AN EVALUATION OF INFANT GROWTH IN THE FIRST YEAR OF LIFE IN A LOW-INCOME PRIMARILY AFRICAN-AMERICAN SAMPLE

By

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Title of Study: AN EVALUATION OF INFANT GROWTH IN THE FIRST YEAR OF LIFE IN A LOW-INCOME PRIMARILY AFRICAN-AMERICAN SAMPLE

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Abstract: The purpose of this study was to describe the prevalence of indicators of malnutrition in a low-income primarily African-American sample and to examine the association between various sociodemographic characteristics and indicators of both undernutrition and overnutrition. The data were derived from the Women, Work and Wee ones project and consisted of 285 mother-infant dyads. Sociodemographic characteristics (maternal and infant) were based on maternal report when infants were three months old. Infant height and weight was measured at three and 12 months and both the CDC 2000 and the WHO 2006 growth charts were used in each analysis. The results indicate that the proportion of infants categorized as displaying non-normative growth (e.g., stunted, overweight) was dependent upon the growth chart used. Results also showed that infants of mothers with an irregular work schedule were significantly more likely to experience rapid weight gain from three to 12 months and breastfeeding at three months was protective against rapid weight gain during infancy. Implications of these findings are discussed for researchers, clinicians, and early prevention and interventionists.

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CHAPTER I

GENERAL INTRODUCTION

Overview

“No aspect of our physical or psychological existence is not affected in some way by nutrition.” (Mehta et al., 2013, p. 477). Proper nutrition is a critical component in health promotion and disease prevention across the life course. The first two years of life are marked by rapid growth and development and are the most critical time to meet a child’s increased nutritional needs (United Nations International Children’s Emergency Fund [UNICEF], 2013). Not only is infant nutritional status an important determinant of postnatal growth (Koletzko et al., 2013) and related pediatric health outcomes (Fulhan, Collier, & Duggan, 2003), but inadequate nutrition during a critical period such as infancy may have lifelong adverse consequences (e.g., risk of chronic disease).

Pediatric malnutrition includes both undernutrition and obesity (Mehta et al., 2013) and in developed countries such as the United States the prevalence of underweight and overweight are higher among economically disadvantaged and ethnic minority groups (Lobstein, Baur, & Uauy, 2004; Miller & Korenman, 1994). Although the physical manifestation of undernutrition and obesity is very different, scholars have recognized that identifying shared risk factors during infancy may contribute to improvements in how nutrition-related health disparities are addressed (Kumanyika, 2008; Wachs, 2008). A growing body of research has focused on early risk factors for infant and child overweight (Weng, Redsell, Swift, Yang, & Glazebrook, 2012), whereas the majority of studies examining determinants of underweight have primarily been conducted in low-income or developing countries. Increasingly, the co-occurrence of overweight and undernutrition is being studied in low-income countries undergoing a nutrition transition (i.e. high prevalence of undernutrition replaced with obesity) as a result of improving economic conditions (e.g., Tzioumis & Adair, 2014). Unfortunately, subgroups of children in the poorest parts of these countries remain undernourished (e.g., micronutrient deficiencies) while experiencing excess energy due to Westernized food choices such as fast food. This double burden of nutrition may also exist in wealthy countries among disadvantaged subpopulations where cheap energy dense foods are abundant and access to healthy affordable foods is scarce (i.e., food deserts) (Walker, Keane, & Burke). Further, research has shown that food deserts are disproportionately common in neighborhoods and communities that are predominantly African-American (Morland & Filomena, 2007). As a result, both forms of malnutrition need to be assessed in order to gain a true picture of the health status of at-risk subgroups in the US.

Growth monitoring is the universally accepted method to assess the nutritional status and health of young children and to track individual growth (World Health Organization [WHO], 1995). To monitor growth, anthropometric measurements are plotted on growth charts that serve as a reference for making comparisons to other children of the same sex and age (WHO, 1994). Growth is a critical indicator of health because for the majority of children, non-normative growth is indicative of environmental conditions less favorable to healthy growth and development (de Onis & Yip, 1996). Identifying children with abnormal growth is especially important in infancy and early childhood, a period of rapid growth and development. Growth impairment during the first two years of life has short- and long-term adverse effects on health and may have irreversible consequences on cognitive development (Victora, de Onis, Hallal, Blössner, & Shrimpton, 2010). Research has also shown that rapid weight gain occurring as early as infancy is associated with later obesity (Baird et al., 2005).

In 2000 the Centers for Disease Control and Prevention (CDC) released updated growth charts (i.e., CDC 2000 growth charts) for the United States; the new charts improved upon those used since 1977 by the National Center for Health Statistics (NCHS) (Ogden et al., 2002). The CDC 2000 growth charts are primarily based on cross-sectional nationally representative data that describe the distribution of children's size-for-age in the United States between 1963 and 1994 (Kuczmarski et al., 2002). Although improvements were made in creating the CDC 2000 growth charts, several limitations have been recognized, especially in relation to the infant data. The majority of infants in the CDC reference population were formula-fed (Ogden et al., 2002) and the sample size in infancy was smaller than recommended to construct growth curves (i.e., 200 per sex and age group) (Garza & de Onis, 2004). As a result, the CDC sample is overall heavier and shorter compared to healthy breastfed infants and the CDC growth charts are not likely to capture the rapid growth that takes place during the first year (de Onis, Garza, Onyango, & Borghi, 2007). Importantly, the CDC growth charts do not generalize to US infants who are breastfed for more than a few months (de Onis & Onyango, 2003) thus the use of the CDC charts for early growth monitoring has implications for feeding advice given to mothers (de Onis et al., 2007).

The observation that growth patterns in the first year of life are different for breastfed compared to formula-fed infants (Dewey, 1998a) prompted the WHO to develop new global growth charts (Dewey, 1998b). For example, de Onis and Onyango (2003) compared the growth of a sample of breastfed infants to the CDC 2000 growth charts and found that infants who are breastfed gain more weight in the first two months of life followed by slower weight gain from three to 12 months resulting in greater overall weight gain in formula-fed infants during the first year (Dewey, 1998a). Thus in 2006, the WHO released updated growth charts for infants and children zero to five years of age that were created using data from the Multicenter Growth Reference Study (MGRS) (de Onis et al., 2004). The MGRS was driven by the hypothesis that regardless of race/ethnicity and geographic location, infants and young children will grow similarly if raised in environmental conditions that support optimal growth (Garza & de Onis, 2004). Thus, the MGRS included longitudinal anthropometric data for children selected from sites in six countries (Brazil, Ghana, India, Norway, Oman, and the United States) living in socioeconomic conditions favorable to growth (Mei, Ogden, Flegal, & Grummer-Strawn, 2008). Further, the mothers of the children selected for the study followed recommended nutritional and health practices, including breastfeeding, appropriate introduction to solid foods, and not smoking (de Onis et al., 2004). A key finding from the MGRS was the similarity in observed linear growth across the diverse study sites, providing strong evidence that all infants and children have similar growth potentials (Garza & de Onis, 2007).

Different from the CDC 2000 growth charts that describe how children grew in a specific time and place and are referred to as a growth reference, the WHO 2006 growth charts describe how children in any setting should grow and are the prescribed gold standard for monitoring infant growth (Mei et al., 2008). Also unique to the WHO 2006 standards is that they were developed such that they are consistent with the US national feeding guidelines and they established the healthy breastfed infant as the norm for assessing growth in children two years old and younger (de Onis et al., 2007). Importantly, the CDC recommends the use of the WHO 2006 growth charts in clinical settings for growth monitoring of US children zero to 24 months of age (Grummer-Strawn, Reinold, & Krebs, 2010). To date, the majority of studies examining infant growth and/or weight outcomes have relied on the CDC 2000 growth charts and studies that have incorporated comparisons using both growth charts have been solely descriptive in nature. As a result, our understanding of infant growth is somewhat limited and the use of the WHO 2006 standards in research will provide a more accurate picture of the health and well-being of any given US sample of infants.

Purpose

The purpose of this thesis is to evaluate indicators of malnutrition in the first year of life in a sample of low-income primarily African-American infants. There are several gaps in the current literature that this thesis addresses. First, research simultaneously examining the prevalence of both undernutrition and obesity is limited. Further, outside of illness- or disease-related undernutrition, there is little research examining factors associated with this form of malnutrition among US infants and children and no studies to date have explored potential shared risk factors for indicators of both forms of malnutrition. Different from previous research, this thesis examines indicators of undernutrition and overnutrition simultaneously. In doing so, there are two primary research goals: 1) to describe the prevalence of indicators of malnutrition in a sample of low-income primarily African-American infants in the first year of life and 2) explore differences in indicators of malnutrition by sociodemographic characteristics previously hypothesized to be associated with child growth and/or weight. By addressing these research questions this thesis will build on our understanding of infant growth in a disadvantaged subpopulation at increased risk of suboptimal growth and will work to possibly inform early childhood prevention programs that target health disparities among economically disadvantaged minority populations.

Thesis Organization

The following thesis includes three chapters. Chapter one is a general introduction to the study of infant malnutrition along with an overview of growth charts used to assess infant and child nutritional status. Chapter two is a manuscript to be submitted to the *Maternal and Child Health Journal* that describes the prevalence of indicators of malnutrition in a low-income primarily African-American sample and examines sociodemographic characteristics associated with each growth indicator. The third chapter provides a conclusion with a discussion of the primary study findings, implications, strengths and limitations, and directions for future research.

