ABSTRACT

Title of Thesis: ASSOCIATIONS AMONG FOOD INSECURITY, DIETARY SODIUM AND POTASSIUM INTAKE LEVELS, AND HYPERTENSION: A CROSS-SECTIONAL STUDY BASED ON NHANES 2007-2010 DATA

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Background: Food insecure persons may have diet patterns that include excessive sodium and inadequate potassium. These patterns contribute to greater risks of hypertension. Objective: Evaluate levels of association among food insecurity, dietary sodium and potassium intake levels and hypertension among NHANES 2007-2010 adult participants. Methods: Compared mean usual sodium and potassium intakes and mean usual sodium-potassium ratios for food secure and food insecure subpopulations. Developed regression models to predict intake levels and hypertension risk. Results: Mean usual sodium intake is not significantly different for food secure and food insecure adults. Mean usual potassium intake is significantly lower and mean usual sodium-potassium ratio is significantly higher for the food insecure. Controlling for age and household size, food insecure adults are 43% more likely to be hypertensive than food secure adults. Conclusion: Public health measures to decrease cardiovascular disease risk should include interventions designed to specifically target populations with food insecurity.
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ASSOCIATIONS AMONG FOOD INSECURITY, DIETARY SODIUM AND POTASSIUM INTAKE LEVELS, AND HYPERTENSION: A CROSS-SECTIONAL STUDY BASED ON NHANES 2007-2010 DATA

by

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LIST OF ABBREVIATIONS

BMI – body mass index

DBP – diastolic blood pressure

DR1DRSTZ – Dietary recall day one status variable

FSDAD – Adult food security variable

HFSSM – Household Food Security Survey Module

IRB – Institutional Review Board

NCHS – National Center for Health Statistics

NHANES – National Health and Nutrition Examination Survey

NHLBI – National Heart, Lung, and Blood Institute

PSU – primary sampling unit

SBP - systolic blood pressure

SNAP – Supplemental Nutrition Assistance Program

USDA – United States Department of Agriculture

USFSSM – United States Food Security Survey Module

USHHS – United States Department of Health and Human Services

WIC – Women, Infants and Children (a government supplemental nutrition program)

Chapter 1: INTRODUCTION

US residents who are food insecure, or who lack access to sufficient food to live active, healthy lives,[1] are likely to have unhealthy dietary intake which may partially account for their higher rates of certain chronic diseases such as hypertension, dyslipidemia and diabetes.[2] The prevalence of household food insecurity has increased from about one in nine households during 2005-2007 to more than one in seven households during 2008-2012.[1] Thus, the magnitude of the issue is significant, persistent and recently increased.

Chronic diseases that are caused and/or exacerbated by poor nutrition account for a very large part of the morbidity, disability, and mortality burden of the US population.[3] Hypertension, or consistently having systolic blood pressure (SBP) greater than or equal to 140 millimeters of mercury (mmHg) or diastolic blood pressure (DBP) greater than or equal to 90 mmHg without anti-hypertensive treatment,[4] is an example of a disease that is influenced by nutrient intake.[5] Since hypertension is a risk factor for other leading causes of death in the US (e.g., cardiovascular, cerebrovascular, renal diseases),[4, 6] an examination of the distribution and determinants of hypertension among the food insecure population as compared with the food secure population can have wide-ranging public health consequences. The overall prevalence of hypertension among US adults has remained at about 30% during 1998-2008,[7] despite development of evidence-based guidelines for hypertension prevention and management, suggesting that more work is needed in primary prevention of hypertension through improved nutrition.

Food insecurity has been shown to have a positive association with hypertension (by self-report and also by examination evidence) using a US nationally representative sample of adults even after taking age, gender, race, education level and income into account.[2] Hypertension is also positively associated with higher sodium and lower potassium intake as well as other factors including genetic background, body mass index (BMI), physical activity and psychosocial influences such as stress.[5] To explore a hypothesized pathway between food insecurity and hypertension, this thesis examines levels of association between food insecurity and nutrient intake levels, between nutrient intake levels and hypertension status, and between food insecurity and hypertension status.

Previous studies with relevance for this investigation are few. To date, there are only two published analyses of nutrient intake levels in US food insecure populations,[8.9] neither of which examined sodium or potassium. Thus, an examination of mean nutrient (sodium and potassium) intake levels among the US population that experiences food insecurity is warranted.

Chapter 2: RESEARCH QUESTIONS AND SPECIFIC AIMS

The overall goal of this thesis is to investigate the influence of sodium and potassium intake levels on the relationship between food insecurity and hypertension. “Food secure” is defined as having the resources to access sufficient food for a healthy, active life; "food insecure” is defined as lacking these resources.[1] The National Health and Nutrition Examination Survey (NHANES), a nationally representative sample of the civilian, non-institutionalized US population, provided the data for this analysis.

Primary prevention to change dietary intake is a worthwhile investment in light of rising healthcare costs; these costs become ever more salient as we consider the aging US population. Studies of this type, which can justify investment in a more nutritious food supply and interventions to affect health behavior (such as cooking classes), are relatively low cost when compared with medical treatment of chronic disease.

This study’s aims are as follows:

1) Compare sodium and potassium intake levels of “food secure” non-pregnant NHANES 2007-2010 adult participants with sodium and potassium intake levels of “food insecure” adults.

2) Assess whether sodium-potassium ratios for non-pregnant NHANES 2007-2010 adult participants vary by food security status.

3) Assess whether sodium intake, potassium intake, and sodium-potassium ratios vary by age, race/ethnicity, education level, poverty, acculturation, marital status, household size, and food assistance program participation among non-pregnant NHANES 2007-2010 adult participants.

4) Assess whether hypertension prevalence for non-pregnant NHANES 2007-2010 adult participants varies by food security status and whether nutrient intake level varies by hypertension status.

The associated hypotheses are:

1)

   a. H_{01a}: The mean usual sodium intake level of food insecure adult non-pregnant NHANES 2007-2010 participants is not significantly different from the mean usual sodium intake level of food secure adult non-pregnant NHANES 2007-2010 participants.

      $H_{a1a:}$ The mean usual sodium intake level of food insecure adult non-pregnant NHANES 2007-2010 participants is significantly different than the mean usual sodium intake level of food secure adult non-pregnant NHANES 2007-2010 participants.

   b. H_{01b}: The mean usual potassium intake level of food insecure adult non-pregnant NHANES 2007-2010 participants is not significantly different from the mean usual potassium intake level of food secure adult non-pregnant NHANES 2007-2010 participants.

      $H_{a1b:}$ The mean usual potassium intake level of food insecure adult non-pregnant NHANES 2007-2010 participants is significantly different than the mean usual potassium intake level of food secure adult non-pregnant NHANES 2007-2010 participants.

2) H_{02}: The mean calculated sodium-potassium ratio of food insecure adult non-pregnant NHANES 2007-2010 participants is not significantly different from the

mean calculated sodium-potassium ratio of food secure adult non-pregnant NHANES 2007-2010 participants.

H_{a2}: The mean calculated sodium-potassium ratio of food insecure adult non-pregnant NHANES 2007-2010 participants is significantly different than the mean calculated sodium-potassium ratio of food secure adult non-pregnant NHANES 2007-2010 participants.

3) H_{03}: The mean usual sodium and potassium intake levels and mean calculated sodium-potassium ratio of adult non-pregnant NHANES 2007-2010 participants is not significantly different for subgroups differentiated by age, race/ethnicity, education level, poverty, acculturation, marital status, household size, and food assistance program participation.

H_{a3}: The mean usual sodium and potassium intake levels and mean calculated sodium-potassium ratio of adult non-pregnant NHANES 2007-2010 participants is significantly different for subgroups differentiated by age, race/ethnicity, education level, poverty, acculturation, marital status, household size, and food assistance program participation.

4)

a. H_{04a}: Hypertension prevalence for non-pregnant NHANES 2007-2010 adult participants does not vary significantly by food security status.

H_{a4a}: Hypertension prevalence for non-pregnant NHANES 2007-2010 adult participants varies significantly by food security status.

b. H_{04b}: Sodium and potassium intake levels for non-pregnant NHANES 2007-2010 adult participants do not vary significantly by hypertension status.

   H_{a1b}: Sodium and potassium intake levels for non-pregnant NHANES 2007-2010 adult participants vary significantly by hypertension status.

Chapter 3: BACKGROUND: REVIEW OF THE LITERATURE

a) Importance of the study

Food insecurity affects approximately 15% of the US population.[1] Current economic conditions portend difficulty reaching the Healthy People 2020 objective of 6%.[10] Since food insecurity is more common among African-American and Hispanic households, individuals living in poverty, and single head of household families,[11] it may contribute to health disparities experienced by these groups.

Individuals with fewer resources for their food supplies are limited in their choices, and the content of their diets likely suffers as a result. Residents dependent on food pantries likely have a higher proportion of foods processed with sodium-based preservatives in their diets. Food insecure adults have been shown to consume fewer fruit and vegetable servings (potassium-rich food sources) per week when compared with their food secure counterparts.[2] These factors may contribute to higher sodium and lower potassium intake for food insecure residents when compared with the general population.

Decreasing dietary sodium and increasing potassium intake levels are key factors for blood pressure control and the consequent prevention of heart and kidney disease as well as stroke.[5] In addition to sodium and potassium's direct effects on the vascular system, the interactions of these minerals with each other are important. Dietary potassium has been demonstrated to reduce sodium sensitivity. Kidney function evolved to retain sodium and excrete potassium; this was advantageous for early humans whose diets were low in sodium and high in potassium. It is disadvantageous in the context of modern high-sodium, low-potassium diets. A low-potassium diet actually increases sodium retention by several direct mechanisms and a high-sodium diet increases potassium excretion, especially for those with existent hypertension. Thus, the ratio of sodium to potassium intake is probably more important than the individual levels of either mineral, and this conclusion is supported by epidemiologic as well as laboratory-based evidence.[12, 13] Analyzing these dietary elements may elucidate the higher levels of hypertension risk observed among food insecure populations. Seligman et al., for example, found food insecure persons to have a 20% increased risk of self-reported hypertension and a 21% increased risk of exam evidence of hypertension.[2] High levels of sodium intake have also been associated with gastro-esophageal cancer and osteoporosis,[14] disease states that are beyond the scope of this thesis.

The percentage of the population meeting the government's sodium intake goal (13 percent in 2004) has shown no significant change since 1998.[15] The Healthy People 2020 sodium consumption objective is that the mean total daily sodium intake will decrease from 3640 mg in 2003-2006 to 2300 mg by 2020 for persons at least 2 years of age.[16] The most recent data from NHANES suggests that there has been a slight decrease in mean total daily sodium intake (3586 mg mean total daily sodium intake during 2007-2010).[17]

Healthy People 2020 does not have an objective specifically tied to potassium intake; however Healthy People 2020 Nutrition and Weight Status objectives 14 and 15, which aim to increase fruit and vegetable consumption respectively,[10] address that concern. This connection is highlighted in the 2010 Dietary Guidelines: "Choose foods that provide more potassium…which are nutrients of concern in American diets. These foods include vegetables, fruits…".[17] Although the Institute of Medicine recommends an average daily dietary intake of 4700 mg, the mean usual intake by the US population (older than 2 years) has remained stable since the mid1990s at about 2640 mg daily. In addition to improving blood pressure, higher potassium intake may reduce osteoporosis and kidney stones.[18]

Between 1998 and 2008 the age-adjusted prevalence of hypertension for people over 18 increased from 25 to 30%. The non-Hispanic black population had the highest prevalence: 42%.[10] The US total cost associated with hypertension in 2010 was estimated to be $76.6 billion.[19] The Healthy People 2020 objective is to reduce the prevalence from 29.9 percent (2005-08 data) to 26.9 percent.[21] An understanding of groups likely to be at particular risk of hypertension (non-Hispanic blacks, the food insecure) and the mediating factors in the disease progression is necessary before effective interventions can be designed. An examination of dietary intake and its determinants (e.g. access to food, nutrition and cooking knowledge) is an important component of the assessment and planning process.

b) Existing knowledge

Studies of associations between food security status and disease prevalence have tended to be cross-sectional and thus no causal relations can be established. Nevertheless, with the generally higher levels of disease burden among the food insecure population, examination of potential component causes of these diseases in these specific populations is a valuable contribution to public health.

