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THE PREVALENCE OF IRON DEFICIENCY AND OBESITY AMONG YOUNG CHILDREN IN THE UNITED STATES

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THE PREVALENCE OF IRON DEFICIENCY AND OBESITY AMONG YOUNG CHILDREN IN THE UNITED STATES

A Thesis

Presented to the

Faculty of

California State University,

San Bernardino

In Partial Fulfillment

of the Requirements for the Degree

Master of Public Health

by

Mirriam Abunaja

May 2022

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ABSTRACT

Background The coexistence of obesity and iron deficiency among children is one manifestation of the double burden of malnutrition (DBM) and is a public health concern. This study aims to provide useful insight on public health knowledge by presenting a current snapshot of the coexistence of obesity and iron deficiency among pre-school aged children as well as specific risk factors.

Methods This analysis utilizes secondary data from a publicly accessible, national database, the National Health and Nutritional Examination Survey (NHANES). The data examined were retrieved from the years 2015-2016 and 2017-2018. Chi-squared tests were used to test each thesis question.

Results Weight status was not found to be a statistically significant risk factor for iron deficiency. Among the complete study sample, the overall prevalence of DBM is 1.25%. In examining younger age, female, and race/ethnicity (Hispanic or Black) as risk factors for the DBM, none were statistically significant in this analysis. In examining household income below the poverty level and caregiver education at or below a high school degree as risk factors for DBM, neither were statistically significant. In examining food insecurity as a risk factor for iron deficiency and for overweight/obesity, I found food insecurity was not statistically significantly associated with iron deficiency but was associated with overweight/obesity (OR (95% CI): 1.57 (1.12, 2.20)).

Conclusion This analysis examined the prevalence of iron deficiency and overweight/obesity among children 1 – 5 years old in the United States. The

literature and analysis suggest that children who experience overweight/obesity should be screened for iron deficiency. This is a pressing public health concern as iron deficiency and overweight/obesity are linked to short-term and long-term health consequences. Overweight/obesity is linked to chronic illness while iron deficiency is linked to cognitive and behavioral delays. More research on this double burden of malnutrition, and environmental and household risk factors are needed and welcomed. The additional research can provide valuable information to programs such as Head Start. This analysis also serves as a foundation for future studies and Head Start professionals in the United States to focus on the double burden of malnutrition.

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TABLE OF CONTENTS

ABSTRACT iii

ACKNOWLEDGEMENTS v

LIST OF TABLES vii

LIST OF FIGURES viii

CHAPTER ONE: INTRODUCTION 1

Problem Statement 1

Purpose of Study 4

Significance to Public Health 5

CHAPTER TWO: LITERATURE REVIEW 8

CHAPTER THREE: METHODS 16

Study Design 16

Data Source and Collection 16

Measures 17

Data Analysis 21

Computer Programs 21

Thesis Questions, Hypothesis, and Statistical Analysis 21

Ethics 24

CHAPTER FOUR: RESULTS 25

CHAPTER FIVE: DISCUSSION 31

Strengths and Limitations 34

Recommendations for Research and Practice 35

Conclusion 37

APPENDIX A: DERIVED VARIABLES FROM NHANES 38

APPENDIX B: NHANES 2015-2016 AND 2017-2018 EXISTING VARIABLES .. 48

REFERENCES 53

LIST OF TABLES

Table 1. Population Demographics..25

Table 2. Odds Ratios for DBM 28

LIST OF FIGURES

Figure 1. Prevalence of Iron Deficiency Among Children 1-5 Years Old Who Are Overweight and Not Overweight 26

Figure 2. Percent of Iron Deficiency Among Children 1-5 Years Old Who Experience Household Food Security and Food Insecurity 29

Figure 3. Percent of Weight Status Among Children 1-5 Years Old Who Experience Household Food Security and Food Insecurity 30

CHAPTER ONE

INTRODUCTION

Problem Statement

The double burden of malnutrition (DBM) is a global health concern that is widely researched in many countries around the world but has not been a predominant focus in the United States. DBM is defined by the World Health Organization (WHO) as “the coexistence of undernutrition along with overweight and obesity, or diet-related noncommunicable diseases, within individuals, households and populations, and across the life course” (WHO, 2021). In 2014, the WHO identified malnutrition among children under the age of five as a worldwide burden with 42 million children overweight or obese, 156 million children stunted (low height-for-age), and 50 million children wasted (low weight-for-height) (WHO, 2021). Low and middle-income countries are experiencing children with obesity and forms of undernutrition at higher rates than richer countries, causing concerns of global malnutrition.

The double burden of malnutrition can be viewed and identified in an individual - for example, obesity with a vitamin deficiency, and at a community level - for example, a prevalence of obesity and malnutrition in the same community or region (WHO, 2021). The National Health and Nutrition Examination Survey (NHANES) and the World Health Organization (WHO) are useful resources to identify certain health variables in communities and regions and examine patterns across the population and across time. NHANES data from

2017-2020 suggests that 19.7% of children in the United States are obese (NHANES, 2021). The same data suggests the prevalence of obesity increased with age, with 12.7% for those aged 2–5 years, 20.7% for 6–11, and 22.2% for 12–19 (NHANES, 2021). These data cause concerns as obesity in children is a health condition that can affect nearly every organ system in the human body and increases the risk of hypertension, dyslipidemia, insulin resistance or diabetes, fatty liver disease, and psychosocial complications, causing DBM (Han et al., 2010).

The coexistence of obesity and micronutrient deficiencies among children is certainly a public health concern. Given the high prevalence of obesity among children in the US, the occurrence of micronutrient deficiencies among children with obesity should be defined. The presence of iron deficiency (ID) is of particular interest, as it is the most common nutritional deficiency in the world and causes risk factors for the health and development in children (Stevens et al., 2013). The prevalence of ID in preschool-aged children has been seen to peak between ages 12 and 24 months because of rapid growth, depletion of prenatally acquired iron stores, and the transition to complementary foods (Bayoumi et al., 2020).

Screening for iron deficiency among children and at-risk populations has been recommended by the Center of Disease Control and Prevention (CDC) since 2001. In the late 1990's, the CDC requested for the Institute of Medicine to build a team of professionals to "develop recommendations for preventing, detecting, and treating iron-deficiency anemia among U.S. children and U.S. women of childbearing age" (CDC, 1998). The resulting recommendations include (1) sound iron nutrition for infants and young children, (2) periodic screenings for anemia among high-risk populations of infants, preschool children, and women of childbearing age, and (3) universal iron supplementation to meet the iron requirements of pregnancy (CDC, 2001). Nead et al. recommends that guidelines for screening children for iron deficiency need to be modified to include children with elevated body mass index (BMI) who otherwise wouldn't be screened, as this could be a high-risk group for ID (2004).

Restricted household resources can also put children at higher risk for various health and nutrition issues, and various federal programs are designed to support these families and improve the health outcomes of the children. Such programs include SNAP, WIC, and Head Start, to name just a few. Head Start is a program that started as a summer nutrition program during the United States president Lyndon B. Johnson Administration's War on Poverty. Now, Head Start provides services to children 0-5 years old and their families in areas such as early learning, health, and family well-being. Head Start programs provide services to low-income families such as health screenings and nutritious meals alongside medical, dental, and mental health services to ensure children and families are receiving the necessary care. Understanding the nutritional status of low-income children who quality for Head Start, can help Head Start to address the needs of the communities they serve (Head Start ECLKC, n.d.).

