 24 hour recalls, including the National Research Council (NRC)

Method, the Iowa State University Foods (ISUF) Method, and a statistical method developed at the National Cancer Institute (NCI).[59] Of these statistical methods, the NCI method has significant advantages, especially for the determination of regional usual intake as it can be used with a relatively small population and requires multiple 24-hour recalls from only a small subset of the study population.[43,56,59]

The NCI Method

Requirements

The basic requirements for using the NCI method to model usual dietary intake is that there is at least one 24-hour recall for all individuals in a sample and two recalls for at least a subsample. The second recall should be conducted at least several days after the first one in order to minimize correlation between the recalls. The distribution of the recall data must also have the potential to be transformed to normality. This means that the data should be ideally unimodal (i.e. one "hump"), and should not have spikes or clumps of identical values near the tails of distribution. One exception to this rule is the case of zero-inflated data, which occurs when a food is episodically consumed. This will be discussed in more detail in a later section.

General Modeling Procedure

The NCI method is applied to dietary data with the use of two macros, MIXTRAN and DISTRIB, both developed by the NCI for use in SAS® software. The first step of the NCI method is to transform dietary data to approximate normality. Distributions of intake tend to be severely skewed with a long right tail. This type of distribution is commonly seen when there is a lower limit of zero and no upper limit on intake, as is the case with nutrients and foods. For example, it is feasible for an individual with a usual consumption of 10 mg of iron per day to consume 30 mg more than his usual intake on any given day; however, it is not possible for this individual to consume 30 mg less iron that his usual intake.

Skewed distributions present many more statistical challenges as compared to normal distributions, the primary reason being that a normal distribution can be fully characterized by its mean and variance. Therefore, the first step of the NCI method is to apply a transformation to the data in order to approximate normality. To accomplish this, the MIXTRAN macro invokes a Box-Cox transformation process in SAS software, which applies a family of power and log distributions to the data. During this process, the appropriate value, λ, is determined, and then the associated power or log transformation is applied. More severely skewed distributions will have smaller absolute values of λ. For example, a moderately skewed distribution might have a λ of 0.50 and a square root transformation will be applied. In contrast, a more severely skewed distribution may have a λ of 0.25 and a fourth root transformation will be applied. The MIXTRAN macro, using procedures available in SAS software, automatically calculate the appropriate λ and apply the transformation.

The next step in the NCI method is to separate within-person from between-person variance in order to estimate the quantiles of a usual intake distribution that exhibits only the between-person variation. This is the process by which the random error is removed from the model and the wider distributions that overestimate tail probability are transformed to the narrower, more accurate distribution. To do this, the NCI method uses a model-based approach which assumes that the between-person and within-person deviations are normally distributed with a mean of zero (i.e. within-person and between-person variance will average zero across recalls and persons). Because the dietary data were transformed to approximate normality in the previous step, it can also be assumed that the distribution of true usual intake is likewise normal. Under these assumptions, probabilities and quantiles can be computed using formulas of standard normal distribution. For example, the 25^{th} percentile of usual intake can be calculated by taking the 25^{th} percentile of the standard normal distribution, multiplying by the standard deviation of the usual intake distribution, and adding the usual intake distribution mean. The DISTRIB macro calculates all quantiles and probabilities in this manner with a Monte Carlo simulation, which randomly draws values from the assumed normal distribution of the between-person deviations, interprets the value as a quantile (i.e. multiplying by the corresponding quantile of the standard normal distribution), and adds the estimated population mean. Next, the MIXTRAN macro fits a nonlinear, mixed effects model to data from the first and second dietary recalls to estimate tail probabilities and incorporate covariates. Finally, the data are back-transformed using the inverse transformation that was used in the first step. For example, data that had a square root transformation would be squared after successful modeling.

Incorporation of Covariates

The models created with the NCI method are mixed models, with population mean as a fixed effect and the within-person and between-person deviations as random effects. This mixed model can be extended to included covariates. Three types of covariates are often included in usual dietary intake models in order to improve the model and generate more precise quantile estimates: individual-level (e.g. age, sex), time-dependent (e.g. weekend, season), and nuisance (e.g. interview sequence). Out of all the methods available to model usual dietary intake, the NCI method is the only one that can incorporate all three of these covariate types with no restrictions.[39] Incorporating covariates can potentially improve quantile estimates by providing the model with more information on between-person variation. Moreover, incorporating covariates can also allow the researcher to evaluate their potential associations with usual dietary intake of a food or nutrient. Covariates can also be used to stratify a population into subpopulations (e.g. along age or gender divisions) and estimate usual dietary intake for these subpopulations. Not only does this reduce the analysis burden by giving the researcher the ability to estimate all subpopulations of interest at once, it also increases the statistical power by incorporating a larger sample size into the analysis.[39]

Modeling Episodically Consumed Foods

As mentioned previously, the NCI method has a unique method of estimating usual dietary intake of episodically consumed foods, which are foods that are not consumed daily by the general population (e.g. whole grains, dark leafy vegetables, and fish).[39] Most foods and food groups are episodically consumed, with the general exception of total grains, fruits, and vegetables. Nutrients are generally not episodically consumed, with the exception of vitamin A and omega 3 fatty acids in some populations. On any given day, an individual has a high likelihood of consuming none of an episodically consumed food, which results in a zero-inflated distribution. Foods and nutrients are classified as commonly or episodically consumed depending on the proportion of the population that has zero-consumption on the recall day. In general, if more than 10% of the population has zero-consumption on the recall day, the food is considered to be episodically consumed.[60] Reasonably accurate estimates of mean intake can still be calculated from zero-inflated data, but estimates of the proportion of the population with deficient intake will be inflated.[59]

The NCI method estimates usual dietary distribution for episodically consumed foods with a two-part usual dietary intake model. In this model, the usual dietary intake of a food is the product of the probability of consuming the food and the amount consumed on the consumption day (Figure 3). For foods and nutrients consumed daily (e.g. calories, grains), the probability of consumption is 1, and therefore only the consumption-day amount requires to be modeled. In episodically consumed foods, however, the probability of consumption must be determined in order to estimate usual dietary intake. The NCI method accomplishes this with a two-part model. The first part of the model determines probability of consuming a food with mixed-mode logistic regression. The second part of the model proceeds as described above, with the transformation of dietary data, the Monte Carlo procedure and estimation of quantiles, and back-transformation to the original scale. Both parts of the model incorporate person-specific effects (random effects) that capture how an individual's intake deviates from the average.

Figure 3. Two-part model for episodically consumed foods.

The NCI method's model for usual dietary intake of episodically consumed foods can also allow for the correlation often seen between probability of consumption and amount consumed on the day of consumption. For example, in the Eating at America's Table Study, there was a positive correlation between the proportion of days that whole grains were consumed and the amount eaten on the days of consumption.[56] Intuitively, this makes sense: it is plausible that people who enjoy a food eat it more often and also eat more of it on the days they eat it. However, this correlation is not observed for all foods and can also vary depending on the population. Hence, when modeling episodically-consumed foods, both a correlated and uncorrelated model are fit, and the significance of correlation between probability and amount is examined in order to choose the most appropriate model. The correlated model correlates probability and amount of consumption by correlating person-specific effects (i.e. random effects that may account for a person's tendency to consume the food) between the two models. The uncorrelated model, although it also includes random, person-specific effects, does not allow these effects to correlate across the two models.

Applying the NCI Method to Regional and National Data

Some of the benefits of the NCI method previously discussed (e.g. the ability to use small sample sizes and the requirement of a second recall from only a subset of the population), lend themselves well to estimating usual dietary intake of regional populations. For these small sample populations, which are typically convenience sampled, data from 24-hour recall software such as the Nutrition Data System for Research 2013 (NDSR) or the Automated Self-administered 24-hour Recall (ASA24) can be exported into SAS software and the NCI method macros can then be directly applied.

Analyzing national data from NHANES is more complicated, however, because of the survey's complex, multistage, probability cluster design.[57] This cluster design means that individuals within each cluster are assumed to be more similar to other individuals within that cluster than they are to individuals in other clusters. The homogeneity of individuals within each cluster can be measured by intra-cluster correlation (ICC), which compares the within-group variance with the between-group variance.[61] It is desirable for the ICC be as small as possible; this can be achieved by sampling more clusters with fewer people within each cluster. However, due to the operational limitations of NHANES surveys, NHANES is only able to sample approximately 30 clusters, called primary sampling units (PSUs), within each 2-year survey cycle. Standard statistical analytic methods which do not take into account the differential weighting and correlation within clusters create biased variance estimates which are too low, leading to overstated statistical significance levels. For this reason, NHANES recommends that balanced repeated replication (BRR), a statistical method for estimating variances of complex samples, be used in NHANES dietary data analyses. In traditional BRR, one PSU of each stratum (which equates to half of the sample) is used at a time to calculate the variance. This process is repeated for many half samples, and then the variances of the parameter estimates are calculated. The NHANES analysis guide recommends creating BRR weights using Fay's BRR method, which uses a Fay coefficient (typically 0.3) to impose a perturbation of the original weights in the full sample. This is a more conservative treatment of weighted data, as the full sample is used for each calculation. When analyzing NHANES dietary data, a minimum of two survey cycles, encompassing four years, should be included in analysis. The total number of replicate rates required for four years of dietary analysis is 32 (the smallest multiple of 4 that is greater than the total number of strata, which number 30). Macros designed to integrate with the NCI method and use BRR weights to estimate variances for NHANES and other complex data are available from the NHANES Dietary Web Tutorial.[57]

II. OBJECTIVES AND HYPOTHESIS

The study described herein was part of a larger study addressing nutrition practices in childcare centers in the community. Previous research examined the nutrition and physical activity environments, policies, and menus of childcare centers in Hays and Bastrop counties. Researchers developed and implemented an intervention designed to improve aspects of childcare centers related to nutrition and physical activity. The intervention involved educational workshops and focus groups for childcare center directors and teachers. During the focus groups, teachers and directors identified parental influence as a major barrier to healthy nutrition environments in childcare centers. Hence, we developed the current phase of research, which focuses on parents.