The literature on nutrient intake levels in food insecure populations is limited. Bhattacharya et al.[21] found that food insecurity tends to be predictive of poor nutritional status in general. Dixon et al.[8] focused on serum concentrations of nutrients and found significantly lower levels of a number of vitamins and minerals among food insecure subjects in a US nationally representative sample (NHANES 1988-1994). Rose et al.[9] analyzed 24-hour dietary recall data from preschoolers, adult women, and elderly participants in the 1989-1991 Continuing Survey of Food Intake by Individuals, finding that household food insufficiency was associated with significantly low levels of several vitamins and minerals for adults but not preschoolers. However, neither of these studies examined dietary sodium and potassium intake.

c) Gaps in literature

While cross-sectional studies have shown associations of food insecurity with disease states, more focused examinations of the US food insecure population's nutrient intake levels are rare in current literature. To date, there are only two published analyses of nutrient intake levels in US food insecure populations,[8,9] but neither of these examined sodium or potassium. Examining the diet patterns of the US food insecure population adds specificity to the complex of factors doubtless responsible for any causal link between food insecurity and disease state. Isolating the specific elements of the potential pathway will make it possible to test causal hypotheses in prospective studies and to test interventions at later time points.

Chapter 4: RESEARCH DESIGN AND METHODS

a) Overall Study Design and Data Source

This project is a cross-sectional study of the potential associations between food insecurity – the exposure and the outcomes, sodium and potassium intake levels as well as hypertension. The data source, the 2007-2010 NHANES cycles, provides a sample population (n~20,000) comparable to that used in prior relevant studies.[2,8] NHANES uses extensive questionnaires, laboratory data and physical examinations to gather socio-demographic, health, and nutrition information about a nationally representative sample of about 5,000 Americans of all ages every year. Participants are selected by housing unit,[22] therefore households without landline telephones are included. In order to produce reliable statistics for minorities, NHANES oversamples certain populations such as those living in poverty, African-Americans, and Hispanics.[23] This sampling scheme is advantageous for this study because these groups are more likely to be food insecure.[1] Thus, the results described below are highly reliable and generalizable to the US food insecure population. However, the sampling scheme excludes the homeless and this limitation is likely a source of bias when considering questions related to food security.

Since NHANES uses a complex multistage probability sampling design, it was necessary to consider geographic clustering and differential selection probabilities during analysis. The sampling frame includes all 50 states along with the District of Columbia. The sampling design includes the selection of 15 primary sampling units (PSUs), then selection of segments within the PSUs, followed by selection of dwelling units (DUs) or households within the segments, and finally selection of individuals within the DUs or households.[23]

Minority populations are oversampled in NHANES to increase the precision of the estimates of the various demographic and health data. For 2007-2010, these oversampled populations were: Hispanics, non-Hispanic Blacks, non-Hispanic white and others at or below 130 percent of level of the federal poverty level, and non-Hispanic white and others aged 80 years of older. The oversampling of Hispanics during this time period allows reliable estimation about Hispanics as a whole and about the Mexican-American subgroup but not about other Hispanic subgroups.[23]

NHANES is a multipart survey, including an interview, a medical exam (including a 24 hour diet recall) and a second 24 hour diet recall by phone interview.[24] Response rates to the survey parts are relatively high, as shown in Table 1:[25]

Table 1: NHANES 2007-2010 Response Rates

Cycle	**Interviewed Sample**	**Examined Sample**
2007-08	78.4 percent	75.4 percent
2009-10	79.4 percent	77.3 percent

Interview, examination and follow-up phone interview weighting schemes adjust for the amount of nonresponse (i.e., participants who refuse to take part in any particular component of the survey). These weights cannot account for refusal of specific items of any component (item non-response). Since participants can refuse to complete any part of the questionnaires or exam, researchers must examine the amounts and types of missing data carefully as part of the analysis (non-response bias analysis for this study is included in section e of this chapter).[23]

NHANES includes several measures of diet quality. This thesis draws upon the food security section of the family questionnaire and the first 24 hour dietary recall (completed during the medical examination). The 2007-08 and 2009-10 cycles do not include food frequency questionnaires, so this mode of nutritional assessment is not relevant for this time period.

Generally, 24 hour dietary recall data are preferred to food frequency questionnaires because the information collected is not limited by the food choices that were written into the questionnaire and because respondents tend to remember the past 24 hours more accurately than longer time periods. Validation studies have confirmed that 24 hour dietary recalls tend to have less measurement error than food frequency questionnaires.[26]

Although dietary recalls of one or two days' intake cannot be seen as accurate measures of an individual's usual intake, it is valid to use a sample of individuals' 24 dietary hour recalls to estimate the mean population usual intake.[27] Moshfegh et al. have established both a general tendency to underreport dietary intake and a specific tendency of obese individuals to underreport their intake to a greater degree than other individuals.[28] Currently, no standard statistical adjustment exists to control for this known bias. Although the NHANES interview, reporting and analysis methods and results are the most precise available at this point, researchers are compelled to acknowledge underreporting as an unmeasured source of error.[29]

Socio-demographic information was drawn from the family and sample person data files. Information on previous knowledge of hypertension was taken from the

Questionnaire data file. Measured blood pressure information was taken from the Examination data file.

b) Study Population

Since the NHANES public use data files that were accessed for this study include participant identification codes, it was possible to link specific participants to their dietary intake data. The inclusion criteria for this study include:

1) age greater than or equal to 20 years (this is a threshold consistent with NHANES sampling subdomains)[30] and

2) having reliable 24 hour dietary recall data (indicated by the NHANES variable DR1DRSTZ for the first 24 hour dietary recall). This variable has three possible values for adult subjects as follows. 1 = reliable and with all pertinent variables having values, 2 = not reliable or with some pertinent variables missing values, 5 = not done. Of particular importance for this proposal is the fact that participants who report fasting (voluntarily or involuntarily) are considered reliable.[27, 31, 32]

Exclusion criteria include:

3) pregnancy,

4) identifying main racial/ethnic identity as other Hispanic or other race – including multi-racial, (NHANES variable RIDRETH1 variable = 2 or 5, respectively), and

5) having 0 mg potassium intake (because this made the calculation of sodium-potassium intake ratio impossible).

Of the 20,868 NHANES 2007-2010 participants, I excluded those less than twenty years old (n = 8.533), pregnant women (*n* = 125), those without reliable Day 1 24 hour dietary recall data (n = 969), those who identified their main racial/ethnic identity as other Hispanic or other race – including multi-racial (n = 1,859), and finally one participant with 0 mg potassium intake.   The final analytic sample size is 9,325 adults.

c) Descriptions of Variables:

i. Dependent variables

Mean usual sodium and potassium intake levels were drawn from the NHANES "Dietary Interview – Total Nutrient Intake files for First Day". These files are based on data collected from the first 24 hour dietary recall, taken during the medical examination. Although dietary recalls tend to underestimate intake, the NHANES dietary recall protocol has been shown to be valid and reliable.[33, 34] Response rate tends to be favorable; for example, 87% of 2003-04 NHANES participants have two days of reliable and complete intake data.[25]

Hypertension prevalence levels were calculated using data from self-report and examination generated variables. Extracting both of these data sources captures those with a hypertension diagnosis, including those whose measurement at the NHANES examination may not have met the NHLBI/National Center for Health Statistics (NCHS) hypertension definition of a systolic blood pressure $\geq$ 140 mmHg and/or diastolic blood pressure $\geq$ 90 mmHg[4, 35], including those treated with anti-hypertensive medication(s) regardless of blood pressure, as well as those with previously undiagnosed hypertension. The examination measurement of blood pressure follows a careful protocol (according to which participants sit quietly for five minutes prior to the measurements) and involves three separate measurements (using a mercury sphygmomanometer), with a fourth measurement if one of the first three is interrupted or incomplete.[36, 37] The three (or four if applicable) measurements were averaged for diagnosis. The hypertension data was summarized in a categorical variable which coded positive (1) for positive self-report, mean SBP greater than or equal to 140 mmHg and/or mean DBP greater than or equal to 90 mmHg or use of antihypertensive medication(s) and negative (2) if none of those conditions were fulfilled. Description of hypertension status in this manner is consistent with earlier research.[2]

ii. Independent variables

Adult food insecurity (NHANES variable name FSDAD), was determined based on the number of food-insecure conditions reported in response to the USDA Household Food Security Survey Module (USFSSM) which is administered as part of the NHANES questionnaire. This module has been validated and deemed reliable for the US population as a whole and for various household types within the national sample.[38] Three or more positive responses defines food insecurity, with further delineation into low and very low categories possible, as shown below. The USFSSM, which is designed to determine household food security, has eighteen questions: ten oriented toward household adults (see Appendix B) and eight relating to household children. NHANES uses the first set of questions to determine adult food security status and uses the same cutoff points established by the USDA.[1, 39, 40]

Table 2: Adult Food Security Assessment via the US Adult Food Security Survey Module

Number of Positive Responses	Food Security Status
0	Full Food Security
1-2	Marginal Food Security
3-5	Low Food Security
6-10	Very Low Food Security

USDA found that households that are classified as experiencing low food security report multiple food access problems but few instances of reduced food intake. These households tend to cope by reducing the variety of food in their diets. Households with very low food security tend to report reduced intake and disrupted eating patterns. In most of these latter households respondents report going hungry.[11] The measure for this study is adult food security, NHANES variable FSDAD. This analysis reports 2 levels of food security: secure (less than three positive responses to the adult food security module) and insecure (three or more positive responses to the adult food security module) in accordance with the procedure developed by the USDA.[1]

It is important to recognize that the USFSSM asks respondents whether they had any instances of food insecurity during the previous twelve months. As a result, as few as one experienced crisis could move a household out of the full food security category. Research over the past several years has shown however, that food insecurity tends to be recurrent in US households. In 2008, for example, food insecure households experienced insecurity on average in seven of the preceding twelve months.[11] Requiring three positive USFFM responses strengthens the food insecurity definition.

iii. Potential Confounders and Effect Modifiers

Socio-demographic variables that may act as confounders and/or effect modifiers, including poverty income ratio, level of education, acculturation status (including country of birth, citizenship status, length of residence in US, languages spoken), marital status, household size, participation in food assistance programs and race/ethnicity, are all available in the NHANES demographics data sets.[41, 42]

Demographic variables such as age, gender, and race/ethnicity have all shown associations with hypertension.[5] Food insecurity has been associated with race/ethnicity, acculturation,[43] and socio-economic status which may be represented by education level, income-poverty ratio, and participation in food assistance programs.[1] Thus, it is important to have measures of all of these variables.

NHANES measures age in years (at the time of the screening interview), with those older than eighty top coded at eighty.[41, 42] These results were categorized into three age ranges (20-39, 40-59, 60 and over), as advised in the NHANES Analytic Guidelines.[23] Race/ethnicity is based on self-report, with results sorted into five categories: Mexican-American, other Hispanic, non-Hispanic white, non-Hispanic black, and other non-Hispanic.[41, 42] During the 2007-2010 NHANES cycles, all Hispanic persons were oversampled. This allows reliable estimates to be made for Mexican-Americans and all Hispanics, but not for the other Hispanic subgroup.[23] For this study, information on the other Hispanic and other non-Hispanic respondents was deleted. The racial/ethnic categories reported here (Mexican-American, non-Hispanic white, and non-Hispanic black) were chosen due to the ability to make reliable estimates for these groups and the relative homogeneity within these subpopulations (compared with the heterogeneity present in the other Hispanic and other non-Hispanic groups) as well as the sizes of these groups as proportions of the US population.

A composite acculturation variable was created, encompassing NHANES variables on country of birth, citizenship status, and length of time in the US.[41, 42] Sample persons were characterized as: 1) US born or naturalized citizens, 2) non-citizens, having immigrated less than five years ago, or 3) non-citizens, having immigrated more than five years ago. These categories relate to food stamp residency requirements (the first and third subgroups meet the requirements, the second subgroup does not), [44] an indicator pertinent to the topic of diet quality of food insecure individuals. In addition, they seem to correlate with other potential measures of acculturation such as language use, and are consistent with earlier examinations of NHANES data in relation to acculturation status.[45-47]

NHANES measures education level with a 7-category variable.[41, 42] These categories were collapsed into three for this study: less than high school graduate, high school graduate, and some college/college graduate. NHANES measures poverty income ratio with a continuous variable ranging from 0 to 5; these values were divided into three categories for the proposed analysis: 0.00 – 1.30, > 1.30 – 3.5 and greater than 3.5.[41, 42] The value of 1.0 corresponds to the federal poverty line, but the cutoffs listed above are relevant for this thesis because they are taken from the eligibility criteria for the Supplemental Nutrition Assistance Program (SNAP),[23] also known as the food stamp program. NHANES calculates this ratio by dividing family income by the USHHS poverty guidelines, which are specific to family size, year and state. Values above 5.0 were set equal to 5.0.[41, 42] Food assistance program participation is measured by several

NHANES variables. For this thesis, a new variable, FA, was created: coded 1 for a positive observation for any of the following three variables: FSD151 (household emergency food received), FSQ171 (household food stamp benefit received in last 12 months) and FSQ162 (household Women, Infants, Children (WIC) benefit: receive in last 12 month) [38, 39] and 0 otherwise (i.e., if all three of these variables had negative observations).