Purpose of Study

Additional research on the recent prevalence of the co-existence of overweight/obesity and iron deficiency among children in the United States can provide supplemental information for public health professionals and support future development in community outreach organizations and federal assistance programs. The purpose of this study is to quantify the prevalence of DBM among children and explore the risk factors for DBM. This research will assist with the understanding of which groups of children are most at risk for DBM in the United States.

Research Questions

This research aims to address four primary research question in the context of the United States:

1A) Are overweight and obese children ages 1- 5 years old (pre-school aged children) more likely to be iron deficient than similar children who are not overweight or obese?

1B) What is the prevalence of double burden of malnutrition among pre-school aged children?

2A) Are individual level demographic characteristics associated with the double burden of malnutrition among pre-school aged children? (i.e. age, gender, and race/ethnicity).

2B) Are household level demographic characteristics associated with the double burden of malnutrition among pre-school aged children? (i.e. household income and caregiver education).

3A) Are children living in food insecure households more likely to be iron deficient when compared to similar children living in food secure households.

3B) Are children living in food insecure households more likely to be overweight/obese when compared to similar children living in food secure households.

Significance to Public Health

In 2018, the Preventative Medicine Reports reported that half of all malnourished households in the United States also experience a double burden of malnutrition. (Bowers et al., 2018). Bowers et al. defines the double burden of malnutrition as present when an individual, household, or community experiences obesity alongside undernutrition (2018). Addressing the DBM concern can increase awareness for healthcare professionals which can then increase health screenings and potentially lower the chances of health disparities. The CDC suggests “integrating relationship-based prevention and intervention services for children early in life, when the brain is developing most rapidly, can optimize developmental trajectories” (2017). With that in mind, this study aims to provide useful insight on public health knowledge by presenting a current snapshot of the coexistence of obesity and iron deficiency among pre-school aged children and providing insights on specific risk factors. Furthermore, this study is being carried out in collaboration with colleagues working with Head Start and will be useful in informing the Head Start program on the DBM among children. By completing this study with Head Start, we aim to produce findings that will be most meaningful and actionable for the program.

This study will assist with the mastery of several Master of Public Health (MPH) competencies, which include:

- Performing effectively on interprofessional teams.
- Interpret results of data analysis for public health research, policy or practice.
- Communicate audience-appropriate public health content, both in writing and through oral presentation.
- Apply principles of leadership, governance, and management, which include creating a vision, empowering others, fostering collaboration, and guiding decision making.
- Analyze quantitative and qualitative data using biostatistics, informatics, computer-based programming, and software, as appropriate.
- Explain the social, political, and economic determinants of health and how they contribute to population health and health inequities.
- Select quantitative and qualitative data collection methods appropriate for a given public health context.

- Assess population needs, assets and capacities that affect communities' health.

CHAPTER TWO

LITERATURE REVIEW

Overweight and obesity has reached unprecedented rates among individuals of all ages and has been declared a global epidemic. Despite the growing concern, obesity rates continue to rise in the United States and worldwide among adults and children alike. According to the World Health Organization (WHO), in 2016, an estimated 41 million children under the age of 5 years were overweight or obese, while 155 million were chronically undernourished (2016). Both iron deficiency and obesity in early childhood are found to be associated with adverse health outcomes later in life (Sypes et al., 2019). During the pre-school years (ages 0-5 years old), children have several growth spurts where they experience periods of rapid development, which also increases their nutritional needs and risk for malnutrition.

Childhood Overweight & Obesity

The World Health Organization (WHO) defines obesity as abnormal or excessive fat accumulation that presents a risk to health (WHO, n.d.). Typically, obesity is measured by the individual's body mass index, which includes weight (kg) divided by height (m^2). In children specifically, obesity is defined as a body mass index (BMI) at or above the 95th percentile of a reference population. Childhood obesity has increased significantly from 1980 to 2010, particularly in the US (Han et al., 2010). In recent years, obesity is prevalent among 13.4% of children ages 2 to 5 years of age (CDC, 2021). The CDC describes obesity as a serious concern in the United States because children with obesity are at greater risk of poor health.

Childhood obesity is a complex disorder that can be determined by genetic and non-genetic factors. This may include individual or household characteristics such as a child's diet, energy expenditure, sleep, ethnic origin, county of birth, residence, and socioeconomic position (Han et al., 2010). One study suggests an individual’s socioeconomic status (SES) background influences their food consumption and physical activity patterns through environmental factors. Specifically, the physical environment can encourage or discourage physical activity, and the availability of food can encourage or discourage a healthy diet (Frederick et al., 2014).

Environmental health and surroundings impact the health of children and ability to participate in physical activity. Environmental health includes air quality, food protection, radiation protection, solid waste management, hazardous waste management, water quality, noise control, environmental control of recreational areas, housing quality, and vector control (Hernandez, 2011). Poor air quality, limited sidewalks and streetlights, and recreational areas that are not maintained can all discourage children and families from physical activity. Food deserts are also a concern in these neighborhoods. A lack of grocery stores and nearby nutritional foods can influence unhealthy eating.

The relationship between SES and childhood obesity provides an example of a pervasive health disparity in the U.S. that can be connected back to disparities in community resources. For example, poorer neighborhoods are found to have limited access to fresh fruits and vegetables, and when fresh produce is available it is costlier than fast food. These same lower-income neighborhoods tend to have limited opportunities for physical activity with fewer playgrounds, sidewalks, and recreational facilities (Frederick et al., 2014). Such factors are influential on a child's overall health.

To address this public health concern, effective solutions must be devised and implemented with the communities in mind. Prevention can be initiated at an individual, household, institutional, community, and healthcare level. Frederick et al. suggests more rigorous government support and targeted programs to address the epidemic and reduce the disparities in physical activity among low SES groups (Frederick et al., 2014). As described by Dr. Han, children with a BMI greater than the 95th percentile should be considered for non-pharmacological treatment for obesity such as first-line therapy (Han et al., 2010). First-line therapy strategies include interventions such as physical activity and healthy eating. Within a household, children may be influenced and encouraged by the parents by offering appropriate food portions and fostering physical activity (Han et al., 2010).

Iron Deficiency During Childhood

Iron deficiency (ID) is another critical form of malnutrition that young children ages 0-5 years are susceptible to. Iron is an essential micronutrient and plays a key role in the overall growth and development of young children;

furthermore, a deficiency in iron has been linked to behavioral and learning difficulties (Nead et al., 2004). ID can result in iron deficiency anemia (IDA), a condition in which the blood lacks healthy red blood cells that are essential for carrying oxygen to the bodies tissue (Mayo Clinic, 2019).

According to the Official Journal of the American Academy of Pediatrics, iron deficiency is the world’s most common nutritional deficiency, and affects nearly 2.4 million children in the United States (2007). An analysis conducted by Gupta et al. using NHANES determined that the prevalence of iron deficiency among children 1 - 5 years old was 7.1%, 3.2% of the children had anemia, and 1.1% had IDA (2016). Both iron deficiency and anemia were the most prevalent in children 1 to 2 years of age.