The primary objective of this thesis was to contribute to a community needs assessment by determining the usual dietary intake of children ages 2-5 attending childcare centers in Hays County, Texas using 24-hour recalls and the NCI method. As previously discussed, young children in this population are at elevated nutritional risk, exhibiting unusually high levels of overweight and obesity and low intakes of vitamin D.[5,43] Although large-scale, national studies provide useful information on dietary trends in the US, they cannot detect the variations in dietary intake that exist across the country due to the influence of geographic location, race and ethnicity, regional and cultural feeding practices, and socioeconomic status.[15] Thus, determining usual dietary intake of preschoolers in Hays County, Texas is a vital step in understanding the role dietary intake may be playing in the increased risk of childhood obesity in this community, and will also inform the planning and implementation of community interventions to prevent and treat childhood obesity.

The secondary objective of this thesis was to place the dietary intake of preschoolers in Hays County, Texas within a national context in order to detect any differences in dietary patterns that could explain why rates of childhood obesity are higher in this community compared to national rates. The most current data on the national dietary intake of children in the US provide the usual dietary intake for age groups that encompass toddlers and older children (i.e. children 1-3 years are grouped together and children 4-8 years are grouped together). Hence, the scope of this thesis included the estimation of usual dietary intake of children 2-5 years using the most recent NHANES dietary data available (2009-2012) and the NCI method in order to facilitate age-matched comparisons between regional and national dietary intake.

With regard to the first objective, preschoolers in Hays County were expected to have obesogenic dietary patterns. Specifically, we expected to see patterns that reflected excessive intake of energy-dense, nutrient-poor foods, resulting in high intake of total energy, saturated fat, and sodium as well as low intake of fiber and potassium. Moreover, as previous research in this region revealed inadequate consumption of vitamin D among infants 4-24 months enrolled in Central Texas WIC,[42] we predicted that we would also see low intake of Vitamin D.[47] With regard to the second objective, which was to place our regional analysis in a national context, we expected the usual dietary intake of preschoolers in Hays County, Texas to compare unfavorably with the usual dietary intake of children nationally. However, during the course of this analysis, we found that regional intake of some nutrients and foods compared favorably to national intake. As 100% of the children in our study consumed at least one meal at childcare center compared to 38% of children participating in NHANES 2009-2012, we wondered whether attending childcare center could be positively associated with diet intake. Hence, we formulated a third research objective, which was to evaluate the potential effects that attending a childcare center may have on usual dietary intake at a national level.

III. METHODS

Recruitment

We recruited parents of children ages 2-5 years who attended childcare centers and preschools in Hays County, TX. Researchers visited the childcare centers during the hours of child pick-up and invited parents to participate in the research project. After providing informed consent, parents were given a study packet containing a survey instrument regarding the home food environment and their child's feeding practices, the *Food Amounts Booklet*, an illustrated guide to portion sizing containing 2D food models, and a copy of the consent form.[40] To incentivize participation, parents were given a $5 grocery gift card for completion of the survey and an additional $5 grocery gift card for each 24-hour recall they completed. Spanish-speaking researchers were present at childcare centers where directors indicate there were parents who preferred to communicate in Spanish. Parents with a child aged 2-5 years were eligible to participate, and only one child from each household was included in the study. All study protocols were pre-approved by the Texas State University Institutional Review Board, 2013Q9495

Data Collection

Telephone Interview

Researchers contacted participants via telephone to complete a 24-hour recall interview. We interviewed parents as proxies for their children as they are considered the best source of information on food intake of children younger than 8 years.[52,53] We conducted interview via telephone as research shows that telephone recalls and face-to-face recalls have similar results.[50,51] Participants were interviewed at random on different days of the week, including both weekdays and weekends.[49]

During the 24-hour recall interview, trained interviewers asked parents to provide a description of their child's diet the proceeding day. Interviewers administered the multiple-pass 24-hour recall with NDSR. During the first pass of the recall, interviewers generated a "quick list" by asking parents to list all food and beverages consumed by their child during the 24-hour period from midnight to midnight the prior day. The "quick list" was then read back to the parent and the interviewer asked if any other foods or beverages were consumed during the 24-hour period. During the second pass, interviewers prompted parents to provide details and amounts of foods consumed by the child. The list of foods and beverages was again read to the parent, and the interviewer asked again if any foods or beverages are missing. Next, the interviewer read a list of commonly forgotten foods such as sweets, snacks, and sodas to the parent, and the interviewer asked the parent if they had forgotten to include any of the commonly forgotten foods. During the next step, the list of foods and beverages was read back to the parent one last time, and the interviewer asked the parent to verify its accuracy. Finally, dietary supplement information for the past 30 days was collected. Specifically, the interviewer asked the parent if the child took any vitamins, minerals, or any other supplement during the previous 30 days. If the parent reported that the child took any type of supplement, the interviewer collected detailed information on supplement usage such as how many of the past 30 days the child took the supplement, how many times per day it was generally taken, how much of the supplement was administered at each instance, and whether the child took the supplement on the day of the recall.

We attempted to contact each parent enrolled in the study until we were notified of withdrawal of consent or reached the end of the data collection period. Interviews were conducted in English or Spanish at the desire of the participant. At least two nonconsecutive days of dietary recall data were required from a 50% of the study population in order to estimate the usual nutrient intake of the population.

Meals Eaten Elsewhere

As we recruited parents from childcare centers, children often consumed meals at the childcare center during the 24-hour recall period. When children ate meals unobserved the parent, we used the following protocol to collect intake data:

1. If the caregiver provided the food (e.g. packed a lunch or a snack), we asked the caregiver to give details about the food they sent with the child. If the caregiver did not know the quantity consumed by the child, we asked permission to contact the childcare provider as soon as possible after the interview to obtain the missing information.
2. If the childcare center provided the food, we contacted the childcare center as soon as possible after the interview to obtain the information from the child's direct care provider.

Training

Interviewers underwent extensive training prior to conducting 24-hour recalls, which included 3 hours of classroom instruction, the completion at least two supervised practice recalls on non-study participants, at least two observations of fully-trained interviewers conducting recalls with study participants, and the close observation of their first two recalls with study participants by the lead researcher. The total training time for each interviewer was approximately 9 hours.

Data Preparation

Hays County data were checked continuously during data collection in order to assure accuracy. Files containing total nutrient intake for each day and files containing total food group intake for each day were exported from NDSR and merged together using SAS Studio software (SAS Institute, Cary, NC, Version 3.4). Surveys administered to parents were exported from SurveyMonkey® into SPSS (IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.). After quality assurance and cleaning, demographic variables were imported in to SAS software and merged with dietary data for analysis.

NHANES dietary and demographic datasets from the 2009-2010 and 2011-2012 survey cycles were downloaded from the Centers for Disease Control and Prevention (CDC) NHANES website.[62] A list and description of files downloaded and used in analysis are provided in Table 2. All files were imported into SAS software. Body mass index (BMI) percentiles for children were calculated using height and weight from NHANES datasets and a SAS macro published by the CDC, which calculates z-scores and BMI percentiles. Demographic files, BMI percentiles, and Total Nutrient Intake files for 2009-2010 and 2011-2012 were appended and merged to create one data set for children aged 2-5. In order to identify children who attended a childcare center, a new, binary variable indicating whether or not a child consumed at least one meal at a childcare center on a recall day was created with the Individual Foods files (which indicate where a food item was consumed). If a food item was consumed at a school cafeteria or at a childcare center, the individual was classified as a child who attended childcare center. In order to calculate the standard errors of percentiles, cut-off points, and the significance of covariates for the complex NHANES data, BRR weights were created. Using SAS software, the MEANS procedure with a Fay's coefficient of 0.3 was used to create 32 replicate weights from the weights provided in the datasets by NHANES.

Table 2. Description of datasets used from NHANES 2009-2012.

Dataset	**2009-2010 File Name**	**2011-2012 File Name**	**Description**
Demographic Variables & Sample Weights	DEMO_G	DEMO_F	Demographic data and sample weights for each participant
Dietary Interview, Total Nutrient Intake, First Day	DR1TOT_G	DR1TOT_F	Total nutrient intake for the 1st recall day
Dietary Interview, Total Nutrient Intake, Second Day	DR2TOT_G	DR2TOT_F	Total nutrient intake for the 2nd recall day
Dietary Interview, Individual Foods, First Day	DR1IFF_G	DR1IFF_F	Details of nutrients and USDA food codes for each individual food item consumed on the 1st recall day
Dietary Interview, Individual Foods, Second Day	DR2IFF_G	DR2IFF_F	Details of nutrients and USDA food codes for individual food items consumed on the 2nd recall day
Body Measures	BMX_G	BMX_F	Anthropometric measurements of participants

In order to estimate usual intake of food groups (e.g. whole grains, fruit juice, milk), the final dataset was merged with the United States Department of Agriculture (USDA) Food Patterns Equivalents Databases, which are SAS data files customized for each NHANES survey cycle.[63] When merged with NHANES dietary data, the USDA codes contained in the NHANES dataset are translated into foods and beverages grouped into 37 USDA Food Pattern components (e.g. fruit juice, dark green vegetables, legumes). The Food Pattern components are defined as the number of cup equivalents of fruit, vegetables, and dairy; ounce equivalents of grains and protein foods; teaspoon equivalents of added sugars; gram equivalents of solid fats and oils; and number of alcoholic drinks.