The NHANES marital status variable, DMDMARTL, was recoded into a binary variable: 1 for single (including the NHANES categories: single, widowed, divorced, and separated) or 2 for being with a partner (including the NHANES response categories married and living with partner).[41, 42] The NHANES household size variable, DMDHHSIZ, is an interval variable, with all responses above 7 set equal to 7.[41, 42] This variable was recoded into a categorical variable, HS, with three categories, namely household sizes of 1-3, 4-5, and 6-7.

d) Human Subjects

Although the data for this project were drawn strictly from public use NHANES datasets, University of Maryland Institutional Review Board approval was requested and obtained. A “not research letter” was published on January 2, 2014. NHANES 2007-2010 obtained prior human subjects approval from the NCHS Research Ethics Review Board (Protocol 2005-06).[48]

e) Data analysis

NHANES is a complex, multistage, clustered survey which oversampled racial/ethnic minority groups, the poor and the elderly. As a result each piece of data has a specific weight variable that must be included in analyses to ensure valid results. These weights account for oversampling (which ensures reliable results for minorities) and for subsampling (taking into account that not every sample person takes part in every subcomponent of NHANES). Thus, when choosing the weight variable to use, one chooses the most specific one. For example, fewer people complete the first 24 hour dietary recall than complete the medical exam; so when dealing with first day 24 hour dietary recalls, one uses WTDRD1, the dietary day 1 sample weight, which is the most specific choice.[23]

Before using the dietary data, any unreliable records [those with the 24 hour dietary recall status variable (DR1DRSTZ for the first 24 hour dietary recall) not equal to one] were excluded. This thesis required analyses of missing data, and normality of distribution and recoding variables as necessary. Missing data were minimal: Education, marital status, and acculturation variables were the only variables (other than poverty income ratio) missing data, but none were missing > 1% of the analytic sample. In accordance with NHANES analytic guidelines if 10% or less of the data were missing for a variable, then the analysis continued without adjustment.[23] There were no significant differences in the amount of missing poverty income ratio data (the other variable with missing data > 1%) in the food secure group versus the food insecure group ($p = 0.9461$).

Descriptive statistics about the demographics of the entire sample and the subcategories of food secure and food insecure were calculated. The observations for the dependent variables (sodium intake, potassium intake and the sodium-potassium ratio) were not normally distributed; thus, a power transformation was necessary prior to parametric hypothesis testing (see Appendix C). I began with the most conservative transformations on the positive skew side of Tukey's ladder of powers: the square root and log transformations. Neither of these produced a normal distribution, so I proceeded with Box-Cox transformations of both variables to determine the ideal lambda value. Both Box-Cox transformations with and without the independent variables that were associated with the exposure yielded an ideal lambda of 0.25. I transformed both the sodium intake and potassium intake data using lambda = 0.25 and ran parametric hypothesis testing using the transformed data as the input. The p-values reported as results in this thesis are based on these transformed data. Two-tailed p-values less than 0.05 were considered significant for all results obtained during the thesis research.

To describe the dependent variable distributions, I detransformed the means and confidence intervals of the transformed data. I provided these weighted means and asymmetrical confidence intervals as descriptive statistical results. These weighted means are smaller than means computed from the raw data because the transformation-detransformation process gave more weight to the smaller observations. The transformation made the measurements of the differences between or among small means more precise. Thus it is appropriate to provide the smaller weighted means.[49] Since the original transformation was skewed, the derived asymmetrical confidence intervals provide a good description of the data distribution.

Participant records were sorted by food security status (food secure versus food insecure) and mean usual intakes of sodium and potassium were computed for both groups as described above. T-tests were used to compare the mean usual nutrient intakes and the mean usual nutrient intake ratios of the food secure group with those of the food insecure group. These testing procedures were repeated for subgroups defined by age, race/ethnicity, marital status, household size, education level, poverty level, acculturation, and food assistance program participation.

A new variable, HTN, was created to compile the hypertension data. This variable has two values: 1 for hypertensive and 2 for normotensive. Participants were coded 1 if they were previously told that they had hypertension or if the average of their three (or four if necessary) blood pressure measurements during the exam fulfills the NHLBI/NCHS hypertension definition (SBP greater than or equal to 140 mmHg and/or DBP greater than or equal to 90 mmHg)[4, 35] or if they take antihypertensive medication(s). Chi-square testing was used to evaluate whether the prevalence of hypertension, measured in this manner, is significantly different for the food secure versus the food insecure population.

Prior to modeling, the level of correlation among the covariates was examined, so that any collinear variables could be excluded. Variance inflation factor values were also examined during preliminary modeling steps to confirm the exclusion of all collinear covariates. Multivariable regression analyses were conducted to examine the independent effects of covariates on nutrient intake levels and on hypertension risk controlling for other potential confounders. Any covariates with insignificant (less than 10% change) effects were eliminated from the pertinent model. The relationship between food security status and nutrient intake levels was described by multivariable linear regressions and the relationship between food security status and hypertension was described with a multivariable logistic regression. The regression coefficients and odds ratios (unadjusted and adjusted) are included in the final results. The analysis was completed with SAS and SUDAAN software.

Chapter 5: RESULTS

Table 3 details the sociodemographic characteristics of the sample population as a whole and divided into subpopulations by food security status. As expected with NHANES data, the final analytic sample's gender, age and race/ethnicity profiles are consistent with trends for the US population as whole.[50-52] Levels of educational attainment and the data on marital status are also consistent with national data.[53, 54] NHANES oversamples those in poverty, thus the estimates calculated for the poverty income ratio categories are reliable and relevant[23].

All of the examined covariates, with the exception of gender, showed significant associations with food security status (see Table 3). Food insecurity was associated with youth, minority race/ethnicity status, low education and poverty. In this sample, food security was more prevalent among single, widowed, divorced and separated adults as compared with those married or living with a partner. Food security was also more common among adults living in households with more than three members. Food insecurity was less common among US born and naturalized citizens when compared with non-US citizens. It was also less prevalent among those who completed the NHANES interview in English. Participation in food assistance programs was much more likely for those classified as food insecure in contrast to those classified as food secure.

The mean usual sodium intake for the analytic sample as a whole is 3037.75 mg (95% CI = 3006.37 mg – 3071.76 mg). Mean usual potassium intake is 2397.29 mg (95% CI 2373.54 mg – 2421.22 mg). The resultant mean usual sodium-potassium ratio is 1.29 (95% CI 1.27 – 1.32). Mean usual sodium intake did not differ significantly between the food secure and food insecure groups ($p = 0.0599$) (see Table 4). The mean usual potassium intake of the food secure population was significantly higher than that of the food insecure population ($p < 0.0001$); and, as a result, the mean usual sodium-potassium ratio of the food secure population was significantly lower than that of the food insecure population ($p < 0.0001$).

With the exception of participation in food assistance programs, sodium intake was associated with each of the covariates (Table 5). Most covariates also showed significant levels of association with mean usual potassium intake levels (also in Table 5). Exceptions include household size and language of sample person interview. It is noteworthy that food assistance program participation was highly associated with potassium intake ($p < 0.0001$). All associations between the covariates and sodium-potassium ratios were significant. Thus, most of the proposed covariates met the definitional requirements for confounding and were considered for inclusion in the regression models.

Tables 6A-6C show nutrient intake levels by food security status for subgroupings of covariate data. Fewer notable associations are found here. Differences in sodium intake are rare: where differences do exist, the trend is for the food insecure population to have lower intake levels (Table 6A). Potassium intake level differences are more common and consistently show the food insecure population to have the lower levels (Table 6B). Consequently, the sodium-potassium ratios tend to be disadvantageous for the food insecure (Table 6C).

The difference between hypertension prevalence of the food secure population (37.10%) was not significantly different ($p = 0.1862$) from the hypertension prevalence of the food insecure population (34.66%). Table 7A shows that both sodium and potassium intake levels were significantly lower ($p < 0.0001$ and p = 0.0 367 respectively) for those with hypertension in the sample. The mean usual sodium-potassium ratio was significantly lower ($p = 0.0154$) for those with hypertension. When further differentiated by food security status (Table 7B), differences remained significant only for potassium intake: food security is associated with higher levels of potassium intake.

Collinearity analyses suggested that language of sample person interview was highly correlated with acculturation and, thus, the former variable was dropped from the modeling process. The multivariate linear regression model for the relationship between food security status and mean usual dietary sodium intake includes the following covariates as confounders: age, race/ethnicity, education, poverty income ratio, marital status, household size, participation in food assistance programs and acculturation (see Table 8A). So, for example, an adult with the reference level values for all the relevant covariates, e.g. who was food secure, 25 years of age, non-Hispanic white, with post-secondary education, with poverty income ratio = 4.0, married, living in a household with 1 other person, not participating in any food assistance programs, and being a US born citizen would be predicted to have a mean usual sodium intake of 4085.82 mg. If the same person were food insecure, then the predicted mean usual sodium intake would be 4139.91 mg. The difference between these values is not statistically significant ($p = 0.6154$).

The multivariate linear regression model for the association between food security status and mean usual dietary potassium intake includes the following covariates as confounders: race/ethnicity, education, income-poverty ratio, marital status, household size, food assistance program participation and acculturation (see Table 8B). For example, an adult with reference level values for all the relevant covariates e.g. who is food secure, non-Hispanic white, with post-secondary education, with income-poverty ratio = 3.6, living with a partner and no one else, not participating in any food assistance program and being a naturalized citizen would be predicted to have a mean usual potassium intake of 3012.40 mg. The predicted mean usual potassium intake for the same person if food insecure would be 3040.18 mg. The difference between these values is not statistically significant (p = 0.6564).

The multivariate linear regression model for the association between food security status and sodium-potassium ratio includes age, race/ethnicity, education, income-poverty ratio, marital status, household size, participation in food assistance programs and acculturation (see Table 8C). The predicted sodium-potassium ratio for an adult with reference level values for al65l the relevant covariates, e.g. who is food secure, aged 30, non-Hispanic white, with post-secondary education, with income-poverty ratio = 3.7, married, living in a household of 3, not participating in any food assistance programs and being a US born citizen would be 1.48. If that same person were food insecure (keeping all other characteristics the same), then the predicted sodium-potassium ratio would be 1.52. The difference between these values is not statistically significant (p = 0.1477).

The likelihood (odds) of having prevalent hypertension among those with food insecurity compared to those without food insecurity was 0.90 with a 95% confidence interval (CI) of 0.76 – 1.06, in an unadjusted model. When adjusted for age, the odds ratios for prevalent hypertension are (compared with the reference group 20-39 year olds): for 40-59 year olds: 3.8 adjusted odds ratio (95% CI: 3.21 - 4.51), for those 60 and older: 13.07 adjusted odds ratio (95% CI: 10.95 – 15.58) . Living in a more populated household is associated with a lower likelihood of hypertension across the levels of household size (see Table 9). When adjusted for age and household size, food insecurity is associated with increased likelihood of prevalent hypertension: 1.43 adjusted odds ratio (95% CI: 1.19-1.72).

Chapter 6: DISCUSSION

This exploration of the relationships between food security status, sodium and potassium intake levels and hypertension provides data to support some of the study hypotheses. As far as the first study aim (compare sodium and potassium intake levels for the food secure versus the food insecure population) the results are mixed. The mean usual sodium intake level of food insecure non-pregnant US adults from 2007-2010 is not significantly different from that of their food secure counterparts. The mean usual potassium intake level of food insecure, non-pregnant US adults is significantly lower than that of their food secure counterparts. Food insecurity may cause an increased reliance on sodium-rich processed foods. This may be mediated by budgetary decisions, transportation limitations that necessitate reliance on shelf-stable items and lack of resources (time, knowledge, equipment) that are necessary to prepare unprocessed foods at home.

The main sources of dietary potassium are produce items. These items are more expensive per calorie, they are in short supply in food pantries and may be seen as not worth the allocation of money and time spent on transportation and preparation. It is well established that when resources are limited, consumers will purchase calorie-dense food items, i.e. not produce.[55,56] Food insecurity researchers have expressed concern about the impact that monthly distributions of food assistance benefits may have on dietary intake.[57] It has been observed that those dependent on such assistance tend to make one grocery shopping trip at the beginning of the month when funds become available. Since they are shopping for the month, they purchase mostly shelf-stable items.[57] Canned produce is affordable and shelf-stable, but less appealing than fresh. In addition, consumers' skepticism about the quality of fresh supermarket produce has been observed as agriculture has been industrialized and supply chains have become (inter-) nationalized.[58] Those with more financial and transportation resources have more options to obtain quality produce,[59] but nutrition assistance programs have the capacity to lessen these disparities.[60] In summary, resource limitations seem to impact potassium intake levels more than sodium intake levels.