Determinants of iron deficiency in children include low birth weight, exclusive breastfeeding beyond 6 months, low or no meat consumption, vegetarian or vegan diets, and poor diets in the second year of life (Mayo Clinic, 2019). Exclusive breastfeeding provides important benefits to infant, mother and society and is highly recommended by experts, though breast milk is low in iron. Thus, after 6 months children require an external source of iron-rich foods to assist with growth and development (CDC, 2021). This may include red meat, beans, dark leafy vegetables, dried fruit, iron-fortified cereals, and peas. Therefore, in conjunction with the recommendation to exclusively breastfeed until 6 months, families must also be encouraged to provide iron-rich foods when complementary food are introduced.

Children experience rapid growth spurts at the age of 2 and 4 years, at which times essential micronutrients like iron are crucial for development. Biochemically, iron carries oxygen in red blood cells to muscles and body tissue. This process is essential for growth spurts in children. Iron deficiency can be prevented or reduced by consuming iron-rich foods and by screening children at high-risk. The American Academy of Pediatrics (AAP) recommends screening children between the ages of 9 to 12 months with additional screening between the ages of 1 and 5 years for patients at risk.

The Co-occurrence of Iron Deficiency and Overweight Among Children

In the study conducted by Sypes et al., the association between BMI and iron deficiency was examined in 1,607 children between 1-3 years old. The study was conducted using a cross-sectional analysis of healthy children who were recruited from The Applied Research Group for Kids (TARGet Kids!) primary care practice between March 2008 and March 2015. To assess children for iron deficiency, serum ferritin tests were conducted using blood samples. To assess obesity, age and sex standardized World Health Organization (WHO) BMI z-scores were calculated using the children's height and weight (Sypes et al., 2019). The results from the study concluded that children with a higher BMI also experienced lower serum ferritin levels; specifically, there is an increased odds of iron deficiency among children with higher BMIs compared to those with lower BMIs.

A secondary analysis conducted by Karen G. Nead et al. investigated the association between weight status and iron deficiency in 9,698 children between 2-16 years old. Of those, 4,553 were between 2-5 years old. NHANES data from 1988 through 1994 were analyzed to determine iron deficiency with and without anemia. Results showed that 2.3% of 2–5-year-old children experienced iron deficiency, with 0.6% presenting with IDA. Nead et al. concluded that iron deficiency was more prevalent among 2- 16-year-old children with higher BMIs compared to children with normal weights. Additionally, children with a BMI above the 85% percentile were approximately twice as likely to be iron-deficient, compared with children of normal weight (Nead at al., 2004).

When examining drivers of malnutrition in all its forms among children, access to nutritious foods is an important variable to consider. Food *security* is defined as "access by all people at all times to enough food for an active, healthy life," while food *insecurity* is defined as "limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable ways" (Eicher-Miller et al., 2009). Approximately 6.1 million children in the U.S. lived in food-insecure households (2020). Eicher-Miller et al. conducted a study to examine the association between food insecurity and IDA and found that food-insecure children may consume a diet that puts them at risk of health outcomes associated with lower intakes of nutrients, including iron (2009).

Limitations of the studies reviewed

As with all studies, the studies that were presented in this literature review have limitations. Below provides a summary of the relevant limitations of the key studies included in the literature review.

- Bayoumi et al.’s observational study found important associations with ID and IDA but couldn’t determine causation. Study participants were recruited from Toronto, Canada, and may not be generalizable to other general populations. Measures of food insecurity were restricted to brief measures; use of the full HFSSM would have provided a more robust measure. Family income and risk of FI were parent-reported and may be subject to social desirability bias, perhaps particularly for FI reporting. This may have biased the results toward the null. Also, self-reported breastfeeding duration may be subject to recall bias, although this is considered a valid and reliable measure in the first 3 years of life (Bayoumi et al., 2020).
- Bowers et al. listed no limitations.
- Frederick et al. included limited research on health inequalities related to obesity. Since the social determinants of obesity are complex, Frederick et al. acknowledged the need for additional research.
- Han et al. experienced limitations during follow-ups as they were short-term. Despite the limitation, Han et al. concluded that the planned interventions provided meaningful results to the participants.

- Eicher-Miller et al.'s limitations included selection bias due to children refusing testing. Additionally, children in the study were less likely to report accurate information about their diets.
- Nead et al. had a small percentage of children who were overweight with iron deficiency anemia, this limited the ability to be compared to children with iron deficiency *without* anemia. Second, with several factors influencing weight status and iron deficiency, residual confounding is possible. Lastly, the data used was cross-sectional meaning the coexistence of weight status and iron deficiency couldn't be determined (Nead et al., 2004).
- Stevens et al. had limited data on anemia and hemoglobin in children.
- Sypes et al. limitations included the cross-sectional design, and therefore the data couldn't be definitively determined. Additionally, the study was conducted in Toronto, Canada, and therefore may not represent other regions of the world, such as the United States.

CHAPTER THREE

METHODS

Study Design

This study utilizes data from the National Health and Nutrition Examination Survey (NHANES). I conducted secondary data analysis to address my research questions using this cross-sectional, nationally representative dataset.

Data Source and Collection

Data were downloaded from the NHANES database on the CDC website. NHANES is a nationally representative survey in the U.S. and is designed to assess the health and nutritional status of adults and children. NHANES collects a variety of data from study participants, including interview data, anthropometric measurements, and biomarkers, and biomarkers, such as those for iron. The major purpose of NHANES is to: 1) estimate prevalence of diseases and risk factors in the U.S., 2) monitor trends in selected diseases, 3) monitor trends in risk behaviors and environmental exposures, 4) study the relationship between nutrition and health, 5) explore emerging public health issues and solutions, and 6) link health characteristics to mortality data.

The NHANES datasets are publicly available online through the CDC. For the current study, data from NHANES 2015-2016 and 2017-2018 were downloaded, compiled, and analyzed.

In total, 9,544 people completed the NHANES 2015-2016 interview and examination, and 8,704 completed the NHANES 2017-2018 interview and examination (*NHANES 2017-2018 Overview*, n.d.). A key subgroup included in the NHANES survey, and the focus of the current analysis, are children 1 to 5 years of age. In this study, children from the NHANESE 2015-2016 and 2017-2018 datasets were included in the analysis if they were:

- between 1 and 5-years-old
- had complete anthropometric and biochemical data

Children were excluded from this analysis, if they were outside of the specified age range, or had missing anthropometrics or iron biomarker data.

A total of 1,276 children between the ages of 1 and 5 year from the NHANES 2015-2016 and 2017-2018 had complete anthropometric and biochemical data, which represents the sample for the current analysis.

Measures

Relevant variables from the NHANES data that were used in this analysis are summarized in **Appendix B**. Using these variables, several additional variables were derived. A summary of the derived variables can be found in **Appendix A**. Below is a description of the variables for this study.

Outcome Variables

Iron deficiency is a binary variable that I generated using the cut-offs for low iron for ferritin and transferrin receptors. The cutoff for serum ferritin is <12 μg/mL and the cutoff for transferrin receptor is >8.5 mg/L for children ages 1-5 years old. If a child has a serum ferritin <12 μg/mL *and/or* transferrin receptor >8.5 mg/L, the child was coded as iron deficient. If serum ferritin ≥12 μg/mL *and* transferrin receptor ≤8.5 mg/L, the child will be coded as not iron deficient. This variable will serve as an outcome variable for research question 1A, and will be used to generate the primary outcome variable of the study, double burden of malnutrition. The analysis included any child with iron deficiency, regardless of the presence of amenia.