Statistical Analysis

Demographic data were tabulated with the FREQ procedure in SAS software. Before proceeding with the NCI method, each food and nutrient was classified as commonly or episodically consumed. A food was considered to be commonly consumed if less than 5% of the population had zero consumption on the recall day (Table 3). The usual intakes of commonly consumed foods and nutrients were estimated by specifying an amounts-only model in the MIXTRAN and DISTRIB macros. Food groups with more than 10% of the population consuming zero on the recall day were classified as episodically consumed (Table 3).[51] The usual intakes of episodically consumed foods were estimated by running both a two-part, correlated model as well as a two-part, uncorrelated model. The significance of correlation between probability and amount of consumption were evaluated, and the best fitting model was selected.[51] If the percentage of the population who consumed zero of the food group on the recall day fell between 5% and 10%, then three models were constructed: amounts-only, a two-part correlated model, and a two-part uncorrelated model. Model fit indices and the significance of correlation between probability and amount of consumption were examined, and the best fitting model was selected (Table 3).[51]

Table 3. Types of models used for commonly and episodically consumed food groups.

	Commonly Consumed (Less than 5% consumed zero on the recall day)	**Episodically Consumed** (More than 10% consumed zero on the recall day)		**Borderline** (5-10% consumed zero on the recall day)	
Model Type	Amount	Correlated	Uncorrelated	Correlated	Amount
Hays County	All nutrients Total fruit Whole fruit Total dairy Milk Protein foods Total grains % kcal from SoFAS	Fruit juice Whole grains	Fruit juice Whole grains		Total vegetables
NHANES 2009-2012	All nutrients Total grains Protein foods	Total fruit Fruit juice Whole fruit Whole grains	Total vegetables	Total dairy % kcal from SoFAS	

The covariates included in the regional and national models included age, gender, race, household income, interview sequence, and whether the recall fell on a weekend or weekday. For NHANES data, the childcare center variable was included in the model in order to evaluate the association of attending childcare center on overall usual dietary intake. Models for nutrients and foods included cut-off points in order to determine the percentage of children below, meeting, or exceeding the recommended intake for nutrients and food groups, as specified in the 2015 Dietary Guidelines for Americans. For regional dietary intake models, standard errors of means, percentiles, and cut-off points were estimated within the MIXTRAN and DISTRIB macros. For models estimating national dietary intake, standard errors were estimated by adapting the Balanced Repeat Replication (BRR) macros described in the NHANES Dietary Web Tutorial.[57]

Median intakes of regional and national data were compared with non-parametric Wilcoxin tests in SAS software. After a Bonferonni correction was applied, we set the significance value at $p<0.0008$. The effects of childcare center attendance on national usual dietary intake were evaluated with macros and code provided in the NHANES Dietary Web Tutorials: Evaluating the Effects of Covariates on Usual Intake of Single Ubiquitously-Consumed Dietary Constitute and Evaluating the Effects of Covariates on Usual Intake of Single Episodically-Consumed Dietary Constitute. These programs invoke the MIXTRAN and BRR macros to calculate the significance of covariates on the consumption of foods and nutrients. These models controlled for age, gender, race, and household income. As the models used in these analyses (i.e. multilevel Beyesian models) inherently address the issue of multiple comparisons by performing partial pooling, no multiple correction was applied and the significance level was set, *a priori*, at $p \leq 0.05$.[64]

During data analysis, some specific foods, nutrients, and subpopulations were of particular interest. Further analysis was undertaken with SAS software to determine important food group contributors to nutrients of interest and demographic characteristics of subpopulations (e.g. children who did not meet specific nutrient goals).

IV. RESULTS

Study Participants

The demographic characteristics of the children and caregivers participating in the regional study are given in Table 4. All BMI values in the regional study were calculated from heights and weights reported by caregivers. As many caregivers did not know their child's height and/or weight, child BMI percentiles were calculated for only 56% of the sample. Of the sample of children whose BMI percentile could be determined, 38.6% were overweight or obese. Of primary caregivers reporting height and weight, 28.0% had BMI scores that classified them as overweight and 27.1% had BMI scores that classified them as obese. Children ages 2-5 years included participating in NHANES had rates of overweight and obesity closer to national rates, with 27% classified as overweight or obese (Table 5). The over a third of children were Hispanic (35%), 27% were white, 25% were non-Hispanic Black, and 13% were of other races and ethnicities.

Table 4. Demographic characteristics of children and their caregivers sampled from childcare centers in Hays County, Texas.

	2-3 y (n=56)		4-5 y (n=68)	
Child Characteristics [a]	n	(%)	n	(%)
Completed second recall	27	(48)	34	(50)
Female	28	(50)	40	(59)
Took supplements	19	(34)	26	(38)
Caregiver Characteristics				
Race/ethnicity				
White	30	(54)	33	(49)
Hispanic or Latino	22	(39)	32	(47)
Other [b]	4	(7)	3	(5)
Age, y (mean = 32.8 ± 7.2)				
18 - 24	9	(16)	8	(12)
25 - 44	45	(80)	55	(81)
45 - 64	2	(4)	5	(7)
BMI category [c d]				
Underweight	2	(4)	3	(4)
Normal weight	25	(45)	23	(34)
Overweight	15	(27)	18	(27)
Obese	11	(20)	21	(31)
Education level [d]				
Less than high school	3	(5)	7	(10)
High school/GED	10	(18)	21	(31)
College degree	24	(43)	17	(25)
Graduate degree	17	(30)	12	(18)
Employment status				
Unemployed	10	(18)	20	(29)
Employed part-time	8	(14)	14	(21)
Employed full-time	38	(68)	34	(50)
Household income [d]				
Less than $10,000	6	(11)	12	(18)
$10,001 - $20,000	8	(14)	12	(18)
$20,001 - $40,000	4	(7)	18	(27)
$40,001 - $75,000	13	(23)	10	(15)
More than $75,001	23	(41)	16	(24)
Household size, persons				
3 - 4	36	(82)	37	(54)
5 or more	20	(36)	31	(46)

a Average weight in kilograms: 14.1±7.7 (ages 2-3); 17.9±8.2 (ages 4-5).
b Black and Asian combined.
c Calculated from self-reported height and weight
d Values <100 due to missing data.

Table 5. Demographic data of children 2-5 years old: NHANES 2009-2012.

	2-3 y (n=965)		4-5 y (n=741)	
Female	488	(56)	376	(45)
BMI (n=852)[a]				
Underweight	21	(4)	14	(4)
Normal	339	(72)	247	(64)
Overweight	60	(13)	53	(14)
Obese	48	(10)	70	(18)
Race				
Hispanic	341	(35)	280	(38)
Non-Hispanic White	256	(27)	208	(28)
Non-Hispanic Black	240	(25)	160	(22)
Other Race - Including Multi-Racial	128	(13)	93	(13)

a values <100 due to missing data.

Usual Dietary Intake

The distribution of usual dietary intake of children aged 2-5 years in Hays County and nationally are provided in Tables 6 through 9, which provide means, usual intake percentiles, percentage of children below, meeting, or exceeding recommendations, and the results of Wilcoxon signed-rank tests between regional and national samples. The usual dietary intake of foods and nutrients of particular interest are described in more detail in this section.

Table 6a. Usual nutrient intake distributions of selected nutrients for preschoolers ages 2-3 years (n=56) in Hays County.

Nutrient	DRI[a]	UL[b]	Mean (SE)	10th	25th	Median	75th	90th	% with intake below recommendation (SE)	% with intake above recommendation (SE)	P[c]
Macronutrients											
Energy (kcal/d)	1000-1400[d]	-	1433 (49)	1083	1227	1404	1596	1783	5 (0.01)	50 (1.2)	0.4
Carbohydrate (g/d)	130	-	186 (7)	129	153	179	205	230	0.7 (0.02)	99.3 (0.02)	0.8
Dietary fiber (g/d)	14 - 19.6[e]	-	14 (1)	8	10	13	16	19	21 (2.4)	19 (1.5)	<.0001
Protein (g/d)	13	-	67 (2)	49	56	65	74	83	0 (0.0)	100 (0.0)	<.0001
Minerals											
Calcium (mg/d)	700	2500	1065 (42)	636	825	1034	1243	1448	14 (1.8)	0 (0.0)	0.2
Iron (mg/d)	7	40	10 (1)	9	9	10	11	12	4 (1.2)	0 (0.0)	0.4
Magnesium (mg/d)	80	65[f]	216 (10)	141	172	207	247	284	4 (0.8)	ND[f]	0.0
Phosphorus (mg/d)	460	3000	1192 (42)	790	957	1142	1334	1524	4 (1.1)	0 (0.0)	0.4
Potassium (mg/d)	3000	-	2035 (94)	1317	1607	1937	2293	2663	96 (1.9)	0 (0.0)	0.3
Sodium (mg/d)	-	1500	2385 (94)	1643	1932	2250	2597	2932	7 (2.1)	93 (1.6)	0.3
Zinc (mg/d)	2.5	7	9 (0)	7	8	9	10	11	3 (0.8)	82 (0.8)	0.05
Vitamins											
Vitamin C (mg/d)	15	400	64 (8)	35	45	60	79	98	4 (0.3)	0 (0.0)	0.4
Vitamin E (µg/d)	6	200[g]	6 (1)	4	5	6	7	8	77 (0.1)	0 (0.0)[g]	0.1
Vitamin D (µg/d)	15	62.5	7 (0)	4	5	7	8	10	100 (0.5)	0 (0.0)	0.9
Vitamin A (µg RAE/d)[h]	300	600	757 (90)	477	579	719	888	1083	5 (0.2)	66 (1.3)[h]	<.0001
Vitamin K (µg/d)	30	-	56 (6)	40	46	53	63	75	4 (0.7)	0 (0.0)	0.002
Vitamin B-12 (µg/d)	1.2	-	4.5 (0.2)	3	3	4	5	6	0 (0.0)	0 (0.0)	0.4
Vitamin B-6 (mg/d)	0.6	40	1.2 (0.1)	1.0	1.1	1.2	1.4	1.5	0 (0.0)	0 (0.0)	0.1
Folate (µg dietary folate equivalents/d)	200	400[f]	281 (13)	236	255	278	303	331	0 (0.0)	1 (0.2)c	0.9[f]
Niacin (mg/d)	8	15d	14 (0.6)	11	12	14	16	18	0 (0.0)	NDd	<.0001
Riboflavin (mg/d)	0.6	-	1.9 (0.1)	1.3	1.5	1.8	2.2	2.5	0 (0.0)	0 (0.0)	0.002
Thiamin (mg/d)	0.6	-	1.2 (0.0)	1.0	1.1	1.2	1.4	1.5	0 (0.0)	0 (0.0)	0.4