CHAPTER II

PREVALENCE AND PREDICTORS OF INDICATORS OF MALNUTRITION IN THE FIRST YEAR OF LIFE IN A LOW-INCOME PRIMARILY AFRICAN-AMERICAN SAMPLE

A manuscript to be submitted to the *Maternal and Child Health Journal*

Sally G. Eagleton

Background

Childhood obesity has reached epidemic proportions and research focusing on best practices for its prevention and treatment is extensive and continues to grow. Importantly, over the past decade it has been argued that these efforts should begin as early as infancy (Institute of Medicine, 2012; Paul et al., 2009). On the other hand, overall improvements in the prevalence of child underweight have been observed. Among low-income children aged two to four years old underweight prevalence decreased from 5.7% in 1994 to 4.6% in 2000, which is below the expected level of five percent in a given population (Sherry, Mei, Scanlon, Mokdad, & Grummer-Strawn, 2004). However, research examining the prevalence of underweight by race/ethnicity tells a different story. For example, using data from the Pediatric Nutrition Surveillance System (PedNSS) from 2000, a national survey that monitored the nutritional status of low-income children in federally funded maternal and child health programs, Sherry et al. (2004) found that 18 of 24 states reported an underweight prevalence greater than five percent among two to four year old African-American children, suggesting that underweight remains a concern for this low-income subpopulation. Even with overall secular improvements in child underweight, attention to the prevalence of undernutrition among low-income African-American children is warranted and research examining both forms of malnutrition simultaneously is needed.

Literature Review

Defining Growth Indicators

The three most commonly used anthropometric indicators to assess infant growth status are weight-for-length, length-for-age, and weight-for-age. For each indicator, growth charts provide a normal range that is defined by the distance between standardized percentiles (or *z*-scores) and the median of the growth chart standards. Based on statistical distributions, established cut points for percentiles and/or *z*-scores define the lower and upper ends of the normal range on each indicator such that a percentile or *z*-score above or below the cutoff value is considered non-normative growth that may be the result of a nutrition-related problem such as undernutrition or overnutrition (Wang & Chen, 2012).

For infants and young children, both the growth chart used and the cutoff values applied influence the prevalence of children in a given sample or population that display non-normative growth. The cutoff values normally used for the CDC 2000 growth charts are the 5^{th} and 95^{th} percentiles, whereas the cutoff values typically used for the WHO 2006 growth charts are the 2.3^{rd} and 97.7^{th} percentiles (equivalent to ± 2 points on a *z*-score scale). In a study that compared the prevalence of overweight, stunting, and underweight among US children aged 0 to 59 months using the CDC 2000 and the WHO 2006 growth charts, underweight was defined as both weight-for-length (wasted) and weight-for-age (underweight) (Mei et al., 2008). Results showed that among children aged 0 to 23 months of age, the prevalence of low weight-for-age was consistently higher than the prevalence of low weight-for-length and regardless of growth chart or cutoff values the prevalence of low weight-for-length (wasted) did not exceed five percent. This is consistent with the assertion that even in poor countries, as long as there is not a significant shortage of food, the prevalence of wasting is typically below five percent (WHO, 2014). Thus, the present study defines underweight as low weight-for-age (underweight) provided it is a more telling indicator of undernutrition especially in higher income countries such as the United States.

A study conducted by Mei et al. (2008) showed that when the 5th and 95th percentiles are applied to both the CDC 2000 and the WHO 2006 growth charts the prevalence of low length-for-age (stunting) and high weight-for-length (overweight) was approximately three to four percentage points higher when using the WHO growth charts compared to the CDC reference. In contrast, the use of the WHO standard revealed a prevalence of low weight-for-age (underweight) approximately three percentage points lower than the CDC reference. However, when the 5th and 95th percentiles were applied to the CDC 2000 charts and the 2.3rd and 97.7th were applied to the WHO 2006 charts, the discrepancies in prevalence rates decreased. For replication purposes, the present study examined infant growth using both the WHO 2006 and the CDC 2000 growth charts with each chart's intended cutoff values (WHO 2006, 2.3rd and 97.7th percentile; CDC 2000, 5th and 95th percentile). Using the intended cutoff values should reduce any major discrepancies. However, due to inherent differences in the populations used to create the two growth charts, it is still expected that differences in prevalence rates of the various growth indicators will exist.

The physical manifestation of infant overnutrition is described as overweight and is determined based on the growth indicator weight-for-length (WHO, 2014). Based on the WHO 2006 growth charts, overweight is defined as > +2 standard deviations (> 97.7th percentile) from the median of the 2006 WHO growth chart for weight-for-length (WHO, 2008) and based on the CDC 2000 growth chart, overweight is defined as ≥ 95th percentile for weight-for-length. On the other hand, the physical manifestation of undernutrition is more complex and depending on its cause may present itself as stunted or underweight. Stunting, which is often a result of exposure to chronic undernutrition or repeated illness (WHO, 2008) is defined as < -2 standard deviations (< 2.3rd percentile) from the median of the 2006 WHO growth chart for length-for-age (UNICEF, 2013). Based on the CDC 2000 growth charts stunting is defined as < 5th percentile for length-for-age. Underweight is defined as < -2 standard deviations (< 2.3rd percentile) from the median of the 2006 WHO growth chart for weight-for-age (UNICEF, 2013) and based on the CDC 2000 growth charts is defined as < 5th percentile of weight-for-age. Underweight can be due to short stature (stunting), thinness (wasting) or a combination of both (WHO, 2008).

In addition to examining growth indicators based on infant size at any given point during infancy, it is also important to consider infant growth during a period that may be implicated in the development of childhood obesity (Ong et al., 2000). Recently, there has been an increased interest in rapid growth early in life and observational evidence suggests that rapid weight gain during the first two years of life is associated with an increased risk of subsequent obesity (Baird et al., 2005) with some studies showing that this association exists into young adulthood (e.g., Stettler, Kumanyika, Hatz, Zemel, & Stallings, 2003). Researchers have defined rapid weight gain using a variety of methods across various age ranges. A systematic review addressing the relation between rapid growth and later obesity found that the most common definition for rapid growth was a change in weight-for-age *z*-score greater than 0.67 between two different ages in childhood (Monteiro & Victora, 2005). On the opposite end of the spectrum a recent consensus report from the Academy of Nutrition and Dietetics and the American Society for parenteral and enteral nutrition recommends using a decline in weight-for-length *z*-score to classify malnutrition related to undernutrition when two or more data points are available (Becker et al., 2014). Specifically, mild, moderate and severe malnutrition are defined as a decline in one, two, or three weight-for-length *z*-scores, respectively.

Prevalence of Growth Indicators

The National Health and Nutrition Examination Survey (NHANES) consistently documents the prevalence of infant and child overweight in the United States, and until 2011 the Pediatric Nutrition Surveillance System (PedNSS) monitored the nutritional status of low-income children in federally funded maternal and child health programs. The most recent data from NHANES showed that based on the WHO 2006 growth charts 7.1% of US infants and toddlers aged 0-23 months have a high weight-for-length (overweight), and based on the CDC 2000 growth charts this prevalence was one percentage point higher at 8.1% (Ogden, Carroll, Kit, & Flegal, 2014). Also based on the WHO 2006 growth charts, the most recent PedNSS data from 2011 showed that 8% of infants aged 0-11 months and 14.1% of toddlers aged 12-23 months had a high weight-for-length (CDC, 2000), suggesting that low-income children under two years of age have a higher overweight prevalence compared to the national average provided by NHANES. Both the NHANES and PedNSS data suggest that compared to Non-Hispanic White infants and toddlers, Non-Hispanic Black infants and toddlers have a higher overweight prevalence. Although these differences were not statistically significant, based on the WHO 2006 charts, Ogden et al. (2014) reported an overweight prevalence of 5.5% in White compared to 7.3% in Black infants and toddlers aged 0-23 months (percentages were slightly higher when using the CDC 2000 charts). Further, based on PedNSS data using the WHO 2006 charts, the prevalence of high weight-for-length was 6.7% in White compared to 7.8% in Black infants aged 0-11 months.

Although monitoring childhood overweight and obesity has been a priority in the United States, very little research has documented the prevalence of indicators of undernutrition (i.e., stunting and underweight) and the prevalence of children currently experiencing acute or chronic undernutrition is not documented in the US (Becker et al., 2014). Using NHANES data from 1999-2004, Mei et al. (2008) showed that 5.2% and 2% of infants aged 0-23 months were stunted and underweight, respectively (Mei et al., 2008). Based on the WHO 2006 charts, the PedNSS data showed that the prevalence of stunting among low-income infants aged 0-11 months was 9.8%, and the prevalence of undernutrition (defined as low weight-for-length) was 5.5% (CDC, 2011), also suggesting a higher prevalence of undernutrition among low-income infants compared to the national average. This data also showed differences in indicators of undernutrition by race/ethnicity, such that the prevalence of stunting and underweight (defined as low weight-for-length) was also higher for non-Hispanic Black compared to non-Hispanic White infants. The prevalence of stunting was 9.9% in White compared to 12.2% in Black infants and the prevalence of underweight was 5.4% in White compared to 7.3% in Black infants (CDC, 2011).

Among low-income US infants, the prevalence of both stunting and underweight was above the expected 5% for a given child population, with considerably higher rates of stunting and underweight among non-Hispanic Black infants. In addition to bringing attention to the prevalence of indicators of both forms of malnutrition in a high-risk sample, it is also important to investigate whether various sociodemographic factors play a role in infant size and growth patterns that may set the stage for disease and weight-related health problems later in life.