Comparisons with earlier US studies are limited by the number and design of those studies. When comparing this thesis' intake data with other sources, it should be noted that detransformed means and confidence intervals are provided here. The statistical methods used in other studies may differ and thus prevent direct comparison. Dixon et al. did not examine sodium or potassium intake levels in their study of 1988-1994 NHANES participants. They did note that those in their sample (20-59 year old adults) with limited food resources consumed fewer dairy products, fruits and vegetables than their more food secure counterparts.[8] Since these food groups are generally high in potassium, these results appear to support this thesis' findings. Rose et al. did not examine sodium or potassium intake levels in their study of the associations between insufficient food resources and dietary intake levels of preschoolers, adult women and the elderly in the 1989 – 1991 Continuing Survey of Food Intake by Individuals.[9] Concern for income inequality in the US may encourage more research in this area. A recent analysis of 2009-2010 NHANES data by Powell-Wiley et al. shows significantly lower levels of ideal fruit and vegetable consumption as defined by eating at least 3 servings of fruits and vegetables daily for food insecure adults as compared with food secure adults.[61]

A literature review of studies from other countries increases the number of related studies. Tarasuk et al.[62] found low intakes of several vitamins and minerals in a small sample of Canadian food insecure women (n = 153), but sodium and potassium intake levels were not measured. Kirkpatrick et al.[63] compared micronutrient intake levels between food secure and food insecure individuals using the 24 hour diet recalls of 35,107 participants (20, 498 adults) in the 2004 Canadian Community Health Survey; the design of this study was similar in design to this thesis. Food insecure individuals in this population had consistently lower intakes of both sodium and potassium. For all of the Canadian adults in Kirkpatrick et al.'s study, differences were more pronounced for potassium as compared with sodium.[63] These findings are similar to my thesis results. Significant differences in nutrient intake were most striking for women aged 31-50.[64] Researchers have noted tendencies of women with children to limit their food intake for the benefit of the children,[64, 65] so that may help to explain this finding. Notably, all of the mothers (n = 21) in Stevens' study specifically expressed the cost and low availability of produce as a factor in their poor diets.[64]

The nutrient intake levels did differ significantly for subpopulations defined by covariate status. Levels of sodium intake (and thus sodium-potassium ratios) decreased with age. This may be related to absolute quantities of food eaten and/or increasing attention to diet quality with age and increased comorbidities. Data collection to evaluate these hypotheses could be the subject of a future study. Differences among racial/ethnic groups, education levels and size of household were noted, but no clear trends emerged. Those who are married or who are living with a partner had lower nutrient intake levels and a healthier mean sodium-potassium ratio. This finding is consistent with some other studies showing associations between marriage and healthier diets[66, 67] and may have some correlation with more home cooking by couples as compared with singles. Again, data to support or refute this idea are outstanding at this point. Those with lower poverty income ratios had lower potassium intake levels and higher sodium-potassium ratios. Food security is highly correlated with income[1] and food acquisition decisions are one part of budgeting financial resources. Those with fewer resources are less able to purchase perishable produce items (major sources of potassium).[56, 57, 59]

It is interesting that sodium intake, potassium intake and the sodium-potassium ratio was higher for those who completed the interview in English compared with NHANES participants unable to complete the interview in English. Overall, this would be consistent with other research which posits a healthier diet as part of the reason for better health outcomes among not yet assimilated immigrants. One example of such research is Akresh's examination of 2132 respondents to the 2003 New Immigrant Survey. Akresh found assimilation (including marriage to an American) to be associated with a decrease in diet quality (specifically an increase in junk food intake and a decrease in produce intake) and in health, although interactions with socio-economic status (higher SES was associated with better health outcomes) were highlighted.[68] Compared with this thesis' results from the language of sample person interview variable the results from the acculturation variable are less straightforward, but they might be somewhat elucidated if US born citizens were separated from naturalized citizens/non-citizens.

Potassium intake and the mean sodium-potassium ratio are both improved for those who participate in food assistance programs. This trend seems to be echoed in a recent comparison of Healthy Eating Index scores for low-income adults who do and do not use

SNAP benefits. In this case Gregory et al. used 2001-2008 NHANES data about low income adults who use or do not use SNAP. SNAP participants were much more likely to consume whole fruits and slightly less likely to consume dark green and orange vegetables than non-participants. The report does not detail potassium intake but it would likely be improved by such a diet pattern. Although the SNAP participants had slightly lower Healthy Eating Index scores than non-participants, the participants' sodium intake was lower than that of their counterparts.[69]

The fact that the results predicted by the linear models were not statistically different for the food secure population as compared with the food insecure population may be due to nondifferential misclassification causing bias toward the null. Evidence to support this idea is provided by Kirkpatrick et al.'s study of micronutrient intake levels of 20,498 adults who participated in the 2004 Canadian Community Health Survey.[63] The researchers calculated ratios of energy intake to estimated energy expenditure to assess underreporting of dietary intake. The amount of underreporting differed between food secure and food insecure respondents in only 2 subgroups of the population (19 – 30 year old women and 51 – 70 year old women). Kirkpatrick et al. hypothesize that what may appear to be differential underreporting may actually be genuinely diminished intake for these food insecure women as has been noted elsewhere.[64, 65]

Hypertension is more prevalent among food insecure US adults as compared to food secure adults, and this is consistent with other research.[2, 61] Nutrient intake levels are generally healthier for the hypertensive population in this study, so clinical nutrition counseling may have had some effect. Within hypertensive and normotensive sub-populations, the healthiest nutrient intake profiles are those of the food secure as opposed to the food insecure – this is consistent with findings for the total analytic sample for this thesis.

a) *Study Strengths And Limitations*

i. *Strengths*

NHANES provides data collected using well-established, validated measures for a large, nationally representative sample. The USFSSM has demonstrated validity and reliability for such a national sample and for several subpopulations defined by characteristics such as gender, race/ethnicity, household composition and poverty income ratio.[38] The NHANES 24 hour diet recall protocol has been shown to produce valid and reliable results.[34]

ii. *Limitations*

Reverse causation likely plays a role of some significance in any associations found: people disabled by chronic conditions may be less likely to earn enough income to afford healthy diets, particularly if medical expenses are high. In any case, the proposed cross-sectional study will not be able to examine causation; rather it is a first step in an effort to contribute important data and insights on the relationship between food security and cardiovascular health, which may ultimately influence future food policy decisions.

NHANES does not capture some part of the US population such as the homeless, the military, the incarcerated, and those in nursing homes. Conclusions about food security, nutrient intake levels and hypertension may be skewed as a result. Results of the USFSSM may be affected by the non-inclusion of certain segments of the population such as the homeless, by the effect of social desirability bias (respondents may not want to admit their lack of resources), and by random measurement errors.

The prevalence of food insecurity varies considerably by geographic location with the general tendency of southern states being most affected and northeastern states the least affected.[11] Urban and rural areas tend to be more affected than suburban ones.[11] Food insecurity prevalence data from 2006-08, averaged to increase reliability, show results ranging from a high of 24.8% (margin of error 3.62%) in Mississippi to a low of 9.5% in North Dakota (margin of error 1.58%).[11] Geographic data on NHANES participants is not available in the public use datasets and, consequently, these data were not accessed for this thesis. Although the results of the proposed study will describe the impact of food insecurity as a nationally averaged trend, local consequences will likely vary widely.

The limitation of self-reported dietary data must be acknowledged. Response bias due to social desirability is likely an important factor. The use of only one 24 hour dietary recall per sample person does not account for intra-individual variation which would weaken estimates of distributions of intake to a greater degree than estimates of mean levels of intake. Thus, means are reported here. However, reporting means assumes a lack of bias, an assumption which must be qualified when using current dietary measurement tools.[70]

Past investigations of the accuracy of reporting of sodium and potassium intake levels show varying levels of misreporting. Espeland et al. examined 24 hour dietary recalls and 24 hour urine collections that were repeated over 3 years of follow-up as part of the Trial of Nonpharacologic Intervention in the Elderly Trial (TONE). Among the sample of 341 particpants, the data from the dietary recalls averaged 22% less sodium intake and 16%

more potassium intake than evidenced by the urine collections.[71] Rhodes et al. published results of a moderately-sized 2013 study (n = 465) comparing 24 hour dietary recall (collected via the USDA's automated multiple-pass method as in NHANES) information with 24 hour urinary sodium excretion data. They found men's and women's diet recalls to be 93% and 90% accurate, respectively. The most accurate results were obtained from participants whose BMIs were less than 25.0 (overall accuracy was 88% for those with BMIs between 25.0 and 30.0; 78% for those with BMIs greater than 30.0). The study population was predominantly non-Hispanic white and well-educated; thus results may not be generalizable to other population subgroups.[72]

The estimation of nutrient intake levels are limited by the USDA's food databases which are used for the calculations. Recipe variations may lead to significantly different intakes of certain nutrients, which likely include sodium.

This study is based upon data collected during the 2007-2010 NHANES cycles. NHANES recommends using at least four years of data for statistically reliable estimates.[23] The most recent set of four years of data available are the 2007-2010 cycles. However, it may be considered problematic to combine these cycles due to the USDA decision to discontinue the post-collection data processing step of salt adjustment at the end of the 2007-08 cycle.[73] (Previously, if respondents reported that they only used salt occasionally or less often during food preparation at home, then processors eliminated some or all of the salt normally attributed to home preparation.)[73] The "Dietary Interview: Individual Foods – First Day" data file could have been examined to carry out the salt adjustment for the 2009-2010 cycle and maintain consistency. Such a time-consuming process was beyond the scope of a Master's thesis. Nevertheless, Zhang et al. compared

2003-2008 data with 2005-2010 data and found only non-significant differences in sodium intake levels, β-coefficients, odds ratios and general conclusions drawn.[74] Based on this precedent, it seems reasonable to combine the 2007-2008 and 2009-2010 cycles for this thesis.

SUDAAN does not provide Type 3 effects, for example a p-value for the race/ethnicity effect in general as might be imagined as an additional column in Tables 8A-8C. This is a limitation, but SUDAAN's ability to handle the complex survey design was a decisive factor in its selection for use in this analysis.

b) Future Studies

Further research could examine additional covariates to further elucidate associations among food insecurity, nutrient intake levels and hypertension. Nutrient intake levels are likely to show associations with total caloric intake and this is a variable that is available in the NHANES datasets and could be included in future studies. Including caloric intake as a variable could help to clarify older adults' pattern of lower sodium intake. The value of this variable may be affected by erratic eating patterns (binging and fasting) that have been noted in earlier studies of the food insecure.[75] Researchers have posited these erratic dietary patterns as a potential cause of increased rates of obesity among the food insecure.[75] Including body mass index (BMI) data in a future study would also be interesting because of the established tendency for those with higher BMIs to underreport their dietary intake to a greater degree than others.[28, 72]

Examining food sources, NHANES variable DR1FS, and even specific food items as detailed in the "Dietary Interview: Individual Foods – First Day" datafile would shed additional light on the subpopulations' habits. For example, it could help to explain whether those with partners or spouses have less healthier diets because they do more home cooking. This type of information would be helpful for those considering interventional studies and policy changes. As mentioned above, the results reported here for the subpopulations categorized by the acculturation variable could be further differentiated. One could consider length of time in the US and whether the participant is a naturalized citizen as more specific measures of acculturation that might support hypothesized dietary differences among immigrants.

c) *Public Health Significance*

This analysis focuses on sodium and potassium intake levels as important factors in the relationship between food insecurity and hypertension. Establishing associations between food insecurity and unhealthy sodium and potassium intake levels can justify a longitudinal study to confirm temporality, thus lending support to food insecurity being a partial cause for certain disease states. Obtaining covariate information will shed light on how to intervene (e.g. changes in urban infrastructure versus individual nutrition education).