NOTES:

SE = standard error; DRI = Dietary Reference Intake; UL = Tolerable Upper Limit; RAE = retinol activity equivalents.
a Daily Recommended Intakes (DRI) as specified in the 2015 Dietary Guidelines for Americans for children ages 2-3 years.[24]
b Tolerable Upper Limits (UL) as set by the Institute of Medicine (IOM), which does not set a UL for every nutrient.[65]
c Significance of Wilcoxon signed-rank test of the difference in median intake between children sampled from Hays County and children in NHANES. Recommendations for calorie intake vary depending on a child's energy requirement, which in turn is influenced by sex, age and activity level. The lowest recommendations are for inactive children, whereas the higher recommendation is for children with high levels of physical activity.[24]
d Recommendations for fiber intake vary depending on calorie intake. This DRI is based on the recommended intake of 1000-1400 calories/day.[24]
e ND=not determined. The UL for magnesium apply only to the synthetic forms obtained from supplements and/or fortified foods, which are not differentiated in nutrition software.[65]
f Percentage above UL for vitamin E and folate based on synthetic forms from fortified foods and supplements.[65]
g Percentage above UL for vitamin A are based on the retinol form only.[65]

Table 6b. Usual nutrient intake distributions of selected nutrients for preschoolers ages 2-3 years: NHANES 2009-2012 (n=965).

Nutrient	DRI[a]	UL[b]	Mean (SE)	10th	25[th]	Median	75[th]	90[th]	% with intake below recommendation (SE)	% with intake above recommendation (SE)	P[c]
Macronutrients											
Energy (kcal/d)	1000-1400[d]	-	1410 (44)	1354	1433	1500	1576	1640	6 (0.1)	16 (3.5)	0.4
Carbohydrate (g/d)	130	-	193 (6)	31	131	168	200	233	5 (0.1)	0 (0.02)	0.8
Dietary fiber (g/d)	14 - 19.6[e]	-	10 (0)	6	8	10	13	15	83 (0.9)	1 (6.4)	<.0001
Protein (g/d)	13	-	49 (2)	29	41	51	62	71	7 (0.2)	93 (0.5)	<.0001
Minerals											
Calcium (mg/d)	700	2500	993 (48)	492	762	1010	1264	1503	20 (1.4)	0 (0.0)	0.2
Iron (mg/d)	7	40	15 (0.6)	15	16	16	17	17	5 (0.9)	0 (0.0)	0.4
Magnesium (mg/d)	80	65[f]	190 (6)	115	161	199	237	272	7 (1.7)	ND[d]	0.0
Phosphorus (mg/d)	460	3000	1049 (42)	976	1061	1119	1184	1217	5 (1.2)	0 (0.0)	
Potassium (mg/d)	3000	-	1924 (70)	1861	1963	2032	2135	2180	100 (0.0)	-	0.3
Sodium (mg/d)	-	1500	1954 (71)	1269	1650	2006	2380	2749	0 (0.0)	83 (1.4)	0.3
Zinc (mg/d)	2.5	7	8 (0)	4	6	8	10	11	7 (1.2)	64 (1.1)	0.05
Vitamins											
Vitamin C (mg/d)	15	400	79.8 (7)	29	51	76	106	137	9 (0.3)	0 (0.0)	0.4
Vitamin E (µg/d)	6	200[g]	5 (0)	3	4	5	6	7	80 (0.5)	0 (0.0)	0.1
Vitamin D (µg/d)	15	62.5	4 (0)	2	3	4	5	6	7 (0.7)	0 (0.0)	
Vitamin A (µg RAE/d)	300	600 [h]	1 (0)	0.7	1	1.3	1.6	1.9	7 (0.8)	0 (0.0)	
Vitamin K (µg/d)	30	-	266 (12)	152	214	272	332	390	10 (0.2)	ND (1)	0.5
Vitamin B-12 (µg/d)	1.2	-	13 (1)	8	11	14	17	20	8 (0.1)	0 (0.0)	0.1
Vitamin B-6 (mg/d)	0.6	40	1.7 (0)	1	1	2	2	3	7 (0.1)	0 (0.0)	0.3
Folate (µg dietary folate equivalents/d)	200	400[f]	1.1 (0)	1	1	1	1	2	7 (0.8)	0 (0.0)	0.0
Niacin (mg/d)	8	15	7 (0.3)	3	5	7	9	11	98 (0.4)	0 (0.0)	0.9
Riboflavin (mg/d)	0.6	-	560 (28)	283	428	566	711	853	11 (0.1)	21 (1.2)	<.0001
Thiamin (mg/d)	0.6	-	42 (3)	18	28	40	55	70	28 (0.6)	0 (0.0)	0.002

NOTES:

SE = standard error; DRI = Dietary Reference Intake; UL = Tolerable Upper Limit; ND = not determined; RAE = retinol activity equivalents.
a Daily Recommended Intakes (DRI) as specified in the 2015 Dietary Guidelines for Americans for children ages 4-5 years.[24]
b Tolerable Upper Limits (UL) set by the Institute of Medicine (IOM).[65]
c Significance of Wilcoxon signed-rank test of the difference in median intake between children sampled from Hays County and children in NHANES.
d Recommendations for calorie intake vary depending on a child's energy requirement, which in turn is influenced by sex, age and activity level. The lowest recommendations are for inactive children, whereas the higher recommendation is for children with high levels of physical activity.[24]
e Recommendations for fiber intake vary depending on calorie intake. This DRI is based on the recommended intake of 1200-1600 calories/day.[24]
f ND=not determined. The UL for magnesium apply only to the synthetic forms obtained from supplements and/or fortified foods, which are not differentiated in nutrition software.[65]
g Percentage above UL for vitamin E and folate based on synthetic forms from fortified foods and supplements.[65]
h Percentage above UL for vitamin A are based on the retinol form only.[65]

Table 7a. Usual nutrient intake distributions of selected nutrients for preschoolers ages 4-5 years in Hays County (n=64).

Nutrient	DRI[a]	UL[b]	Mean (SE)	10th	25th	Median	75th	90th	% with intake below recommendation (SE)	% with intake above recommendation (SE)	P[c]
Macronutrients											
Energy (kcal/d)	1200-1600[d]	-	1430 (9)	1090	1238	1416	1607	1793	21 (0.5)	74 (1.3)	0.2
Carbohydrate (g/d)	130	-	184 (6)	140	159	183	209	235	0 (0.0)	100 (0.1)	0.04
Dietary fiber (g/d)	16.8 - 22.4[e]	-	14 (1)	9	11	13	16	19	79 (0.1)	3 (0.2)	0.0004
Protein (g/d)	19	-	67 (2)	50	57	67	76	85	0 (0.0)	100 (0.1)	0.002
Minerals											
Calcium (mg/d)	1000	2500	1083 (7)	713	867	1062	1278	1478	42 (1.4)	0 (0.0)	0.005
Iron (mg/d)	10	40	10 (0)	9	10	10	11	12	43 (2.4)	0 (0.0)	
Magnesium (mg/d)	130	110[f]	214 (8)	151	179	213	252	291	4 (0.8)	ND	0.06
Phosphorus (mg/d)	500	3000	1189 (40)	854	1005	1178	1373	1555	4 (0.2)	0 (0.0)	
Potassium (mg/d)	3800	-	2037 (77)	1425	1674	1994	2361	2731	100 (0.8)	0 (0.0)	0.3
Sodium (mg/d)	-	1900	2374 (86)	1782	2033	2343	2681	2999	14 (1.7)	86 (2.1)	0.5
Zinc (mg/d)	5	12	9 (0)	7	8	9	10	11	0 (0.01)	7 (1.2)	0.2
Vitamins											
Vitamin C (mg/d)	25	650	64 (4)	34	45	60	79	98	2 (0.5)	0 (0.0)	0.4
Vitamin E (µg/d)	7	300[g]	6 (0)	4	5	6	7	8	92 (1.6)	0 (0.0)	0.6
Vitamin D (µg/d)	15	75	4.5 (0.2)	3	3	4	5	6	0 (0.0)	0 (0.0)	0.06
Vitamin A (µg RAE/d)	400	900[h]	1.2 (0.1)	1.0	1.1	1.2	1.4	1.5	0 (0.0)	0 (0.0)	0.0003
Vitamin K (µg/d)	55	-	281 (13)	236	255	278	303	331	0 (0.0)	1 (0.2)	0.0003
Vitamin B-12 (µg/d)	1.2	-	14 (0.6)	11	12	14	16	18	0 (0.0)	0 (0.0)	0.3
Vitamin B-6 (mg/d)	0.6	40	1.9 (0.1)	1.3	1.5	1.8	2.2	2.5	0 (0.0)	0 (0.0)	0.5
Folate (µg dietary folate equivalents/d)	200	400[g]	1.2 (0.0)	1.0	1.1	1.2	1.4	1.5	0 (0.0)	0 (0.0)	0.5
Niacin (mg/d)	8	15	7 (0.1)	4	5	7	8	10	100 (0.0)	0 (0.0)	0.1
Riboflavin (mg/d)	0.6		656 (62)	480	582	719	893	1086	12 (0.9)	23 (2.1)	0.05
Thiamin (mg/d)	0.6		55 (3)	40	46	53	62	72	57 (1.1)	0 (0.0)	0.9