Sociodemographic Characteristics and Malnutrition

The sociodemographic factors of interest include both maternal and infant characteristics and are variables that have been explored in previous research due to their hypothesized association with child weight or growth. Previous research examining the relation between sociodemographic factors and infant and child overweight has overwhelmingly resulted in conflicting or inconclusive evidence and the majority of studies have focused on weight outcomes in children over two years of age. Outside of research in developing countries and/or US research with hospitalized acute or chronically ill children, the association between sociodemographic factors and indicators of undernutrition has been relatively unexplored. Further, with a growing number of studies examining rapid weight gain and later obesity, researchers have expressed a need for studies examining factors that contribute to this potentially problematic early growth pattern (Baird et al., 2005).

The maternal characteristics examined in the present study included age, racial/ethnic minority status, marital status, educational attainment, work schedule, and parity (i.e., the number of previous deliveries). Several maternal characteristics that have been examined in relation to child overweight have resulted in mixed findings or have showed no association. Based on the results of a meta-analysis with 30 prospective observational studies that followed children for a minimum of two years beginning at birth (Weng et al., 2012), maternal age, ethnicity, and education level showed no association with child overweight. In contrast, these three maternal characteristics have been shown to be associated with low birthweight (Lee, Ferguson, Corpuz, & Gartner, 1988), which is a potential risk factor for child overweight via its association with postnatal catch-up growth that often occurs in infants with an initial size deficit (Ong, Preece, Emmett, Ahmed, & Dunger, 2002). Although overweight was not measured directly as an outcome, Taveras, Gillman, Kleinman, Rich-Edwards, and Rifas-Shiman (2010) found that compared to White children, Black and Hispanic children were more likely to experience a range of risk factors for child obesity such as rapid weight gain and early introduction to solid foods. In addition, the Weng et al. (2012) meta-analysis pointed to inconclusive evidence for studies examining the influence of marital status and parity although research has also found significant positive associations between these two variables and low birthweight (Lee et al., 1988; Ong et al., 2002)

Finally, a maternal characteristic that has not been directly examined in relation to infant growth is nonstandard work schedules. A growing body of literature has examined the influence of parents' nonstandard work schedules, which refers to the majority of work hours falling outside the normative daytime Monday to Friday work week (Li et al., 2012), and child health and development. According to a recent review of the literature, the negative effect of nonstandard work schedules appears to be particularly damaging for children in the first few years of life and evidence suggests that the association between nonstandard schedules and poor outcomes are stronger for children of single mothers and children in low-income families (Li et al., 2014). However, studies examining the association between nonstandard schedules and weight outcomes have primarily focused on school-aged children and adolescents and studies have typically combined various types of nonstandard schedules (e.g., evening, night, and rotating shifts) into one category. Previous research has shown a positive association between the number of years a mother is employed and children's body mass index (Anderson, Butcher, & Levine, 2003; Morrissey, Dunifon, & Kalil, 2011) as well as an association between maternal nonstandard schedules and a significant increase in adolescent body mass index (Miller & Han, 2008). Studies with infants have not examined this association directly, but have found an inverse association between length of maternity leave and breastfeeding initiation and duration (Guendelman et al., 2009; Ogbuanu, Glover, Probst, Liu, & Hussey, 2011). Similarly, research has shown that unhealthy infant feeding is higher among mothers with nonstandard work schedules (i.e., works weekends, evening or night hours, or a variable schedule) (Grzywacz, Tucker, Clinch, & Arcury, 2010) and that mothers working a full-time nonstandard job during the child's first year of life were less sensitive and had less supportive and stimulating home environments compared to mothers working a full-time standard job (i.e., works Monday-Friday, 8-5 schedule) (Grzywacz, Daniel, Tucker, Walls, & Leerkes, 2011). A few studies have examined the nuances of different types of nonstandard schedules and although some studies with older children have shown that irregular work schedules are associated with positive outcomes such as fewer adolescent risk behaviors (e.g., Han, Miller, & Waldfogel, 2010), it may be that an irregular schedule marked by unpredictable maternal time at home is associated with indicators of infant malnutrition as a result of suboptimal feeding practices.

The infant characteristics examined in the present study included gender, premature birth, low birthweight, breastfeeding, and early introduction to solid foods. Although the evidence for the association between infant feeding and child weight and growth has been mixed with some studies showing a protective effect (e.g., Hawkins, Cole, & Law, 2008) and others showing no significant associations (e.g., Reilly et al., 2005), studies restricted to the first year of life have consistently shown that compared to exclusively breastfed infants, formula-fed infants are more likely to be overweight in the second half of infancy (e.g., Moschonis, Grammatikaki, & Manios, 2008). Inconsistent findings for breastfeeding may be due to different effects that depend on ethnicity, socioeconomic status or the timing of introduction to solid foods. For example, Grummer-Strawn and Mei (2004) found a dose-response protective effect of breastfeeding for overweight in a low-income sample of US four year olds in non-Hispanic Whites, but not among

Hispanics and non-Hispanic Blacks. Another study found no association between early introduction to solid foods and overweight among breastfed infants but found a six times greater risk of obesity at three years of age among formula-fed infants (Huh, Rifas-Shiman, Taveras, Oken, & Gillman, 2011). Besides research that has compared the populations of distinct growth charts (i.e., CDC 2000 and WHO 2006) that are able to make inferences about how early growth differs by feeding method, the majority of community- or population-based research has focused on weight outcomes in children over two years of age with few studies examining feeding method and weight/growth outcomes in infancy.

There are several possible reasons for the null findings and mixed evidence surrounding various sociodemographic characteristics and child growth and weight outcomes. First, the wide range of children's ages comprising this body of literature has made comparisons across studies difficult. Second, it is possible that the influence of variables such as maternal education, high or low parity, and marital status results in different outcomes depending on socioeconomic status. Further, it is possible that examining overweight and underweight simultaneously will provide more consistent results, especially in a low-income sample in which more stressors and less support have a greater impact, thus increasing the risk of child malnutrition. By examining the association between these sociodemographic characteristics and indicators of infant malnutrition this study will identify both risk and protective factors for both forms of malnutrition in a sample of infants at increased risk of both undernutrition and overnutrition.

Summary, Research Goals, and Hypotheses

In summary, although research has consistently documented the prevalence of and factors associated with overweight among US infants and children, there is limited research examining the prevalence of indicators of infant undernutrition, especially during the first year of life. Similarly, studies that have examined factors associated with overweight have failed to explore whether the same factors also contribute to indicators of undernutrition. Finally, the majority of studies examining infant growth and/or weight have relied on the CDC 2000 growth charts when the WHO 2006 standard is currently recommended as the standard to which all children two years and younger should be compared.

To address these gaps in the literature, there were two primary research goals. The first research goal was to describe the prevalence of indicators of overnutrition and undernutrition in a sample of low-income primarily African American infants in the first year of life. High weight-for-length (risk-of-overweight and overweight/obesity) was the indicator used to assess overnutrition at three and 12 months and rapid weight gain was used to assess potential malnutrition related to excess energy from three to 12 months of age. Low length-for-age (stunted) and low weight-for-age (underweight) were the indicators of undernutrition at three- and 12-months and a decline in weight-for-length was used to assess malnutrition related to inadequate energy from three to 12 months. All indicators of malnutrition were examined using both the WHO 2006 and the CDC 2000 growth charts with each of its intended cutoff values. Based on national prevalence rates provided by NHANES and PedNSS, the first research goal had three primary hypotheses:

1. The majority of infants will display normative growth; the second highest proportion of infants will have a high weight-for-length, and a greater percentage of infants will be overweight with increasing age.
2. Greater than 5% of infants will have a low length-for-age and/or low weight-for-age.
3. A higher proportion of infants will display rapid weight gain as opposed to change in growth indicative of undernutrition.

The second research goal was to explore differences in indicators of both forms of malnutrition by sociodemographic factors. There were four hypotheses related to this research goal:

1. Maternal sociodemographic factors expected to be related to indicators of undernutrition included older age, single marital status, identifying as a racial/ethnic minority as well as low educational attainment, high parity, and an irregular work schedule.

2. Infant sociodemographic factors expected to be related to indicators of undernutrition include premature birth, low birthweight, not being breast-fed at three months, and introduction to solid foods prior to three months of age.
3. Maternal sociodemographic factors expected to be related to indicators of overnutrition include single marital status and identifying as a racial/ethnic minority as well as having low educational attainment, high parity, and an irregular work schedule.
4. Infant sociodemographic factors expected to be related to indicators of overnutrition include not being breastfed at three months (a positive association is expected at three months and a negative association at 12 months) and introduction to solid foods prior to three months of age.

Method

The data for this study were derived from the Women, Work and Wee Ones Project, an ongoing longitudinal cohort study designed to determine if maternal employment in a nonstandard schedule poses developmental risk for infants and toddlers. The sampling, recruitment, and data collection procedures were approved by the University of North Carolina Greensboro Institutional Review Board (UNCG IRB) and supported by IRBs of three additional academic institutions and two hospitals. The sampling frame and recruitment procedures were structured with the goal of creating a sample representative of low-income working mothers of infants in the Piedmont Triad region of central North Carolina.