BMI-for-age percentiles and z-scores by gender is a continuous variable that I created based on the Center for Disease Control and Prevention (CDC) and the World Health Organization (WHO) growth charts, for children 2-5 years old and 12-24 months old, respectively. The CDC growth charts for BMI reflect age and gender norms based on a reference population of typical children in the United States. The charts represent children's age in months and reflects BMI as a percentile, ranging from 3^{rd} to 95^{th} BMI-for-age percentiles. The WHO growth charts are similar to those of the CDC and are recommended for use of children under 2 in the United States. The primary difference between the WHO and CDC growth charts are the reference populations, where the WHO reference populations are globally representative of optimal child growth. This variable will be used to generate a variable for weight status.

Weight status is a dichotomous variable that I generated from BMI-for-age percentile, using the cut-offs: at or above the 85^{th} percentile for children 2-5 years old (CDC growth chart) and a BMI-for-age z score of 2 or more for children 12-24 months (WHO growth chart). Children above these cutoffs were coded as overweight or obese and children below these cut-offs where coded as not overweight. This variable will serve as a predictor variable for research question for 1A.

Double burden of malnutrition (DBM) is a dichotomous variable that I generated from iron deficiency and overweight. The DBM in this study will consist of overweight/obesity and iron deficiency among children ages 1 – 5 years of age in the United States. The variable will serve as an outcome variable for research question 1B, 2A, 2B, and 3.

Household-Level Determinants

Family income above or below the poverty level is a binary variable for household income. The family income poverty level is determined by the Census Bureau family income to poverty guidelines. For this analysis, the 100% (a ratio of 1.00) of the poverty guidelines cutoff will be used to determine a household's income to poverty. The binary variable I generated for this study is coded as (1) at or below the poverty level and (0) above the poverty level.

Caregiver education greater or less than high school is a binary variable for caregiver education. The NHANES variable Education Level is a categorical variable that includes (1) less than 9th grade, (2) 9 – 11th grade (includes 12th grade with no diploma), (3) high school graduate/GED or equivalent, (4) some college or AA degree, (5) college graduate or above, will be collapsed into two groups: (1) high school graduate or less and (2) greater than high school graduate (at least some college).

Food security is a binary variable that I generated for household food security. The NHANES variable Child Food Security Category which is a categorical variable that includes (1) full or marginal food security, (2) marginal food security, (3) low security, and (4) very low food security, will be collapsed into two groups: (1) food secure [(1) full or marginal food security] and (0) not food secure [(2) marginal food security, low security, and very low food security].

Participation in food assistance programs is a binary variable that I generated for food security. The NHANES variable that questions if a household ever used WIC is a binary variable that includes (1) yes and (2) no. The NHANES variable that questions if a household ever used SNAP is a binary variable that includes (1) yes and (2) no. The two variables will be combined into an effect modifier. If the household ever used WIC or SNAP, it will be coded (1) received WIC or SNAP ever and (2) did not receive WIC or SNAP ever.

Individual-Level Determinants

Under 2 years old is a binary variable for age in years among children. The NHANES data includes two different continuous variables for age at the time of screening: age in years for (DMDHRAGZ) and age in months for children who are 24 months or younger (RIDAGEMN). The new binary variable I generated for this study, “under 2 years old” is coded as (1) children 12 - 24 months of age, and (0) 2 - 5 years of age.

Gender is a binary variable for the sex of the participants. The NHANES variable includes two binary variables (1) males and (2) females. I recoded the variable for the purpose of this study: (1) male and (0) female.

Race/ethnicity is a categorical variable for the race or ethnicity of the participants. The NHANES Race/Hispanic Origin with Non-Hispanic Asian which is a categorical variable that includes (1) Mexican American, (2) Other Hispanic, (3) Non-Hispanic White, (4) Non-Hispanic Black, (6) Non-Hispanic Asian, (7) Other race – including multi-racial. The new categorical variable I generated for this study is (1) Hispanic, (2) non-Hispanic Black, (3) non-Hispanic White, (4) non-Hispanic Asian, and (6) other or multi-racial.

Data Analysis

Computer Programs

Stata version 16.1 and IBM SPSS Statistics version 28 was used to clean and analyze the data, respectively. Below, the statistical approach to address each research question and test each of my hypotheses is organized by research question.

Thesis Questions, Hypothesis, and Statistical Analysis

In question 1A I aim to determine whether overweight and obese children ages 1- 5 years old (pre-school aged children) more likely to be iron deficient than similar children who are not overweight or obese? I hypothesize 6.2% overweight children ages 1 – 5 will experience iron deficiency compared to 2.3% normal-weight children. To test hypothesis 1A, a chi-squared will be used to test the difference in iron deficiency among children with overweight/obesity and children without overweight/obesity.

In question 1B I aim to determine what the prevalence of double burden of malnutrition among pre-school aged children. I hypothesize approximately 1.3% children ages 1 – 5 years of age are expected to experience a double burden of malnutrition (DBM), where DBM is defined as children with iron deficiency (with serum ferritin <12 μg/mL and/or transferrin receptor >8.5 mg/L) and overweight or obesity (BMI-for-age percentile at or above the 85th percentile). For hypothesis 1B, point prevalence of the DBM will be determined along with a 95% confidence interval.

In question 2A I aim to determine if individual-level demographic characteristics (i.e., age, gender, and race/ethnicity) are associated with the double burden of malnutrition among pre-school aged children. I hypothesize females 1 – 5 years of age are at greater risk of experiencing a double burden of malnutrition compared with similar male children; Black and Hispanic children 1 – 5 years of age are at greater risk of experiencing a double burden of malnutrition compared with children who are White or Asian; and children ages 12 to 24 months are at greater risk of experiencing a double burden of malnutrition compared with children who are 2 to 5 years of age. To test hypothesis 2A, a chi-squared will be used to test the difference in the double burden of malnutrition among children with different demographics (i.e. gender, age, race/ethnicity).

In question 2B I aim to determine if household-level demographic characteristics (i.e., household income and caregiver education) are associated with the double burden of malnutrition among pre-school aged children. I hypothesize children 1 – 5 years of age whose caregiver has a high school graduate/GED or equivalent, or less, are at greater risk of experiencing a double burden of malnutrition compared with children whose caregiver has any education beyond a high school or GED degree. Children 1 – 5 years of age whose family income is at or below the poverty index are at greater risk of experiencing a double burden of malnutrition compared with children whose family income is greater than the poverty index. To test hypothesis 2B, a chi-squared will be used to test the difference in the double burden of malnutrition among children with different household demographics (i.e. family income to poverty and caregiver education level).

In question 3A I aim to determine if children living in food insecure households are more likely to be iron deficient when compared with similar children living in food secure households. I hypothesize iron deficiency will be more prevalent among children who experience food insecurity compared with similar children living in food-secure households. To test hypothesis 3A, a chi-squared will be used to test the prevalence of iron deficiency among children who experience household food security and food insecurity.