NOTES:

SE = standard error; DRI = Dietary Reference Intake; UL = Tolerable Upper Limit; ND = not determined; RAE = retinol activity equivalents.
a Daily Recommended Intakes (DRI) as specified in the 2015 Dietary Guidelines for Americans for children ages 4-5 years.[24]
b Tolerable Upper Limits (UL) set by the Institute of Medicine (IOM).[65]
c Significance of Wilcoxon signed-rank test of the difference in median intake between children sampled from Hays County and children in NHANES.
d Recommendations for calorie intake vary depending on a child's energy requirement, which in turn is influenced by sex, age and activity level. The lowest recommendations are for inactive children, whereas the higher recommendation is for children with high levels of physical activity.[24]
e Recommendations for fiber intake vary depending on calorie intake. This DRI is based on the recommended intake of 1200-1600 calories/day.[24]
f ND=not determined. The UL for magnesium apply only to the synthetic forms obtained from supplements and/or fortified foods, which are not differentiated in nutrition software.[65]
g Percentage above UL for vitamin E and folate based on synthetic forms from fortified foods and supplements.[65]
h Percentage above UL for vitamin A are based on the retinol form only.[65]

Table 7b. Usual nutrient intake distributions of selected nutrients for preschoolers ages 4-5 years: NHANES 2009-2012 (n=741).

	Recommended Daily Intake					**Usual Intake Percentiles**					
Nutrient	DRI[a]	UL[b]	Mean (SE)	10th	25th	Median	75th	90th	% with intake below recommendation (SE)	% with intake above recommendation (SE)	P[c]
Macronutrients											
Energy (kcal/d)	1200-1600[d]	-	1580 (47)	1531	1609	1675	1754	1813	6 (0.3)	77 (0.7)	0.4
Carbohydrate (g/d)	130	-	214 (6)	150	188	222	257	290	5 (0.4)	0 (0.9)	0.8
Dietary fiber (g/d)	16.8 - 22.4[e]	-	11 (0)	6	9	12	14	17	90 (0.5)	1 (0.5)	<.0001
Protein (g/d)	19	-	54 (2)	33	45	56	67	77	7 (0.9)	93 (0.2)	<.0001
Minerals											
Calcium (mg/d)	1000	2500	1009 (50)	515	777	1024	1278	1522	47 (0.6)	0 (0.1)	0.2
Iron (mg/d)	10	40	17 (0.4)	16	17	18	18	19	5 (0.4)	0 (0.0)	0.4
Magnesium (mg/d)	130	110[f]	200 (6)	126	170	210	248	284	11 (0.4)	ND[f]	0.0
Phosphorus (mg/d)	500	3000	1112 (44)	1054	1137	1182	1242	1277	5 (0.8)	0 (0.0)	0.4
Potassium (mg/d)	3800	-	1943 (56)	1888	1974	2098	2142	2185	100 (0.2)	0 (0.0)	0.3
Sodium (mg/d)	-	1900	2273 (85)	1517	1936	2333	2756	3160	0 (0.2)	77 (0.3)	0.3
Zinc (mg/d)	5	12	8 (0)	5	7	9	10	12	10 (0.2)	11 (0.2)	0.05
Vitamins											
Vitamin C (mg/d)	25	650	78 (5)	28	50	74	104	135	9 (0.8)	0 (0.0)	0.4
Vitamin E (µg/d)	7	300	5 (0)	3	4	5	6	8	85 (0.1)	0 (0.1)[g]	0.1
Vitamin D (µg/d)	1.2	-	4 (0)	2	3	4	5	7	7 (0.8)	0 (0.0)	0.9
Vitamin A (µg RAE/d)	0.6	40	1.2 (0)[h]	0.7	1.0	1.3	1.6	1.9	8 (0.1)	0 (0.0)[h]	<.0001
Vitamin K (µg/d)	200	400	306 (10)	187	252	313	377	437	12 (0.3)	ND (1)	0.002
Vitamin B-12 (µg/d)	8	15[d]	15 (1)	9	13	16	19	22	8 (0.1)	0 (0.0)	0.4
Vitamin B-6 (mg/d)	0.6		1.7 (0)	1.0	1.4	1.8	2.2	2.5	7 (0.9)	0 (0.0)	0.1
Folate (µg dietary folate equivalents/d)	0.6	400[g]	1.3 (0.1)	0.8	1.1	1.3	1.5	1.7	7 (0.6)	0 (0.1)	0.9[g]
Niacin (mg/d)	15	75	6 (0.3)	2	4	6	8	11	99 (0.9)	0 (0.0)	<.0001
Riboflavin (mg/d)	400	900	566 (32)	290	433	571	717	861	20 (0.1)	1 (0.4)	0.002
Thiamin (mg/d)	55	-	48 (2)	21	33	47	63	79	64 (0.6)	0 (0.1)	0.4

NOTES:
SE = standard error; DRI = Dietary Reference Intake; UL = Tolerable Upper Limit; ND = not determined; RAE = retinol activity equivalents.
a Daily Recommended Intakes (DRI) as specified in the 2015 Dietary Guidelines for Americans for children ages 4-5 years.[24]
b Tolerable Upper Limits (UL) set by the Institute of Medicine (IOM).[65]
c Significance of Wilcoxon signed-rank test of the difference in median intake between children sampled from Hays County and children in NHANES.
d Recommendations for calorie intake vary depending on a child's energy requirement, which in turn is influenced by sex, age and activity level. The lowest recommendations are for inactive children, whereas the higher recommendation is for children with high levels of physical activity.[24]
e Recommendations for fiber intake vary depending on calorie intake. This DRI is based on the recommended intake of 1200-1600 calories/day.[24]
f ND=not determined. The UL for magnesium apply only to the synthetic forms obtained from supplements and/or fortified foods, which are not differentiated in nutrition software.[65]
g Percentage above UL for vitamin E and folate based on synthetic forms from fortified foods and supplements.[65]
h Percentage above UL for vitamin A are based on the retinol form only.[65]

Table 8. Usual intake distributions of selected food groups for preschoolers age 2-3 years in Hays County (n=56) compared to age-matched children participating in NHANES 2009-2012 (n=965).

		Hays County, Texas						**NHANES 2009-2012**						
Food Group[a]	USDA Food Pattern[b]	Mean (SE)	25th	50th	75th	% with intake below pattern (SE)	% with intake above pattern (SE)	Mean (SE)	25th	50th	75th	% with intake below pattern (SE)	% with intake above pattern (SE)	P[c]
Fruit (c-eq)[d]	1 - 1.5	1.1 (0.4)	0.5	0.9	1.5	54 (3.8)	24 (0.3)	1.3 (0.5)	0.7	1.2	1.7	41 (0.3)	32 (1.2)	0.5
Fruit, whole (c-eq)[e]	.5-.75	0.8 (0.2)	0.4	0.7	1	36 (0.3)	42 (0.7)	0.7 (0.2)	0.3	0.6	1.0	41 (3.3)	39 (3.7)	0.06
Fruit juice (c-eq)[f]	<0.75	0.3 (0.1)	0.1	0.2	0.4	-	18 (1.6)	0.6 (0.2)	0.2	0.5	0.8	-	30 (1.6)	<.0001
Vegetables (c-eq)[g]	1 - 1.5	0.7 (0.2)	0.5	0.7	0.8	95 (2.4)	0 (0.4)	0.6 (0.2)	0.4	0.5	0.7	92 (1.3)	1 (3.1)	0.04
Dairy (c-eq)[h]	2 c	2.6 (0.1)	2	2.6	3.2	27 (2.6)	52 (0.4)	2.5 (0.1)	1.6	2.2	3.0	41 (2.7)	41 (3.7)	0.2
Milk (c-eq)[i]	<2 c	1.4 (0.2)	0.6	1.2	1.9	-	13 (3.3)	1.8 (0.3)	0.8	1.5	2.3	-	34 (2.1)	0.4
Protein foods (oz-eq)[j]	2-4	3.1 (0.3)	2.3	3	3.9	15 (3.9)	21 (0.1)	2.5 (0.2)	1.5	2.3	3.2	39 (0.6)	10 (3.3)	0.03
Grain (oz-eq)[k]	3-5	4.3 (0.2)	3.6	4.3	5	11 (2.2)	62 (0.7)	4.2 (0.2)	3.5	4.3	5.1	15 (1.4)	59 (0.8)	0.2
Whole grain (oz-eq)[l]	1.5-2.5	1.3 (0.1)	0.8	1.1	1.6	71 (2.4)	4 (4.0)	0.6 (0.1)	0.2	0.5	0.8	97 (1.6)	1 (0.7)	<.0001
SoFAS (% of total kcal)[m]	<8%	22 (0.1)	21	23	25	-	97 (1.2)	11.5 (0.0)	11	12	14	-	91 (1.0)	<.0001