Participants and Procedures

Data were collected from 285 mother-infant dyads when infants were three and 12 months of age. At the three-month data collection point, mothers were between the ages of 18 and 43 (*M* = 27.14, *SD* = 5.26) and the majority of mothers were African-American (63.9% African-American, 29.8% European American, 6.3% other). A large proportion of the mothers interviewed were in the low-income range (39.1% of mothers had an income less than $15,000 a year; *Median* household annual income of $13,277), and 30.5% of mothers indicated having received a high school degree, GED equivalent, or less. Further, 93% of mothers reported receiving government assistance in the past year and 64.9% of mothers indicated that they were a single parent. On average, families consisted of 4.13 (*SD* = 1.45) household members, with approximately 2.19 (*SD* = 1.25) children per household, and about half of the infants in the sample were female (47%).

Trained interviewers conducted in-home visits when infants were three and 12 months of age that consisted of face-to-face interviews with mothers and videotaped observation tasks with mother-infant dyads lasting a total of 60-90 minutes. The face-to-face interviews assessed demographics, maternal (e.g., work information, health, social support), child (e.g., temperament, health) and family (e.g., finances, home environment) characteristics. The videotaped portion of each visit consisted of four episodes that each lasted about five minutes: 1) unstructured free play, 2) structured play, 3) measurement series, and 4) a limitations task. Infant anthropometry was collected during the measurement series using a standardized protocol. Measurements were taken with help from the child's mother while the child was dressed in limited clothing (i.e., diaper only). Infant recumbent length was measured using a stadiometer. To ensure accuracy, two measurements were recorded that were within at least 0.50 centimeters of one another. At three months, infants were weighed in a car seat provided by the study and infant weight was calculated by subtracting the weight of the car seat from the total weight of the infant in the car seat. At 12 months, infant weight was measured by having the child either sit or stand on the center of a child scale without touching or holding anything for at least a few seconds. Two measurements were recorded (both standing or both sitting) within at least 0.20 kilograms of one another.

Measures

Sociodemographic characteristics. All predictor variables were based on maternal report at the three-month assessment. Maternal age, educational attainment, and parity were coded such that three categories were examined [Age (18-24, 25-34 (reference), 35+); Education (high school or less, some post high school education (reference), 4 year degree or more); Parity (0 previous deliveries, 1-2 (reference), 3 or more)]. Binary variables were created for marital status (single = 1), minority status (racial/ethnic minority = 1), irregular work schedule (yes = 1), infant gender (female = 1), premature birth (yes = 1), low birthweight (yes = 1), breastfed at three months (yes =1), and introduction to solid foods prior to three months (yes = 1).

Infant Malnutrition. To assess infant malnutrition, measured length and weight were used to determine indicators of overnutrition and undernutrition. Growth indicators were used to assess infant size at three and 12 months of age as well as infant growth from three to 12 months. High weight-for-length (risk-of-overweight, overweight/obese) and rapid weight gain were used as indicators of overnutrition. Rapid weight gain was determined based on the recommendations of Monteiro and Victora (2005) in which rapid weight gain is defined as an increase in weight-for-length *z*-score greater than 0.67. Low length-for-age (stunted), low weight-for-age (underweight), and a decline in weight-for-length *z*-score greater than or equal to one (Becker et al., 2014) were used as indicators of undernutrition. Both the CDC 2000 growth reference (cutoff values defined as the 5^{th} and 95^{th} percentile) and the WHO 2006 growth standard (cutoff values defined as the 2.3^{rd} or 97.7^{th} percentile) were used to assess infant size and growth.

Results

Analyses

To examine Research Goal #1, frequencies were computed to determine the prevalence of stunting, underweight, risk-of-overweight, and overweight/obese at three and 12 months of age using both the WHO 2006 and CDC 2000 growth charts. In addition, frequencies were computed to document the prevalence of rapid weight gain (acceleration in weight-for-age) and a decrease in weight-for-length indicative of undernutrition from three to 12 months of age. Paired samples *t*-tests were used to determine whether there were statistically significant differences in the proportion of infants categorized as displaying non-normative growth (e.g., stunted, overweight/obese) with the use of the WHO 2006 standard versus the CDC 200 reference. To explore whether sociodemographic factors were associated with indicators of malnutrition to address Research Goal #2, a series of multivariate logistic regressions were used to calculate odds ratios (OR) of the risk of each growth indicator predicted by maternal characteristics (entered on Step one) and infant characteristics (Step two). Separate regressions were computed for stunting, underweight, risk-of-overweight, and overweight/obese at three and 12 months of age as well as rapid weight gain and a decline in weight-for-length indicative of undernutrition.

Descriptive Statistics

Frequencies for all sociodemographic variables were computed. Table 1 displays the percentage of mothers and infants who fall into each sociodemographic category of interest. As indicated in Table 1, the majority of mothers were racial/ethnic minorities and single mothers. Approximately half of mothers were 25-34 years of age, had completed some form of post high school education, and had previously given birth one to two times prior to the infant participating in the current study. About 11% of infants were born prematurely and 6.3% of infants had a low birthweight. 12 infants were born both prematurely with a low birthweight, 19 infants were born prematurely at a normal birthweight, and only six of the 253 infants who were born at term had a low birthweight. Further, only 30% of mothers reported breastfeeding at the three-month data collection point and 37% of mothers reported that the infant had been introduced to solid foods at or prior to three months of age.

Research Goal #1

Table 2 shows a comparison of the prevalence of indicators of malnutrition at three and 12 months using both the WHO 2006 and CDC 2000 growth charts. Examining weight-for-length, the majority of infants displayed normative growth at both time points using both growth charts. Combining the percentage of infants categorized as risk-of-overweight and overweight/obese (i.e., high weight-for-length), the second highest proportion of infants were those with a high weight-for-length and this was observed at both time points with both growth charts. However, some differences emerged in the prevalence of high weight-for-length depending on overweight category, infant age, and growth chart used. Comparing the WHO and CDC growth charts, there was a significant difference in the proportion of infants classified as risk-of-overweight at three months (*t* = -2.93 (284), *p* = .004) and overweight/obese at three (*t* = 2.25 (284), *p* = .025) and 12 months (*t* = 2.87 (239), *p* = .004). Further, combining the risk-of-overweight and overweight/obese growth categories, there was a larger discrepancy in the percentage of infants with a high weight-for-length at 12 months (WHO: 30%; CDC: 23.3%) than at three months (WHO: 29.5%; CDC: 31.2%). With the CDC growth chart, the proportion of infants classified as risk-of-overweight or overweight/obese decreased from three to 12 months (combined decrease from 31.2% to 23.3%). Using the WHO growth charts, although there was a decrease in overweight/obese (9.5% to 8.3%), there was an increase in risk-of-overweight (20% to 21.7%) resulting in a very slight increase from 29.5% to 30% for risk-of-overweight and overweight/obese combined.

Examining indicators of undernutrition at three months, 25.3% of infants were stunted using the WHO charts compared to 4.6% with the CDC charts (*t* = 8.61 (284), *p* = .000), and 8.8% of infants were underweight using the WHO standard compared to 1.8% with the CDC reference (*t* = 4.63 (284), *p* = .000). At 12 months, there was a much smaller discrepancy between the two growth charts for stunted (WHO: 2.9%; CDC: 2.1%) and underweight (WHO: 1.2%; CDC: 3.7%), although the difference in the proportion of infants classified as underweight was significantly different (*t* = -2.48 (284), *p* = .004) but not for stunted at 12 months.

Examining change in growth from three to 12 months, a greater proportion of infants displayed rapid weight gain as opposed to a decline in weight-for-length *z*-score greater than one (see Table 3). Comparing the use of the two growth charts, a higher percentage of infants experienced rapid weight gain using the WHO standard (WHO: 60.3; CDC: 24.8%) (*t* = 11.53 (239), *p* = .000), whereas a higher percentage of infants experienced change in growth indicative of undernutrition based on the CDC reference (WHO: 24.6%; CDC: 30.4%) (*t* = 3.85 (239), *p* = .000).

Research Goal #2

To explore the association between sociodemographic characteristics and indicators of malnutrition in the first year of life, separate multivariate logistic regressions were computed for each indicator of undernutrition and overnutrition using both the WHO and CDC growth charts. Tables 4-7 show the risk (odds ratio) of each growth indicator predicted by each maternal and infant characteristic at three (tables four and five) and 12 months (Tables 6 and 7). Table 8 shows the risk of rapid weight gain and Table 9 shows the risk of a decline in weight-for-length *z*-score indicative of undernutrition from three to 12 months predicted by each maternal and infant characteristic, respectively. When cell sizes were too small to produce meaningful results the growth indicator was not analyzed and thus was not included in the appropriate table (e.g., only five infants were categorized as underweight based on the CDC growth chart for weight-for-age at three months).

Indicators of undernutrition. The number of infants categorized as stunted or underweight was too small to compute regressions using the CDC growth charts at three months and too small to compute regressions regardless of growth chart used at 12 months. As a result, the findings for indicators of undernutrition at three months were based on the WHO standard only. At three months, none of the maternal sociodemographic characteristics in model one predicted low length-for-age (stunted) or low weight-for-age (underweight). Although not statistically significant, when infant characteristics were accounted for (model 2), compared to infants of mothers with one to two previous deliveries (moderate multiparity), infants of mothers with three or more previous deliveries (high multiparity) were more likely to be stunted at three months of age (*OR* = 2.79, *p* = .050).