In question 3B I aim to determine if children living in food insecure households more likely to be overweight/obese when compared with similar children living in food secure households. I hypothesize overweight/obesity will be more prevalent among children who experience food insecurity compared with similar children living in food-secure households. To test hypothesis 3B, a chi-squared will be used to test the prevalence of overweight/obesity among children who experience household food security and food insecurity.

Ethics

This study did not require Institutional Review Board (IRB) approval as secondary data was utilized from a publicly accessible, national database. NHANES 2015-2016 and 2017-2018 data was approved by the National Center for Health Statistics (NCHS) Research Ethics Review Board (ERB) Protocol Continuation of Protocol #2011-17 and #2018-01.

CHAPTER FOUR

RESULTS

The sample included in this analysis consisted of 1,276 children in the United States between the ages 1 – 5 years old. Table 1 presents the population demographics of this study.

Table 1. Population Demographics

	Percent	n
Age		
12-24 months	21%	271
2-5 years of age	79%	1,005
Gender		
Male	51%	649
Female	49%	627
Race/ethnicity		
White	33%	425
Black	24%	302
Hispanic	28%	360
Asian	5%	66
Other/mixed racial	10%	123
Iron Deficiency		
Not iron deficient	95%	1,213
Iron deficient	5%	63
Weight Status		
Not overweight/obese	82%	1,048
Overweight/obese	18%	228
Poverty Status		
At or below poverty level	33%	427
Above poverty level	57%	724
Missing	10%	125
Caretaker Education		
<12th grade	24%	303
High school graduate or higher	30%	385
Missing	46%	588

Food Security		
Food secure	77%	977
Food insecure	20%	254
Missing	3%	45

Figure 1 presents the prevalence of iron deficiency among children 1 – 5 years old who are overweight and not overweight. The prevalence of iron deficiency among children who are overweight or obese is 7.0%, and the prevalence among children who are not overweight or obese is 4.5% (OR (95% confidence interval (CI)): 1.61 (0.90, 2.89)). The difference in the prevalence of iron deficiency by weight status was not statistically significant.

Among the complete study sample (n=1,276), the overall prevalence of DBM is 1.25% (n=16) (95% CI 0.64, 1.87).

Figure 1. Prevalence of Iron Deficiency Among Children 1-5 Years Old Who Are Overweight and Not Overweight

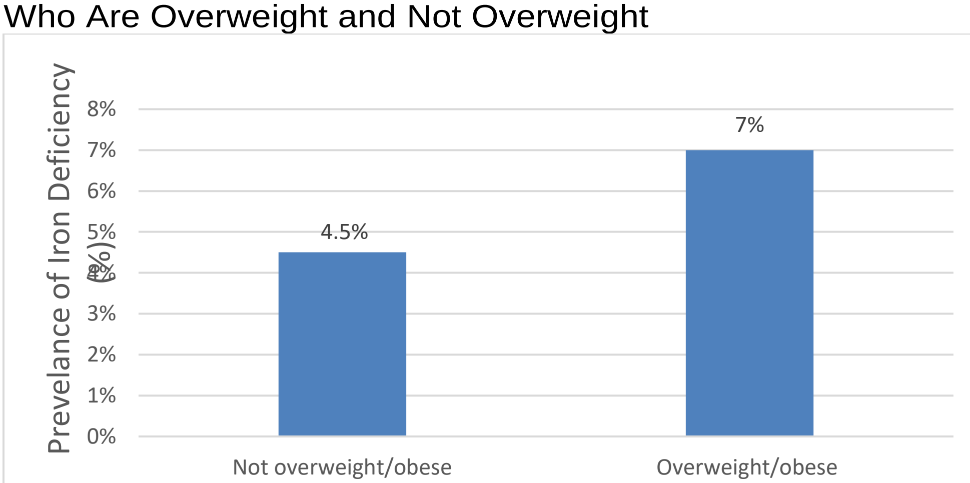


Table 2 presents the demographic determinants of this double burden of malnutrition (DBM). Children under 2 years of age experienced a lower prevalence of DBM [0.4% (n=1)] when compared with children 2 – 5 years old [1.5% (n=15)] (OR (95% CI): 0.24 (0.03, 1.86)). The difference in the prevalence of DBM by age was not statistically significant.

Females had a slightly lower prevalence of DBM compared to males (1.4% vs. 1.1%) (OR (95% CI): 0.80 (0.30, 2.17)), though this difference was not statistically significant.

The race/ethnicity with the highest prevalence of the DBM is non-Hispanic Asians [3.03% (n=2)], followed by Hispanics [2.50% (n=9)], and non-Hispanic White [1.18% (n=5)]. Non-Hispanic Black and other/multi-racial had 0 cases of DBM in this analysis. To test my hypothesis, I collapsed Hispanic and Non-Hispanic Black together and non-Hispanic White and Asia together, and excluded other/multi-racial. The prevalence of DBM was slightly lower among Hispanic & Non-Hispanic Black (1.36%) compared with Non-Hispanic White & Asian (1.43%) children, though this difference was not statistically significant (OR (95%CI): 0.95 (0.35, 2.58)).

Approximately 1.9% (n=8) of children living in a household with an income at or below the poverty level experienced the DBM, compared with 1.1% (n=8) of children living in a household with an income above the poverty level (OR (95% CI): 1.71 (0.64, 4.59)). The difference in the prevalence of the DBM by household poverty level was not statistically significant.

Approximately 1.7% (n=5) of children whose caregiver has a high school graduate degree or less experienced the DBM, compared to 0.8% (n=3) of similar children whose caregiver had a greater than a high school degree (OR (95% CI): 2.14 (0.51, 9.01)). The difference in the prevalence of the DBM by caregiver education was not statistically significant.

Table 2. Odds Ratios for DBM

	Odds Ratios	**95% Confidence Interval**	**P-value**
Age			
12-24 months	0.24	0.03, 1.86	0.14
2-5 years of age	1.00		
Gender			
Male	1.00		
Female	0.80	0.3, 2.2	0.66
Race/ethnicity			
Non-Hispanic White and non-Hispanic Asian	1.00		
Hispanic and non-Hispanic Black	0.95	0.35, 2.58	0.02
Poverty Status			
At or below poverty level	1.71	0.64, 4.59	0.30
Above poverty level	1.00		
Caretaker Education			
<12th grade	2.14	0.51, 9.01	0.29
High school graduate or higher	1.00		

*P-value is based on chi-squared
*Each variable is independent of each other

Figure 2 presents iron deficiency among children who experience household food security and food insecurity. Among the children living in food secure households, 5% (n=49) experienced iron deficiency. Children living in food insecure households had a slightly lower prevalence of iron deficiency [4.7% (n=12)], but was not statistically significant (OR (95% CI): 0.94 (0.50, 1.80)).