The practical import of this work lies in its insights for interventions into community food systems on multiple levels. The most powerful of these could be applications on a national scale. In 2008, 55% of food insecure households participated in at least one of the three largest US federal food and nutrition assistance programs.[11] The public health ramifications of this research could thus impact policy decisions about types of food to be included in such programs. The tremendous disease burden imposed by hypertension can be significantly mitigated by such a population approach of primary prevention via lifestyle change.[4] During 2007-2008, about 80 percent of Americans with hypertension were aware of their diagnosis. However, only about half of this group had their condition under control.[76] High risk group strategies based on medication compliance have not improved the overall level of successful outcomes. Population-wide effects on blood pressure via lifestyle changes are likely to be small, but can still significantly affect morbidity and mortality.[4]

This examination of the socio-demographics and dietary patterns of food insecure adults can inform policy makers in several ways. Information presented here that conditions may be worse for those aged 20-39 and for non-Hispanic blacks can focus interventions. Information on intake of specific nutrients could affect food industry regulation, agricultural subsidy, and educational programs. Following upon research that has established connections between certain dietary patterns and specific disease states (e.g. sodium/potassium balance and hypertension), this project has the potential to support calls for changes in the US food supply to positively affect the health of the nation. This analysis in context with other findings such as the recent study of SNAP's effect on diet quality[69] justifies subsidies for produce purchases. Increasing vegetable and fruit consumption may be easier than reducing sodium consumption and it may be more effective at improving cardiovascular health via improved sodium-potassium ratios. In this regard, Rahkovsky et al. analyzed the costs and benefits of government taxes and subsidies and determined that subsidies would be more effective than taxes. A dollar of subsidy for whole grains and vegetables was calculated to save $13.20 and $3.60 in medical costs respectively.[77]

The conclusions drawn here are supported by recommendations from several nationally important organizations. The Institute of Medicine calls for a population approach to curtail hypertension and highlights the importance of limiting sodium and increasing fruit and vegetable intake.[78] The American Public Health Association advocates for partnerships with food manufacturers to reduce the sodium content of processed foods, for collaborations with local health departments' nutrition education initiatives, and for discussions with foreign governmental agencies in countries (e.g. France and Great Britain) where reduction of dietary sodium intake is a priority.[79] The Academy of Nutrition and Dietetics position on food insecurity encompasses sufficient financial support for federal nutrition assistance programs, enhancement of community infrastructure (e.g. local food pantries), nutrition education, community gardens and farm-to-school initiatives.[80] The American Heart Association recommends a healthy diet pattern, such as the Dietary Approaches to Stop Hypertension (DASH) diet which is lower in sodium and higher in potassium than the average American diet.[81]

As referenced above, investigations such as this one that examine the effect of social determinants on dietary intake and diet-exacerbated disease states are a prerequisite to meeting national health policy goals. The findings described here are relevant for several of the Healthy People 2020 objectives. These include encouraging polices to align the food supply with government nutrition recommendations, reduce food insecurity increase fruit and vegetable consumption and decrease sodium intake.[10] Changing the national infrastructure to create a more nutritious food system may lead to better financial outcomes for our nation due to improved workforce productivity and decreased per capita health care costs.[82]

MPH COMPETENCIES ADDRESSED IN THESIS

The following table illustrates the complete list of MPH competencies that were addressed in this thesis.

Competencies for MPH in Epidemiology	Thesis	Addressed in this Thesis
1) Demonstrate the importance of epidemiology for informing scientific, ethical, economic, and political discussion of health issues.	✓	Epidemiologic analysis of variables associated with dietary sodium and potassium intake and the public health significance of this study with suggestions for possible policy applications
2) Assess a public health problem in terms of magnitude, person, time and place.	✓	Examine factors associated with food insecurity
3) Distinguish the basic terminology and definitions of epidemiology.	✓	Statistical analysis and interpretation of results.
4) Discriminate key sources of data for epidemiological purposes.	✓	Use of 2007-2010 NHANES, strengths, and limitations
5) Calculate basic epidemiology measures.	✓	Descriptive statistics displaying socio-demographic characteristics in the sample among adult non-pregnant NHANES participants
6) Identify the principles and limitations of public health screening programs.		
7) Evaluate strengths and limitations of epidemiologic reports.	✓	Strengths and weaknesses in introduction and discussion sections
8) Draw appropriate inferences from epidemiologic data.	✓	Results and discussion sections
9) Explain criteria for causality	✓	Results and discussion sections (e.g. limitations)
10) Calculate advanced epidemiologic measures.	✓	P-values, standard errors, linear regression model, regression coefficients, unadjusted and adjusted odds ratios
11) Communicate epidemiologic information to lay and professional audiences.	✓	Written thesis report; oral thesis proposal and final presentation of results and public health significance to audiences
12) Compare basic ethical and legal principles pertaining to the collection, maintenance,	✓	Obtain IRB approval before data analysis process.

use and dissemination of epidemiologic data.		
13) Design, analyze, and evaluate an epidemiologic study.	✓	Design, conduct and write up thesis
14) Design interventions to reduce prevalence of major public health problems.	✓	Discuss public health significance, future research and policy interventions to improve dietary intake
15) Demonstrate program administration and organizational leadership		

TABLES AND FIGURES

Table 3: Sociodemographic characteristics by food security status (weighted)

Characteristic	Total	Food secure (n = 7820)*	Food insecure (n = 1505)**	p-value
Gender – %				0.5849
Male	48.58	48.66	47.95	
Female	51.42	51.34	52.05	
Age in years – %				< 0.0001
20-39	35.10	33.35	49.18	
40-59	39.26	39.32	38.72	
60 and over	25.64	27.32	12.10	
Race/ethnicity – %				< 0.0001
Mexican-American	9.29	7.81	21.20	
Non-Hispanic white	78.04	80.96	54.56	
Non-Hispanic black	12.67	11.23	24.25	
Education level – (n = 9313) - %				< 0.0001
Less than High School graduate	18.61	15.99	39.72	
High School graduate	24.77	24.35	28.12	
Some college/college graduate	56.62	59.66	32.15	
Poverty Income Ratio – (n = 8624) - %				< 0.0001
0.0-1.3	19.88	15.03	58.72	
> 1.30 – 3.50	35.70	35.85	34.53	
Greater than 3.5	44.42	49.12	6.75	
Language of Sample Person Interview - %				< 0.0001
English	94.72	95.84	85.73	
Other	5.28	4.16	14.27	
Marital Status (n = 9321) - %				< 0.0001
Single/Widowed/Divorced/Separated	36.28	34.50	50.64	
Married/Living with partner	63.72	65.50	49.36	
Household Size – %				< 0.0001
1-3	66.94	68.52	54.16	
4-5	26.36	25.82	30.77	
>= 6	6.70	5.66	15.07	
Participation in any food assistance program - %				< 0.0001
Participation	17.24	12.10	58.71	
No participation	82.76	87.90	41.29	
Acculturation – (n = 9263) - %				<0.0001
US born or naturalized citizen	93.77	94.78	85.58	
Non-citizen, immigrated < 5 years ago	1.17	1.00	2.56	
Non-citizen, immigrated ≥ 5 years ago	5.06	4.23	11.86	

P-values were calculated using chi-square tests.
*For education level n = 7809, for poverty income ration n = 7222, for marital status n = 7816, acculturation n = 7780.
**For education level n = 1504, for poverty income ratio n = 1402, for marital status n = 1505, for acculturation n = 1483.

Table 4: Mean sodium intake, potassium intake, sodium-potassium ratio by food security status (weighted)

Nutrient Intake	Mean Usual Sodium Intake in mg (CI)	Mean Usual Potassium Intake in mg (CI)	Mean Usual Sodium-Potassium Ratio (CI)
Total	3037.75 (3006.37-3071.76)	2397.29 (2373.54-2421.22)	1.29 (1.27-1.32)
Food Secure (n = 7820)	3052.40 (3017.47-3087.64)	2430.72 (2405.16-2456.48)-	1.28 (1.26-1.30
Food Insecure (n = 1505)	2970.62 (2882.62-3058.72)	2229.14 (2167.47-2292.21)	1.39 (1.34-1.44)
p-value	0.0599	<0.0001	< 0.0001

The p-values are for t-tests using the raw data transformed for normality. The means and CIs are detransformed data, i.e. they are weighted means and asymmetrical CIs.

Table 5: Mean Usual Nutrient Intake by sociodemographic characteristics and food assistance program participation (weighted)

Variable	Usual Sodium Intake in mg		Usual Potassium Intake in mg		Usual Sodium-potassium ratio	
	Mean (CI)	**p-value**	**Mean (CI)**	**p-value**	**Mean (CI)**	**p-value**
Age in years		< 0.0001		< 0.0001		< 0.0001
20-39 (n = 2925)	3376.78 (3284.39-3471.11)		2408.96 (2330.72-2489.16)		1.43 (1.09 - 1.47)	
40-49 (n = 3042)	3284.83 (3196.09-3375.40)		2639.77 (2565.42-2715.72)		1.27 (1.23 - 1.30)	
60 and over (n = 3358)	2778.85 (2706.67-2851.71)		2442.77 (2379.99-2506.78)		1.16 (1.13 1.18)	
Race/ethnicity		< 0.0001		< 0.0001		< 0.0001
Mexican-American (n = 1928)	2990.24 (2889.04-3094.06)		2446.40 (2355.58-2539.82)		1.24 (1.21 – 1.28)	
Non-Hispanic white (n = 5275)	3238.29 (3160.92-3317.07)		2589.20 (2512.98-2667.14)		1.27 (1.25 – 1.30)	
Non-Hispanic black (n = 2122)	2972.87 (2881.01-3071.35)		2078.00 (2001.28-2156.90)		1.46 (1.42 – 1.50)	
Marital Status		< 0.0001		< 0.0001		< 0.0001
Single/Widowed/ Divorced/Separated (n = 3785)	3241.30 (3178.11-3305.43)		2603.19 (2534.95-2672.79)		1.34 (1.31 – 1.37)	
Married/Living with Partner (n = 5536)	3080.10 (2989.60-3172.63)		2350.90 (2291.92-2411.01)		1.27 (1.24 – 1.29)	

Household Size		< 0.0001		0.1768		<0.0001
1-3 (n = 6021)	3161.80 (3083.39-3241.69)		2534.67 (2470.10-2600.49)		1.27 (1.25 – 1.30)	
4-5 (n = 2339)	3249.25 (3161.02-3339.32)		2467.92 (2392.23-2545.39)		1.34 (1.29 – 1.39)	
≥ 6 (n = 965)	3102.27 (2949.24-3261.17)		2376.55 (2254.56-2503.42)		1.34 (1.28 – 1.41)	
Education level		< 0.0001		< 0.0001		0.0021
Less than High School graduate (n = 2655)	2912.23 (2818.90 – 3007.85)		2217.03 (2137.08 – 2299.19)		1.35 (1.31 – 1.38)	
High School graduate (n = 3323)	3117.38 (3036.86 – 3199.49)		2437.11 (2363.57 – 2512.34)		1.31 (1.06 – 1.34)	
Some college/college graduate (n = 2646)	3387.78 (3312.81 – 3463.83)		2700.83 (2635.74 – 2767.13)		1.27 (1.23 – 1.30)	
Poverty income ratio		< 0.0001		< 0.0001		0.0021
0.0 - 1.3 (n = 2655)	2912.23.75 (2815.28 - 3011.65)		2217.03 (2133.99-22302.46)		1.35 (1.31 – 1.38)	
> 1.3 – 3.5 (n = 3323)	3117.38 (3033.73 - 3202.74)		2437.11 (2360.72-2515.33)		1.31 (1.27 – 1.34)	
Greater than 3.5 (n = 2646)	3387.60 (3309.72-3466.85)		2700.83 (2633.21-2769.76)		1.27 (1.24 – 1.30)	

Language of sample person interview		< 0.0001		0.2641		<0.0001
English (n = 8232)	3203.70 (3139.44-3268.93)		2507.81 (2447.21-2569.53)		1.30 (1.28 – 1.33)	
Other (n = 1093)	2760.92 (2566.72-2965.94)		2482.05 (2374.85-2592.83)		1.13 (1.08 – 1.18)	
Acculturation		< 0.0001		0.0008		<0.0001
US born or naturalized citizen (n = 8286)	3197.45 (3133.45-3262.42)		2497.64 (2437.25-2559.16)		1.30 (1.28 – 1.33)	
Non-citizen, immigrated < 5 years ago (n = 163)	2897.57 (2561.92-3265.17)		2492.37 (2163.41-2857.49)		1.18 (1.08 – 1.30)	
Non-citizen, immigrated ≥ 5 years ago (n = 814)	2930.15 (2757.83-3110.43)		2660.81 (2528.71-2798.02)		1.12 (1.07 – 1.17)	
Participation in any food assistance program		.0654		<0.0001		<0.0001
Participation (n = 2355)	3008.35 (2918.81-3099.94)		2228.57 (2154.13-2304.92)		1.38 (1.34 – 143)	
No participation (n = 6970)	3218.02 (3147.62-3289.59)		2569.18 (2510.00-2629.39)		1.27 (1.25 – 1.30)	

The p-values are for ANOVA tests using the raw data transformed for normality. The means and CIs are detransformed data, i.e. they are weighted means and asymmetrical CIs.