Two infant characteristics were associated with both stunted and underweight at three months. First, female infants were less likely to be stunted (*OR* = 0.34, *p* = .002) or underweight (*OR* = 0.27, *p* = .025) compared to males. Differently, low birthweight infants were more likely to be stunted (*OR* = 41.10, *p* = .000) or underweight (*OR* = 27.71, *p* = .000), however the 95%

confidence intervals for both indicators of undernutrition were quite large, reducing our confidence in the association between low birthweight and the two indicators of undernutrition.

Finally, there were no significant associations between the sociodemographic characteristics and infant growth from three to 12 months indicative of undernutrition. However, there was a trend level association between infants who were premature and a decreased likelihood of experiencing a decrease in weight-for-length indicative of undernutrition from three to 12 months of age (*OR* = 0.28, *p* = .097).

Indicators of overnutrition. At three months, none of the maternal or infant characteristics were associated with high weight-for-length (i.e., risk-of-overweight or overweight/obese) regardless of growth chart used. Although not statistically significant, high multiparity was marginally associated with a greater likelihood of infant overweight/obesity in model one (*OR* = 2.71, *p* = .099) using the WHO growth chart but not in model two with the addition of infant characteristics. In model two, being breastfed at three months was marginally associated with a greater chance of infant overweight/obesity (*OR* = 2.24, *p* = .080).

Using the WHO growth charts at 12 months, infants of mothers with low educational attainment were less likely to be at risk-of-overweight (*OR* = 0.31, *p* = .007) compared to infants of mothers with moderate educational attainment. This association remained significant after the addition of infant characteristics in model two (*OR* = 0.30, *p* = .006). With overweight/obese as the outcome, infants of mothers with an irregular work schedule were more likely to have a high weight-for-length in both models (model 2: *OR* = 3.80, *p* = .017).

Using the CDC growth chart at 12 months, infants who were breastfed at three months were less likely to be at risk-of-overweight compared to infants who were not breastfed at three months (*OR* = 0.35, *p* = .024). Although not statistically significant, infants of mothers that reported being a racial/ethnic minority had a marginal increased likelihood of risk-of-overweight in both models (model 2: *OR* = 2.30, *p* = .068) and low maternal educational attainment was marginally associated with a decreased likelihood of infant risk-of-overweight in both models (model 2: *OR* = 0.41, *p* = .051).

Based on the WHO growth charts, infants of mothers who identified as racial/ethnic minorities were more likely to experience rapid weight gain from three to 12 months (*OR* = 2.12, *p* = .019). In addition, infants who were breastfed at three months were less likely to experience rapid weight gain (*OR* = 0.49, *p* = .033) and there was a marginal positive association between low birthweight and the likelihood of rapid weight gain (*OR* = 5.13, *p* = .062). Based on the CDC growth charts, infants of mothers who indicated having an irregular work schedule were more likely to experience rapid weight gain (*OR* = 2.05, *p* = .046). Finally, infants of mothers who identified as racial/ethnic minorities were marginally more likely to experience rapid weight gain in both models (model 2: *OR* = 2.15, *p* = .057).

Discussion

Research Goal #1:

Hypothesis #1 was partially supported. As expected, the majority of infants displayed normative growth at both time points and the second highest percentage of infants had a high weight-for-length. Contrary to hypothesis #1, the percentage of infants classified as overweight/obese decreased from three to 12 months using both growth charts and the number of infants classified as at risk-of-overweight decreased using the CDC reference (increased slightly based on WHO). Weight-for-length is comprised of both infant length and weight measurements, thus one possible explanation for this slight discrepancy is the decrease in the percentage of infants with a low length-for-age (stunting) from the three-month to the 12-month time point. Further, compared to the use of the WHO standard, a greater proportion of infants experienced a decline in weight-for-length *z*-score from three to 12 months using the CDC reference.

Hypothesis #2 was also partially supported. The only instance in which greater than the expected 5% of the sample was stunted or underweight was at three months using the WHO standard. It is difficult to make direct comparisons to previous research documenting rates of indicators of undernutrition in early infancy. Whereas the current study obtained prevalence rates at two specific time points, larger studies show mean percentages from children ranging in age from birth to 11 months, 11 to 23 months or birth to 23 months (e.g., Mei et al., 2008; CDC, 2011). Consistent with hypothesis #2, more infants were classified as stunted compared to underweight with the exception of the 12-month time point using the CDC reference. In addition, more infants were classified as stunted when using the WHO standard compared to the CDC reference, which is to be expected because children in the WHO sample are overall taller compared to the CDC reference (de Onis et al., 2007). This finding is in line with previous studies comparing children to the WHO and CDC samples (de Onis et al., 2007) and a study comparing the two growth charts with a nationally representative sample of children aged 0 to 59 months (Mei et al., 2008).

Comparing the use of the WHO standard to the CDC reference in this sample, there was a noticeably larger discrepancy between the rate of stunting at three months (20.7 percentage points) than at 12 months (0.8 percentage points) and the stunting rate at three months based on the WHO standard (25.3%) was considerably higher than that of the nationally representative sample in the Mei et al. (2008) study which was 5.2%. There are several possible reasons for these differences. First, the tighter variability in the WHO length-for-age curves compared to that of the CDC may be more prominent in early infancy (de Onis et al., 2007). Multiple datasets were used to construct the CDC length-for-age curves from birth to about six months. The additional data included supplementary length measurements from PedNSS, which targeted low-income US children and may be more similar to the current study's sample than the nationally representative data used to construct the curves at older ages. Further, measurement error obtaining infant length during data collection may have been higher with three month olds compared to 12 month olds. However, this is less probable considering much smaller differences in high weight-for-length between the use of the WHO standard and CDC reference at three months which relied on the same length measurements. Similar to the prevalence of stunting in this sample, there was a greater discrepancy in underweight between the use of the WHO standard and CDC reference at three months compared to 12 months.

Interestingly, a higher percentage of infants were identified as underweight based on the WHO standard at three months whereas a higher percentage of infants were identified as underweight based on the CDC reference at 12 months. This change in pattern was also observed in the Mei et al. (2008) study with infants aged 0 to 5 and 6 to 12 months. Although the sample used to construct the CDC curves is overall heavier than the sample used to construct the WHO curves, the average weight-for-age of infants in the WHO sample is above the median of the CDC curve until about six months and then crosses and remains below the CDC median until about 32 months (de Onis et al., 2007), which likely accounts for the observed pattern in the current data. This is also consistent with research documenting greater weight gain among breastfed infants in the first half of infancy followed by greater weight gain among formula-fed infants in the latter half of infancy (Dewey, 1998a). We can also expect the current sample to be more similar to the CDC reference in terms of infant feeding based on the low rate of breastfeeding observed in this study.

Capitalizing on obtaining anthropometric measurements at two time points, this study also examined indicators of malnutrition based on change in growth from three to 12 months. Partially supporting hypothesis #3, a greater proportion of infants showed rapid weight gain when using the WHO standard whereas more infants showed a decline in weight-for-length indicative of undernutrition using the CDC reference. Further, there was a much smaller discrepancy between the two growth charts in the percentage of infants categorized as having experienced undernutrition versus the percentage of infants categorized as having experienced rapid weight gain. A possible reason for these differences is the larger decrease in the proportion of infants categorized as having a high weight-for-length from three to 12 months with the CDC compared to the WHO charts. A decrease in the proportion of infants categorized as underweight using the WHO reference but an increase using the CDC sample may help explain the differences found for rapid weight gain. This finding may further highlight the possibility that there is a greater similarity between the study sample and the CDC reference compared to the WHO standard.

Research Goal #2

The four hypotheses regarding the second research goal were partially supported. Overall, fewer maternal and infant characteristics were associated with indicators of malnutrition than expected, especially for undernutrition. It is important to note that in some cases cell sizes were too small to analyze certain hypotheses and in some cases it is likely that our statistical power was insufficient which may have resulted in various type II errors.

Indicators of undernutrition. With the lack of US research examining infant undernutrition it is difficult to make conclusions regarding the sociodemographic factors associated with stunting and underweight in the current study. For example, the finding that male infants were more likely to be stunted or underweight compared to females at three months is consistent with results from a review based on survey evidence from over 30 countries. In this review, Marcoux (2002) showed that when gender differences in growth indicators do exist boys are generally worse off than girls. This finding was unexpected given the previous belief of an anti-female bias in food allocation in low-income countries and according to Marcoux (2002) has led some nutritionists to believe that girls are more resilient to an inadequate food supply in terms of physical development. Although food insecurity was not assessed in the present study, it is likely to be present in this low-income sample and future anthropometric research with US infants and children that also examines household food security is warranted. In addition, low birthweight was significantly associated with both stunting and underweight at three months. However, the association was no longer significant at 12 months which may be explained by the high percentage of infants who experienced rapid weight gain from three to 12 months.

In addition, low birthweight was associated with an increased risk of indicators of undernutrition at three months. Unfortunately, cell sizes were too small to examine indicators of undernutrition at 12 months, thus it is unknown whether low birthweight remains a risk factor for inadequate energy at the end of the first year.

Indicators of overnutrition. As expected in a high-income country such as the US, a greater number of sociodemographic factors were associated with indicators of overnutrition rather than indicators of undernutrition. This was especially true at 12 months compared to three months, which may be a result of a greater impact of the postnatal environmental on weight gain with increasing infant age. Consistent with differing growth patterns of breastfed versus formula-fed infants discussed above (e.g., Dewey, 1998a), infants who were breastfed at three months were marginally more likely to be overweight at three months but significantly less likely to be at risk-of-overweight at 12 months.