Figure 2. Percent of Iron Deficiency Among Children 1-5 Years Old Who Experience Household Food Security and Food Insecurity

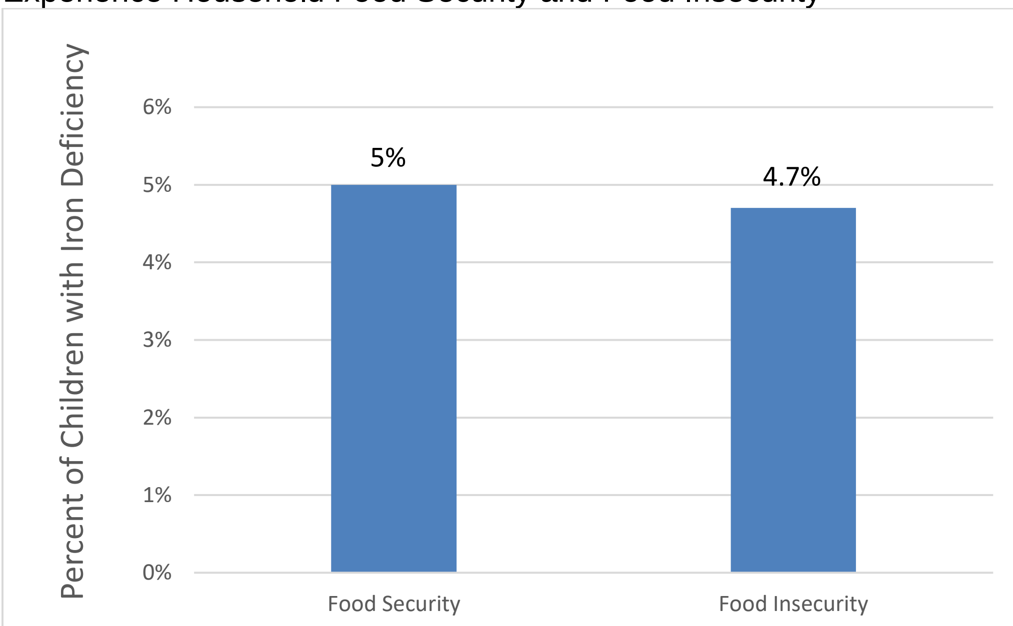
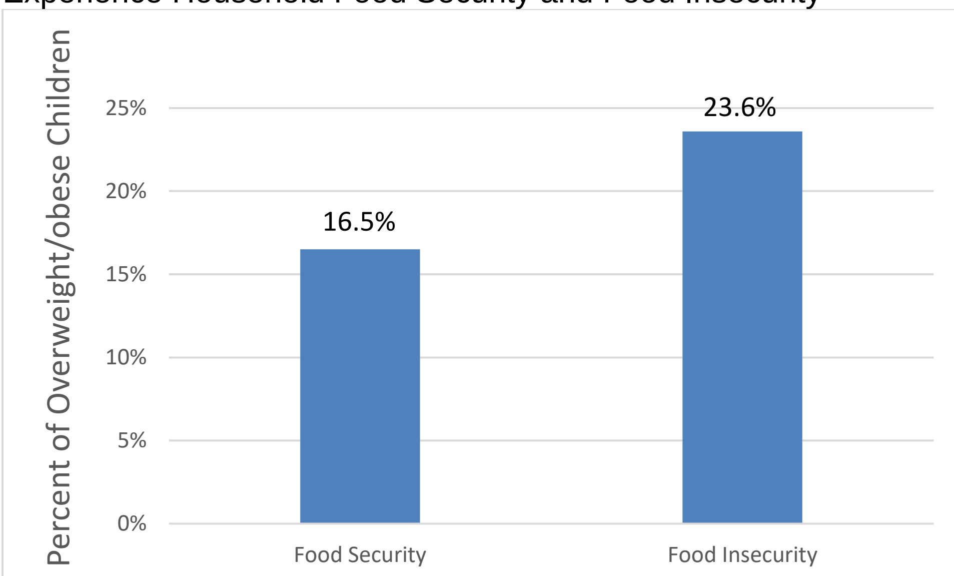


Figure 3 presents weight status among children who experience household food security and food insecurity. Among the children who experienced food security, 16.5% (n=161) experienced overweight/obesity. Among the children who experienced food insecurity, 23.6% (n=60) experienced overweight/obesity and is statistically significant (OR (95% CI): 1.57 (1.12, 2.20)).

Figure 3. Percent of Weight Status Among Children 1-5 Years Old Who Experience Household Food Security and Food Insecurity



CHAPTER FIVE

DISCUSSION

This analysis focused on examining the prevalence of iron deficiency and overweight/obesity among children 1 – 5 years old in the United States. In this analysis we discovered that overweight/obese children 1 – 5 years old had a higher prevalence of iron deficiency when compared to not overweight/obese children (7.0% vs. 4.5%), but this difference was not statistically significant. In the analysis conducted by Nead et al., children and adolescents who were at-risk of being overweight or were overweight (at or above the 85^{th} percentile for BMI-for-age) had a significantly increased risk of iron deficiency (Nead at al., 2004). Specifically, children with a BMI above the 85th percentile were approximately twice as likely to be iron-deficient, compared with children of normal weight (Nead at al., 2004).

Although Nead et al. used similar variables from NHANES and experienced similar results. She not only had a larger sample size (n= 9,698), but she also analyzed children and adolescents 2 – 16 years of age which present with higher percentages of both iron deficiency and overweight compared with pre-school aged children. Furthermore, Nead et al. examined iron deficiency and iron deficiency anemia among her population which may have increased the statistical significance.

The overall prevalence of the DBM in this analysis is 1.25%, which may be driven by the low prevalence of ID. A larger sample size could have assisted with a larger number of children with ID possible increasing the prevalence of DBM results. Additionally, several studies that were referenced in this analysis examined ID and IDA, and hence enhancing their results. If IDA was analyzed in this analysis, there could have been a different outcome.

The prevalence of the DBM in this analysis was higher among older children (2 – 5 years of age) but was not statistically significant. The prevalence of the DBM among the older children is consistent with Nead's analysis on the DBM. The higher prevalence of DBM among the older age group may relate to the change in diets at around 6 months of age. After 6 months children require complementary foods to breast milk or formula, and specifically as an external source of iron-rich foods to assist with growth and development (CDC, 2021). This may include red meat, beans, dark leafy vegetables, dried fruit, iron-fortified cereals, and peas. If iron-rich foods are not included in early complementary feeding, an infant's iron stores will continue to decline and can lead to ID. Additionally, children experience rapid growth spurts at the age of 2 and 4 years, at which times essential micronutrients like iron are crucial for development.

There was a higher, non-statistically significant, prevalence of the DBM among non-Hispanic Whites and non-Hispanic Asians, which seemed to be driven in this case by the higher prevalence of ID among non-Hispanic Asian children. However, the prevalence of overweight/obesity was highest among Hispanic and non-Hispanic Black children, which is consistent with national statistics (CDC, 2021). The sample size for the subgroups and prevalence of

DBM across groups was small. Additionally, children at or below the poverty level and children whose caregivers obtained a high school degree or less also had a higher prevalence of the DBM. Children at or below the poverty level and whose caregiver has a high school degree or less may experience several barriers such as lack of access to environments for physical activities and access to healthy nutritious foods. Lower-income neighborhoods tend to have limited opportunities for physical activity with fewer playgrounds, sidewalks, and recreational facilities (Frederick et al., 2014). Such factors are influential on a child's overall health. Food deserts are also a concern in lower-income neighborhoods. A lack of grocery stores and nearby nutritional foods can influence unhealthy eating.