Table 6A: Mean usual sodium intake by sociodemographic characteristics/food assistance program participation and food security status

Variable	**Food Secure**	**Food Insecure**	**p-value**
Observation (n Food Secure, Food Insecure)	Mean (CI)	Mean (CI)	
<u>Age in years</u>			
20-39 (2291, 634)	3478.92 (3408.44 - 3550.50)	3180.97 (3018.16-3350.28)	0.0021
40-49 (2465, 577)	3353.81 (3285.24 - 3423.45)	3197.95 (2939.45 - 3473.13)	0.2500
60 and over (3064, 294)	2808.83 (2748.82 - 2869.82)	2470.34 ((2257.79 - 2697.55)	0.0054
<u>Race/Ethnicity</u>			
Mexican-American (1451, 477)	3080.53 (2921.61 – 3245.84)	2902.58 (2691.57 – 3125.76)	0.2689
Non-Hispanic white (4658, 617)	3301.24 (3233.48 – 3370.06)	3147.22 (2891.84 – 3419.16)	0.1944
Non-Hispanic black (1711, 411)	2934.35 (2872.33 – 3061.39)	3130.45 (3001.25 – 3263.77)	0.0128
<u>Marital Status</u>			
Single/Widowed/Divorced/ Separated (n = 3017, 768)	3113.74 (3048.89 – 3179.62)	3031.21 (2843.56 – 3227.99)	0.3535
Married/Living with Partner (n = 4799, 737)	3301.24 (3233.48 – 3370.06)	3164.06.(3001.90 – 3332.71)	0.0702
<u>Household Size</u>			
1-3 (n = 5247, 774)	3197.95 (3131.79 – 3265.15)	3097.10 (2875.47 – 3331.30)	0.3292
4-5 (n = 1902, 437)	3353.81 (3285.24 – 3423.45)	3097.10 (2906.38 – 3297.06)	0.0181
>= 6 (n = 671, 294)	3232.10 (3003.20 – 3194.55)	3031.21 (2813.15 – 3261.70)	0.1693
<u>Education Level</u>			
Less than High School graduate (1950, 719)	2982.48 (2572.92 – 3111.07..)	2871.07 (2690.97 – 3027.94)	0.1897
High School graduate (1905, 385)	3164.06 (3066.00 – 3231.73)	3407.01 (3168.79 – 3658.42)	0.0685
Some college/college graduate (3954, 400)	3336.22 (3267.92 – 3405.58)	3113.74 (2891.21. – 3348.88)	0.0822
<u>Poverty income ratio</u>			
0.0 - 1.3 (1746, 909)	2966.37 (2872.96 – 3062.04)	2966.37 (2811.92 – 3127.10)	1.000
> 1.3– 3.5 (2887, 436)	3130.45 (3065.34 – 3196.59)	3232.10 (3003.20 – 3473.85)	0.3342
> 3.5 (2589, 57)	3424.88 (3355.22 – 3495.62)	3588.92 (2823.06 – 43500.96)	0.7038
<u>Language of sample person interview</u>			
English (7055, 1177)	3249.29 (3182.33 – 3317.29)	3130.45 (2969.59 – 3297.76)	0.0776
Other (765, 328)	2824.30 (2617.61 – 3042.99)	2886.79 (2618.78 – 3174.88)	0.6576
<u>Acculturation</u>			
US born/naturalized citizen (7095, 1191)	3249.29 (3182.33 – 3317.29)	3130.45 (2969.59 – 3297.76)	0.0859
Non-citizen, immigrated < 5 yrs ago (116. 47)	2950.33 (2563.00 – 3379.98)	2555.51 (2133.61 – 3037.09)	0.1599
Non-citizen, immigrated <u>></u> 5 yrs ago (569, 245)	3046.58 (2828.64 – 3279.00)	3014.90 (2737.90 – 3312.40)	0.8457

Participation in any food assistance program Participation (1411, 944) No participation (6409, 561)	3080.53 (2984.42 – 3178.94) 3266.53 (3199.31 – 3334.81)	2998.66 (2404.75 – 3160.69) 3232.10 (3003.20 – 3473.85)	0.4300 0.7269

The p-values are for t-tests using the raw data transformed for normality. The means and CIs are detransformed data, i.e. they are weighted means and asymmetrical CIs.

Table 6B: Mean usual potassium intake by sociodemographic characteristics/food assistance program participation and food security status

Variable	Food Secure	Food Insecure	p-value
Observation (n Food Secure, Food Insecure)	Mean (CI)	Mean (CI)	
Age in years			
20-39 (2291, 634)	2470.34 (2388.95 - 2553.79)	2227.55 (2127.59 - 2330.98)	0.0003
40-49 (2465, 577)	2672.49 (2614.68 - 2731.25)	2442.43 (2283.05 – 2610.00)	0.0138
60 and over (3064, 294)	2470.34 (2415.85 - 2525.74)	2063.67 (1900.79 - 2236.90)	<0.0001
Race/Ethnicity			
Mexican-American (1451, 477)	2498.49 (2416.40 – 2582.65)	2387.31 (2205.32 - 2580.33)	0.3309
Non-Hispanic white (4658, 617)	2628.16 (2571.08 – 2686.19)	2346.59 (2217.19 -2481.57)	0.0003
Non-Hispanic black (1711, 411)	2063.67(1992.59 – 2136.63)	2075.94 (1935.01 – 2224.44)	0.9414
Marital Status			
Single/Widowed/Divorced/ Separated (n = 3017, 768)	2387.31 (2334.21 – 2441.31)	2163.40 (2065.63 – 2264.61)	0.0007
Married/Living with Partner (n = 4799, 737)	2628.16 (2571.08 – 2686.19)	2414.75 (2282.52 – 2552.64)	0.0032
Household Size			
1-3 (n = 5247, 774)	2569.92 (2513.79 – 2626.99)	2293.11 (2165.94 – 2425.79)	0.0018
4-5 (n = 1902, 437)	2512.66 (2457.47 - 2568.77)	2293.11 (2141.16 – 2453.00)	0.0098
>= 6 (n = 671, 294)	2470.34 (2335.82 – 2610.59)	2214.61 (2042.68 – 2397.16)	0.0452
Education Level			
Less than High School graduate (1950, 719)	2319.73 (2242.11 – 2399.35)	2266.71 (2140.65 – 2398.26)	0.4278
High School graduate (1905, 385)	2428.56 (2374.77 – 2483.26)	2266.71 (2140.65 – 2398.26)	0.0679
Some college/college graduate (3954, 400)	2657.65 (2600.08 – 2716.17)	2319.73 (2166.45 – 2481.01)	0.0002
Poverty income ratio			
0.0 - 1.3 (1746, 909)	2266.71 (2190.43-2344.97)	2176.12 (2053.89-2303.73)	0.1899
> 1.3– 3.5 (2887, 436)	2456.35 (2375.31-2539.45)	2414.75 (2256.74-2580.91)	0.7274
> 3.5 (2589, 57)	2702.35 (2644.05-2761.60)	2584.39 (2208.93.-3005.80)	0.6038
Language of sample person interview			
English (7055, 1177)	2555.51 (2499.62 – 2612.34)	2240.55 (2140.15 – 2344.43)	<0.0001
Other (765, 328)	2512.66 (2376.40 – 2654.69)	2555.51 (2363.90 – 2758.55)	0.7108
Acculturation			
US born/naturalized citizen (7095), 1191)	2541.17 (2485.51 – 2597.76)	2240.55 (2140.15 – 2344.43)	<0.0001
Non-citizen, immigrated < 5 yrs ago (116, 47)	2526.88 (2284.64 – 2787.90)	2201.72 (1891.96 – 2548.05)	0.0920
Non-citizen, immigrated ≥ 5 yrs ago (569, 245)	2732.46 (2558.97 – 2914.62)	2598.92 (2404.84 – 2804.51)	0.3146

<u>Participation in any food assistance program</u> Participation (1411, 944) No participation (6409, 561)	2266.71 (2215.64 – 2318.66) 2584.39 (2528.02 – 2641.69)	2227.55 (2103.14 – 2357.40) 2373.68 (2192.48 – 2565.88)	0.5264 0.0358

The p-values are for t-tests using the raw data transformed for normality. The means and CIs are detransformed data, i.e. they are weighted means and asymmetrical CIs.

Table 6C: Mean usual sodium-potassium ratio by sociodemographic characteristics/food assistance program participation and food security status

Variable	**Food Secure**	**Food Insecure**	**p-value**
Observation (n Food Secure, Food Insecure)	Mean (CI)	Mean (CI)	
<u>Age in years</u>			
20-39 (2291, 634)	1.44 (1.41 - 1.47)	1.47 (1.41 – 1.53)	0.3706
40-49 (2465, 577)	1.27 (1.24 - 1.31)	1.34 (1.29 – 1.39)	0.0379
60 and over (3064, 294)	1.16 (1.13 - 1.18)	1.23 (1.12 – 1.33)	0.1990
<u>Race/Ethnicity</u>			
Mexican-American (1451, 477)	1.25 (1.21 – 1.30)	1.25 (1.19 – 1.30)	0.8478
Non-Hispanic white (4658, 617)	1.28 (1.25 - 1.30)	1.38 (1.33 – 1.43)	0.0029
Non-Hispanic black (1711, 411)	1.45 (1.42 - 1.48)	1.55 (1.46 – 1.64)	0.0408
<u>Marital Status</u>			
Single/Widowed/Divorced/ Separated (n = 3017, 768)	1.33 (1.31 – 1.35)	1.44 (1.36 – 1.51)	0.0040
Married/Living with Partner (n = 4799, 737)	1.27 (1.22-1.39)	1.34 (1.28 – 1.39)	0.0258
<u>Household Size</u>			
1-3 (n = 5247, 774)	1.27 (1.24 – 1.29)	1.38 (1.33 – 1.44)	0.0006
4-5 (n = 1902, 437)	1.35 (1.32 – 1.39)	1.38 (1.30 – 1.46)	0.5872
6 or larger (n = 671, 294)	1.34 (1.28 – 1.41)	1.44 (1.34 – 1.54)	0.1733
<u>Education Level</u>			
Less than High School graduate (1950, 719)	1.31 (1.28 – 1.35)	1.30 (1.23 – 1.37)	0.6212
High School graduate (1905, 385)	1.33 (1.29 – 1.36)	1.53 (1.47 – 1.59)	<0.0001
Some college/college graduate (3954, 400)	1.27 (1.25 – 1.30)	1.39 (1.30 – 1.49)	0.0275
<u>Poverty income ratio</u>			
0.0 - 1.3 (1746, 909)	1.34 (1.31 – 1.37)	1.39 (1.34-1.45)	0.1028
> 1.3– 3.5 (2887, 436)	1.30 (1.27 – 1.34)	1.39 (1.31-1.47)	0.0506
> 3.5 (2589, 57)	1.28 (1.25 – 1.32)	1.39 (1.22-1.64)	0.3743
<u>Language of sample person interview</u>			
English (7055, 1177)	1.30 (1.28 – 1.32)	1.43 (1.39 – 1.48)	<0.0001
Other (765, 328)	1.14 (1.09 – 1.19)	1.15 (1.09 – 1.21)	0.7667

Acculturation US born/naturalized citizen (7095, 1191) Non-citizen, immigrated < 5 yrs ago (116, 47) Non-citizen, immigrated ≥ 5 yrs ago (569, 245)	1.30 (1.28 – 1.33) 1.18 (1.07 - 1.29) 1.13 (1.08 – 1.19)	1.43 (1.38 – 1.45) 1.19 (1.00 – 1.41) 1.18 (1.10 – 1.25)	<0.0001 0.8797 0.3954
Participation in any food assistance program Participation (1411, 944) No participation (6409, 561)	1.39 (1.35 – 1.42) 1.28 (1.26 – 1.31)	1.39 (1.34 – 1.44) 1.39 (1.32 – 1.45)	0.8533 0.0038

The p-values are for t-tests using the raw data transformed for normality. The means and CIs are detransformed data, i.e. they are weighted means and asymmetrical CIs.

Table 7A: Mean nutrient intakes by hypertension status levels

Hypertension Status	**Mean Usual Sodium Intake in mg (CI)**	**Mean Usual Potassium Intake in mg (CI)**	**Mean Usual Sodium-Potassium Ratio (CI)**
Total (n = 9325)	3037.75 (3006.37-3071.76)	2397.29 (2373.54-2421.22)	1.31 (1.26 – 1.31)
Hypertensive (n = 4040)	3047.58 (2983.77 – 3112.41))	2456.35 (2402.10 – 2511.52)	1.26 (1.22 – 1.31)
Normotensive (n = 5285)	3318.69 (3250.66 – 3387.79)	2555.51 (2499.62 – 2612.34)	1.31 (1.26 – 1.36)
p-value	< 0.0001	0.0367	0.0154

The p-values are for t-tests using the raw data transformed for normality. The means and CIs are detransformed data, i.e. they are weighted means and asymmetrical CIs.