Contrary to hypothesis #3, compared to infants of mothers with moderate educational attainment infants of mothers with low educational attainment were less likely to be at risk-of-overweight at 12 months using the WHO standards and a trend in the same direction was observed using the CDC reference. Interestingly, low educational attainment did not decrease the risk of infant overweight/obesity suggesting that the relation between educational attainment and high weight-for-length is not linear. Breastfeeding status at three months also contradicted this finding. In line with previous studies consistently showing that more educated mothers breastfeed for longer durations compared to their less educated counterparts (Thulier & Mercer, 2009), breastfeeding rates at three months increased with increasing maternal education (low education: 11.5%; moderate education: 34.6%; high education: 47.6%). Thus, we would expect that higher maternal education would be associated with a decreased risk of overweight due to a longer duration of breastfeeding. However, instead of observing a protective effect of higher educational attainment associated with a higher rate of breastfeeding, the protective effect was seen for infants of mothers with lower educational attainment. There are several explanations for this finding. First, it is possible that mothers with moderate education have just enough of an income advantage compared to mothers with low education to spend money on calorically dense readily available snacks for their young children. Second, food allocation to multiple children in the home may be an issue among mothers with low education based on our data showing that these mothers were significantly less likely to be first time mothers (data not shown). This may be especially problematic for infants experiencing lower rates of breastfeeding marked by mothers with lower educational attainment.

Finally, consistent with hypothesis #3, infants of mothers with an irregular work schedule were approximately three times more likely to be overweight at 12 months using the WHO standard, and infants who were breastfed at three months were 65% less likely to be at risk-of-overweight at 12 months using the CDC reference. Interestingly, both irregular work schedule and breastfeeding also predicted rapid weight gain from three to 12 months in the same direction that was observed at the 12-month time point. Opposite of what was seen for high weight-for-length at 12 months, having an irregular work schedule was a significant predictor of rapid weight gain using the CDC reference instead of the WHO standard and breastfeeding was a significant predictor using the WHO standard instead of the CDC reference.

This finding builds on previous work with older children showing that nonstandard work schedules predict increases in youth BMI (Miller & Han, 2008) by showing that the association between mothers' work schedules and an increased risk of child weight gain may begin as early as the first year of life. Further, it appears that compared to infants of mothers with a regular work schedule (standard or non-standard), infants of mothers with an irregular work schedule are at an increased risk of high weight-for-length at 12 months as well as rapid weight gain from three to 12 months. Mothers with an irregular work schedule may be less likely to consistently adhere to recommended feeding practices (e.g., may introduce to solid foods earlier) compared to infants of mothers with regular or more consistent work schedules. A next step for future research is to explore feeding practices as a potential mediator of the relation between irregular work schedules and child overweight. These findings provide further support of the need for increased public health efforts to promote breastfeeding in low-income African-American women. Previous research has shown that not only are attitudes towards breastfeeding important for breastfeeding initiation, but a positive attitude towards formula-feeding strongly predicts breastfeeding intentions in first-time mothers with African-American women having the highest level of comfort with formula feeding compared to other racial ethnic groups (Nommsen-Rivers, Chantry, Cohen, & Dewey, 2009). Further, a study based on an annual national mail survey to US adults showed that from 1999 to 2003 there was a significant increase in the attitude that formula is as good as breastmilk with the largest increase occurring among low-income adults (Li, Rock, Grummer-Strawn, 2007). Based on a study with African-American women using focus groups, Ringel-Kulka et al. (2011) concluded that African-American women may experience a lack of breastfeeding support on multiple levels including the home and workplace as well as from peers and health care providers. It appears that barriers to breastfeeding are particularly high among this subpopulation and that being employed further stacks the deck.

Although the association only trended towards significance, parity was the only sociodemographic characteristic associated with both forms of malnutrition, which was in line with hypothesis #1 and hypothesis #3. At three months, infants of mothers with high multiparity were more likely to be stunted or overweight/obese compared to infants of mothers with moderate multiparity. This is in contrast to a study by Ong et al. (2002) that was conducted with a relatively affluent birth cohort of 1335 infants born between 1991 and 1992 in the south-west of England that found that infants of primiparous mothers were shorter and lighter compared to infants of multiparous mothers. However, the infants of primiparous mothers showed greater increases in both weight and length compared to infants of multiparous mothers in the first year of life. The more affluent sample, the use of a different growth reference (i.e., U.K. 1990 growth reference) and the focus on anthropometric measures at birth in the Ong et al. (2002) sample may explain these contradictory findings.

Additionally, the present study did not find differences in indicators of undernutrition between infants of primiparous mothers and infants of mothers with one to two previous deliveries, but there was a trend towards a greater likelihood of stunting in infants of mothers with three or more previous deliveries compared to one or two previous deliveries. This finding may provide initial evidence of a threshold effect for the number of children in the household and a lack of resources to support optimal infant nutrition among low-income populations. On the other hand, the trend of high multiparity associated with a higher rate of overweight at three months was no longer significant at a trend level with the addition of infant characteristics to the model. It is possible that breastfeeding status at three months, the only infant characteristic marginally associated with overweight at three months (supporting hypothesis #4), may influence the relation between high multiparity and overweight. A higher rate of breastfeeding was observed among infants of mothers with high multiparity (34.5%) compared to infants of mothers with moderate multiparity (26.7%), whereas breastfeeding rates were more similar between mothers with high multiparity and primiparous mothers (33.6%).

CHAPTER III

CONCLUSION

The findings from this study build on the current body of infant growth literature in several ways. First, it is clear that the prevalence of indicators of malnutrition differ based on the growth chart used as well as the time point during infancy that is being examined. Building on previous research showing that differences in the use of the two growth charts do exist (e.g., Mei et al., 2008), the findings from the present study show that discrepancies are even greater when observations are confined to the first year of life. Second, this study provides additional evidence that breastfed infants gain weight faster in the first half of infancy followed by decreased weight gain in the latter half (Dewey et al., 1998a). This finding is important in our sample of limited generalizability given the fact that previous research showing these patterns has typically been conducted with more representative samples. Finally, this study included several relevant sociodemographic characteristics in the model and was able to highlight a select few that appear to significantly influence early growth, although future research that replicates these findings is needed.

Implications

The results from this study posit important implications for researchers, clinicians, and early prevention programs. Moving forward it is important for future research to consider the possibility of obtaining different results depending on the growth chart used. Although certain associations were consistent regardless of growth chart, if findings are to be translated to clinical practice it may require researchers to adopt the use of the recommended WHO 2006 growth charts. In addition, it is important for clinicians to understand that the use of the CDC growth reference may underestimate indicators of undernutrition (especially in the first three months) and overestimate indicators of overnutrition by the end of the first year. Best practices for growth monitoring are particularly important during the first year when growth is rapid and the impact of an unidentified nutrition-related growth problem may be irreversible.

Maternal work schedules and breastfeeding stand out as two potential sociodemographic characteristics that can be targeted for early prevention programs. Their association with either high weight-for-length at 12 months or rapid weight gain from three to 12 months using both growth charts provides evidence that both may be implicated in establishing an increased risk of obesity early in life. Based on these results, along with the low rate of breastfeeding that is consistently reported among low-income African-American mothers (Thulier & Mercer, 2009), an increased emphasis on breastfeeding education and greater support for breastfeeding among this high-risk subpopulation is needed.

Strengths and Limitations

Although the current study has several strengths, there are also limitations that must be addressed. First, the relatively small sample resulted in small cell sizes in several of the regression analyses, which hindered our ability to explore associations between sociodemographic characteristics and specific growth indicators (e.g., stunted and underweight using the CDC reference). Another limitation is related to each outcome variable (e.g., stunted, overweight/obese) in the logistic regressions such that the various reference groups are not mutually exclusive. For example, the reference group for overweight/obese includes infants that are not overweight/obese but may also include infants that are underweight or stunted. As a result, not all infants in each reference group can be definitively categorized as displaying normative growth. In addition, the results lack generalizability to other geographic regions in the US outside of the Piedmont Triad region of central North Carolina. However, due to the specific sampling procedures our findings are likely to generalize to other groups of low-income African-American working mothers with young children. It is also important to note that the sampling procedures limited the variability of the sociodemographic characteristics resulting in restricted range, which may explain a lack of significant findings especially in relation to indicators of undernutrition. By far the greatest limitation is the lack of data on parental anthropometry. Maternal overweight is the most consistent predictor of child weight outcomes (Whitaker, Wright, Pepe, Seidel, & Dietz, 1997) and it is possible that the addition of maternal weight or body mass index into the study analyses may produce different results. Although a strength of the study is that the two data collection points (i.e., three and 12 months) represent two distinct infant growth periods that depend on feeding method, additional data points (e.g., 3, 6, 9, 12 months) are needed to truly account for the rapid growth that takes place during the first year of life. Obtaining multiple anthropometric measurements during infancy will allow future research to examine infant growth trajectories, which will provide unique information regarding distinct patterns of growth.