Children in food secure households experienced a higher prevalence of ID compared with children in food insecure households, but this difference was not statistically significant. Although this analysis suggests an association between food secure households and ID, existing literature on this relationship suggests an association between food insecurity and IDA. Food-insecure children may consume a diet that puts them at risk of health outcomes associated with lower intakes of nutrients, including iron (Eicher-Miller et al., 2009). Additionally, Eicher-Miller et al. suggests children in food insecure households are nearly 3 times as likely to have iron deficiency anemia than children in food-secure households (2009). This concept can circle back to households that live in food deserts and other areas with lower or unreliable access to healthy foods.

Children in food insecure households experienced a higher prevalence of overweight/obesity compared with children in food secure households, which was statistically significant. Literature suggests a household's socioeconomic status (SES) background can influence a child's food consumption and physical activity patterns through environmental factors. Specifically, the physical environment can encourage or discourage physical activity, and the availability of food can encourage or discourage a healthy diet (Frederick et al., 2014). Children in low-income households tend to have higher rates of obesity when compared to children in high-income households (CDC, 2021). This can be addressed by programs such as Women, Infants, and Children (WIC) that provide food vouchers for nutritious foods and education resources for mothers and families of children up to 5 years of age.

Strengths and Limitations

The strengths of this analysis include its observational participants in the data. Quality-controlled, nationally representative data from the Center for Disease Control and Prevention (CDC) NHANES 2015-2016 and 2017-2018 were analyzed. Furthermore, this data set allowed us to examine children across the United States.

The overall sample size of my analysis is quite robust (n=1,276), however, the outcome (DBM) turned out to be rare (1.25%), thus my statistical power for DBM by demographic characteristics was limited. Additionally, there was a significant amount of data missing for the food security, caregiver education, and poverty status variables. Approximately 10% (n=125) of observations had missing data on poverty status, 46% (n=588) for caregiver education, and 3% (n=45) for food security. If these data were *not* missing at random, then the missing data could bias my results.

This analysis is the first to quantify the coexistence iron deficiency and overweight/obesity (i.e. DBM) among pre-school aged children in the United States, to our knowledge. Nead et al. did quantify iron deficiency and overweight/obesity in children, but the analysis is over a decade old and did not explicitly look at the double burden. I found it important to quantify the DBM to bring awareness to childhood malnutrition in all its forms in the United States. Literature suggests the health risks associated with iron deficiency and overweight/obesity can carry into adulthood (Sypes et al., 2019). Short and long-term consequences of overweight/obesity and iron deficiency in children include social and emotional development, high blood pressure and high cholesterol, cardiovascular disease, breathing problems/asthma, and joint problems (Aeberli, 2010).

Recommendations for Research and Practice

As a result of this analysis, the DBM was found to be prevalent in 1.25% of children 2 – 5 years old. The prevalence of iron deficiency was greater among children with overweight/obese (7%) compared to those not overweigh/obese (4.5%), though not found to be statistically significant in this analysis. This analysis supports the idea that overweight/obese children could be at a higher risk for iron deficiency and should therefore be screened for iron deficiency. With that in mind, primary screening for iron deficiency and overweight/obesity is recommended for children in that age range to prevent the DBM. Additional recommendations include replicating this analysis with a dataset with a larger sample of participants. Having a larger sample of participants will allow for a better understanding of childhood iron deficiency, overweight/obesity, and DBM. Additionally, a case control study may be more efficient rather than this analysis as a case control study could sample participants based on the rare DBM outcome.

The results were presented to Head Start staff serving birth to five-year-old children to provide information on the long-term health risks of iron deficiency, overweight/obesity, and the DBM. Head Start staff were encouraged to screen at-risk children for the DBM and were encouraged to provide interventions to reduce risk of overweight/obesity and iron deficiency. The Office of Head Start federal regulations require health screenings and assessments for their participants. Recipients are required to conduct screenings of children to identify health concerns early in addition to keeping children on their schedule of well childcare according to their state's EPSDT requirements (Head Start, ECLKC, 2021.) The American Academy of Pediatrics recommends screening children ages 6 to 24 months living in the United States for iron deficiency. Literature suggests an association between social determinants and health in early childhood and encourages screening for social needs in clinical care (Bayoumi et al., 2020).

Conclusion

This analysis examined the prevalence of iron deficiency and overweight/obesity among children 1 – 5 years old in the United States. The literature and analysis suggest that children who experience overweight/obesity should be screened for iron deficiency. This is a pressing public health concern as iron deficiency and overweight/obesity are linked to short-term and long-term health consequences. Overweight/obesity is linked to chronic illness while iron deficiency is linked to cognitive and behavioral delays. More research on this double burden of malnutrition, and environmental and household risk factors are needed and welcomed. The additional research can provide valuable information to programs such as Head Start. This analysis also serves as a foundation for future studies and Head Start professionals in the United States to focus on the double burden of malnutrition.

APPENDIX A

DERIVED VARIABLES FROM NHANES

New Variable	**Described**	**Existing variable use**	**Rules for creating new variable**
IronDeficiency	This will be a binary variable for iron deficiency among kids. If either indicator indicates low iron, the child will be coded as iron deficient = 1. If both indicators are normal, the child will be coded as not iron deficient = 0.	Ferritin (LBXFER) Transferrin Receptor (LBXTFR)	LBXFER: <12 μg/mL (1-5 years) LBXTFR: >8.5 mg/L (1-5 years) Males 1-5 that are iron deficient: Females 1-5 that are iron deficient:
BMI-for-age percentile by Gender	This will be a ternary variable for high BMI among children. If any value is not abnormal, the child will be coded as average BMI = 0. If any value is abnormal, the child will be coded as	BMXRECUM (height in cm) BMXWT (weight in kg) RIDAGEYR (age in years)	Males 0 – 2 years Length-for-age (cm): 54.3 – 93.5 Males 0 – 2 Weight-for-age (kg): 4.3 – 15.3 Females 0 – 2 years Length-for-

	above average BMI = 1.		age (cm): 53.8 – 91.9 Females 0 – 2 Weight-for-age (kg): 4.2 – 14.7 Males 2 – 5 years Stature-for-age (cm): 92.2 – 116.7 Males 2 – 5 years Weight-for-age (kg): 15.2 – 23.5 Males 2 – 5 years BMI-for-age (95th percentile): 19.3 – 17.9 Females 2 – 5 years Stature-for-age (cm): 90.7 – 119.4 Females 2 – 5 years Weight-for-age (kg): 14.6 – 23.8