Table 7B: Mean usual nutrient intakes by hypertension and food security status

	Hypertensive			**Normotensive**		
Food Security Status (n Hyper-, Normotensive)	**Usual Sodium Intake Mean mg (CI)**	**Usual Potassium Intake Mean mg (CI)**	**Mean Usual Sodium-potassium ratio (CI)**	**Usual Sodium Intake Mean mg (CI)**	**Usual Potassium Intake Mean mg (CI)**	**Mean Usual Sodium-potassium ratio (CI)**
Total (4040, 5285)	3047.58 (2983.77 – 3112.41)	2456.35 (2402.10 – 2511.52)	1.27 (1.24 - 1.29)	3318.69 (3250.64 – 3387.79)	2555.51 (2499.62 – 2612.34)	1.32 (1.30 – 1.35)
Food Secure (3449, 4371)	3064.02 (2999.95 - 3129.11)	2484.38 (2429.67 – 2540.02)	1.26 (1.23 – 1.29)	3336.22 (3267.92 – 3405.58)	2584.39 (2528.02 – 2641.70)	1.31 (1.29 – 1.34)
Food Insecure (591, 914)	2918.43 (2706.55 - 3142.52)	2188.89 (2042.20 – 2343.35)	1.37 (1.30 - 1.43)	3197.95 (3034.48 – 3367.94)	2333.13 (2229.62 – 2440.20)	1.40 (1.35 – 1.46)
p-value	0.1643	0.0007	0.0043	0.0696	0.0001	0.0073

The p-values are for t-tests using the raw data transformed for normality. The means and CIs are detransformed data, i.e. they are weighted means and asymmetrical CIs.

Table 8A: Multivariable linear regression model for mean usual sodium intake

Predictor	**Beta-Coefficient (mg)**	**Standard error (mg)**	**p-value**
Intercept	4085.82	59.94	< 0.0001
Food Secure	(Ref)		
Food Insecure	54.09	106.63	0.6154
Age in years			
20-39	(Ref)		
40-59	-196.04	60.26	0.0027
60 and over	-841.90	59.57	<0.0001
Race/Ethnicity			
Mexican-American	-178.41	118.27	0.1412
Non-Hispanic White	(Ref)		
Non-Hispanic Black	-283.43	65.62	<0.0001
Education			
< High School	2.45	78.69	0.9754
Graduate	12.31	53.28	0.8187
Some college/ college graduate	(Ref)		
Poverty income ratio			
0.0 – 1.3	-316.47	84.46	0.0007
> 1.3 – 3.5	-195.54	55.02	0.0012
Greater than 3.5	(Ref)		
Marital Status			
Single/Widowed/ Divorced/Separated	-132.01	58.49	0.0310
Married/with partner	(Ref)		
Household Size			
1-3	(Ref)		
4-5	-27.89	64.65	0.6691
>= 6	-5.98	98.33	0.9519
Food Assistance			
Yes	1.49	77.24	0.9847
No	(Ref)		

<u>Acculturation</u>				
US Citizen	(Ref)	0.00	---	
Non-Citizen, immigrated < 5 years ago	-418.32	184.00		
Non-Citizen, immigrated ≥ 5 years ago	-164.15	135.22	0.2337	

Table 8B: Multivariable linear regression model for mean usual potassium intake

Predictor	Beta-Coefficient (mg)	Standard error (mg)	p-value
Intercept	3012.40	45.71	< 0.0001
Food Secure	(Ref)		
Food Insecure	27.78	61.86	0.6564
<u>Race/Ethnicity</u>			
Mexican-American	-119.90	65.53	0.0766
Non-Hispanic White	(Ref)		
Non-Hispanic Black	-427.69	51.57	< 0.0001
<u>Education</u>			
< High School	-169.21	49.27	0.0017
Graduate	-181.25	36.99	< 0.0001
Some college/college Graduate	(Ref)		
<u>Poverty income ratio</u>			
0.0 - 1.3	-265.90	58.78	0.0001
> 1.3– 3.5	-135.98	51.95	0.0134
Greater than 3.5	(Ref)		
<u>Marital Status</u>			
Single/Widowed/ Divorced/Separated	-156.84	29.38	< 0.0001
Married/with partner	(Ref)		
<u>Acculturation</u>			
US Citizen	(Ref)		
Non-Citizen, immigrated. < 5 years ago	196.47	40.27	0.1880
Non-Citizen, immigrated ≥ 5 years ago	371.69	67.26	0.5297
<u>Food Assistance</u>			
Yes	21.95	56.31	0.6993
No	(Ref)		
<u>Household Size</u>			
1-3	(Ref)		
4-5	-54.18	40.27	0.1880
>= 6	-42.74	67.26	0.5297

Table 8C: Multivariable linear regression model for mean usual sodium-potassium ratio

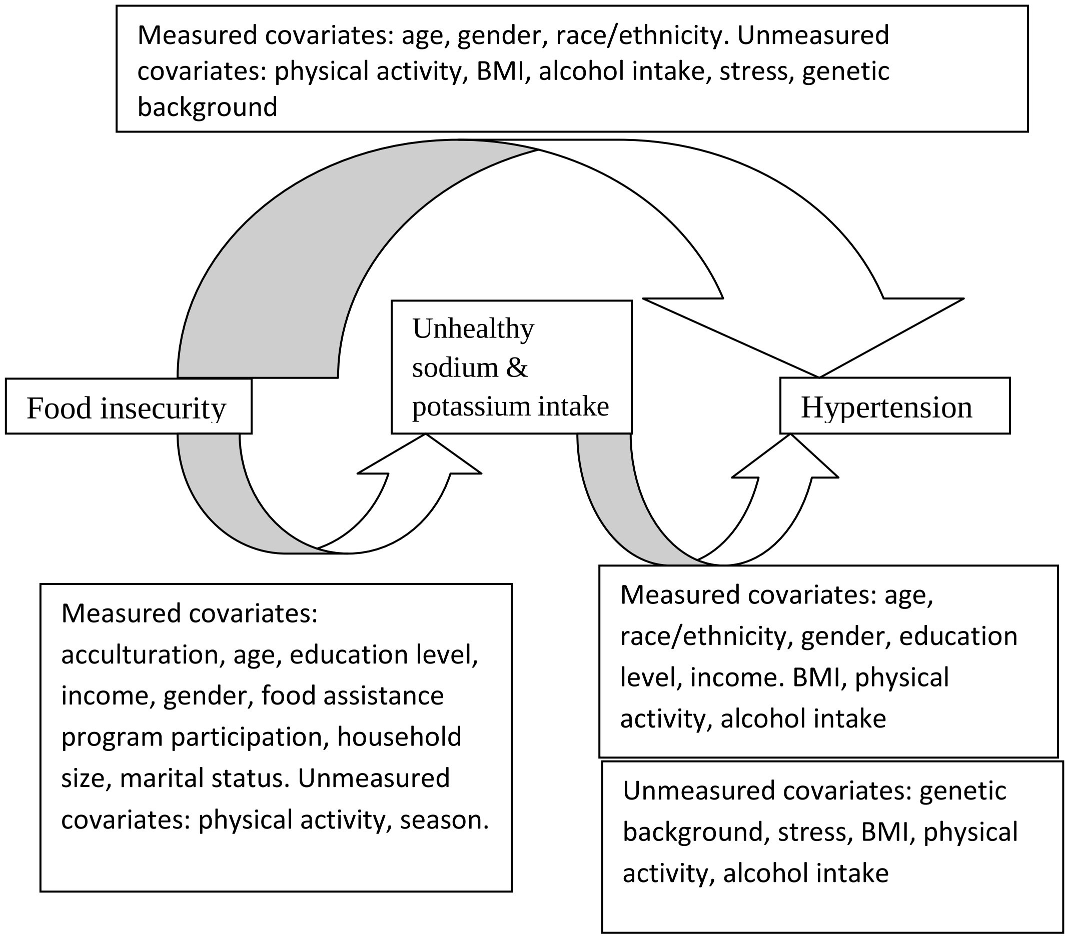
Predictor	**Beta-Coefficient**	**Standard error**	**p-value**
Intercept	1.48	0.02	< 0.0001
Food Secure	(Ref)		
Food Insecure	0.04	0.03	0.1477
<u>Age in years</u>			
20-39	(Ref)		
40-59	-0.17	0.02	<0.0001
60 and over	-0.32	0.02	< 0.0001
<u>Race/Ethnicity</u>			
Mexican-American	-0.05	0.03	0.1201
Non-Hispanic White	(Ref)		
Non-Hispanic Black	0.15	0.02	< 0.0001
<u>Education</u>			
< High School	0.09	0.03	0.0028
Graduate	0.09	0.02	0.0001
Some college/college Graduate	(Ref)		
<u>Poverty income ratio</u>			
0.0 - 1.3	0.02	0.02	0.5356
> 1.3 – 3.5	0.01	0.03	0.7964
Greater than 3.5	(Ref)		---
<u>Marital Status</u>			
Single/Widowed/ Divorced/Separated	0.04	0.02	0.1093
Married/with partner	(Ref)		
<u>Household Size</u>			
1-3	(Ref)		
4-5	0.02	0.02	0.3772
>= 6	0.06	0.04	0.1461
<u>Food Assistance</u>			
Yes	0.02	0.03	0.4785
No	(Ref)		
<u>Acculturation</u>			
US Citizen	(Ref)		
Non-Citizen, immigrated. < 5 years ago	-0.29	0.05	<0.0001
Non-Citizen, immigrated.	-0.23	0.03	< 0.0001

≥ 5 years ago			

Table 9: Odds Ratios for the Effect of Food Security Status on Hypertension Risk

Variable	**OR (95% CI)**	**AOR (95% CI)**
Intercept		0.16 (0.14 – 0.19)
Food Secure		Ref
Food Insecure	0.90 (0.76 – 1.06)	1.43 (1.19 – 1.72)
<u>Age in years</u>		
20-39		Ref
40-59		3.80 (3.21-4.51)
60 and over		13.07 (10.95 – 15.58)
<u>Household Size</u>		
1-3		Ref
4-5		0.81 (0.69 – 0.94)
>= 6		0.71 (0.57 – 0.89)

Figure 1: Diagram of factors associated with nutrient intake levels and hypertension



APPENDICES

Appendix A: Variable Tables

Organizational

#	**Variable**	**Type**	**Label**	**Note**
1	SEQN	N/A	Respondent Sequence Number	
2	SDDSRVYR	N/A	Data Release Number	
3	SDMVPSU	Interval	Masked Variance Pseudo-PSU	
4	SDMVSTRA	Interval	Masked Variance Pseudo-Stratum	
5	WTINT2YR	Continuous	Full Sample 2 Year Interview Weight	
6	WTMEC2YR	Continuous	Full Sample 2 Year Mobile Exam Center (MEC) Exam Weight	
7	DR1DRSTZ	Categorical	Dietary recall day 1 status	Reliability
8	WTDRD1	Continuous	Dietary day one sample weight	

Demographic

#	**Variable**	**Type**	**Label**	**Note**
9	RIAGENDR	Categorical	Gender	
10	RIDAGEYR	Interval	Age at Screening Adjudicated – Recode	
11	RIDRETH1	Categorical	Race/Ethnicity – Recode	RIDRETH1 = 2 or 5 deleted
12	DMDEDUC2	Categorical	Education Level – Adults 20+	Recoded to ED
13	DMDMARTL	Categorical	Marital Status	Recoded to MS

14	DMDHHSIZ	Categorical	Total number of people in the Household	Recoded to HS
15	INDFMPIR	Continuous	Ratio of Family Income to poverty	Recoded to IPR
16	RIDEXPRG	Categorical	Pregnancy Status at Exam – Recode	
17	DMDCITZN	Categorical	Citizenship Status	Combined into CIT
18	DMDYRSUS	Categorical	Length of time in US	
19	SIALANG	Categorical	Language of Sample Person (SP) Interview	

Food Security

20	FSDAD	Categorical	Adult food security category	Composite variable based on variables 20-30
21	FSD151	Categorical	HH Emergency food received	Combined into new variable, FA. Any positive response = 1, else = 0.
22	FSQ171	Categorical	HH FS benefit: receive in last 12 months	
23	FSQ162	Categorical	HH (Women, Infants, Children) WIC receive in last 12 months	

Dietary

24	DR1TSODI	Interval	Day One Sodium (mg)	
25	DR1TPOTA	Interval	Day One Potassium (mg)	

Health Status

26	BPQ020	Categorical	Ever told you had high blood pressure	
27	BPXSY1	Interval	Systolic: Blood pres (1st rdg) mm Hg	Variables 37-40 were averaged to determine systolic blood pressure (variable = MEANBPS)
28	BPXSY2	Interval	Systolic Blood pres (2nd rdg) mm Hg	
29	BPXSY3	Interval	Systolic Blood pres (3rd rdg) mm Hg	
30	BPXSY4	Interval	Systolic Blood pres (4th rdg) mm Hg	
31	BPXDI1	Interval	Diastolic Blood pres (1st rdg) mm Hg	Variables 41-44 were averaged to determine diastolic blood pressure (variable = MEANBPD)
32	BPXDI2	Interval	Diastolic Blood pres (2nd rdg) mm Hg	
33	BPXD13	Interval	Diastolic Blood pres (3rd rdg) mm Hg	
34	BPXDI4	Interval	Diastolic Blood pres (4th rdg) mm Hg	
35	BPQ040A	Categorical	Taking prescription for hypertension	
	HTN	Categorical	Hypertension status	Composite variable

				including variables BPQ020, MEANBPS, MEANBPD, BPQ040A.