NOTES:
SE = standard error
a Food group amounts shown in cup-(c) or ounce-equivalents (oz-eq) recommended for children on a 1,000-1,4000 calorie level pattern in the 2015 Dietary Guidelines for Americans.[24]
b Daily amount of food recommended for children on a 1,000-1,4000 calorie level pattern.[24]
c Significance of Wilcoxon signed-rank test of the difference in median intake between children sampled from Hays County and children in NHANES.
d Fruit group includes all fresh, frozen, canned, and dried fruits and fruit juices.
e The 2015 Dietary Guidelines for Americans recommends that half of fruit intake be composed of whole fruit.

f The American Academy of Pediatrics recommends that children 1-6 years consume no more than 6 oz (.75 cups) of fruit juice daily.
g Vegetable group includes all fresh, frozen, canned, and dried vegetables and vegetable juices, including legumes.
h Dairy group includes all milks, including lactose-free products and fortified soymilk (soy beverage), and foods made from milk that retain their calcium content, such as yogurt and cheese. Foods made from milk that have little to no calcium, such as cream cheese, cream, and butter, are not part of the group.
i The American Academy of Pediatrics recommends that children consume no more than 2 cups of milk daily.
j Protein foods group includes meat, poultry, seafood, eggs, processed soy products, and nuts and seeds.
k Grains group includes all foods made from wheat, rice, oats, cornmeal, barley, such as bread, pasta, oatmeal, breakfast cereals, tortillas, and grits.
l The 2015 Dietary Guidelines for Americans recommends that half of total grains consumed be comprised of whole grains.
m SoFAS = solid fats and added sugars.

Table 9. Usual intake distributions of selected food groups for preschoolers age 4-5 years in Hays County (n=64) compared to age-matched children participating in NHANES 2009-2012 (n=741).

Food Group[a]	USDA Food Pattern[b]	Mean (SE)	25th	50th	75th	% with intake below pattern (SE)	% with intake above pattern (SE)	Mean (SE)	25th	50th	75th	% with intake below pattern (SE)	% with intake above pattern (SE)	P[c]
Fruit (c-eq)[d]	1 - 1.5	1.2 (0.2)	0.6	1	1.5	74 (0.6)	13 (3.7)	1.2 (0.2)	0.6	1.0	1.5	49 (1.9)	25 (1.5)	0.3
Fruit, whole (c-eq)[e]	.5-.75	0.8 (0.1)	0.4	0.7	1.1	54 (2.5)	28 (0.3)	0.7 (0.1)	0.3	0.6	0.9	65 (3.0)	14 (1.3)	<.0001
Fruit juice (c-eq)[f]	<0.75	0.3 (0.1)	0.1	0.2	0.5	-	23 (0.9)	0.5 (0.2)	0.1	0.4	0.7	-	76 (1.4)	0.05
Vegetables (c-eq)[g]	1 - 1.5	0.7 (0.1)	0.6	0.7	0.8	100 (3.4)	0 (3.0)	0.7 (0.1)	0.4	0.6	0.8	99 (0.04)	1 (0.02)	1.0
Dairy (c-eq)[h]	2 c	2.7 (0.1)	2.1	2.7	3.3	42 (3.3)	35 (3.8)	2.4 (0.1)	1.5	2.2	2.9	62 (0.2)	15 (2.9)	<.0001
Milk (c-eq)[i]	<2 c	1.5 (0.2)	0.8	1.3	2.1	-	27 (3.6)	1.7 (0.2)	0.7	1.4	2.2	-	69 (0.4)	0.3
Protein foods (oz-eq)[j]	2-4	3.1 (0.2)	2.4	3	3.7	50 (2.6)	6 (2.4)	2.9 (0.2)	1.8	2.7	3.6	59 (3.1)	35 (2.2)	0.6
Grains (oz-eq)[k]	3-5	4.4 (0.2)	3.7	4.4	5	36 (0.2)	26 (3.0)	5.1 (0.2)	4.3	5.3	6.2	18 (1.2)	24 (0.3)	0.9
Whole grains (oz-eq)[l]	1.5-2.5	1.2 (0.1)	0.8	1.1	1.6	88 (3.6)	2 (1.1)	0.7 (0.1)	0.3	0.5	0.9	98.7 (0.02)	1.2 (0.5)	<.0001
SoFAS (% of total kcal)[m]	<8%	23 (0.0)	21	23	25	-	100 (0.05)	11.5 (0.0)	11	12	14	-	8 (0.3)	<.0001

NOTES:
SE = standard error
a Food group amounts shown in cup-(c) or ounce-equivalents (oz-eq) recommended for children on a 1,000-1,4000 calorie level pattern in the 2015 Dietary Guidelines for Americans.[24]
b Daily amount of food recommended for children on a 1,200-1,6000 calorie level pattern.[24]
c Significance of Wilcoxon signed-rank test of the difference in median intake between children sampled from Hays County and children in NHANES.

d Fruit group includes all fresh, frozen, canned, and dried fruits and fruit juices.
e The 2015 Dietary Guidelines for Americans recommends that half of fruit intake be composed of whole fruit.
f The American Academy of Pediatrics recommends that children 1-6 years consume no more than 6 oz (.75 cups) of fruit juice daily.
g Vegetable group includes all fresh, frozen, canned, and dried vegetables and vegetable juices, including legumes.
h Dairy group includes all milks, including lactose-free products and fortified soymilk (soy beverage), and foods made from milk that retain their calcium content, such as yogurt and cheese. Foods made from milk that have little to no calcium, such as cream cheese, cream, and butter, are not part of the group.
i The American Academy of Pediatrics recommends that children consume no more than 2 cups of milk daily.
j Protein foods group includes meat, poultry, seafood, eggs, processed soy products, and nuts and seeds.
k Grains group includes all foods made from wheat, rice, oats, cornmeal, barley, such as bread, pasta, oatmeal, breakfast cereals, tortillas, and grits.
l The 2015 Dietary Guidelines for Americans recommends that half of total grains consumed be comprised of whole grains.
m SoFAS = solid fats and added sugars.

Macronutrients

The median calorie intake for subjects in Hays County, Texas was not significantly different than national intake. However, compared to the national sample, a larger proportion of children ages 2-3 years in Hays County consumed calories in excess of recommendations, with 50% consuming more than 1400 calories daily compared to 16% of children ages 2-3 years nationally. Median calorie intake was likewise not significantly different between regional and national samples of children ages 4-5 years. Of note, a large proportion of children ages 4-5 years consumed fewer calories than the DRI, with 21% consuming less than 1200 calories/day. Further analysis revealed that the majority (71%) of these children were female, and most were 4 years of age (71%). The main food sources of calories for children in the Hays County sample were grain products (28%), milk and milk products (20%), fruit (14%), and meat, poultry, and fish (14%). The main food sources of calories for children in NHANES were grain products (38%), milk and milk products (21%), and meat, poultry, and fish (13%).

Children in the regional sample consumed significantly more fiber than children in the national sample. The differences were particularly notable for children ages 2-3 years, with a median intake of 3g/day higher than the national median ($p<0.0001$), with almost 80% of children in Hays County meeting the DRI for fiber compared to 17% nationally. Although the median intake of fiber among younger and older preschoolers was the same (13g/day), fiber recommendations for children ages 4-5 years are higher and 79% of children ages 4-5 years in Hays County did not consume the recommended amount of fiber. The main food sources of fiber for children in Hays County were grain products (33%), fruits (30%), and vegetables (20%). The main sources of fiber for children nationally were grain products (47%), fruits (21%), and vegetables (20%).

Intake of protein among children in both the regional and national samples was well in excess of the DRIs. Notably, children ages 2-3 years in Hays County consumed significantly more protein than children in NHANES, with a median intake of 65 g/day compared to 49 g/day, respectively ($p<0.0001$). The main three food sources of protein for children in Hays County were the same as for children nationally, and each provided between 28-31% of the daily protein: milk and milk products, meat products, and grains.

Minerals

The majority of children ages 2-3 years in both samples met the DRI for calcium; however, almost half of children ages 4-5 years in both the regional and national samples did not. With respect to iron, 95% or more of children ages 2-3 years in both samples and children ages 4-5 in the national sample met the DRI. However, in the regional sample, almost half of children ages 4-5 (43%) did not consume adequate amounts of iron.

For both samples, consumption of potassium was low and consumption of sodium was excessive. Among children ages 2-3 years, a large proportion of children consumed zinc in excess of the UL, with 82% of children regionally and 64% of children nationally consuming more than 2.5 mg/day. The main food sources of zinc for children in Hays County were meat, poultry, and fish (30%), milk and milk products (28%), and grain products (18%). The main food sources of zinc for children nationally were grain products (38%), milk and milk products (29%), and meat, poultry, and fish (20%).

Vitamins

Intake of vitamins E and D were well below the DRI for children regionally and nationally. Intake of pre-formed vitamin A was significantly higher for children regionally compared to children nationally, with 66% of children ages 2-3 years and 23% of children ages 4-5 years consuming pre-formed vitamin A in excess of the UL. The main sources of retinol in the diets of children in Hays County were milk and milk products (69%) and grain products (13%). Nationally, grains comprise a significantly larger proportion of retinols (35%) than in Hays County, however milk and milk products are still the predominant source (53%).

Food Groups

The usual dietary intake of several food groups was significantly different between children in the regional and national samples. Specifically, children in Hays County consumed more whole fruit ($p < 0.0001$) and whole grains ($p < 0.0001$), and less fruit juice ($p < 0.0001$) than children nationally. Children in the regional sample consumed more calories from saturated fats and added sugars (SOFAS) than were consumed nationally, with a median intake of 23% of daily calories from SOFAS in Hays County compared to 12% nationally ($p < 0.0001$). Dairy intake among children ages 4-5 years in the regional sample was greater than national intake, with a median intake of 2.7 oz./day compared to 2.2 oz./day, respectively ($p < 0.0001$). Overall, intakes of fruits, vegetables, and whole grains were below recommendations for the majority of children regionally and nationally.