			Females 2 – 5 years BMI-for-age (95^{th} percentile): 19.1 – 18.2
Overweight	Dichotomous	BMI-for-age	CDC and WHO percentile cutoff for overweight is 95^{th} percentile
DBM	This will be a binary variable for the double burden of malnutrition. If both indicators are low, the child will be coded as DBM= 1. If no indicators are low, the child will be coded as no DBM = 0.	Overweight IronDeficiency	DBM = 1 No DBM = 0
FoodSecure	This will be a binary variable for household food security among children. If either indicator is low, the child will be coded as food secure = 0. If no indicator is	FSDCH	FSDCH = 1 then food insecure = 1 FSDCH = 2-4 then food secure = 0

	low, the child will be coded as food secure = 1.		
Under2yo	This will be a binary variable for age in years among children. If a child is between the ages 12 – 24 months, the code is = 1. If the child is 2 – 5 years of age, the code is = 2.	RIDAGEYR	RIDAGEYR = 1 then children 12 – 24 months = 1 RIDAGEYR =0 then children 2 – 5 years = 0
Race/Ethnicity	This will be a binary variable for race/ethnicity. If a child is identified as Hispanic or non-Hispanic Black, it will be coded = 1. If the child is identified as non-Hispanic White or non-Hispanic Asian it will be coded = 0.	RIDRETH3	Hispanic or non-Hispanic Black = 1 non-Hispanic White or non-Hispanic Asian = 0
HSGrad_orLess	This will be a binary variable for caregiver education level. If a	DMDEDUC – Caregiver Education Level – Adults 20+	1 = HS graduation or less 0 = Greater than HS graduation (at

	caregiver has a HS degree of less, it will be coded = 1. If caregiver has greater than HS degree (at least some college), it will be coded = 0.		least some college)
Poverty Level	This will be a binary variable for household poverty level. If a child is identified as at or below the poverty level it will be coded = 1. If the child is above the poverty level it will be coded = 0.	INDFMMPIR	At or below the poverty level = 1 Above the poverty level = 0.
New Variable	**Described**	**Existing variable use**	**Rules for creating new variable**
IronDeficiency	This will be a binary variable for iron deficiency among kids. If either indicator indicates low iron,	Ferritin (LBXFER) Transferrin Receptor (LBXTFR)	LBXFER: <12 μg/mL (1-5 years) LBXTFR: >8.5 mg/L (1-5 years)

	the child will be coded as iron deficient = 1. If both indicators are normal, the child will be coded as not iron deficient = 0.		Males 1-5 that are iron deficient: Females 1-5 that are iron deficient:
BMI-for-age percentile by Gender	This will be a ternary variable for high BMI among children. If any value is not abnormal, the child will be coded as average BMI = 0. If any value is abnormal, the child will be coded as above average BMI = 1.	BMXRECUM (height in cm) BMXWT (weight in kg) RIDAGEYR (age in years)	Males 0 – 2 years Length-for-age (cm): 54.3 – 93.5 Males 0 – 2 Weight-for-age (kg): 4.3 – 15.3 Females 0 – 2 years Length-for-age (cm): 53.8 – 91.9 Females 0 – 2 Weight-for-age (kg): 4.2 – 14.7 Males 2 – 5 years Stature-for-age (cm): 92.2 – 116.7

			Males 2 – 5 years Weight-for-age (kg): 15.2 – 23.5 Males 2 – 5 years BMI-for-age (95th percentile): 19.3 – 17.9 Females 2 – 5 years Stature-for-age (cm): 90.7 – 119.4 Females 2 – 5 years Weight-for-age (kg): 14.6 – 23.8 Females 2 – 5 years BMI-for-age (95th percentile): 19.1 – 18.2
Overweight	Dichotomous	BMI-for-age	CDC percentile cutoff for overweight is 95th percentile
FoodSecure	This will be a binary variable for	FSDCH	FSDCH = 1 then food secure = 1

	household food security among children. If either indicator is low, the child will be coded as food secure = 0. If no indicator is low, the child will be coded as food secure = 1.		FSDCH = 2-4 then food secure = 0
Under 2 yo	This will be a binary variable for age in years among children. If a child is between the ages 12 – 24 months, the code is = 1. If the child is 2 – 5 years of age, the code is = 2.	RIDAGEYR	RIDAGEYR = 1 then children 12 – 24 months = 1 RIDAGEYR =0 then children 2 – 5 years = 2
Received-WIC-or-SNAP	This will be a binary variable for Households who ever received WIC or SNAP benefits. If a HH ever received WIC or SNAP, it will be coded Yes = 1. If	FSQ653 – Ever received WIC FSQ012 – Ever received SNAP	1 = Yes 0 = No

	WIC or SNAP was never received, it will be coded No = 0.		

APPENDIX B

NHANES 2015-2016 AND 2017-2018 EXISTING VARIABLES

Variables Name	**Descriptive Name**	**Target**	**Rules for Variable**
RIDAGEYR	Age in years at screening	Both males and females 0 YEARS – 150 YEARS	1 = 1 - 5 years 0 = >5 years
RIAGENDR	Gender	Both males and females 0 YEARS – 150 YEARS	1 = males 2 = female
BMXRECUM	Recumbent Length (cm)	Both males and females 0 – 47 MONTHS	BMXRECUM = 49.1 – 111.3 (cm)
BMXHT	Standing Height (cm)	Both males and females 2 – 150 YEARS	BMXHT = 78.3 – 197.7 (cm)
BMXWT	Weight (kg)	Both males and females 0 YEARS – 150 YEARS	BMXWT = 3.2 – 242.6 (kg)
BMXBMI	Body Mass Index (kg/m2)	Both males and females 2 YEARS – 150 YEARS	BMXBMI = 12.3 – 86.2
BMDBMIC	BMI Category – Children/Youth 2015-2016 ONLY	Both males and females 2 YEARS – 19 YEARS	1 = Underweight 2 = Normal weight 3 = Overweight 4 = Obese

RIDRETH1	Race/Hispanic origin	Both males and females 0 YEARS – 150 YEARS	1 = Mexican American 2 = Other Hispanic 3 = Non-Hispanic White 4 = Non-Hispanic Black 5 = Other Race – Including Multi-Racial
RIDRETH3	Race/Hispanic origin with Non-Hispanic Asian	Both males and females 0 YEARS – 150 YEARS	1 = Mexican American 2 = Other Hispanic 3 = Non-Hispanic White 4 = Non-Hispanic Black 6 = Non-Hispanic Asian 7 = Other Race – Including Multi-Racial
INDFMMPIR	Ratio of family income to poverty	Both males and females 0 YEARS – 150 YEARS	Range of Values = 0 – 4.98
DMDEDUC	Education level – Adults 20+	Both males and females 20	1 = Less than 9th grade

		YEARS – 150 YEARS	2 = 9-11th grade (includes 12th grade with no diploma) 3 = High school graduate/GED or equivalent 4 = Some college or AA degree 5 = College graduate or above 9 = Don't know
FSDCH	Child Food Security Category	Both males and females 0 YEARS – 150 YEARS	1 = CH full or marginal food security: 0 2 = CH marginal food security: 1 3 = CH low food security: 2-4 4 = CH very low food security: 5-8
LBXFER	Ferritin (ng/mL)	Both males and females 1 YEARS - 5 YEARS and Both males and females 12 YEARS – 150 YEARS	LBXFER = 1.04 - 5190 (ng/mL)

LBXTFR	Transferrin Receptor (mg/L)	Both males and females 1 YEARS – 150 YEARS	LBXTFR = 1.01 – 41.3 (mg/L)
Variables Name	**Descriptive Name**	**Target**	**Rules for Variable**
RIDAGEYR	Age in years at screening	Both males and females 0 YEARS – 150 YEARS	1 = 1 - 5 years 0 = >5 years
RIAGENDR	Gender	Both males and females 0 YEARS – 150 YEARS	1 = males 2 = female
BMXRECUM	Recumbent Length (cm)	Both males and females 0 – 47 MONTHS	BMXRECUM = 49.1 – 111.3 (cm)
BMXHT	Standing Height (cm)	Both males and females 2 – 150 YEARS	BMXHT = 78.3 – 197.7 (cm)
BMXWT	Weight (kg)	Both males and females 0 YEARS – 150 YEARS	BMXWT = 3.2 – 242.6 (kg)

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