APPENDIX B: USDA Household Food Security Survey Module used to determine NHANES variable FSDAD adult food security

1. I worried whether my food would run out before I got money to buy more. Was that often true, sometimes true or never true for you in the last 12 months?

    Responses: Often true = 1
    Sometimes true = 2
    Never true = 3
    Refused = 7
    Don't know = 9

2. The food that I bought just didn't last and I didn't have money to get more. Was that often, sometimes or never true for you in the last 12 months?

    Responses: same as 1.

3. I couldn't afford to eat balanced meals. Was that often, sometimes or never true for you in the last 12 months?

    Responses: same as 1.

4. In the last 12 months, since last (name of current month) did you ever cut the size of your meals or skip meals because there wasn't enough money for food?

    Responses: Yes = 1
    No = 2
    Refused = 7
    Don't know = 9

5. If yes, how often did this happen – almost every month, some months but not every month, or in only 1 or 2 months?

    Responses: same as 5.

6. In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money for food?

    Responses: same as 5.

7. In the last 12 months, were you ever hungry but didn't eat because there wasn't enough money for food?

    Responses: same as 5.

8. In the last 12 months, did you lose weight because there wasn't enough money for food?

    Responses: same as 5.

9. In the last 12 months, did you ever not eat for a whole day because there wasn't enough money for food?

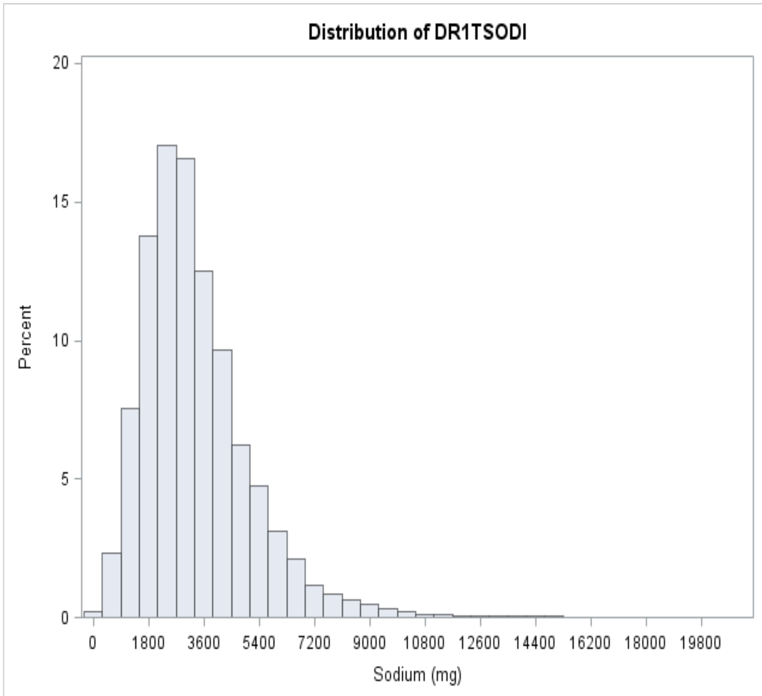
    Responses: same as 5.

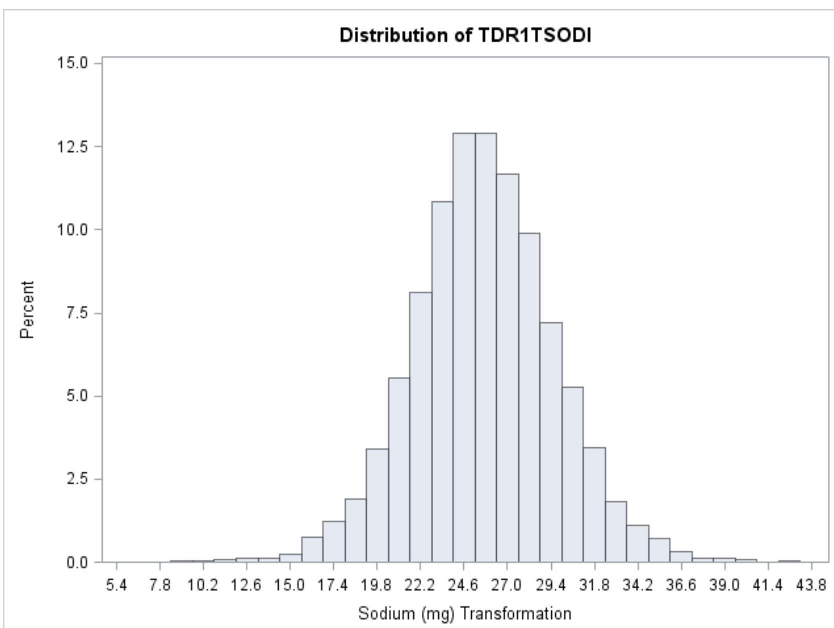
10. If yes, how often did this happen – almost every month, some months but no every month or in only 1 or 2 months?

    Responses: same as 5.

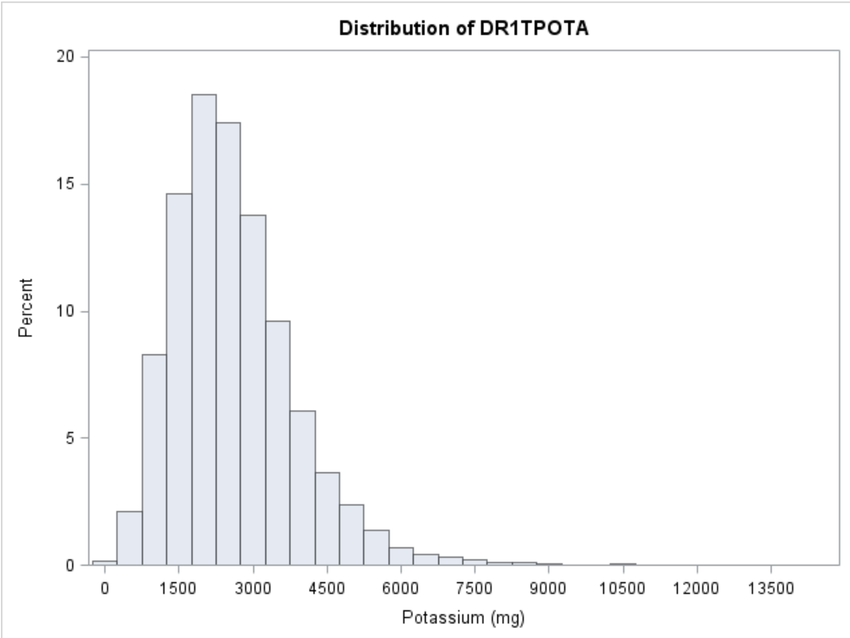
Appendix C: Data Transformation Histograms

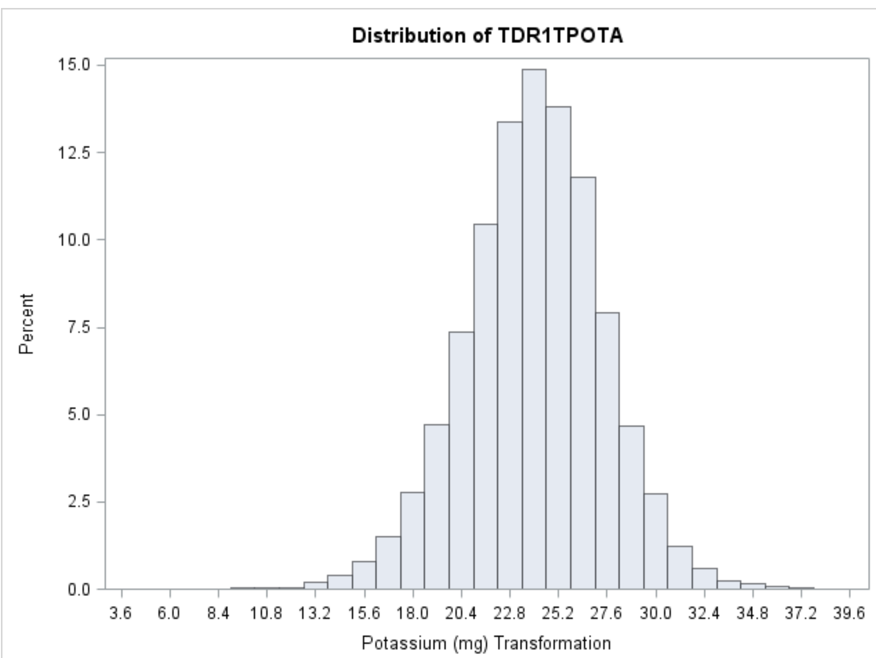
1. Transformation of Mean Usual Sodium Intake



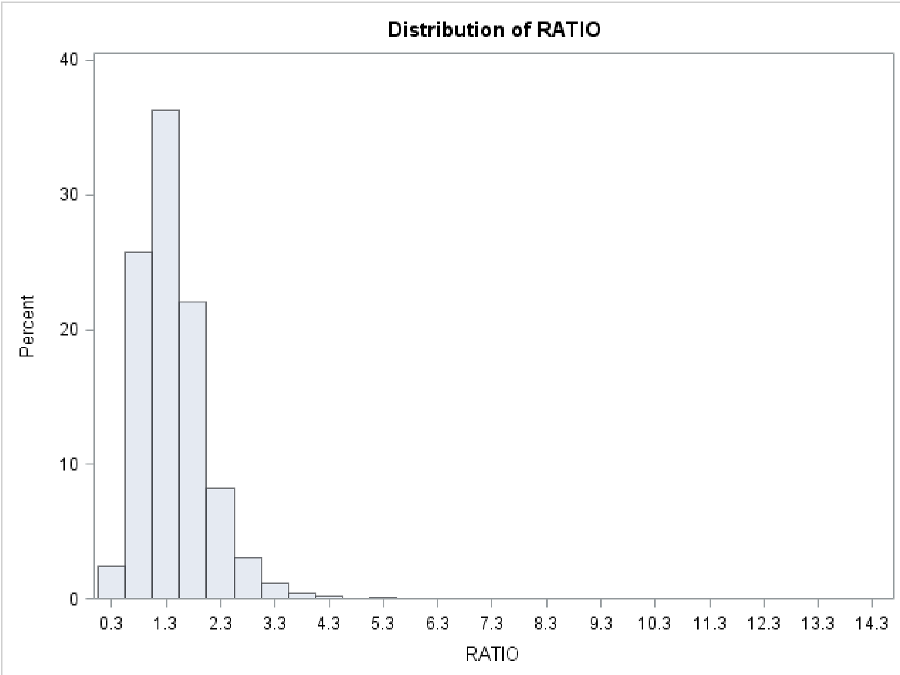


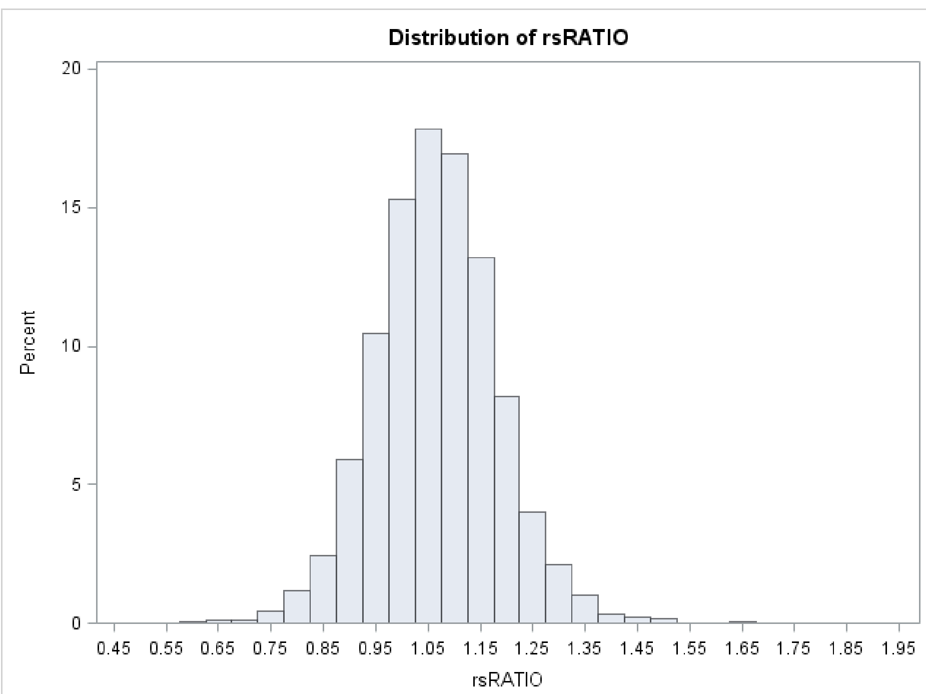
2. Transformation of Mean Usual Potassium Intake





3. Transformation of Mean Usual Sodium:Potassium Ratio





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