Association of Dietary Patterns and Childcare Centers

The usual dietary intake of children in the NHANES sample who attended a childcare center on at least one of their recall days (i.e. children who consumed at least one meal at a childcare center) compared to those who did not are provided in Tables 10 and 11. Attending a childcare center on at least one of the days studied was positively associated with the probability of consuming any total fruit, whole fruit, and milk and was positively correlated with the amount of whole grains consumed.

Table 10. Usual dietary intake among children ages 2-3 years who consumed a meal at child care (n=140) compared those who did not (n=845), adjusted for race, household income, gender, and age: NHANES 2009-2012.

	Children who did not consume a meal at childcare[a]	Children who consumed a meal at childcare[b]	USDA[c] food pattern[d]	% of non-childcare center children who consumed less than recommendations[a]	% of childcare center children who consumed less than recommendations[b]	P[c]	
	←mean±standard error→			←% ±standard error→		Probability	Amount
Fruit (c-eq)	1.3 ± 0.02	1.4 ± 0.06	1 - 1.5	43 ± 0.7	33 ± 1.4	0.04	0.4
Fruit, whole (c-eq)	0.7 ± 0.03	0.9 ± 0.02	.5 - .75	44 ± 1.8	29 ± 0.7	0.01	0.3
Fruit juice (c-eq)	0.6 ± 0.04	0.6 ± 0.05	< .75	70 ± 4.5	67 ± 5.1	0.2	0.6
Vegetables (c-eq)	0.6 ± 0.02	0.7 ± 0.03	1 - 1.5	91 ± 2.9	86 ± 3.7	0.01	0.2
Dairy (c-eq)	2.4 ± 0.05	2.7 ± 0.06	2	42 ± 0.9	33 ± 0.7	-	0.4
Milk (c-eq)	1.8 ± 0.05	2.0 ± 0.06	<2	67 ± 1.9	58 ± 1.8	0.04	0.1
Protein foods (oz-eq)	2.7 ± 0.09	2.7 ± 0.10	2-4	33 ± 1.1	32 ± 1.2	-	0.7
Grains (oz-eq)	4.4 ± 0.03	4.7 ± 0.04	3-5	16 ± 0.1	11 ± 0.1	-	0.5
Whole grains (oz-eq)	2.4 ± 0.02	2.7 ± 0.03	1.5-2.5	42 ± 0.3	33 ± 0.4	0.5	0.03
SoFAS (% of total kcal)	11 ± 0.1	11 ± 0.1	<8%	8 ± 0.4	7 ± 02	-	0.4

NOTES:
SoFAS = Solid fats and added sugars.
a Children who consumed at least one meal at a childcare center on at least one of the recall days.
b Children who did not consume a meal at a childcare center on at least one of the recall days.
c Signifcance of consuming a meal at a childcare center was test for both the probability and amount of consumption with the NCI method.

Table 11. Usual dietary intake among children ages 4-5 years who consumed a meal at child care (n=282) compared those who did not (n=459), adjusted for race, household income, gender, and age: NHANES 2009-2012.

	Children who did not consume a meal at childcare[a]	Children who consumed a meal at childcare[b]	USDA[c] food pattern[d]	% of non-childcare center children who consumed less than recommendations[a]	% of childcare center children who consumed less than recommendations[b]	P[c]	
	←mean±standard error→			←% ±standard error→		Probability	Amount
Fruit (c-eq)	1.2 ± 0.02	1.2 ± 0.06	1.5-2	75 ± 1.3	72 ± 3.5	0.04	0.4
Fruit, whole (c-eq)	0.7 ± 0.03	0.7 ± 0.02	.75-1 c	47 ± 2.1	40 ± 1.1	0.01	0.3
Fruit juice (c-eq)	0.5 ± 0.04	0.6 ± 0.05	<0.75	78 ± 6.0	73 ± 6.4	0.2	0.6
Vegetables (c-eq)	0.6 ± 0.02	0.7 ± 0.03	1.5-2	89 ± 2.7	84 ± 3.5	0.01	0.2
Dairy (c-eq)	2.3 ± 0.05	2.5 ± 0.06	2.5	65 ± 1.4	58 ± 1.4	-	0.4
Milk (c-eq)	1.6 ± 0.05	1.7 ± 0.06	<2	75 ± 2.4	67 ± 2.3	0.04	0.1
Protein foods (oz-eq)	5.4 ± 0.03	5.6 ± 0.04	4-5 oz	20 ± 0.1	15 ± 0.1	-	0.7
Grains (oz-eq)	2.3 ± 0.02	2.5 ± 0.03	2-3 oz	47 ± 0.4	39 ± 0.5	-	0.5
Whole grains (oz-eq)	3.1 ± 0.09	3.2 ± 0.10	3-5 oz	56 ± 1.6	51 ± 1.6	0.5	0.03
SoFAS (% of total kcal)	12 ± 0.3	12 ± 0.2	<8%	9 ± 0.4	7 ± 0.2	-	0.4

NOTES:
SoFAS = Solid fats and added sugars.
a Children who consumed at least one meal at a childcare center on at least one of the recall days.
b Children who did not consume a meal at a childcare center on at least one of the recall days.
c Signifcance of consuming a meal at a childcare center was test for both the probability and amount of consumption with the NCI method.

V. DISCUSSION

This is the first study to use the NCI method to determine usual dietary intake for regional sample of preschool-aged children. By using the NCI method to estimate usual dietary intake, we were able to go beyond simple determination of mean intake, creating reliable and statistically robust estimates of the proportion of children ages 2-5 years whose usual dietary intakes are below, meeting, or exceeding key nutrient and food group recommendations. We also used the NCI method to create age-matched estimations of national dietary intake, which allowed us to examine regional findings within the context of a nationally representative sample. The results of this research will inform a community-based childhood obesity prevention intervention, which can be tailored to the specific dietary concerns unique to this community.

Given the elevated rates of childhood overweight and obesity in Hays County, we expected to see obesogenic dietary patterns among the children in our sample.[66] Indeed, children had low dietary intakes of produce and whole grains and excessive intakes of calories, solid fats, and added sugars. The vast majority of children in the Hays County sample did not consume the recommended amounts of fruits and vegetables, with fewer than 5% of children consuming the recommended amount of vegetables. While intake of fruit was closer to recommendations, only one-quarter of children ages 4-5 years consumed fruit in the recommended amounts. Implementing strategies to increase the consumption of fruits and vegetables among children in Hays County has significant potential to mitigate the risk of overweight and obesity while promoting growth and development in several ways. First, consuming fruits and vegetables, which have low energy density, can support the maintenance of a healthy body weight by displacing energy-dense foods.[24] Moreover, increasing produce intake among children in Hays County could also increase the usual dietary intake of several important nutrients that were found to be lacking in the diets. For example, fruits and vegetables are an excellent source of fiber, which was under-consumed in the majority of children ages 4-5 years in the regional sample. Intake of fiber among young children has been associated with decreased risk of overweight or obesity in later childhood and adulthood.[67] Another strategy to increase fiber intake could be to promote intake of whole grains. The 2015 Dietary Guidelines for Americans recommends that half of total grain intake be comprised of whole grains, however only a fourth of grains consumed by children in this regional sample were whole grains.

Although there were no significant differences in median calorie intake between regional and national samples, a larger proportion of children ages 2-3 years in Hays County consumed calories in excess of the DRI compared to children nationally. Likewise, three-quarters of children ages 4-5 years consumed more calories than recommended. Notably, a substantial subset of children ages 4-5 years (composed mostly of females and children who were 4 years old) consumed fewer calories than were recommended for their age group. Given that required energy intake is highly dependent on factors that were not captured in this study, such as physical activity levels and body mass, it cannot be said with certainty that all of the children whose intakes were above or below the recommended calorie intake levels actually exceeded or fell short of their required energy intakes. However, future nutrition assessments of young children Hays County should more fully explore the possibility of undernutrition in this community and obesity prevention interventions should include education for caregivers on the energy requirements of young children and dietary strategies to ensure children do not consume excessive calories.