Future Directions

Moving forward, it is important for future research to consider the use of the WHO 2006 standards as opposed to the CDC reference to gain a more meaningful interpretation of growth in the first year of life. It is also necessary for future research to explore more complex models predicting indicators of malnutrition by exploring potential mediating and/or moderating variables. For example, it is possible that the association between an irregular work schedule and indicators of overnutrition is explained by breastfeeding status. If this is the case, working mothers with inconsistent work schedules may need more tailored guidance and support in establishing a plan to meet US infant feeding guidelines. However, it is important to note that implementing a feeding plan that meets both the family's needs and employers' work demands may require qualitative research to gain greater insight into the day-to-day life of these mothers and/or certain policy changes. Food insecurity is another construct that will be important for infant growth research to study. To our knowledge, food insecurity has not been examined in relation to infant growth and is particularly relevant to infant feeding practices and may help explain our unexpected findings with regard to educational attainment.

Conclusion

Incorporating the use of the WHO standards to current research is necessary in order to be consistent with clinical practice guidelines and will provide more meaningful conclusions of research findings. Although the rate of stunting and underweight was above the expected five percent at three months, it is encouraging that by 12 months of age these rates were below five percent in this low-income primarily African-American sample. However, some evidence suggests that infancy is a critical period in terms of nutritional programming for later health outcomes (Koletzko, Brands, Poston, Godfrey, & Demmelmair, 2012) and it is unknown at this time whether the high rates of indicators of undernutrition that appeared early in life will impact later physical and/or cognitive development in this sample.

Overall, the current study points to important maternal and infant characteristics that can be included in obesity or nutrition-related prevention programs and/or policies that have an impact on working mothers. Although the childhood obesity epidemic is a pressing public health problem that requires primary prevention efforts as early as infancy, focusing solely on indicators of overnutrition may obscure early nutritional problems associated with inadequate energy. This may unintentionally inhibit early prevention programs targeting health disparities among economically disadvantaged and ethnic minority populations in which infants are at an increased risk of malnutrition related to both over and undernutrition.

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APPENDICES

Table 1

Frequencies for all maternal and infant sociodemographic characteristics (N = 285)

Maternal characteristics:	
Age	
18-24	36.1%
25-34	54.0%
35 +	9.8%
Racial/ethnic minority	73.7%
Single mother	64.9%
Education	
High school, GED, or less	30.5%
Post high school or certificate	54.7%
Four year degree +	14.7%
Irregular work schedule	21.4%
Parity	
0	38.6%
1-2	51.2%
≥ 3	10.2%
Infant characteristics:	
Female	47.0%
Premature birth	10.9%
Low birth weight	6.3%
Breastfed at 3- months	30.2%
Early introduction to solids	36.8%

Table 2

Prevalence of growth indicators at 3 and 12 months based on the WHO 2006 and the CDC 2000 growth charts, with the percentile cutoff values recommended by the CDC and the z-score cutoff values recommended by the WHO

	Stunted (length-for-age)	**Underweight (weight-for-age)**	**Risk-of-overweight (weight-for-length)**	**Overweight/obese (weight-for-length)**	**Normal weight (weight-for-length)**
3-months (*N* = 285)					
WHO	25.3%***	8.8%***	20.0%**	9.5%*	69.8%
CDC	4.6%	1.8%	23.5%	7.7%	68.1%
12-months (*Ns* = 240-242)					
WHO	2.9%	1.2%*	21.7%	8.3%**	69.2%**
CDC	2.1%	3.7%	18.3%	5.0%	75.0%

CDC percentile cutoff values: $< 5^{th}$ percentile to define indicators of undernutrition, $\geq 85^{th}$ and $< 95^{th}$ for risk-of-overweight and $\geq 95^{th}$ to define overweight/obese.
WHO *Z*-score cutoff values: < -2 *z*-score points to define indicators of undernutrition, > 1 *z*-score points to define possible risk-of-overweight and > +2 *z*-score points to define overweight/obese.

*Proportion of infants using the WHO 2006 charts is significantly different from the proportion of infants using the CDC charts (***p < .001, **p < .01, *p < .05)

Table 3

Prevalence of growth indicators based on an increase or decrease in z-score values from 3 to 12 months of age using both the CDC 2000 and WHO 2006 growth charts

	Rapid weight gain (*N* = 242)	**Undernutrition (*N* = 240)**
WHO	60.3%***	24.6%***
CDC	24.8%	30.4%

Rapid weight gain: defined by an increase in weight-for-age *z*-score > 0.67 points when two data points are available.
Undernutrition: defined by a decline in weight-for-length *z*-score ≥ -1 points when two data points are available.

*Proportion of infants using the WHO 2006 charts is significantly different from the proportion of infants using the CDC charts (***p < .001, **p < .01, *p < .05)

Table 4

Odds ratios (and 95% confidence intervals) of the association between maternal and infant characteristics with indicators of undernutrition and overnutrition at 3 months using the WHO 2006 growth charts

	Stunted		**Underweight**		**Risk-of-overweight**		**Overweight/obese**	
Maternal characteristics	**M1**	**M2**	**M1**	**M2**	**M1**	**M2**	**M1**	**M2**
Age								
18-24	0.64	0.71	0.59	0.42	1.53	1.44	0.59	0.61
	(0.32-1.28)	(0.33-1.54)	(0.19-1.79)	(0.12-1.48)	(0.76-3.10)	(0.70-2.97)	(0.20-1.71)	(0.21-1.81)
35 +	0.50	0.41	0.22	**0.14**§	0.88	0.91	1.71	1.38
	(0.18-1.37)	(0.13-1.28)	(0.03-1.78)	(0.02-1.37)	(0.30-2.62)	(0.30-2.79)	(0.54-5.48)	(0.40-4.76)
Racial/ethnic minority	1.43	1.42	2.41	2.44	1.50	1.53	0.91	0.92
	(0.71-2.87)	(0.65-3.10)	(0.67-8.77)	(0.61-9.76)	(0.71-3.16)	(0.72-3.26)	(0.35-2.37)	(0.35-2.41)
Single mother	1.20	0.92	0.90	0.59	0.82	0.84	0.84	0.88
	(0.66-2.20)	(0.47-1.77)	(0.36-2.22)	(0.21-1.64)	(0.44-1.55)	(0.44-1.61)	(0.36-1.99)	(0.37-2.10)
Education								
High school, GED, or less	0.84	0.82	1.13	1.21	0.78	0.72	0.96	1.17
	(0.44-1.62)	(0.39-1.74)	(0.42-3.06)	(0.38-3.91)	(0.39-1.57)	(0.35-1.48)	(0.37-2.52)	(0.43-3.22)
4 year degree +	0.68	0.61	1.34	1.51	0.61	0.65	0.64	0.53
	(0.29-1.58)	(0.23-1.59)	(0.43-4.23)	(0.41-5.55)	(0.23-1.61)	(0.24-1.74)	(0.17-2.44)	(0.13-2.08)
Parity								
0	0.69	0.68	**0.36**§	**0.31**§	0.79	0.78	1.89	1.80
	(0.35-1.36)	(0.32-1.45)	(0.11-1.18)	(0.08-1.14)	(0.39-1.59)	(0.38-1.61)	(0.69-5.16)	(0.65-4.96)
≥ 3	2.04	**2.79**§	1.35	1.85	1.04	1.08	**2.71**§	2.62
	(0.84-4.96)	(0.10-7.82)	(0.39-4.68)	(0.41-8.31)	(0.36-2.94)	(0.37-3.14)	(0.83-8.84)	(0.76-9.06)
Irregular work schedule	0.90	0.75	0.89	0.99	1.25	1.30	1.12	1.03
	(0.46-1.79)	(0.34-1.65)	(0.31-2.56)	(0.31-3.11)	(0.62-2.52)	(0.64-2.67)	(0.43-2.95)	(0.38-2.74)
Infant characteristics								
Female		**0.34****		**0.27****		1.02		0.90
		(0.17-0.67)		(0.09-0.85)		(0.56-1.89)		(0.38-2.13)
Premature birth		1.48		0.71		0.63		0.88
		(0.53-4.17)		(0.16-3.19)		(0.19-2.14)		(0.18-4.28)
Low birthweight		**41.10*****		**27.71*****		0.69		1.14
		(7.53-224.4)		(5.48-140.01)		(0.13-3.65)		(0.17-7.81)

Table 4 continues

Table 4 (cont.)

Breastfed	0.96 (0.47-1.97)	1.49 (0.51-4.33)	0.73 (0.35-1.49)	**2.24**§ (0.91-5.51)
Early introduction to solids	0.70 (0.35-1.41)	2.17 (0.76-6.20)	1.13 (0.59-2.15)	0.88 (0.34-2.26)

$^{§}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Table 5

Odds ratios (and 95% confidence intervals) of the association between maternal and infant characteristics with indicators of overnutrition at 3 months using the CDC 2000 growth charts

	Risk-of-overweight		Overweight/obese	
Maternal characteristics	**M1**	**M2**	**M1**	**M2**
Age				
18-24	1.26 (0.64-2.47)	1.20 (0.60-2.40)	0.92 (0.30-2.83)	0.91 (0.29-2.83)
35 +	1.03 (0.39-2.73)	1.01 (0.37-2.76)	1.89 (0.53-6.78)	1.48 (0.38-5.75)
Racial/ethnic minority	1.27 (0.64-2.51)	1.27 (0.64-2.53)	1.27 (0.42-3.86)	1.29 (0.42-3.94)
Single mother	0.71 (0.39-1.27)	0.75 (0.41-1.37)	0.98 (0.38-2.55)	0.94 (0.36-2.50)
Education				
High school, GED, or less	0.74 (0.38-1.43)	0.76 (0.38-1.50)	0.80 (0.28-2.30)	0.84 (0.28-2.54)
4 year degree +	0.99 (0.51-1.91)	0.58 (0.23-1.45)	0.52 (0.11-2.48)	0.43 (0.09-2.12)
Parity				
0	0.99 (0.51-1.91)	0.98 (0.50-1.92)	1.17 (0.39-3.48)	1.25 (0.41-3.79)
≥ 3	1.29 (0.49-3.37)	1.35 (0.50-3.66)	1.69 (0.45-6.38)	1.81 (0.46-7.16)
Irregular work schedule	1.03 (0.53-2.04)	1.07 (0.54-2.15)	1.34 (0.48-3.72)	1.20 (0.42-3.41)
Infant characteristics				
Female		1.06 (0.60-1.89)		0.68 (0.26-1.75)
Premature birth		1.15 (0.40-3.28)		0.49 (0.07-3.32)
Low birthweight		0.18 (0.02-1.52)		2.34 (0.33-16.35)

Table 5 continues

Table 5 (cont.)