One significant contributor of calories in the diets of children in the regional population were calories from solid fats and added sugars (SoFAS). The 2015 Dietary Guidelines for Americans recommends that young children consume fewer than 8% of their daily calories from SoFAS; however, more than 97% of children in the Hays County sample exceeded this recommendation.[68] The recommended intake of SoFAS is set at a lower level for young children compared to adults because children's nutrient needs are higher relative to their energy requirements. Specifically, after consuming enough of each food group to meet essential nutrient requirements, children have only 100 to 170 calories per day remaining.[68] Therefore, it is difficult to accommodate nutrient-poor and energy-dense foods, such as foods high in SoFAS, while remaining within recommended calorie limits.[22]

Another significant contributor of excessive calories in diets of children in the regional population was excessive intake of protein. Although the mean intake of protein was much greater than the DRI across all age groups in both regional and national samples, children ages 2-3 years in Hays County had a mean intake of protein which was five times the DRI and 30% greater the protein intake of age-matched children nationally. Although elevated protein intake in adults has been associated with increased satiety and energy expenditure and purportedly effective in maintaining a healthy body weight, the same may not hold true for young children.[69] Indeed, strong correlations have been observed between high protein intake in early childhood with higher BMI values and with increased body fat mass.[70,71] It has been hypothesized that excessive protein intake in early childhood may be linked to obesity later in life, perhaps mediated through hormonal responses, such as an enhanced secretion of insulin-like growth factor-1 (IGF-1), which can accelerate growth and lipogenesis.[72]

With few exceptions, the usual micronutrient intakes of children in the regional sample were similar to those of children in the national sample. Specifically, both children in Hays County and children in the NHANES sample had low intakes of vitamin D, calcium, vitamin E, and potassium and excessive intakes of sodium, pre-formed vitamin A, and zinc. There are, however ongoing debates regarding the accuracy of the DRIs set for vitamin E, vitamin A, and zinc. For example, although the majority of Americans consume less than the recommended amount of vitamin E, symptoms of vitamin E deficiency are rare.[73] Likewise, due to the ubiquitous over-consumption of zinc and pre-formed vitamin A, coupled with the scarcity of reported harmful side effects, there have been calls to reexamine and perhaps relax the UL for zinc across all age groups, and for pre-formed vitamin A for all age groups, with the exception of pregnant and breastfeeding women.[23] In summary, given the more immediate concerns associated with deficiencies in other nutrients such as calcium, vitamin D, and iron, and the lack of adverse symptoms related to the under- or over-consumption of zinc, vitamin E, and pre-formed vitamin A among children, it is sensible to focus intervention efforts on nutrients and foods which offer a more compelling cost-benefit proposition.

One of these vital nutrients is vitamin D, which is under consumed by the majority of Americans. Vitamin D is a prohormone that plays a key role in the regulation of calcium and phosphorus metabolism and in the maintenance of bone health.[74] The association between vitamin D deficiency and bone disorders such as rickets, osteomalacia, low bone mineral density, and osteoporosis has been well-established.[74] More recently, vitamin D status has been associated with non-skeletal diseases, such as type 1 diabetes, multiple sclerosis, Crohn's disease, and rheumatoid arthritis in observational studies.[75] Vitamin D deficiency has also been linked with common childhood diseases such as acute respiratory infection, asthma, atopic dermatitis, food allergy.[75,76] However, taken together, the literature linking deficient intake of vitamin D to adverse health outcomes other than rickets or osteomalacia is discordant.

The major source of vitamin D for children is the endogenous production of vitamin D in the skin as a result of sun exposure; however, the ability of children to synthesize sufficient amounts of vitamin D can be limited by factors such as dark skin pigmentation, northern latitudes, air pollution, sunscreen, or limited time spent outside.[75] As few foods naturally contain significant amounts of vitamin D, fortified foods provide most of the vitamin D in the American diet.[77] Indeed, the major food source of vitamin D for children in Hays County were dairy products, such as milk and yogurt, which are commonly fortified with 100 IU/cup.[78] Other commonly fortified foods include breakfast cereals, orange juice, and margarine. To promote increased consumption of vitamin D among children in Hays County, children and their caregivers should be encouraged to consume foods naturally high in vitamin D (e.g. salmon and mushrooms), and to choose dairy brands that fortify their products with vitamin D.

Although intake of calcium for children ages 2-3 years in both the regional and national sample met the DRI, almost half of children ages 4-5 years in both samples consumed inadequate amounts of calcium. Calcium is an essential mineral, required for vascular contraction and dilation, muscle function, nerve transmission, hormonal secretion, and intracellular signaling.[78] Ninety-nine percent of the body's calcium supply is stored in the bones, where it continuously resorbed and deposited. The balance between the resorption and deposition of calcium changes throughout the lifespan. During childhood, a period of development and growth, the deposition of calcium (i.e. bone formation) exceeds calcium resorption. This is a critical period for the formation of bones, as the ability of the body to increase bone density (i.e. deposit more calcium onto bones) decreases as one enters adulthood. As individuals age, the rate of bone resorption exceeds deposition, causing loss of bone mineral density and increasing the risk of developing osteoporosis. Therefore, deficient intake of calcium during childhood can increase the risk of low bone mineral density and osteoporosis later in life. The main food source of calcium for children in Hays County were dairy products such as milk, yogurt, and cheese. As the majority of children in Hays County did not consume inadequate amounts of dairy products, interventions designed to increase calcium consumption should focus on encouraging intake of dairy and other natural food sources, such as bok choy, broccoli, and kale. Plant sources of calcium offer the additional benefits of increased calcium bioavailability and lower caloric density compared to dairy.[78]

Potassium and sodium are essential dietary minerals which play vital roles as electrolytes in the body. Potassium is the principal intercellular cation and sodium is the primary principal extracellular cation.[79] The concentrations of potassium and sodium inside and outside of cells create the electrochemical gradient vital to heart function, nerve impulse transmission, and muscle contraction. In the typical American diet, intake of sodium (primarily in the form of sodium chloride) is approximately three times higher than the daily intake of potassium, while the ratio of sodium to potassium consumption is reversed in primitive cultures, with 1 mole of sodium consumed for every 7 moles of potassium.[80] The increase of sodium consumption in Western cultures has occurred while potassium intakes have decreased. Importantly, the relative deficiency of dietary potassium may play a role in the pathology of some chronic diseases that are typically attributed primarily to excessive sodium intake, such as hypertension. For the majority Americans, intake of potassium is inadequate relative to intake of sodium, and sodium intake is well above the UL. The primary sources of sodium in the American diet are processed foods and meals consumed in restaurants. Potassium is found in fruits and vegetables, which are under consumed by the majority of Americans. Not surprisingly, the diets of children in the Hays County included sodium well in excess of the UL, and the vast majority of the sample (over 96%) did not consume the recommended amount of potassium. Strategies to decrease sodium intake should target consumption of processed foods and meals eaten in restaurants. Potassium intake would increase with increased consumption of fruits and vegetables.

Iron intake in the regional and national subgroups were not similar. While the vast majority of children ages 2-3 years in both the regional and national samples and children ages 4-5 in the national sample met the DRI for iron, almost half of children ages 4-5 (43%) in the regional sample did not consume adequate amounts of iron. Inadequate intake of iron among infants in this community was reported in an earlier study, with 100% of infants ages 6 – 11.9 months consuming iron in amounts below the RDA compared to just 25% nationally.[43] Alarmingly, iron deficiency in children has been strongly linked to poor cognitive development, lower intelligence quotients, poor school achievement, and behavior problems. Although iron from animal sources (i.e. heme iron) comprises only 10-15% of total iron in the American diet, its bioavailability is so much higher than non-heme iron that it can provide up to a third of the total iron absorbed from the diet. However, as children in the regional sample already consumed excessive amounts of protein-rich foods, nutritional interventions in this community should focus on encouraging instead iron consumption by employing strategies to increase the bioavailability of iron found in plant sources, such pairing iron-rich produce with vitamin C and other organic acids.

Childcare Center Analysis

As previously mentioned, rates of childhood overweight and obesity in Hays County are higher than those nationally.[5] Indeed, of the children for which height and weight data were provided, 39% were overweight or obese, significantly higher than the national obesity rate of 22.8% for children ages 2-5 years. We were therefore not surprised to see the obesogenic dietary patterns among the children in the regional sample, such as intake of excessive calories and SoFAs, and inadequate intakes of fruits, vegetables, and whole grains.[66] We were surprised, however, when the data revealed that the median dietary intakes of some healthful foods and nutrients, such as fiber, whole fruits, and whole grains, were significantly greater than those of the national sample, and that the median intake of fruit juice, which is generally thought to promote weight gain among children, was significantly lower.[81] We considered the possibility that the regional sample, which, due to our sampling methods, was comprised entirely of children who attended a childcare center, may have consumed more of these healthful foods while they were at their childcare centers. This led to our third research objective, which was to investigate the potential association that consuming meals at a childcare center may have with the usual dietary intake of key food groups and nutrients. We hypothesized that the diets of children participating in NHANES who consumed at least meal at a childcare center on at least one recall day would have usual dietary intake distributions that would be more similar to the regional sample.

After controlling for race, age, gender, and household income, we found that among children included in the NHANES dataset, consuming at least one meal at a childcare center was significantly associated with the probability of consuming any fruit, whole fruit, and milk on the recall day. We also found that consuming a meal at a childcare center was positively correlated with the total amount of whole grains consumed. The beneficial effects childcare centers seem to have on the usual dietary intake of preschoolers could be due, at least in part, to the participation of some centers in the Child and Adult Care Food Program (CACFP), which sets minimum amounts of fruits and vegetables that must be served at meals and snacks served in childcare centers.[82] However, as CACFP participation is not ubiquitous among childcare centers, and the preponderance of currently available research reports unhealthful dietary practices in childcare centers (e.g. excessive reliance on refined, salty grain snacks and fruit juice),[27–29] more research comparing the diet quality of foods offered in childcare centers and in the home should be undertaken.

Strengths and Limitations

Limitations of this study include the use of convenience sampling to determine usual dietary intake for preschoolers in Hays County, which resulted in a sample of children who attend childcare. Additionally, while collecting 24-hour recalls for the regional analysis, we found that parents often did not know what their child consumed while at childcare center, forcing us to call the childcare center's teacher and inquire about the food served on that day. While this protocol is typical of that used in other childcare studies,[23] it is possible that results obtained in this manner were less accurate than if information was collected from parents. Strengths of this study included the use of 24-hour recalls and the NCI method, which are the gold-standard for determination of usual dietary intake, allowing us to make precise estimates of the proportion of children in our sample who over- or under-consumed key foods and nutrients. Another benefit to using these tools, which are used for national dietary surveillance, is that they allow for comparison of regional samples to national dietary intakes. Using the NCI method macros to association of childcare centers with dietary intake also allowed us to control for demographic covariates and estimate standard errors appropriate for the clustered design of NHANES dietary data.

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