Breastfed	1.03 (0.53-1.98)	1.52 (0.56-4.10)
Early introduction to solids	1.14 (0.62-2.10)	0.73 (0.26-2.07)

§p < .10, *p < .05, **p < .01, ***p < .001

Table 6

Odds ratios (and 95% confidence intervals) of the association between maternal and infant characteristics with indicators of overnutrition at 12 months using the WHO 2006 growth charts

	Risk-of-overweight		**Overweight/obese**	
Maternal characteristics	**M1**	**M2**	**M1**	**M2**
Age				
18-24	0.68	0.69	0.64	0.45
	(0.31-1.51)	(0.31-1.57)	(0.19-2.15)	(0.13-1.62)
35 +	1.07	1.04	1.91	1.97
	(0.34-3.36)	(0.32-3.40)	(0.44-8.42)	(0.41-9.52)
Racial/ethnic minority	1.23	1.18	1.40	1.47
	(0.57-2.63)	(0.55-2.54)	(0.45-4.40)	(0.45-4.78)
Single mother	1.08	1.07	0.67	0.76
	(0.54-2.16)	(0.53-2.16)	(0.25-1.81)	(0.27-2.12)
Education				
High school, GED, or less	**0.31****	**0.30****	0.70	0.65
	(0.13-0.73)	(0.12-0.70)	(0.23-2.16)	(0.20-2.12)
4 year degree +	0.50	0.50	0.47	0.47
	(0.19-1.29)	(0.19-1.33)	(0.10-2.27)	(0.09-2.41)
Parity				
0	1.63	1.79	0.83	0.10
	(0.77-3.44)	(0.84-3.85)	(0.26-2.65)	(0.30-3.36)
≥ 3	1.39	1.47	0.50	0.49
	(0.42-4.55)	(0.43-4.96)	(0.09-2.87)	(0.08-3.09)
Irregular work schedule	0.92	0.92	**2.99***	**3.80***
	(0.42-1.98)	(0.41-2.04)	(1.12-8.00)	(1.27-11.31)
Infant characteristics				
Female		0.78		0.86
		(0.40-1.51)		(0.32-2.32)
Premature birth		1.17		
		(0.37-3.71)		0.00

Table 6 continues

Table 6 (cont.)

Low birthweight	0.42	
	(0.07-2.49)	0.00
Breastfed	0.81	0.94
	(0.38-1.72)	(0.29-2.99)
Early introduction to solids	0.68	1.99
	(0.33-1.40)	(0.69-5.72)

$^{\S}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Table 7

Odds ratios (and 95% confidence intervals) of the association between maternal and infant characteristics with risk-of-overweight at 12 months using the CDC 2000 growth charts

	Risk-of-overweight	
Maternal characteristics	**M1**	**M2**
Age		
18-24	1.06	1.03
	(0.47-2.39)	(0.43-2.43)
35 +	0.48	0.63
	(0.10-2.32)	(0.13-3.16)
Racial/ethnic minority	**2.29**§	**2.30**§
	(0.95-5.53)	(0.94-5.62)
Single mother	0.68	0.69
	(0.33-1.40)	(0.33-1.46)
Education		
High school, GED, or less	**0.47**§	**0.41**§
	(0.19-1.12)	(0.17-1.00)
4 year degree +	0.89	1.13
	(0.34-2.29)	(0.42-3.05)
Parity		
0	1.31	1.52
	(0.60-2.86)	(0.67-3.45)
≥ 3	0.80	0.79
	(0.20-3.21)	(0.19-3.38)
Irregular work schedule	1.57	1.78
	(0.73-3.36)	(0.79-4.02)
Infant characteristics		
Female		1.04
		(0.51-2.12)
Premature birth		1.57
		(0.46-5.37)
Low birthweight		0.24
		(0.02-2.35)

Table 7 continues

Table 7 (cont.)

Breastfed	**0.35*** (0.14-0.87)
Early introduction to solids	0.74 (0.34-1.60)

§p < .10, *p < .05, **p < .01, ***p < .001

Table 8

Odds ratios (and 95% confidence intervals) of the association between maternal and infant characteristics with indicators of undernutrition and overnutrition from 3 to 12 months using the WHO 2006 growth charts

	Rapid weight gain		Undernutrition	
Maternal characteristics	**M1**	**M2**	**M1**	**M2**
Age				
18-24	0.62 (0.33-1.18)	0.59 (0.30-1.16)	1.17 (0.56-2.42)	1.19 (0.56-2.52)
35 +	1.27 (0.44-3.63)	1.44 (0.48-4.34)	0.55 (0.15-2.07)	0.52 (0.13-2.04)
Racial/ethnic minority	**2.00*** (1.09-3.67)	**2.12*** (1.13-3.98)	0.67 (0.34-1.32)	0.66 (0.33-1.31)
Single mother	0.97 (0.55-1.71)	0.86 (0.48-1.56)	0.91 (0.48-1.73)	0.89 (0.46-1.72)
Education				
High school, GED, or less	1.12 (0.60-2.06)	1.08 (0.57-2.07)	1.20 (0.59-2.40)	1.06 (0.52-2.19)
4 year degree +	1.01 (0.46-2.27)	1.31 (0.56-3.09)	1.87 (0.79-4.42)	1.58 (0.65-3.86)
Parity				
0	1.16 (0.63-2.17)	1.24 (0.64-2.38)	1.02 (0.51-2.04)	1.04 (0.51-2.13)
≥ 3	1.14 (0.41-3.19)	1.37 (0.46-4.08)	1.27 (0.40-4.00)	1.27 (0.39-4.13)
Irregular work schedule	1.11 (0.59-2.09)	1.27 (0.65-2.47)	0.77 (0.37-1.60)	0.68 (0.32-1.45)
Infant characteristics				
Female		0.64 (0.36-1.12)		0.90 (0.48-1.69)
Premature birth		1.76 (0.56-5.55)		0.28 (0.06-1.26)
Low birthweight		**5.13**[§] (0.92-28.57)		2.04 (0.45-9.19)

Table 8 continues

Table 8 (cont.)

Breastfed	**0.49***	1.08
	(0.25-0.94)	(0.53-2.23)
Early introduction to solids	1.44	0.60
	(0.78-2.64)	(0.30-1.20)

§p < .10, *p < .05, **p < .01, ***p < .001

Table 9

Odds ratios (and 95% confidence intervals) of the association between maternal and infant characteristics with indicators of undernutrition and overnutrition from 3 to 12 months using the CDC 2000 growth charts

	Rapid weight gain		Undernutrition	
Maternal characteristics	**M1**	**M2**	**M1**	**M2**
Age				
18-24	0.64 (0.30-1.35)	0.73 (0.33-1.59)	1.63 (0.82-3.23)	1.69 (0.83-3.42)
35 +	1.35 (0.47-3.85)	1.39 (0.46-4.23)	0.59 (0.18-1.96)	0.56 (0.16-1.93)
Racial/ethnic minority	**2.11**§ (0.98-4.52)	**2.15**§ (0.98-4.75)	0.86 (0.45-1.65)	0.85 (0.44-1.65)
Single mother	0.81 (0.42-1.55)	0.68 (0.34-1.34)	0.87 (0.47-1.59)	0.86 (0.47-1.60)
Education				
High school, GED, or less	0.96 (0.47-1.94)	1.04 (0.50-2.19)	1.19 (0.62-2.28)	1.07 (0.54-2.10)
4 year degree +	0.66 (0.26-1.64)	0.65 (0.25-1.71)	1.89 (0.83-4.29)	1.66 (0.71-3.86)
Parity				
0	1.02 (0.49-2.12)	1.04 (0.49-2.21)	0.90 (0.47-1.74)	0.93 (0.47-1.84)
≥ 3	1.14 (0.41-3.18)	1.19 (0.41-3.45)	1.60 (0.56-4.59)	1.63 (0.55-4.81)
Irregular work schedule	**2.07*** (1.05-4.04)	**2.05*** (1.01-4.15)	0.75 (0.38-1.50)	0.67 (0.33-1.36)
Infant characteristics				
Female		0.65 (0.34-1.25)		0.94 (0.52-1.69)
Premature birth		2.14 (0.75-6.07)		0.38 (0.10-1.39)
Low birthweight		2.35 (0.64-8.64)		1.24 (0.29-5.22)

Table 9 continues

Table 9 (cont.)

Breastfed	0.95 (0.46-1.97)	1.00 (0.51-1.98)
Early introduction to solids	0.81 (0.40-1.62)	0.59 (0.31-1.12

$^{§}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

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